

TITLE OF THE APPLICATION

BENZO[b]THIOPHENE COMPOUNDS AS STING AGONISTS

FIELD OF THE INVENTION

5 The present disclosure relates to compounds and derivatives thereof that may be useful as STING (Stimulator of Interferon Genes) agonists that activate the STING pathway. The present disclosure also relates to processes for the synthesis and to uses of such compounds.

REFERENCE TO SEQUENCE LISTING SUBMITTED ELECTRONICALLY

10 The sequence listing of the present application is submitted electronically via EFS-Web as an ASCII-formatted sequence listing, with a file name of “24170_SEQLIST-OCT2017”, a creation date of August 24, 2017, and a size of 25KB. This sequence listing submitted via EFS-Web is part of the specification and is herein incorporated by reference in its entirety.

15 BACKGROUND OF THE INVENTION

 The immune system has evolved to recognize and neutralize different types of threats in order to maintain the homeostasis of the host, and it is generally broken down into two arms: adaptive and innate. The adaptive immune system is specialized to recognize as foreign those antigens not naturally expressed in the host and to mount an anti-antigen response through
20 the coordinated actions of many leukocyte subsets. The hallmark of adaptive immune responses is their ability to provide “memory” or long-lasting immunity against the encountered antigen. While this specific and long-lasting effect is critical to host health and survival, the adaptive immune response requires time to generate a full-blown response.

 The innate immune system compensates for this time delay and is specialized to
25 act quickly against different insults or danger signals. It provides the first line of defense against bacteria, viruses, parasites and other infectious threats, but it also responds strongly to certain danger signals associated with cellular or tissue damage. The innate immune system has no antigen specificity but does respond to a variety of effector mechanisms. Opsonization, phagocytosis, activation of the complement system, and production of soluble bioactive
30 molecules such as cytokines or chemokines are all mechanisms by which the innate immune system mediates its response. By responding to these damage-associated molecular patterns (DAMPs) or pathogen-associated molecular patterns (PAMPs) described above, the innate immune system is able to provide broad protection against a wide range of threats to the host.

Free cytosolic DNA and RNA are among these PAMPs and DAMPs. It has recently been demonstrated that the main sensor for cytosolic DNA is cGAS (cyclic GMP-AMP synthase). Upon recognition of cytosolic DNA, cGAS catalyzes the generation of the cyclic-dinucleotide 2'3'-cGAMP, an atypical second messenger that strongly binds to the ER-
5 transmembrane adaptor protein STING. A conformational change is undergone by cGAMP-bound STING, which translocates to a perinuclear compartment and induces the activation of critical transcription factors IRF-3 and NF- κ B. This leads to a strong induction of type I interferons and production of pro-inflammatory cytokines such as IL-6, TNF- α and IFN- γ .

The importance of type I interferons and pro-inflammatory cytokines on various
10 cells of the immune system has been very well established. In particular, these molecules strongly potentiate T-cell activation by enhancing the ability of dendritic cells and macrophages to uptake, process, present and cross-present antigens to T-cells. The T-cell stimulatory capacity of these antigen-presenting cells is augmented by the up-regulation of critical co-stimulatory molecules, such as CD80 or CD86. Finally, type I interferons can rapidly engage their cognate
15 receptors and trigger the activation of interferon-responsive genes that can significantly contribute to adaptive immune cell activation.

From a therapeutic perspective, type I interferons are shown to have antiviral activities by directly inhibiting human hepatitis B virus and hepatitis C virus replication, and by stimulating immune responses to virally infected cells. Compounds that can induce type I
20 interferon production are used in vaccines, where they act as adjuvants, enhancing specific immune responses to antigens and minimizing side effects by reducing dosage and broadening the immune response.

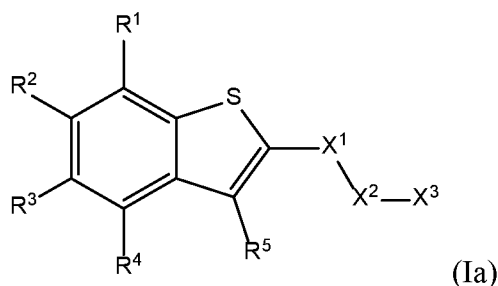
In addition, interferons, and compounds that can induce interferon production, have potential use in the treatment of human cancers. Such molecules are potentially useful as
25 anti-cancer agents with multiple pathways of activity. Interferons can inhibit human tumor cell proliferation directly and may be synergistic with various approved chemotherapeutic agents. Type I interferons can significantly enhance anti-tumor immune responses by inducing activation of both the adaptive and innate immune cells. Finally, tumor invasiveness may be inhibited by interferons by modulating enzyme expression related to tissue remodeling.

In view of the potential of type I interferons and type I interferon-inducing
30 compounds as anti-viral and anti-cancer agents, there remains a need for new agents that can induce potent type I interferon production. With the growing body of data demonstrating that the cGAS-STING cytosolic DNA sensory pathway has a significant capacity to induce type I

interferons, the development of STING activating agents is rapidly taking an important place in today's anti-tumor therapy landscape.

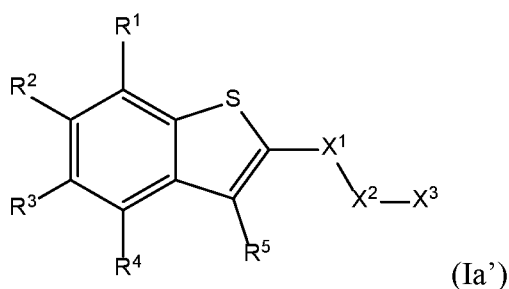
SUMMARY OF THE INVENTION

5 The present disclosure relates to novel compounds of general formula (Ia). In particular, the present disclosure relates to compounds having the general structural formula (Ia):



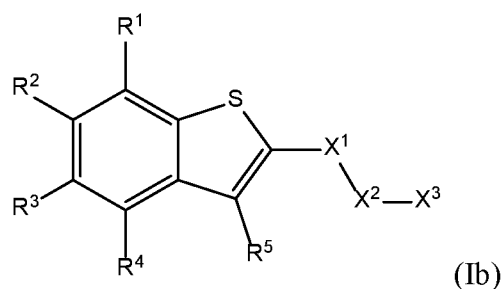
or pharmaceutically acceptable salts thereof, as described herein. Embodiments of the disclosure include compounds of general formula (Ia), and pharmaceutically acceptable salts thereof, as well as synthesis and isolation of compounds of general formula (Ia), and pharmaceutically acceptable salts thereof. Uses of compounds of general formula (Ia) are also disclosed.

The present disclosure also relates to novel compounds of general formula (Ia'). In particular, the present disclosure relates to compounds having the general structural formula (Ia'):



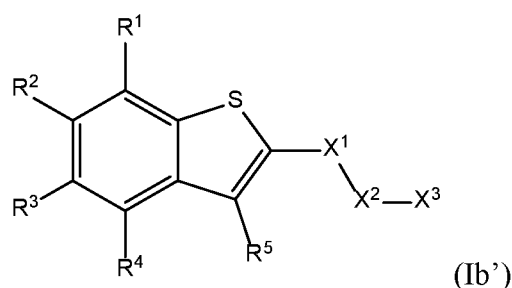
or pharmaceutically acceptable salts thereof, as described herein. Embodiments of the disclosure include compounds of general formula (Ia'), and pharmaceutically acceptable salts thereof, as well as synthesis and isolation of compounds of general formula (Ia'), and pharmaceutically acceptable salts thereof. Uses of compounds of general formula (Ia') are also disclosed.

20 The present disclosure also relates to novel compounds of general formula (Ib). In particular, the present disclosure relates to compounds having the general structural formula (Ib):



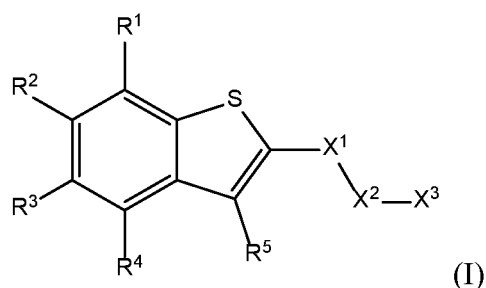
or pharmaceutically acceptable salts thereof, as described herein. Embodiments of the disclosure include compounds of general formula (Ib), and pharmaceutically acceptable salts thereof, as well as synthesis and isolation of compounds of general formula (Ib), and pharmaceutically acceptable salts thereof. Uses of compounds of general formula (Ib) are also disclosed.

The present disclosure also relates to novel compounds of general formula (Ib'). In particular, the present disclosure relates to compounds having the general structural formula (Ib'):



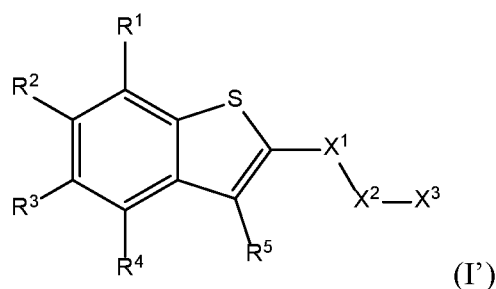
or pharmaceutically acceptable salts thereof, as described herein. Embodiments of the disclosure include compounds of general formula (Ib'), and pharmaceutically acceptable salts thereof, as well as synthesis and isolation of compounds of general formula (Ib'), and pharmaceutically acceptable salts thereof. Uses of compounds of general formula (Ib') are also disclosed.

In addition, this disclosure relates to uses of compounds of general formula (I):



or pharmaceutically acceptable salts thereof, as described herein.

In addition, this disclosure relates to uses of compounds of general formula (I'):



or pharmaceutically acceptable salts thereof, as described herein.

Other embodiments, aspects and features of the present disclosure are either further described in or will be apparent from the ensuing description, examples and appended
 5 claims.

DETAILED DESCRIPTION OF THE INVENTION

The present disclosure includes compounds of general formula (Ia), and pharmaceutically acceptable salts thereof. These compounds and their pharmaceutically
 10 acceptable salts may be useful as agents to induce immune responses, to induce STING-dependent type I interferon production, and/or to treat a cell proliferation disorder.

The present disclosure includes compounds of general formula (Ia'), and pharmaceutically acceptable salts thereof. These compounds and their pharmaceutically acceptable salts may be useful as agents to induce immune responses, to induce STING-
 15 dependent type I interferon production, and/or to treat a cell proliferation disorder.

The present disclosure also includes compounds of general formula (Ib), and pharmaceutically acceptable salts thereof. These compounds and their pharmaceutically acceptable salts may be useful as agents to induce immune responses, to induce STING-
 dependent type I interferon production, and/or to treat a cell proliferation disorder.

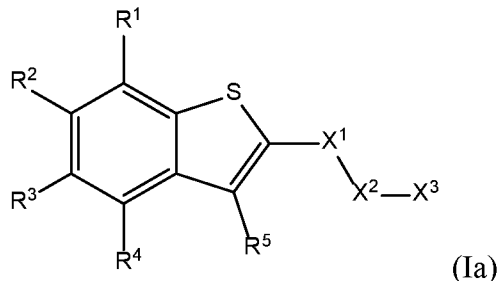
The present disclosure also includes compounds of general formula (Ib'), and pharmaceutically acceptable salts thereof. These compounds and their pharmaceutically acceptable salts may be useful as agents to induce immune responses, to induce STING-
 20 dependent type I interferon production, and/or to treat a cell proliferation disorder.

In addition, the present disclosure includes uses of compounds of general formula
 25 (I), and pharmaceutically acceptable salts thereof. The compounds of general formula (I) may be useful as agents to induce immune responses, to induce STING-dependent type I interferon production, and/or to treat a cell proliferation disorder.

In addition, the present disclosure includes uses of compounds of general formula (I'), and pharmaceutically acceptable salts thereof. The compounds of general formula (I') may

be useful as agents to induce immune responses, to induce STING-dependent type I interferon production, and/or to treat a cell proliferation disorder.

A first embodiment relates to compounds of general formula (Ia):



- 5 or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^2 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^3 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , $COOR^6$, and $C(O)N(R^6)_2$; each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl; X^1 is C(O); X^2 is $(C(R^8))_{(1-3)}$; each R^8 is independently selected from the group consisting of H, halogen, C_1 - C_6 alkyl, CN, OR^6 , $N(R^6)_2$, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, C_1 - C_6 alkyl substituted by OR^6 , and C_1 - C_6 alkyl substituted by $N(R^6)_2$; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle; X^3 is selected from the group consisting of $COOR^6$, $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 ; wherein

when $X^1-X^2-X^3$ is $X^1-CHR^8-X^3$ or $X^1-CHR^8CH_2-X^3$, at least one of R^2 and R^3 is not selected from the group consisting of halogen, OR^6 , C_1-C_6 alkyl, and C_1-C_6 haloalkyl.

In a first aspect of the first embodiment, R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$. In instances of this aspect, R^1 is selected from the group consisting of H, F, Cl, C_1-C_3 alkyl, and C_1-C_3 haloalkyl. In particular instances of this aspect, R^1 is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above.

In a second aspect of the first embodiment, R^2 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkenyl substituted by OR^6 , C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_2-C_6 alkynyl substituted by OR^6 , C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$. In instances of this aspect, R^2 is selected from the group consisting of halogen, C_1-C_3 alkyl, C_1-C_3 haloalkyl, OC_1-C_3 alkyl, C_2-C_3 alkenyl, and $N(R^6)_2$. In particular instances of this aspect, R^2 is selected from the group consisting of Br, Cl, CH_3 , CH_2CH_3 , $CH=CH_2$, OCH_3 , and $N(R^6)_2$. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first aspect described above.

In a third aspect of the first embodiment, R^3 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkenyl substituted by OR^6 , C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_2-C_6 alkynyl substituted by OR^6 , C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$. In instances of this aspect, R^3 is selected from the group consisting of halogen, C_1-C_3 alkyl, C_1-C_3 haloalkyl, OC_1-C_3 alkyl, C_2-C_3 alkenyl, and $N(R^6)_2$. In particular instances of this aspect, R^3 is selected from the group consisting of Br, Cl, CH_3 , CH_2CH_3 , $CH=CH_2$, OCH_3 , and $N(R^6)_2$. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through second aspects described above.

In a fourth aspect of the first embodiment, R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$. In instances of this aspect, R^4 is selected from the group consisting of H, F, Cl, C_1-C_3 alkyl, and C_1-C_3 haloalkyl. In particular

instances of this aspect, R^4 is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through third aspects described above.

In a fifth aspect of the first embodiment, R^5 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , $COOR^6$, and $C(O)N(R^6)_2$. In instances of this aspect, R^5 is selected from the group consisting of H, F, Cl, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl. In particular instances of this aspect, R^5 is H. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through fourth aspects described above.

In a sixth aspect of the first embodiment, each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl. In instances of this aspect, each R^6 is independently selected from the group consisting of H, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl. In particular instances of this aspect, each R^6 is independently selected from the group consisting of H and CH_3 . In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through fifth aspects described above.

In a seventh aspect of the first embodiment, X^3 is selected from the group consisting of $COOR^6$, $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$. In instances of this aspect, X^3 is selected from the group consisting of $COOR^6$, SO_2R^6 , and $C(O)N(R^9)_2$. In particular instances of this aspect, X^3 is $COOR^6$. In even more particular instances of this aspect, X^3 is $COOH$. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through sixth aspects described above.

In an eighth aspect of the first embodiment, each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 . In instances of this aspect, each R^9 is independently H. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through seventh aspects described above.

In a ninth aspect of the first embodiment, X^2 is $(C(R^8)_2)_{(1-3)}$, wherein each R^8 is independently selected from the group consisting of H, halogen, C_1 - C_6 alkyl, CN, OR^6 , $N(R^6)_2$, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, C_1 - C_6 alkyl substituted by OR^6 , and C_1 - C_6 alkyl substituted by $N(R^6)_2$; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In a first instance of this aspect, X^2 is CH_2CHR^8 , where R^8 is selected from the group consisting of H, C_1 - C_3 alkyl, C_1 - C_3 alkyl substituted by OH, C_1 - C_3 alkyl substituted by OC_1 - C_3 alkyl, and C_3 - C_6

cycloalkyl. In particular occurrences of this first instance, X^2 is CH_2CHR^8 , wherein R^8 is selected from the group consisting of H, CH_3 , CH_2OH , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}(\text{CH}_3)_2$, CH_2OCH_3 , and cyclopropyl. In a second instance of this aspect, X^2 is CHR^8CHR^8 , where R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ alkyl substituted by OH, $\text{C}_1\text{-C}_3$ alkyl substituted by $\text{OC}_1\text{-C}_3$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring. In particular occurrences of this second instance, X^2 is CHR^8CHR^8 , where R^8 is selected from the group consisting of H and $\text{C}_1\text{-C}_3$ alkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring. In a third instance of this aspect, X^2 is $\text{CH}_2\text{C}(\text{R}^8)_2$, where R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ alkyl substituted by OH, $\text{C}_1\text{-C}_3$ alkyl substituted by $\text{OC}_1\text{-C}_3$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In particular occurrences of this third instance, X^2 is $\text{CH}_2\text{C}(\text{R}^8)_2$, where R^8 is selected from the group consisting of H and $\text{C}_1\text{-C}_3$ alkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above or the first through eighth aspects described above.

In a tenth aspect of the first embodiment, R^1 is selected from the group consisting of H, F, Cl, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl; R^2 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{C}_2\text{-C}_3$ alkenyl, and $\text{N}(\text{R}^6)_2$; R^3 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{C}_2\text{-C}_3$ alkenyl, and $\text{N}(\text{R}^6)_2$; R^4 is selected from the group consisting of H, F, Cl, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl; R^5 is selected from the group consisting of H, F, Cl, OR^6 , $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl; each R^6 is independently selected from the group consisting of H, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl; X^2 is CH_2CHR^8 ; each R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ alkyl substituted by OH, $\text{C}_1\text{-C}_3$ alkyl substituted by $\text{OC}_1\text{-C}_3$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl; and X^3 is selected from the group consisting of COOR^6 , SO_2R^6 , and $\text{C}(\text{O})\text{N}(\text{R}^9)_2$; wherein $X^1\text{-X}^2\text{-X}^3$ is selected from the group consisting of $\text{C}(\text{O})\text{-CH}_2\text{CHR}^8\text{-COOR}^6$, $\text{C}(\text{O})\text{-CH}_2\text{CHR}^8\text{-SO}_2\text{R}^6$, and $\text{C}(\text{O})\text{-CH}_2\text{CHR}^8\text{-C}(\text{O})\text{N}(\text{R}^9)_2$. In instances of this aspect, R^1 is selected from the group consisting of H and F; R^2 is selected from the group consisting of Br, Cl, CH_3 , CH_2CH_3 , $\text{CH}=\text{CH}_2$, OCH_3 , and $\text{N}(\text{R}^6)_2$; R^3 is selected from the group consisting of Br, Cl, CH_3 , CH_2CH_3 , $\text{CH}=\text{CH}_2$, OCH_3 , and $\text{N}(\text{R}^6)_2$; R^4 is selected from the group consisting of H and F; R^5 is H; each R^6 is independently selected from the group consisting of H and CH_3 ; X^2 is CH_2CHR^8 ; R^8 is

selected from the group consisting of H, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl; and X³ is COOH; wherein X¹-X²-X³ is C(O)-CH₂CHR⁸-COOH. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above.

In an eleventh aspect of the first embodiment, R¹ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R⁴ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁵ is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; each R⁶ is independently selected from the group consisting of H, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; X² is CHR⁸CHR⁸; each R⁸ is selected from the group consisting of H, C₁-C₃ alkyl, C₁-C₃ alkyl substituted by OH, C₁-C₃ alkyl substituted by OC₁-C₃ alkyl, and C₃-C₆ cycloalkyl, and where optionally 2 R⁸ are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; and X³ is selected from the group consisting of COOR⁶, SO₂R⁶, and C(O)N(R⁹)₂; wherein X¹-X²-X³ is selected from the group consisting of C(O)-CHR⁸CHR⁸-COOR⁶, C(O)-CHR⁸CHR⁸-SO₂R⁶, and C(O)-CHR⁸CHR⁸-C(O)N(R⁹)₂. In instances of this aspect, R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R³ is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R⁴ is selected from the group consisting of H and F; R⁵ is H; each R⁶ is independently selected from the group consisting of H and CH₃; X² is CHR⁸CHR⁸; each R⁸ is selected from the group consisting of H and C₁-C₃ alkyl, and where optionally 2 R⁸ are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; and X³ is COOH; wherein X¹-X²-X³ is C(O)-CHR⁸CHR⁸-COOH. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above.

In a twelfth aspect of the first embodiment, R¹ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R⁴ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁵ is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; each R⁶ is independently selected from the group consisting of H, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; X² is CH₂C(R⁸)₂; each R⁸ is selected from the group consisting of H, C₁-C₃ alkyl,

C₁-C₃ alkyl substituted by OH, C₁-C₃ alkyl substituted by OC₁-C₃ alkyl, and C₃-C₆ cycloalkyl, and where optionally 2 R⁸ are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle; and X³ is selected from the group consisting of COOR⁶, SO₂R⁶, and C(O)N(R⁹)₂; wherein X¹-X²-X³ is selected from the group consisting of C(O)-CH₂C(R⁸)₂-COOR⁶, C(O)-CH₂C(R⁸)₂-SO₂R⁶, and C(O)-CH₂C(R⁸)₂-C(O)N(R⁹)₂. In instances of this aspect, R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R³ is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R⁴ is selected from the group consisting of H and F; R⁵ is H; each R⁶ is independently selected from the group consisting of H and CH₃; X² is CH₂C(R⁸)₂; each R⁸ is selected from the group consisting of H and C₁-C₃ alkyl, and where optionally 2 R⁸ are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle; and X³ is COOH; wherein X¹-X²-X³ is C(O)-CH₂C(R⁸)₂-COOH. In this aspect, all other groups are as provided in the general formula (Ia) of the first embodiment above.

A thirteenth aspect of the first embodiment relates to a pharmaceutical composition, said pharmaceutical composition comprising (a) a compound according to general formula (Ia) of the first embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof; and (b) a pharmaceutically acceptable carrier.

A fourteenth aspect of the first embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ia) of the first embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A fifteenth aspect of the first embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

A sixteenth aspect of the first embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ia) of the first embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A seventeenth aspect of the first embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a

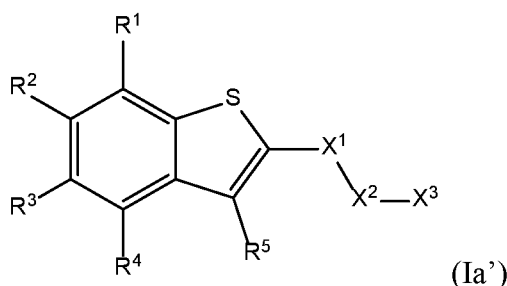
therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

An eighteenth aspect of the first embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ia) of the first embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A nineteenth aspect relates to methods of inducing a STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

In each aspect of the first embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (Ia), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

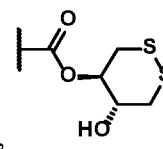
A second embodiment relates to compounds of general formula (Ia'):



or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl, wherein said C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl are optionally substituted with OH, $O(C_1$ - C_3 alkyl), and $O(C_1$ - C_3 haloalkyl); X^1 is $C(O)$; X^2 is $(C(R^8)_2)_{(1-3)}$; each R^8 is independently selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; optionally 2 R^8 on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; optionally 2 R^8 on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-



membered spirocycle; X^3 is selected from the group consisting of COOR^6 , C(O)SR^6 , C(S)OR^6 , SO_2R^6 , and $\text{C(O)N(R}^9)_2$; and each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; wherein when $\text{X}^1\text{-X}^2\text{-X}^3$ is $\text{X}^1\text{-CHR}^8\text{-X}^3$ or $\text{X}^1\text{-CHR}^8\text{CH}_2\text{-X}^3$, at least one of R^2 and R^3 is not selected from the group consisting of halogen, OR^6 , $\text{C}_1\text{-C}_6$ alkyl, and $\text{C}_1\text{-C}_6$ haloalkyl.

In a first aspect of the second embodiment, R^1 is selected from the group consisting of H, halogen, OR^6 , $\text{N(R}^6)_2$, SR^6 , $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ alkyl substituted by OR^6 , $\text{C}_1\text{-C}_6$ alkyl substituted by SR^6 , $\text{C}_1\text{-C}_6$ alkyl substituted by $\text{N(R}^6)_2$, $\text{C}_1\text{-C}_6$ haloalkyl substituted by OR^6 , $\text{C}_1\text{-C}_6$ haloalkyl substituted by SR^6 , and $\text{C}_1\text{-C}_6$ haloalkyl substituted by $\text{N(R}^6)_2$. In instances of this aspect, R^1 is selected from the group consisting of H, F, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl. In particular instances of this aspect, R^1 is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above.

In a second aspect of the second embodiment, R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $\text{N(R}^6)_2$, COOR^6 , $\text{C(O)N(R}^6)_2$, SR^6 , SO_2R^6 , $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $\text{N(R}^6)$, wherein said $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $\text{N(R}^6)_2$, and SR^6 , and wherein said $\text{C}_3\text{-C}_6$ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of $\text{C}_1\text{-C}_3$ alkyl and $\text{C}_1\text{-C}_3$ haloalkyl. In instances of this aspect, R^2 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{OC}_1\text{-C}_3$ haloalkyl, OH, $\text{C}_2\text{-C}_3$ alkenyl, $\text{C}_2\text{-C}_3$ alkynyl, $\text{N(C}_1\text{-C}_3\text{ alkyl)}_2$, $\text{NH(C}_1\text{-C}_3\text{ alkyl)}$, and $\text{SC}_1\text{-C}_3$ alkyl. In particular instances of this aspect, R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, CH=CH_2 , $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 . In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first aspect described above.

In a third aspect of the second embodiment, R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $\text{N(R}^6)_2$, COOR^6 , $\text{C(O)N(R}^6)_2$, SR^6 , SO_2R^6 , $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $\text{N(R}^6)$, wherein said $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $\text{N(R}^6)_2$, and SR^6 , and wherein said $\text{C}_3\text{-C}_6$ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of $\text{C}_1\text{-C}_3$ alkyl and $\text{C}_1\text{-C}_3$ haloalkyl. In instances of this aspect, R^3 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{OC}_1\text{-C}_3$ haloalkyl, OH, $\text{C}_2\text{-C}_3$ alkenyl, $\text{C}_2\text{-C}_3$ alkynyl, $\text{N(C}_1\text{-C}_3\text{ alkyl)}_2$, $\text{NH(C}_1\text{-C}_3\text{ alkyl)}$, and $\text{SC}_1\text{-C}_3$ alkyl. In particular instances of this aspect, R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, CH=CH_2 , $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 . In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first aspect described above.

C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In instances of this aspect, R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl. In particular instances of this aspect, R³ is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through second aspects described above.

In a fourth aspect of the second embodiment, R⁴ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂. In instances of this aspect, R⁴ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R⁴ is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through third aspects described above.

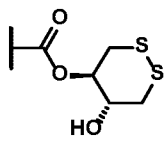
In some instances of the third and fourth aspects of the second embodiment, R³ and R⁴ are taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶) wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In a first such instance, R³ and R⁴ are taken together with the atoms to which they are attached form a fused 5-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and N, and that heterocyclic ring is optionally substituted optionally substituted with or more C₁-C₃ alkyl. In a second such instance, R³ and R⁴ are taken together with the atoms to which they are attached form a fused 5-membered heterocyclic ring including 1 to 2 ring members selected from the

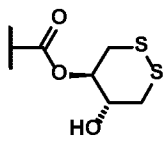
group consisting of O and N, and that heterocyclic ring is optionally substituted optionally substituted with CH₃. In such instances, all other groups are as provided in the general formula (Ia') of the second embodiment above.

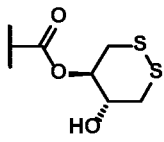
In a fifth aspect of the second embodiment, R⁵ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, CN, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂. In instances of this aspect, R⁵ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R⁵ is selected from the group consisting of H and Cl. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through fourth aspects described above.

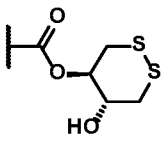
In a sixth aspect of the second embodiment, each R⁶ is independently selected from the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl, wherein said C₁-C₆ alkyl, and C₁-C₆ haloalkyl are optionally substituted with OH, O(C₁-C₃ alkyl), O(C₁-C₃ haloalkyl). In instances of this aspect, each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through fifth aspects described above.

In a seventh aspect of the second embodiment, X³ is selected from the group

consisting of COOR⁶, , C(O)SR⁶, C(S)OR⁶, SO₂R⁶, and C(O)N(R⁹)₂. In instances

of this aspect, X³ is selected from the group consisting of COOR⁶, , SO₂R⁶, and C(O)N(R⁹)₂. In particular instances of this aspect, X³ is selected from the group consisting of

COOR⁶ and . In even more particular instances of this aspect, X³ is selected from

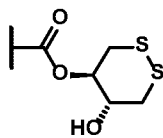
the group consisting of COOH, COOC(CH₃)₃, and . In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through sixth aspects described above.

In an eighth aspect of the second embodiment, each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 . In instances of this aspect, each R^9 is independently H. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above or the first through seventh aspects described above.

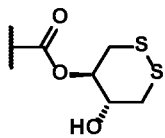
5 In a ninth aspect of the second embodiment, X^2 is $(C(R^8)_2)_{(1-3)}$, wherein each R^8 is independently selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-
 10 C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3-C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl. In a first instance of this aspect, X^2 is CH_2CHR^8 , where R^8 is selected from the group consisting
 15 of H, C_1-C_4 alkyl, C_1-C_4 alkyl substituted by OH, C_1-C_4 alkyl substituted by OC_1-C_4 alkyl, and C_3-C_6 cycloalkyl. In particular occurrences of this first instance, X^2 is CH_2CHR^8 , wherein R^8 is selected from the group consisting of H, CH_3 , CH_2OH , CH_2CH_3 , $CH_2CH_2CH_3$, $CH(CH_3)_2$, CH_2OCH_3 , and cyclopropyl. In a second instance of this aspect, X^2 is CHR^8CHR^8 , where R^8 is selected from the group consisting of H, C_1-C_4 alkyl, C_1-C_4 alkyl substituted by OH, C_1-C_4 alkyl
 20 substituted by OC_1-C_4 alkyl, and C_3-C_6 cycloalkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring. In particular occurrences of this second instance, X^2 is CHR^8CHR^8 , where R^8 is selected from the group consisting of H and C_1-C_4 alkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring. In specific occurrences of this
 25 second instance, X^2 is CHR^8CHR^8 , where the 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3-membered fused ring. In a third instance of this aspect, X^2 is $CH_2C(R^8)_2$, where R^8 is selected from the group consisting of H, OH, C_1-C_4 alkyl, C_1-C_4 alkyl substituted by OH, C_1-C_4 alkyl substituted by OC_1-C_4 alkyl, and C_3-C_6 cycloalkyl, and optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-
 30 membered spirocycle. In particular occurrences of this third instance, X^2 is $CH_2C(R^8)_2$, where R^8 is selected from the group consisting of H, OH, and CH_3 . In additional occurrences of this third instance, X^2 is $CH_2C(R^8)_2$, where the 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In this aspect, all other groups are as

provided in the general formula (Ia') of the second embodiment above or the first through eighth aspects described above.

In a tenth aspect of the second embodiment, R^1 is selected from the group consisting of H, F, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; R^2 is selected from the group consisting of halogen, C_1 - C_3 alkyl, C_1 - C_3 haloalkyl, OC_1 - C_3 alkyl, OC_1 - C_3 haloalkyl, OH, C_2 - C_3 alkenyl, C_2 - C_3 alkynyl, $N(C_1$ - C_3 alkyl) $_2$, $NH(C_1$ - C_3 alkyl), and SC_1 - C_3 alkyl; R^3 is selected from the group consisting of halogen, C_1 - C_3 alkyl, C_1 - C_3 haloalkyl, OC_1 - C_3 alkyl, OC_1 - C_3 haloalkyl, OH, C_2 - C_3 alkenyl, C_2 - C_3 alkynyl, $N(C_1$ - C_3 alkyl) $_2$, $NH(C_1$ - C_3 alkyl), and SC_1 - C_3 alkyl; R^4 is selected from the group consisting of H, F, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; R^5 is selected from the group consisting of H, F, Cl, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; each R^6 is independently selected from the group consisting of H, C_1 - C_4 alkyl, and C_1 - C_4 haloalkyl; X^1 is $C(O)$; X^2 is CH_2CHR^8 ; X^3 is



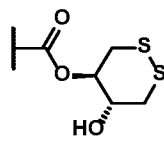
selected from the group consisting of $COOR^6$, , SO_2R^6 , and $C(O)N(R^9)_2$, where each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 ; and R^8 is selected from the group consisting of H, C_1 - C_4 alkyl, C_1 - C_4 alkyl substituted by OH, C_1 - C_4 alkyl substituted by OC_1 - C_4 alkyl, and C_3 - C_6 cycloalkyl. In instances of this aspect, R^1 is selected from the group consisting of H and F; R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH, OCH_3 , OCH_2CH_3 , $OCHF_2$, SCH_3 , and $NHCH_3$; R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH, OCH_3 , OCH_2CH_3 , $OCHF_2$, SCH_3 , and $NHCH_3$; R^4 is selected from the group consisting of H and F; R^5 is selected from the group consisting of H and Cl; each R^6 is independently selected from the group consisting of H, C_1 - C_4 alkyl, and C_1 - C_4 haloalkyl; X^1 is $C(O)$; X^2 is CH_2CHR^8 ; X^3 is selected from the group consisting of $COOH$, $COOC(CH_3)_3$,



and ; and R^8 is selected from the group consisting of H, CH_3 , CH_2OH , CH_2CH_3 , $CH_2CH_2CH_3$, $CH(CH_3)_2$, CH_2OCH_3 , and cyclopropyl. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above.

In an eleventh aspect of the second embodiment, R^1 is selected from the group consisting of H, F, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; R^2 is selected from the group consisting of halogen, C_1 - C_3 alkyl, C_1 - C_3 haloalkyl, OC_1 - C_3 alkyl, OC_1 - C_3 haloalkyl, OH, C_2 - C_3 alkenyl, C_2 - C_3 alkynyl, $N(C_1$ - C_3 alkyl) $_2$, $NH(C_1$ - C_3 alkyl), and SC_1 - C_3 alkyl; R^3 is selected from the group

consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl; R⁴ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁵ is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CHR⁸CHR⁸;



X³ is selected from the group consisting of COOR⁶, SO₂R⁶, and C(O)N(R⁹)₂,

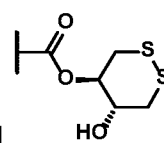
where each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶;

and each R⁸ is selected from the group consisting of H, C₁-C₄ alkyl, C₁-C₄ alkyl substituted by OH, C₁-C₄ alkyl substituted by OC₁-C₄ alkyl, and C₃-C₆ cycloalkyl, and where optionally 2 R⁸

are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring. In instances of this aspect, R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F,

CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃; R³ is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH,

OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃; R⁴ is selected from the group consisting of H and F; R⁵ is selected from the group consisting of H and Cl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CHR⁸CHR⁸; X³ is



selected from the group consisting of COOH, COOC(CH₃)₃, and

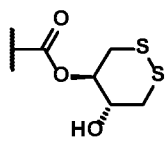
selected from the group consisting of H and C₁-C₄ alkyl. In additional instances of this aspect,

R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃,

OCHF₂, SCH₃, and NHCH₃; R³ is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

R⁴ is selected from the group consisting of H and F; R⁵ is selected from the group consisting of

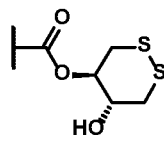
H and Cl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CHR⁸CHR⁸; X³ is selected from the group consisting of COOH,



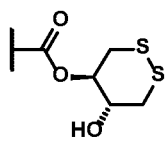
COOC(CH₃)₃, and ; and the 2 R⁸ are taken together, along with the atoms to which

they are attached, to form a 3- to 6-membered fused ring. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above.

In a twelfth aspect of the second embodiment, R^1 is selected from the group consisting of H, F, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; R^2 is selected from the group consisting of halogen, C_1 - C_3 alkyl, C_1 - C_3 haloalkyl, OC_1 - C_3 alkyl, OC_1 - C_3 haloalkyl, OH, C_2 - C_3 alkenyl, C_2 - C_3 alkynyl, $N(C_1$ - C_3 alkyl) $_2$, $NH(C_1$ - C_3 alkyl), and SC_1 - C_3 alkyl; R^3 is selected from the group consisting of halogen, C_1 - C_3 alkyl, C_1 - C_3 haloalkyl, OC_1 - C_3 alkyl, OC_1 - C_3 haloalkyl, OH, C_2 - C_3 alkenyl, C_2 - C_3 alkynyl, $N(C_1$ - C_3 alkyl) $_2$, $NH(C_1$ - C_3 alkyl), and SC_1 - C_3 alkyl; R^4 is selected from the group consisting of H, F, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; R^5 is selected from the group consisting of H, F, Cl, OR^6 , C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl; each R^6 is independently selected from the group consisting of H, C_1 - C_4 alkyl, and C_1 - C_4 haloalkyl; X^1 is $C(O)$; X^2 is $CH_2C(R^8)_2$;

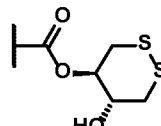


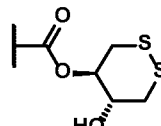
X^3 is selected from the group consisting of $COOR^6$, SO_2R^6 , and $C(O)N(R^9)_2$, where each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 ; and each R^8 is selected from the group consisting of H, OH, C_1 - C_4 alkyl, C_1 - C_4 alkyl substituted by OH, C_1 - C_4 alkyl substituted by OC_1 - C_4 alkyl, and C_3 - C_6 cycloalkyl, and where optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In instances of this aspect, R^1 is selected from the group consisting of H and F; R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH, OCH_3 , OCH_2CH_3 , $OCHF_2$, SCH_3 , and $NHCH_3$; R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH, OCH_3 , OCH_2CH_3 , $OCHF_2$, SCH_3 , and $NHCH_3$; R^4 is selected from the group consisting of H and F; R^5 is selected from the group consisting of H and Cl; each R^6 is independently selected from the group consisting of H, C_1 - C_4 alkyl, and C_1 - C_4 haloalkyl; X^1 is $C(O)$; X^2 is $CH_2C(R^8)_2$; X^3 is selected from the group consisting of $COOH$, $COOC(CH_3)_3$, and



; and each R^8 is selected from the group consisting of H, OH, and CH_3 . In additional instances of this aspect, R^1 is selected from the group consisting of H and F; R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH, OCH_3 , OCH_2CH_3 , $OCHF_2$, SCH_3 , and $NHCH_3$; R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $CH_2CH_2CH_3$, CH_2CH_2F , $CH=CH_2$, $C\equiv CH$, OH,

OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃; R⁴ is selected from the group consisting of H and F; R⁵ is selected from the group consisting of H and Cl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CH₂C(R⁸)₂; X³ is



selected from the group consisting of COOH, COOC(CH₃)₃, and ; and the 2 R⁸ are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle. In this aspect, all other groups are as provided in the general formula (Ia') of the second embodiment above.

A thirteenth aspect of the second embodiment relates to a pharmaceutical composition, said pharmaceutical composition comprising (a) a compound according to general formula (Ia') of the second embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof; and (b) a pharmaceutically acceptable carrier.

A fourteenth aspect of the second embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ia') of the second embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A fifteenth aspect of the second embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

A sixteenth aspect of the second embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ia') of the first embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A seventeenth aspect of the second embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

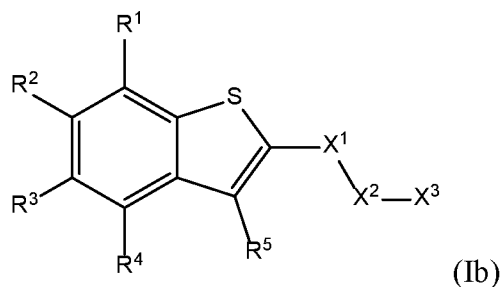
An eighteenth aspect of the second embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically

effective amount of a compound according to general formula (Iaa) of the second embodiment above or the first through twelfth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A nineteenth aspect of the second embodiment relates to methods of inducing a STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition according to the thirteenth aspect described above to the subject.

In each aspect of the second embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (Ia'), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

A third embodiment relates to compounds of general formula (Ib):



or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^2 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^3 is selected from the group consisting of halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , $COOR^6$, and $C(O)N(R^6)_2$; each R^6 is independently selected from

the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl; X¹ is C(O); X² is CH₂CHR⁸; each R⁸ is independently selected from the group consisting of halogen, C₁-C₆ alkyl, CN, OR⁶, N(R⁶)₂, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, C₁-C₆ alkyl substituted by OR⁶, and C₁-C₆ alkyl substituted by N(R⁶)₂; X³ is selected from the group consisting of COOR⁶, C(O)SR⁶, C(S)OR⁶, SO₂R⁶, and C(O)N(R⁹)₂; and each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶; wherein X¹-X²-X³ is X¹-CH₂CHR⁸-X³.

In a first aspect of the third embodiment, R¹ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, COOR⁶, and C(O)N(R⁶)₂. In instances of this aspect, R¹ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R¹ is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above.

In a second aspect of the third embodiment, R² is selected from the group consisting of halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkenyl substituted by OR⁶, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₂-C₆ alkynyl substituted by OR⁶, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and N(R⁶). In instances of this aspect, R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂. In particular instances of this aspect, R² is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first aspect described above.

In a third aspect of the third embodiment, R³ is selected from the group consisting of halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkenyl substituted by OR⁶, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₂-C₆ alkynyl substituted by OR⁶, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and N(R⁶). In instances of this aspect, R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂. In particular instances of this aspect, R³ is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through second aspects described above.

In a fourth aspect of the third embodiment, R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$. In instances of this aspect, R^4 is selected from the group consisting of H, F, Cl, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl. In particular
 5 instances of this aspect, R^4 is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through third aspects described above.

In a fifth aspect of the third embodiment, R^5 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 ,
 10 $COOR^6$, and $C(O)N(R^6)_2$. In instances of this aspect, R^5 is selected from the group consisting of H, F, Cl, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl. In particular instances of this aspect, R^5 is H. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through fourth aspects described above.

In a sixth aspect of the third embodiment, each R^6 is independently selected from
 15 the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl. In instances of this aspect, each R^6 is independently selected from the group consisting of H, C_1 - C_3 alkyl, and C_1 - C_3 haloalkyl. In particular instances of this aspect, each R^6 is independently selected from the group consisting of H and CH_3 . In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through fifth aspects described above.

In a seventh aspect of the third embodiment, X^3 is selected from the group
 20 consisting of $COOR^6$, $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$. In instances of this aspect, X^3 is selected from the group consisting of $COOR^6$, SO_2R^6 , and $C(O)N(R^9)_2$. In particular instances of this aspect, X^3 is $COOR^6$. In even more particular instances of this aspect, X^3 is $COOH$. In this aspect, all other groups are as provided in the general formula (Ib) of the third
 25 embodiment above or the first through sixth aspects described above.

In an eighth aspect of the third embodiment, each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 . In instances of this aspect, each R^9 is independently H. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through seventh aspects described above.

In a ninth aspect of the third embodiment, X^2 is CH_2CHR^8 , wherein each R^8 is
 30 independently selected from the group consisting of halogen, C_1 - C_6 alkyl, CN, OR^6 , $N(R^6)_2$, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, C_1 - C_6 alkyl substituted by OR^6 , and C_1 - C_6 alkyl substituted by $N(R^6)_2$. In instances of this aspect, R^8 is selected from the group consisting of C_1 - C_3 alkyl, C_1 - C_3

alkyl substituted by OH, C₁-C₃ alkyl substituted by OC₁-C₃ alkyl, and C₃-C₆ cycloalkyl. In particular instances, R⁸ is selected from the group consisting of CH₃, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above or the first through eighth aspects described above.

In a tenth aspect of the third embodiment, R¹ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, C₂-C₃ alkenyl, and N(R⁶)₂; R⁴ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁵ is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; each R⁶ is independently selected from the group consisting of H, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁸ is selected from the group consisting of C₁-C₃ alkyl, C₁-C₃ alkyl substituted by OH, C₁-C₃ alkyl substituted by OC₁-C₃ alkyl, and C₃-C₆ cycloalkyl; and X³ is selected from the group consisting of COOR⁶, SO₂R⁶, and C(O)N(R⁹)₂; wherein X¹-X²-X³ is selected from the group consisting of C(O)-CH₂CHR⁸-COOR⁶, C(O)-CH₂CHR⁸-SO₂R⁶, and C(O)-CH₂CHR⁸-C(O)N(R⁹)₂. In instances of this aspect, R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R³ is selected from the group consisting of Br, Cl, CH₃, CH₂CH₃, CH=CH₂, OCH₃, and N(R⁶)₂; R⁴ is selected from the group consisting of H and F; R⁵ is H; each R⁶ is independently selected from the group consisting of H and CH₃; R⁸ is selected from the group consisting of CH₃, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl; and X³ is COOH; wherein X¹-X²-X³ is C(O)-CH₂CHR⁸-COOH. In this aspect, all other groups are as provided in the general formula (Ib) of the third embodiment above.

An eleventh aspect of the third embodiment relates to a pharmaceutical composition, said pharmaceutical composition comprising (a) a compound according to general formula (Ib) of the third embodiment above or the first through eleventh aspects described above or a pharmaceutically acceptable salt thereof; and (b) a pharmaceutically acceptable carrier.

A twelfth aspect of the third embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ib) of the third embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A thirteenth aspect of the third embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

A fourteenth aspect of the third embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ib) of the third embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

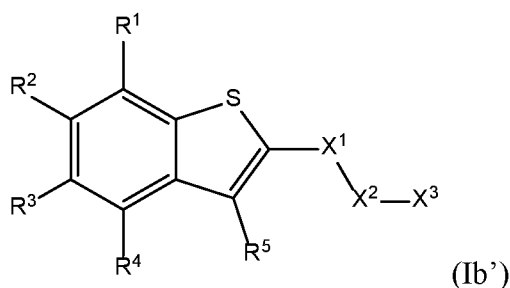
A fifteenth aspect of the third embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

A sixteenth aspect of the third embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ib) of the third embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A seventeenth aspect of the third embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

In each aspect of the third embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (Ib), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

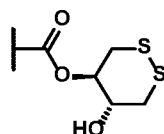
A fourth embodiment relates to compounds of general formula (Ib'):



or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 -

C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl, wherein said C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl are optionally substituted with OH, O(C_1 - C_3 alkyl), and O(C_1 - C_3 haloalkyl); X^1 is C(O); X^2 is CH_2CHR^8 ; each R^8 is independently selected

from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;



X³ is selected from the group consisting of COOR⁶, C(O)SR⁶, C(S)OR⁶, SO₂R⁶, and C(O)N(R⁹)₂; and each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶; wherein X¹-X²-X³ is C(O)-CH₂CHR⁸-X³.

In a first aspect of the fourth embodiment, R¹ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂. In instances of this aspect, R¹ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R¹ is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above.

In a second aspect of the fourth embodiment, R² is selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SR⁶, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In instances of this aspect, R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl),

and SC₁₋₃ alkyl. In particular instances of this aspect, R² is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first aspect described above.

5 In a third aspect of the fourth embodiment, R³ is selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SR⁶, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In instances of this aspect, R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁₋₃ alkyl. In particular instances of this aspect, R³ is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through second aspects described above.

In a fourth aspect of the fourth embodiment, R⁴ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂. In instances of this aspect, R⁴ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R⁴ is selected from the group consisting of H and F. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through third aspects described above.

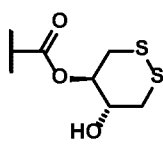
30 In some instances of the third and fourth aspects of the fourth embodiment, R³ and R⁴ are taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶) wherein said heterocyclic ring is optionally substituted with or more members of the

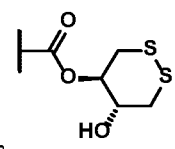
group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In a first such instance, R³ and R⁴ are taken together with the atoms to which they are attached form a fused 5-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and N, and that heterocyclic ring is optionally substituted optionally substituted with or more C₁-C₃ alkyl. In a second such instance, R³ and R⁴ are taken together with the atoms to which they are attached form a fused 5-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O and N, and that heterocyclic ring is optionally substituted optionally substituted with CH₃. In such instances, all other groups are as provided in the general formula (Ib') of the fourth embodiment above.

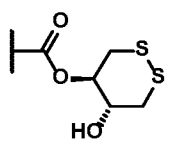
In a fifth aspect of the fourth embodiment, R⁵ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, CN, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂. In instances of this aspect, R⁵ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl. In particular instances of this aspect, R⁵ is selected from the group consisting of H and Cl. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through fourth aspects described above.

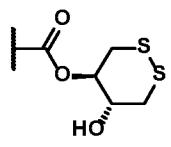
In a sixth aspect of the fourth embodiment, each R⁶ is independently selected from the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl, wherein said C₁-C₆ alkyl, and C₁-C₆ haloalkyl are optionally substituted with OH, O(C₁-C₃ alkyl), and O(C₁-C₃ haloalkyl). In instances of this aspect, each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through fifth aspects described above.

In a seventh aspect of the fourth embodiment, X³ is selected from the group

consisting of COOR⁶, , C(O)SR⁶, C(S)OR⁶, SO₂R⁶, and C(O)N(R⁹)₂. In instances

of this aspect, X³ is selected from the group consisting of COOR⁶, , SO₂R⁶, and C(O)N(R⁹)₂. In particular instances of this aspect, X³ is selected from the group consisting of

COOR⁶ and . In even more particular instances of this aspect, X³ is selected from

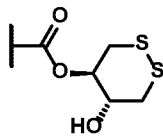
the group consisting of COOH, COOC(CH₃)₃, and . In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through sixth aspects described above.

5 In an eighth aspect of the fourth embodiment, each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶. In instances of this aspect, each R⁹ is independently H. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through seventh aspects described above.

10 In a ninth aspect of the fourth embodiment, X² is CH₂CHR⁸, wherein each R⁸ is independently selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl. In instances of this aspect, R⁸ is selected from the group consisting of H, C₁-C₄ alkyl, C₁-C₄ alkyl substituted by OH, C₁-C₄ alkyl substituted by OC₁-C₄ alkyl, and C₃-C₆ cycloalkyl. In particular instances, R⁸ is selected from the group consisting of H, CH₃, CH₂OH, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above or the first through eighth aspects described above.

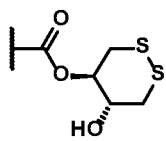
25 In a tenth aspect of the fourth embodiment, R¹ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl; R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl; R⁴ is selected from

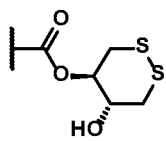
the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; R⁵ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CH₂CHR⁸; X³ is



selected from the group consisting of COOR⁶, , SO₂R⁶, and C(O)N(R⁹)₂, where each

- 5 R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶; and R⁸ is selected from the group consisting of H, C₁-C₄ alkyl, C₁-C₄ alkyl substituted by OH, C₁-C₄ alkyl substituted by OC₁-C₄ alkyl, and C₃-C₆ cycloalkyl. In instances of this aspect, R¹ is selected from the group consisting of H and F; R² is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and
10 NHCH₃; R³ is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃; R⁴ is selected from the group consisting of H and F; R⁵ is selected from the group consisting of H and Cl; each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl; X¹ is C(O); X² is CH₂CHR⁸; X³ is selected from the group consisting of COOH, COOC(CH₃)₃,



- 15 and ; and R⁸ is selected from the group consisting of H, CH₃, CH₂OH, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl. In this aspect, all other groups are as provided in the general formula (Ib') of the fourth embodiment above.

An eleventh aspect of the fourth embodiment relates to a pharmaceutical composition, said pharmaceutical composition comprising (a) a compound according to general
20 formula (Ib') of the fourth embodiment above or the first through eleventh aspects described above or a pharmaceutically acceptable salt thereof; and (b) a pharmaceutically acceptable carrier.

A twelfth aspect of the fourth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a
25 compound according to general formula (Ib') of the fourth embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

A thirteenth aspect of the fourth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

5 A fourteenth aspect of the fourth embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ib') of the fourth embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

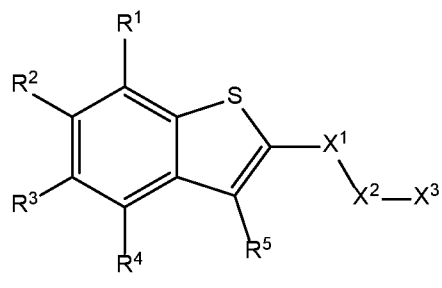
10 A fifteenth aspect of the fourth embodiment relates to methods of inducing a STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

15 A sixteenth aspect of the fourth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound according to general formula (Ib') of the fourth embodiment above or the first through tenth aspects described above or a pharmaceutically acceptable salt thereof to the subject.

20 A seventeenth aspect of the fourth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition according to the eleventh aspect described above to the subject.

25 In each aspect of the fourth embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (Ib'), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

30 Aspects of a fifth embodiment of this disclosure relate to uses of compounds of general formula (I), and pharmaceutically acceptable salts thereof. The compounds of general formula (I) may be useful as agents to induce immune responses, to induce STING-dependent type I interferon production, and/or to treat a cell proliferation disorder. In these aspects of the fifth, the compound of formula (I) is



or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkenyl substituted by OR^6 , C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_2 - C_6 alkynyl substituted by OR^6 , C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, and $N(R^6)$; R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, $COOR^6$, and $C(O)N(R^6)_2$; R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , $COOR^6$, and $C(O)N(R^6)_2$; each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl; X^1 is C(O); X^2 is $(C(R^8)_2)_{(1-3)}$; each R^8 is independently selected from the group consisting of H, halogen, C_1 - C_6 alkyl, CN, OR^6 , $N(R^6)_2$, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, C_1 - C_6 alkyl substituted by OR^6 , and C_1 - C_6 alkyl substituted by $N(R^6)_2$; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; optionally 2 R^8 may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle; X^3 is selected from the group consisting of $COOR^6$, $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 .

A first aspect of the fifth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound of general formula (I) above or a pharmaceutically acceptable salt thereof to the subject.

A second aspect of the fifth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I) above or a pharmaceutically acceptable salt thereof to the subject.

5 A third aspect of the fifth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound of general formula (I) or a pharmaceutically acceptable salt thereof to the subject.

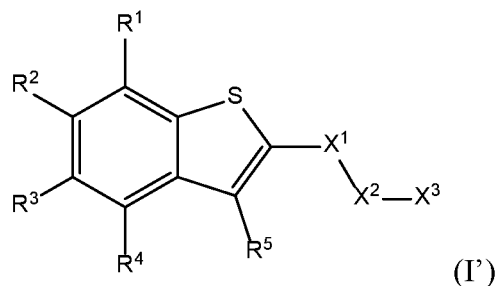
10 A fourth aspect of the fifth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I) above or a pharmaceutically acceptable salt thereof to the subject.

15 A fifth aspect of the fifth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound of general formula (I) above or a pharmaceutically acceptable salt thereof to the subject.

20 A sixth aspect of the fifth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I) above or a pharmaceutically acceptable salt thereof to the subject.

In each aspect of the fifth embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (I), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

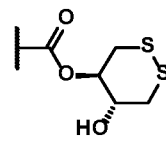
25 Aspects of a sixth embodiment of this disclosure relate to uses of compounds of general formula (I'), and pharmaceutically acceptable salts thereof. The compounds of general formula (I') may be useful as agents to induce immune responses, to induce STING-dependent type I interferon production, and/or to treat a cell proliferation disorder. In these aspects of the fifth, the compound of formula (I') is



or a pharmaceutically acceptable salt thereof, wherein R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl; R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$; optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring

is optionally substituted with or more members of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl; R⁵ is selected from H, halogen, OR⁶, N(R⁶)₂, CN, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂; each R⁶ is independently selected from the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl, wherein said C₁-C₆ alkyl, and C₁-C₆ haloalkyl are optionally substituted with OH, O(C₁-C₃ alkyl), and O(C₁-C₃ haloalkyl); X¹ is C(O); X² is (C(R⁸)₂)₍₁₋₃₎; each R⁸ is independently selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl; optionally 2 R⁸ on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring; optionally 2 R⁸ on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-

membered spirocycle; X³ is selected from the group consisting of COOR⁶, C(O)SR⁶, C(S)OR⁶, SO₂R⁶, and C(O)N(R⁹)₂; and each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶.



A first aspect of the sixth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound of general formula (I') above or a pharmaceutically acceptable salt thereof to the subject.

A second aspect of the sixth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I') above or a pharmaceutically acceptable salt thereof to the subject.

A third aspect of the sixth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically

effective amount of a compound of general formula (I') or a pharmaceutically acceptable salt thereof to the subject.

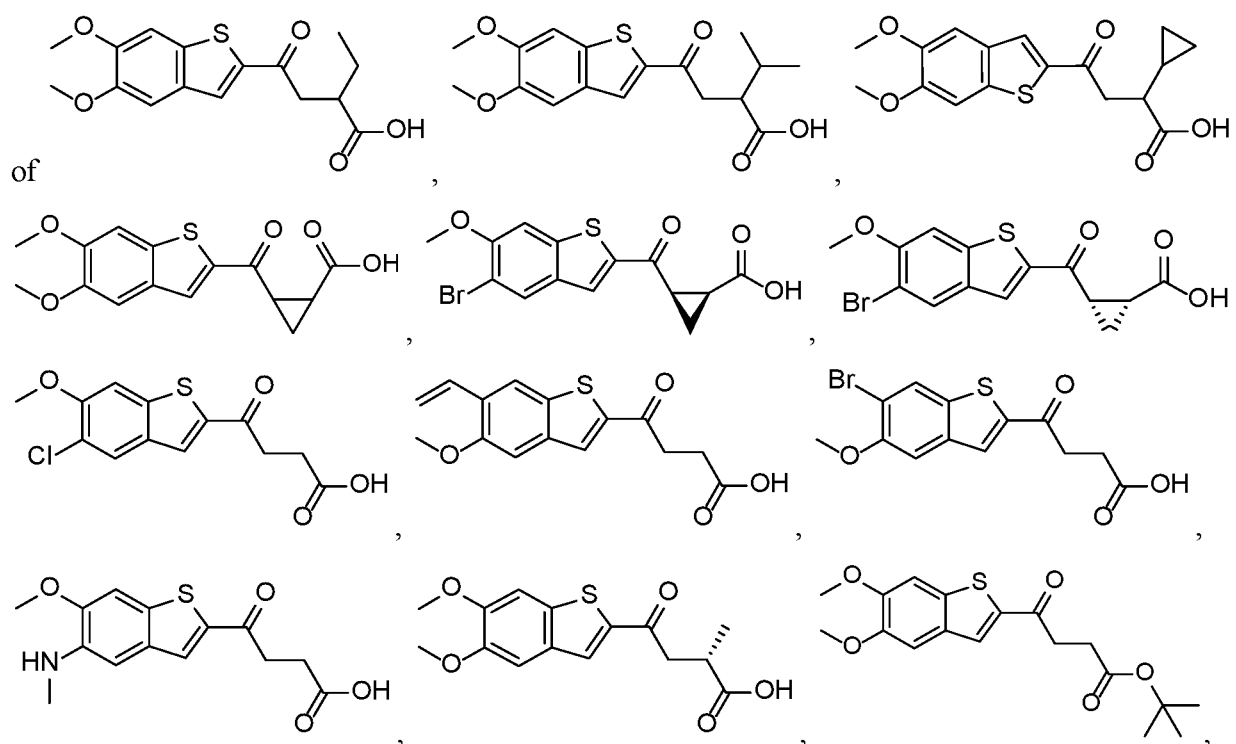
A fourth aspect of the sixth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I') above or a pharmaceutically acceptable salt thereof to the subject.

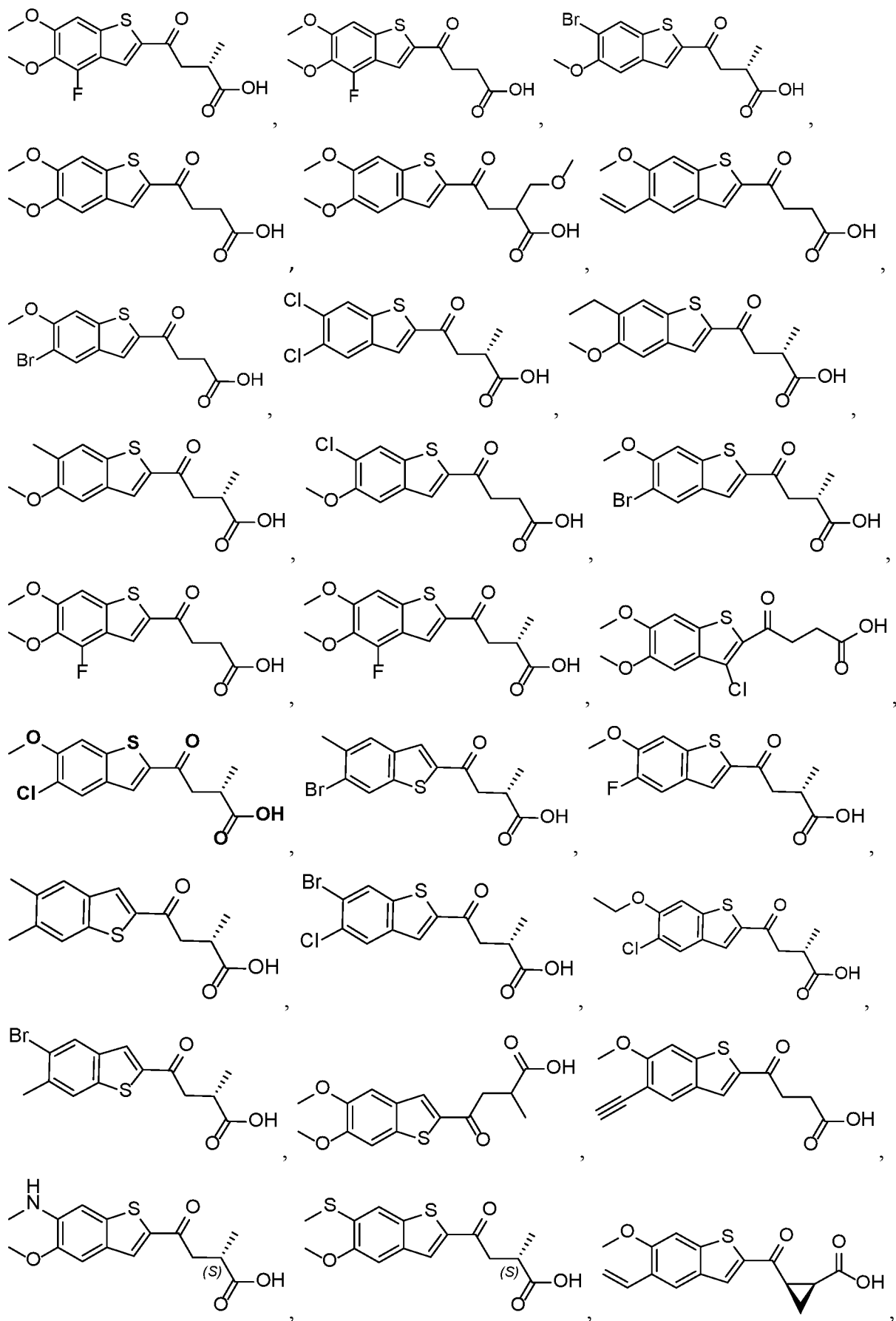
A fifth aspect of the sixth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound of general formula (I') above or a pharmaceutically acceptable salt thereof to the subject.

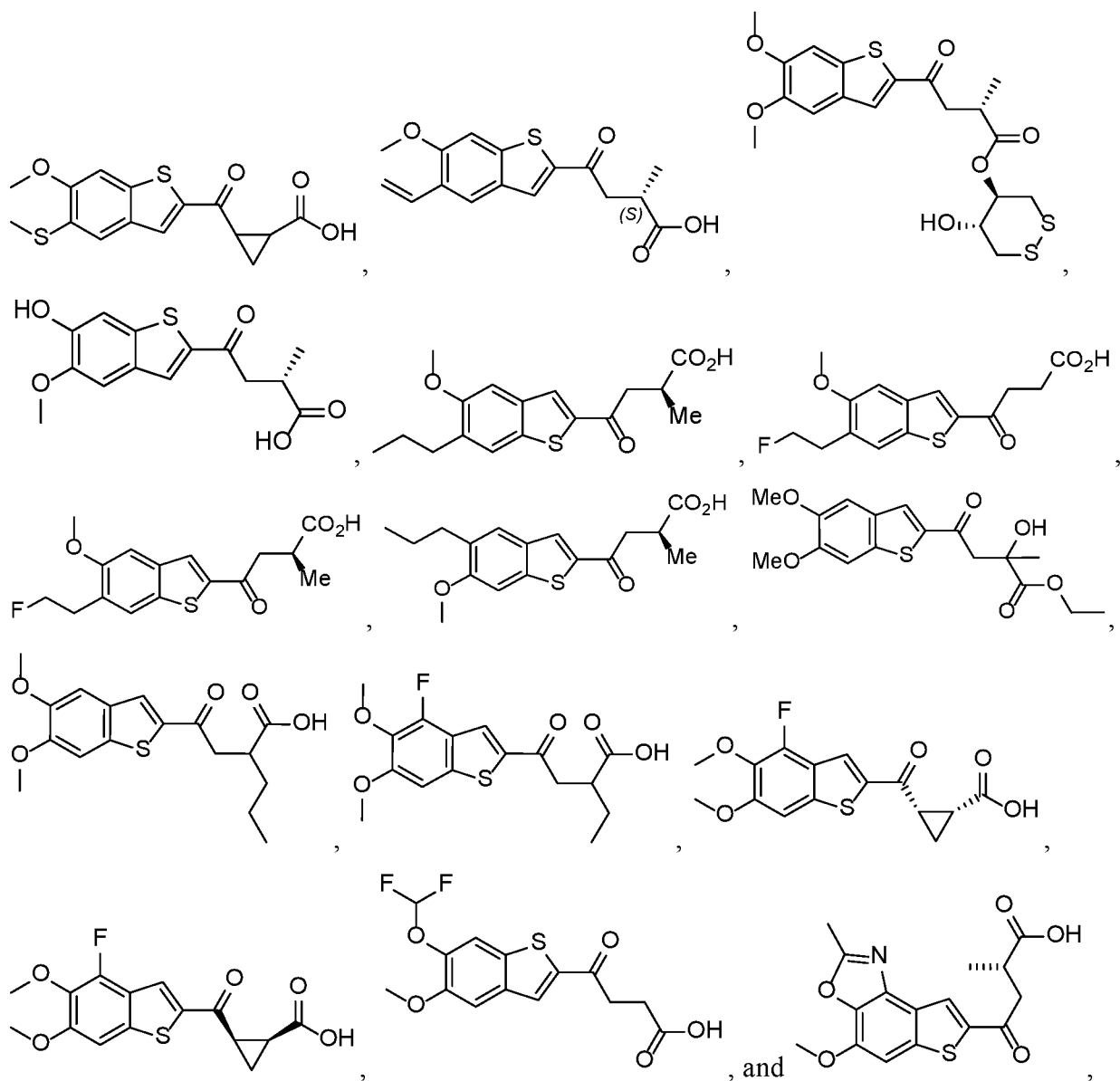
A sixth aspect of the sixth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound of general formula (I') above or a pharmaceutically acceptable salt thereof to the subject.

In each aspect of the sixth embodiment described herein, variables R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , R^9 , X^1 , X^2 , and X^3 of general formula (I'), and the various aspects and instances thereof, are each selected independently from each other, with the proviso that at least one of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 is not H.

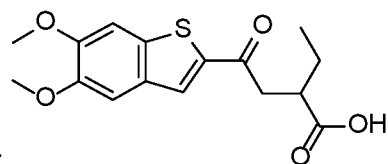
A seventh embodiment relates to a compound selected from the group consisting



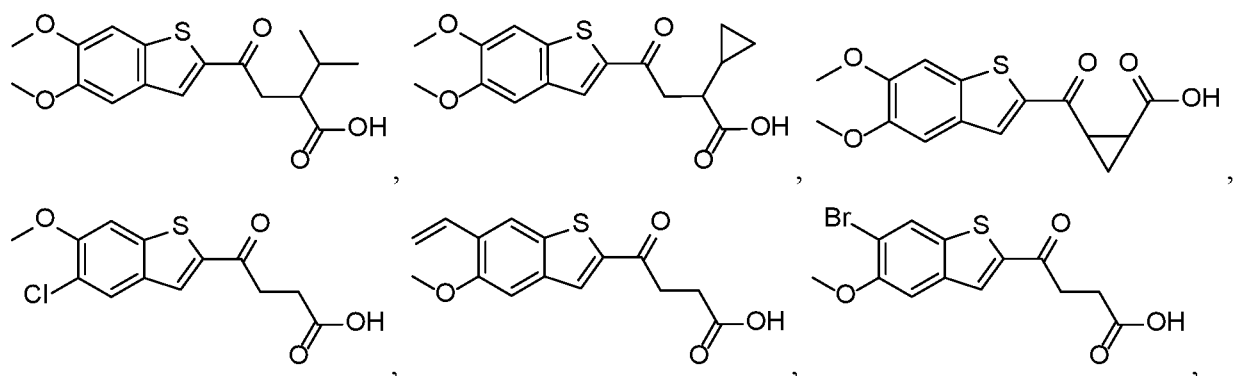


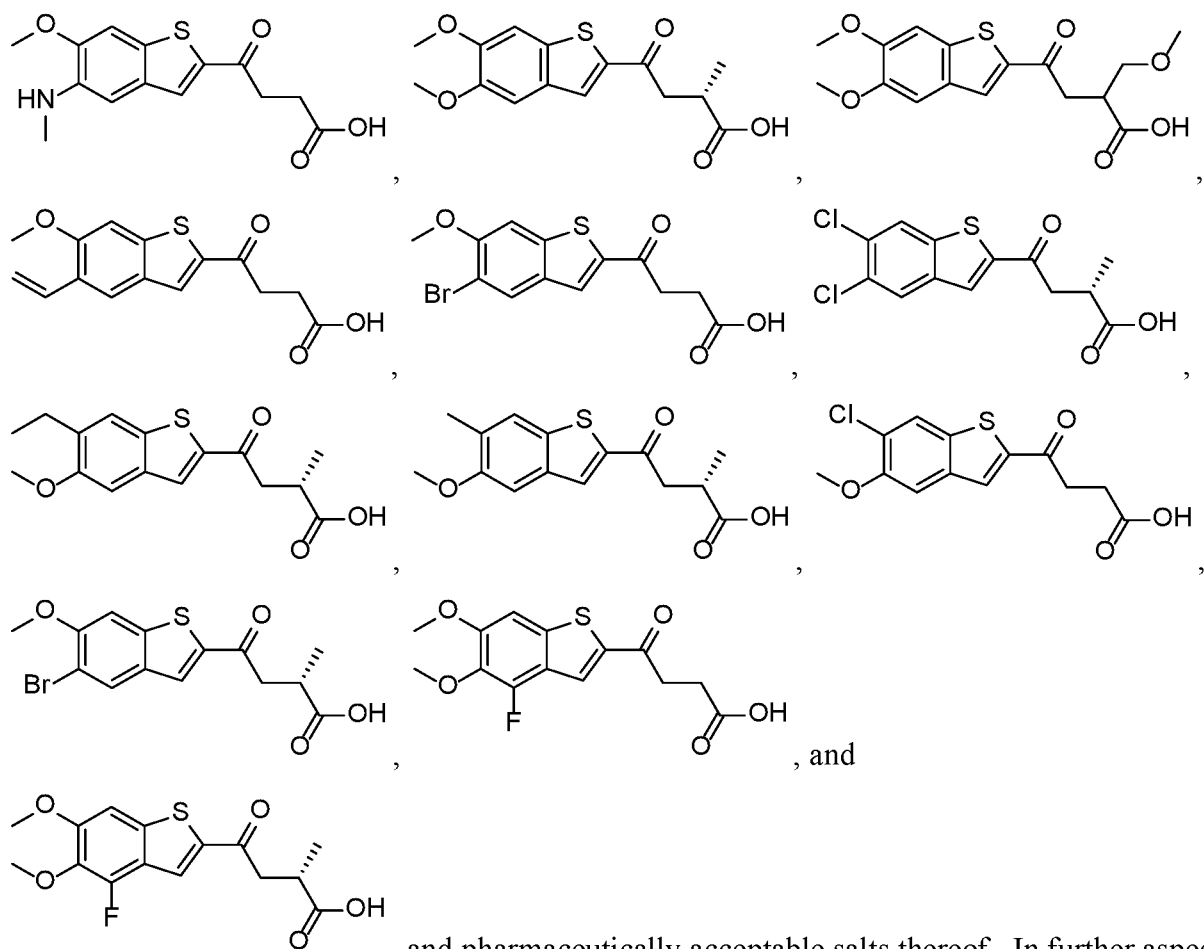


and pharmaceutically acceptable salts thereof. In aspects of this seventh embodiment, the

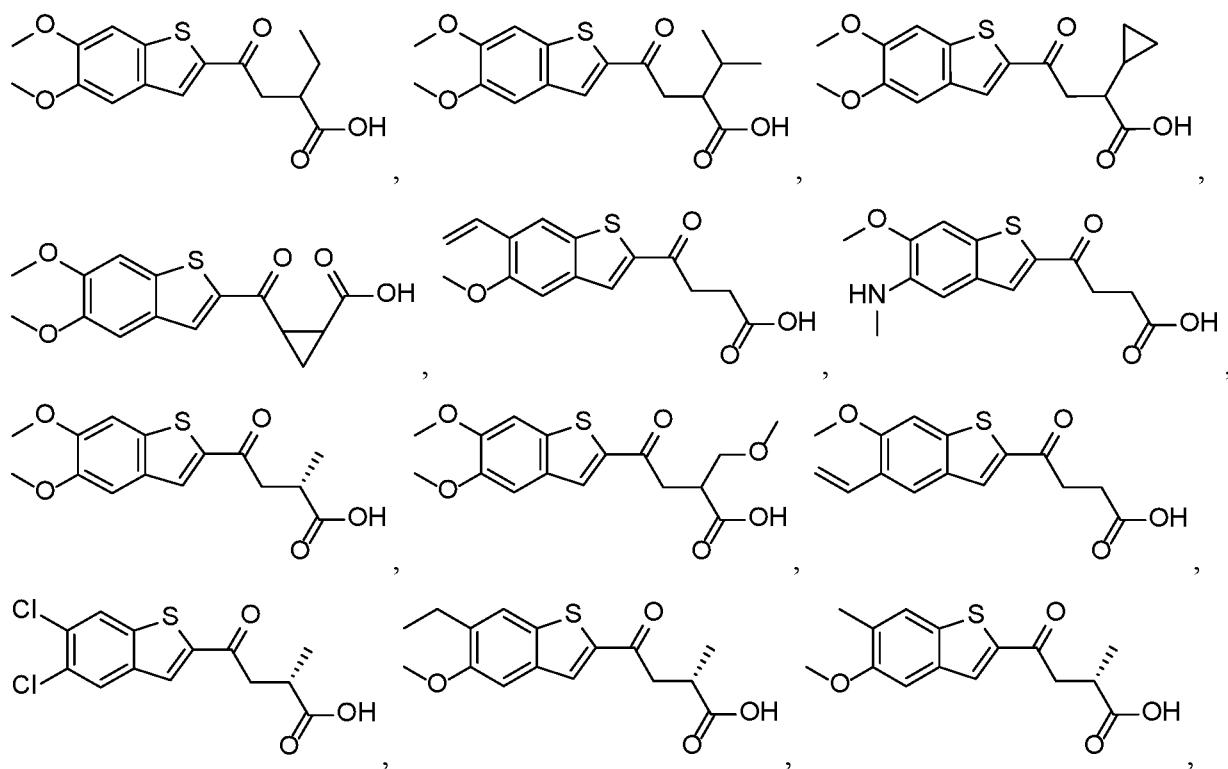


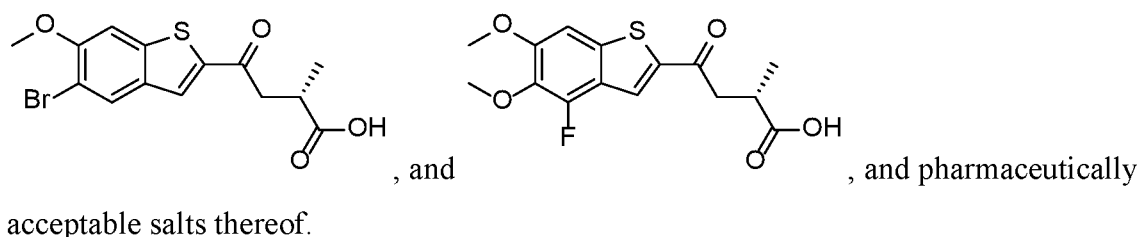
compound is selected from the group consisting of





of this embodiment, the compound is selected from the group consisting of





A first aspect of the seventh embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A second aspect of the seventh embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A third aspect of the seventh embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A fourth aspect of the seventh embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A fifth aspect of the seventh embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A sixth aspect of the seventh embodiment relates to methods of inducing a STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the seventh embodiment above or a pharmaceutically acceptable salt thereof to the subject.

An eighth embodiment relates to a compound selected from the exemplary species depicted in Examples 1 through 54 shown below.

A first aspect of the eighth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a

compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A second aspect of the eighth embodiment relates to methods of inducing an immune response in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A third aspect of the eighth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A fourth aspect of the eighth embodiment relates to methods of inducing STING-dependent type I interferon production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A fifth aspect of the eighth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

A sixth aspect of the eighth embodiment relates to methods of inducing STING-dependent cytokine production in a subject, comprising administering a therapeutically effective amount of a composition comprising a compound according to the eighth embodiment above or a pharmaceutically acceptable salt thereof to the subject.

Other embodiments of the present disclosure include the following:

(a) A pharmaceutical composition comprising an effective amount of a compound of general formula (Ia), or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

(b) A pharmaceutical composition comprising an effective amount of a compound of general formula (Ia'), or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

(c) A pharmaceutical composition comprising an effective amount of a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

(d) A pharmaceutical composition comprising an effective amount of a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

(e) The pharmaceutical composition of (a), further comprising an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents.

(f) The pharmaceutical composition of (b), further comprising an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents.

(g) The pharmaceutical composition of (c), further comprising an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents.

(h) The pharmaceutical composition of (d), further comprising an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents.

(i) A pharmaceutical combination that is (i) a compound of general formula (Ia), or a pharmaceutically acceptable salt thereof, and (ii) an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents; wherein the compound of general formula (Ia), or pharmaceutically acceptable salt thereof, and the active agent are each employed in an amount that renders the combination effective for inducing an immune response in a patient.

(j) A pharmaceutical combination that is (i) a compound of general formula (Ia'), or a pharmaceutically acceptable salt thereof, and (ii) an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents; wherein the compound of general formula (Ia), or pharmaceutically acceptable salt thereof, and the active agent are each employed in an amount that renders the combination effective for inducing an immune response in a patient.

(k) A pharmaceutical combination that is (i) a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof, and (ii) an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents; wherein the compound of general formula (Ib), or pharmaceutically acceptable salt thereof, and the active agent are each employed in an amount that renders the combination effective for inducing an immune response in a patient.

(l) A pharmaceutical combination that is (i) a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof, and (ii) an active agent selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer and chemotherapeutic agents; wherein the compound of general formula (Ib), or pharmaceutically acceptable salt thereof, and the active agent are each employed in an amount that renders the combination effective for inducing an immune response in a patient.

(m) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ia), or a pharmaceutically acceptable salt thereof.

(n) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ia'), or a pharmaceutically acceptable salt thereof.

(o) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof.

(p) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof.

(q) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (I), or a pharmaceutically acceptable salt thereof.

(r) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (I'), or a pharmaceutically acceptable salt thereof.

(s) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (a), a composition of (e), or a combination of (i).

5 (t) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (b), a composition of (f), or a combination of (j).

(u) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (c), a composition of (g), or a combination of (k).

10 (v) A method of inducing an immune response in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (d), a composition of (h), or a combination of (l).

(w) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a
15 compound of general formula (Ia), or a pharmaceutically acceptable salt thereof.

(x) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ia'), or a pharmaceutically acceptable salt thereof.

20 (y) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof.

(z) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof.

25 (a1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (I), or a pharmaceutically acceptable salt thereof.

(b1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a
30 compound of general formula (I'), or a pharmaceutically acceptable salt thereof.

(c1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (a), a composition of (e), or a combination of (i).

(d1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (b), a composition of (f), or a combination of (j).

5 (e1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (c), a composition of (g), or a combination of (k).

(f1) A method of inducing STING-dependent type I interferon production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (d), a composition of (h), or a combination of (l).

10 (g1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ia), or a pharmaceutically acceptable salt thereof.

(h1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound
15 of general formula (Ia'), or a pharmaceutically acceptable salt thereof.

(i1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof.

20 (j1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof.

(k1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (I), or a pharmaceutically acceptable salt thereof.

25 (l1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a compound of general formula (I'), or a pharmaceutically acceptable salt thereof.

(m1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition
30 of (a), a composition of (e), or a combination of (i).

(n1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (b), a composition of (f), or a combination of (j).

(o1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (c), a composition of (g), or a combination of (k).

5 (p1) A method of inducing STING-dependent cytokine production in a patient, which comprises administering to the subject a therapeutically effective amount of a composition of (d), a composition of (h), or a combination of (l).

(q1) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (Ia), or a pharmaceutically acceptable salt thereof to the subject;

10 (r1) The method of (q1), wherein the cell proliferation disorder is cancer.

(s1) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (Ia'), or a pharmaceutically acceptable salt thereof to the subject;

(t1) The method of (s1), wherein the cell proliferation disorder is cancer.

15 (u1) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (Ib), or a pharmaceutically acceptable salt thereof to the subject;

(v1) The method of (u1), wherein the cell proliferation disorder is cancer.

20 (w1) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (Ib'), or a pharmaceutically acceptable salt thereof to the subject;

(x1) The method of (w1), wherein the cell proliferation disorder is cancer.

25 (y1) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (I), or a pharmaceutically acceptable salt thereof to the subject;

(z1) The method of (y1), wherein the cell proliferation disorder is cancer.

(a2) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound of general formula (I'), or a pharmaceutically acceptable salt thereof to the subject;

30 (b2) The method of (a2), wherein the cell proliferation disorder is cancer.

(c2) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a composition of (a), a composition of (e), or a combination of (i) to the subject.

(d2) The method of (c2), wherein the cell proliferation disorder is cancer.

(e2) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a composition of (b), a composition of (f), or a combination of (j) to the subject.

5 (f2) The method of (e2), wherein the cell proliferation disorder is cancer.

(g2) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a composition of (c), a composition of (g), or a combination of (k) to the subject.

(h2) The method of (g2), wherein the cell proliferation disorder is cancer.

10 (i2) A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a composition of (d), a composition of (h), or a combination of (l) to the subject.

(j2) The method of (i2), wherein the cell proliferation disorder is cancer.

The present disclosure also includes a compound of the present disclosure for use

15 (i) in, (ii) as a medicament for, or (iii) in the preparation of a medicament for: (a) inducing an immune response in a patient, or (b) inducing STING-dependent cytokine production in a patient. In these uses, the compounds of the present disclosure can optionally be employed in combination with one or more active agents selected from STING agonist compounds, anti-viral compounds, antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other
20 immunomodulatory agents, lipids, liposomes, peptides, anti-cancer agents, and chemotherapeutic agents.

Additional embodiments of the disclosure include the pharmaceutical compositions, combinations and methods set forth in (a) through (j2) above and the uses set forth in the preceding paragraph, wherein the compound of the present disclosure employed therein is
25 a compound of one of the embodiments, aspects, instances, occurrences, or features of the compounds described above. In all of these embodiments, the compound may optionally be used in the form of a pharmaceutically acceptable salt, as appropriate.

In the embodiments of the compound provided above, it is to be understood that each embodiment may be combined with one or more other embodiments, to the extent that such
30 a combination provides a stable compound and is consistent with the description of the embodiments. It is further to be understood that the embodiments of compositions and methods provided as (a) through (j2) above are understood to include all embodiments of the compounds, including such embodiments as result from combinations of embodiments.

The term “subject” (alternatively “patient”) as used herein refers to a mammal that has been the object of treatment, observation, or experiment. The mammal may be male or female. The mammal may be one or more selected from the group consisting of humans, bovine (*e.g.*, cows), porcine (*e.g.*, pigs), ovine (*e.g.*, sheep), capra (*e.g.*, goats), equine (*e.g.*, horses),
5 canine (*e.g.*, domestic dogs), feline (*e.g.*, house cats), Lagomorpha (rabbits), rodents (*e.g.*, rats or mice), *Procyon lotor* (*e.g.*, raccoons). In particular embodiments, the subject is human.

As used herein, the term “immune response” relates to any one or more of the following: specific immune response, non-specific immune response, both specific and non-specific response, innate response, primary immune response, adaptive immunity, secondary
10 immune response, memory immune response, immune cell activation, immune cell proliferation, immune cell differentiation, and cytokine expression. In certain embodiments, a compound of general formula (Ia), a compound of general formula (Ia’), a compound of general formula (Ib), a compound of general formula (Ib’), a compound of general formula (I), a compound of general formula (I’), or a pharmaceutically acceptable salt of the foregoing, is administered in
15 conjunction with one or more additional therapeutic agents including anti-viral compounds, vaccines intended to stimulate an immune response to one or more predetermined antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer agents, and chemotherapeutic agents, etc. In certain
20 embodiments, a compound of general formula (Ia), a compound of general formula (Ia’), a compound of general formula (Ib), a compound of general formula (Ib’), a compound of general formula (I), a compound of general formula (I’), or a pharmaceutically acceptable salt of the foregoing, is administered in conjunction with one or more additional compositions including
25 anti-viral compounds, vaccines intended to stimulate an immune response to one or more predetermined antigens, adjuvants, CTLA-4 and PD-1 pathway antagonists and other immunomodulatory agents, lipids, liposomes, peptides, anti-cancer agents, and chemotherapeutic agents, etc.

Compounds

The term “alkyl” refers to a monovalent straight or branched chain, saturated
30 aliphatic hydrocarbon radical having a number of carbon atoms in the specified range. Thus, for example, “C₁₋₆ alkyl” (or “C₁-C₆ alkyl”) refers to any of the hexyl alkyl and pentyl alkyl isomers as well as *n*-, *iso*-, *sec*- and *tert*-butyl, *n*- and *iso*-propyl, ethyl, and methyl. As another example, “C₁₋₄ alkyl” refers to *n*-, *iso*-, *sec*- and *tert*-butyl, *n*- and isopropyl, ethyl, and methyl.

As used herein, the term “alkylene” refers to a bivalent straight chain, saturated aliphatic hydrocarbon radical having a number of carbon atoms in the specified range.

As used herein, the term “alkenyl” refers to a monovalent straight or branched chain, unsaturated aliphatic hydrocarbon radical having a number of carbon atoms in the specified range and including one or more double bonds.

As used herein, the term “alkenylene” refers to a bivalent straight chain, unsaturated aliphatic hydrocarbon radical having a number of carbon atoms in the specified range and including one or more double bonds.

As used herein, the term “alkynyl” refers to a monovalent straight or branched chain, unsaturated aliphatic hydrocarbon radical having a number of carbon atoms in the specified range and including one or more triple bonds.

As used herein, the term “alkynylene” refers to a bivalent straight chain, unsaturated aliphatic hydrocarbon radical having a number of carbon atoms in the specified range and including one or more triple bonds.

The term “halogen” (or “halo”) refers to fluorine, chlorine, bromine, and iodine (alternatively referred to as fluoro, chloro, bromo, and iodo or F, Cl, Br, and I).

The term “haloalkyl” refers to an alkyl group as defined above in which one or more of the hydrogen atoms have been replaced with a halogen. Thus, for example, “C₁₋₆ haloalkyl” (or “C₁-C₆ haloalkyl”) refers to a C₁ to C₆ linear or branched alkyl group as defined above with one or more halogen substituents. The term “fluoroalkyl” has an analogous meaning except the halogen substituents are restricted to fluoro. Suitable fluoroalkyls include the series (CH₂)₀₋₄CF₃ (*i.e.*, trifluoromethyl, 2,2,2-trifluoroethyl, 3,3,3-trifluoro-n-propyl, etc.).

As used herein, the term “haloalkenyl” refers to an alkenyl group as defined above in which one or more of the hydrogen atoms have been replaced with a halogen.

As used herein, the term “haloalkynyl” refers to an alkynyl group as defined above in which one or more of the hydrogen atoms have been replaced with a halogen.

As used herein, the term “alkoxy” as used herein, alone or in combination, includes an alkyl group connected to the oxy connecting atom. The term “alkoxy” also includes alkyl ether groups, where the term ‘alkyl’ is defined above, and ‘ether’ means two alkyl groups with an oxygen atom between them. Examples of suitable alkoxy groups include methoxy, ethoxy, n-propoxy, i-propoxy, n-butoxy, s-butoxy, t-butoxy, methoxymethane (also referred to as ‘dimethyl ether’), and methoxyethane (also referred to as ‘ethyl methyl ether’).

As used herein, the term “cycloalkyl” refers to a saturated hydrocarbon containing one ring having a specified number of carbon atoms. Examples of cycloalkyl include cyclopropyl, cyclobutyl, cyclopentyl, and cyclohexyl.

As used herein, the term “heterocycle”, “heterocyclyl”, or “heterocyclic”, as used herein, represents a stable 3- to 6-membered monocyclic that is either saturated or unsaturated, and that consists of carbon atoms and from one to two heteroatoms selected from the group consisting of N, O, and S. The heterocyclic ring may be attached at any heteroatom or carbon atom which results in the creation of a stable structure. The term includes heteroaryl moieties. Examples of such heterocyclic elements include, but are not limited to, azepinyl, benzimidazolyl, benzisoxazolyl, benzofurazanyl, benzopyranyl, benzothiopyranyl, benzofuryl, benzothiazolyl, benzothienyl, benzoxazolyl, chromanyl, cinnoliny, dihydrobenzofuryl, dihydrobenzothienyl, dihydrobenzothiopyranyl, dihydrobenzothiopyranyl sulfone, 1,3-dioxolanyl, furyl, imidazolidinyl, imidazoliny, imidazolyl, indoliny, indolyl, isochromanyl, isoindoliny, isoquinoliny, isothiazolidinyl, isothiazolyl, isothiazolidinyl, morpholiny, naphthyridiny, oxadiazolyl, 2-oxoazepiny, oxazolyl, 2-oxopiperaziny, 2-oxopiperdiny, 2-oxopyrrolidinyl, piperidyl, piperaziny, pyridyl, pyraziny, pyrazolidiny, pyrazolyl, pyridaziny, pyrimidinyl, pyrrolidinyl, pyrroly, quinazoliny, quinoliny, quinoxaliny, tetrahydrofuryl, tetrahydroisoquinoliny, tetrahydroquinoliny, thiamorpholiny, thiamorpholiny sulfoxide, thiazolyl, thiazoliny, thienofuryl, thienothienyl, triazolyl and thienyl.

As used herein, the term “fused ring” refers to a cyclic group formed by substituents on separate atoms in a straight or branched alkane, or to a cyclic group formed by substituents on separate atoms in another ring.

As used herein, the term “spirocycle” or “spirocyclic ring” refers to a pendant cyclic group formed by substituents on a single atom.

Unless expressly stated to the contrary, all ranges cited herein are inclusive; *i.e.*, the range includes the values for the upper and lower limits of the range as well as all values in between. As an example, temperature ranges, percentages, ranges of equivalents, and the like described herein include the upper and lower limits of the range and any value in the continuum there between. Numerical values provided herein, and the use of the term “about”, may include variations of $\pm 1\%$, $\pm 2\%$, $\pm 3\%$, $\pm 4\%$, $\pm 5\%$, $\pm 10\%$, $\pm 15\%$, and $\pm 20\%$ and their numerical equivalents.

As used herein, the term “one or more” item includes a single item selected from the list as well as mixtures of two or more items selected from the list.

In the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and pharmaceutically acceptable salts of the foregoing, the atoms may exhibit their natural isotopic abundances, or one or more of the atoms may be artificially enriched in a particular isotope having the same atomic number, but an atomic mass or mass number different from the atomic mass or mass number predominantly found in nature. The present disclosure is meant to include all suitable isotopic variations of the the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and pharmaceutically acceptable salts of the foregoing. For example, different isotopic forms of hydrogen (H) include protium (^1H), deuterium (^2H), and tritium (^3H). Protium is the predominant hydrogen isotope found in nature. Enriching for deuterium may afford certain therapeutic advantages, such as increasing *in vivo* half-life or reducing dosage requirements, or may provide a compound useful as a standard for characterization of biological samples. Isotopically-enriched the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and pharmaceutically acceptable salts of the foregoing, can be prepared without undue experimentation by conventional techniques well known to those skilled in the art or by processes analogous to those described in the Schemes and Examples herein using appropriate isotopically-enriched reagents and/or intermediates.

In particular embodiments of the the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and pharmaceutically acceptable salts of the foregoing, the compounds are isotopically enriched with deuterium. In aspects of these embodiments, one or more of R^1 , R^2 , R^3 , R^4 , R^5 , R^6 , R^8 , and R^9 may include deuterium.

As shown in the general structural formulas and the structures of specific compounds as provided herein, a straight line at a chiral center includes both (R) and (S) stereoisomers and mixtures thereof. Also, unless otherwise specified (*e.g.*, 100% purified compound), reference to a particular stereochemistry at a position provides a compound having the indicated stereochemistry but does not exclude the presence of stereoisomers having different stereochemistry at the indicated position.

Recitation or depiction of a specific compound in the claims (*i.e.*, a species) without a specific stereoconfiguration designation, or with such a designation for less than all chiral centers, is intended to encompass, for such undesignated chiral centers, the racemate, racemic mixtures, each individual enantiomer, a diastereoisomeric mixture and each individual diastereomer of the compound where such forms are possible due to the presence of one or more asymmetric centers. The separation of a mixture of stereoisomers can be carried out at an intermediate step during the synthesis of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, or it can be done on a final racemic product. Absolute stereochemistry may be determined by X-ray crystallography of crystalline products or crystalline intermediates, which are derivatized, if necessary, with a reagent containing a stereogenic center of known configuration. Alternatively, absolute stereochemistry may be determined by Vibrational Circular Dichroism (VCD) spectroscopy analysis. The present invention includes all such isomers, as well as salts, solvates (including hydrates), and solvated salts of such racemates, enantiomers, diastereomers, tautomers, and mixtures thereof.

The invention includes all possible enantiomers and diastereomers and mixtures of two or more stereoisomers, for example mixtures of enantiomers and/or diastereomers, in all ratios. Thus, enantiomers are a subject of the invention in enantiomerically pure form, both as levorotatory and as dextrorotatory antipodes, in the form of racemates and in the form of mixtures of the two enantiomers in all ratios. In the case of a cis/trans isomerism, the invention includes both the cis form and the trans form, as well as mixtures of these forms in all ratios. The preparation of individual stereoisomers can be carried out, if desired, by separation of a mixture by customary methods, for example by chromatography or crystallization, by the use of stereochemically uniform starting materials for the synthesis or by stereoselective synthesis. Optionally a derivatization can be carried out before a separation of stereoisomers. The separation of a mixture of stereoisomers can be carried out at an intermediate step during the synthesis of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, or it can be done on a final racemic product. Absolute stereochemistry may be determined by X-ray crystallography of crystalline products or crystalline intermediates that are derivatized, if necessary, with a reagent containing a stereogenic center of known configuration.

Unless a particular isomer, salt, solvate (including hydrates) or solvated salt of such racemate, enantiomer, or diastereomer is indicated, the present invention includes all such isomers, as well as salts, solvates (including hydrates), and solvated salts of such racemates, enantiomers, diastereomers, and mixtures thereof.

5 The term “compound” refers to the compound and, in certain embodiments, to the extent they are stable, any hydrate or solvate thereof. A hydrate is the compound complexed with water, and a solvate is the compound complexed with a solvent, which may be an organic solvent or an inorganic solvent.

10 A “stable” compound is a compound that can be prepared and isolated and whose structure and properties remain or can be caused to remain essentially unchanged for a period of time sufficient to allow use of the compound for the purposes described herein (*e.g.*, therapeutic administration to a subject). The compounds of the present invention are limited to stable compounds embraced by general formula (Ia), general formula (Ia’), general formula (Ib), general formula (Ib’), general formula (I), and general formula (I’), or pharmaceutically
15 acceptable salts thereof.

Salts

As indicated above, the compounds of the present invention can be employed in the form of pharmaceutically acceptable salts. Those skilled in the art will recognize those
20 instances in which the compounds of the invention may form salts. Examples of such compounds are described herein by reference to possible salts. Such reference is for illustration only. Pharmaceutically acceptable salts can be used with compounds for treating patients. Non-pharmaceutical salts may, however, be useful in the preparation of intermediate compounds.

25 The term “pharmaceutically acceptable salt” refers to a salt (including an inner salt such as a zwitterion) that possesses effectiveness similar to the parent compound and that is not biologically or otherwise undesirable (*e.g.*, is neither toxic nor otherwise deleterious to the recipient thereof). Thus, an embodiment of the invention provides pharmaceutically acceptable salts of the compounds of the invention. The term “salt(s)”, as employed herein, denotes any of the following: acidic salts formed with inorganic and/or organic acids, as well as basic salts
30 formed with inorganic and/or organic bases. Salts of compounds of the invention may be formed by methods known to those of ordinary skill in the art, for example, by reacting a compound of the invention with an amount of acid or base, such as an equivalent amount, in a medium such as one in which the salt precipitates or in aqueous medium followed by lyophilization.

Exemplary acid addition salts include acetates, ascorbates, benzoates, benzenesulfonates, bisulfates, borates, butyrates, citrates, camphorates, camphorsulfonates, fumarates, hydrochlorides, hydrobromides, hydroiodides, lactates, maleates, methanesulfonates (“mesylates”), naphthalenesulfonates, nitrates, oxalates, phosphates, propionates, salicylates, succinates, sulfates, tartarates, thiocyanates, toluenesulfonates (also known as tosylates) and the like. Suitable salts include acid addition salts that may, for example, be formed by mixing a solution of a compound with a solution of a pharmaceutically acceptable acid such as hydrochloric acid, sulfuric acid, acetic acid, trifluoroacetic acid, or benzoic acid. Additionally, acids that are generally considered suitable for the formation of pharmaceutically useful salts from basic pharmaceutical compounds are discussed, for example, by P. Stahl *et al*, Camille G. (eds.), *Handbook of Pharmaceutical Salts. Properties, Selection and Use*. (2002) Zurich: Wiley-VCH; S. Berge *et al*, *Journal of Pharmaceutical Sciences* (1977) 66(1) 1-19; P. Gould, *International J. of Pharmaceutics* (1986) 33 201-217; Anderson *et al*, *The Practice of Medicinal Chemistry* (1996), Academic Press, New York; and in *The Orange Book* (Food & Drug Administration, Washington, D.C. on their website). These disclosures are incorporated herein by reference thereto.

Exemplary basic salts include ammonium salts, alkali metal salts such as sodium, lithium, and potassium salts, alkaline earth metal salts such as calcium and magnesium salts, salts with organic bases (for example, organic amines) such as dicyclohexylamine, *t*-butyl amine, choline, and salts with amino acids such as arginine, lysine and the like. Basic nitrogen-containing groups may be quarternized with agents such as lower alkyl halides (*e.g.*, methyl, ethyl, and butyl chlorides, bromides and iodides), dialkyl sulfates (*e.g.*, dimethyl, diethyl, and dibutyl sulfates), long chain halides (*e.g.*, decyl, lauryl, and stearyl chlorides, bromides and iodides), aralkyl halides (*e.g.*, benzyl and phenethyl bromides), and others. Compounds carrying an acidic moiety can be mixed with suitable pharmaceutically acceptable salts to provide, for example, alkali metal salts (*e.g.*, sodium or potassium salts), alkaline earth metal salts (*e.g.*, calcium or magnesium salts), and salts formed with suitable organic ligands such as quaternary ammonium salts. Also, in the case of an acid (-COOH) or alcohol group being present, pharmaceutically acceptable esters can be employed to modify the solubility or hydrolysis characteristics of the compound.

All such acid salts and base salts are intended to be pharmaceutically acceptable salts within the scope of the invention and all acid and base salts are considered equivalent to the free forms of the corresponding compounds for purposes of the invention.

In addition, when a compound of the invention contains both a basic moiety, such as, but not limited to an aliphatic primary, secondary, tertiary or cyclic amine, an aromatic or heteroaryl amine, pyridine or imidazole, and an acidic moiety, such as, but not limited to tetrazole or carboxylic acid, zwitterions (“inner salts”) may be formed and are included within the terms “salt(s)” as used herein. It is understood that certain compounds of the invention may exist in zwitterionic form, having both anionic and cationic centers within the same compound and a net neutral charge. Such zwitterions are included within the invention.

Methods of Preparing Compounds

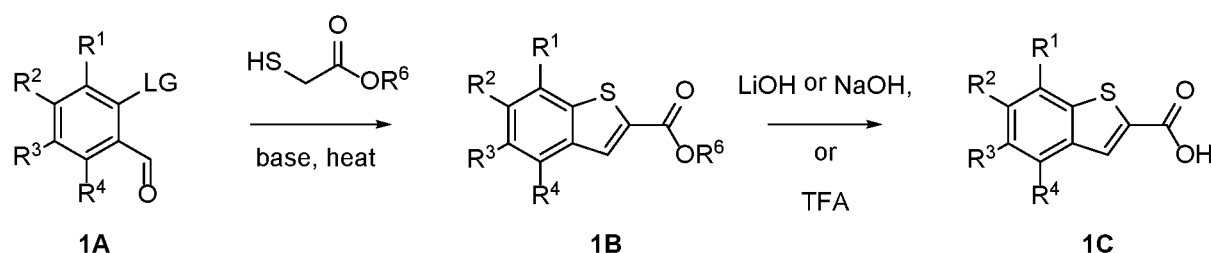
Several methods for preparing the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and pharmaceutically acceptable salts of the foregoing, are described in the following Schemes and Examples. Starting materials and intermediates are purchased from commercial sources, made from known procedures, or are otherwise illustrated. In some cases the order of carrying out the steps of the reaction schemes may be varied to facilitate the reaction or to avoid unwanted reaction products.

In the following Methods and Schemes, LG represents a leaving group, which may be a halide or triflate group. The variables R^1 , R^2 , R^3 , R^4 , R^6 , R^8 , and X^2 , have the same meaning as provided above.

Method 1

Benzo[*b*]thiophene 2-carboxylic acids b, and pharmaceutically acceptable salts thereof, are typically prepared from *ortho*-halo benzaldehydes. The sequence starts with treatment with an alpha-thio acetic acid ester under basic conditions. The ester in the resulting compound was cleaved to the carboxylic acid under basic conditions to provide the desired substituted benzo[*b*]thiophene 2-carboxylic acid 1C.

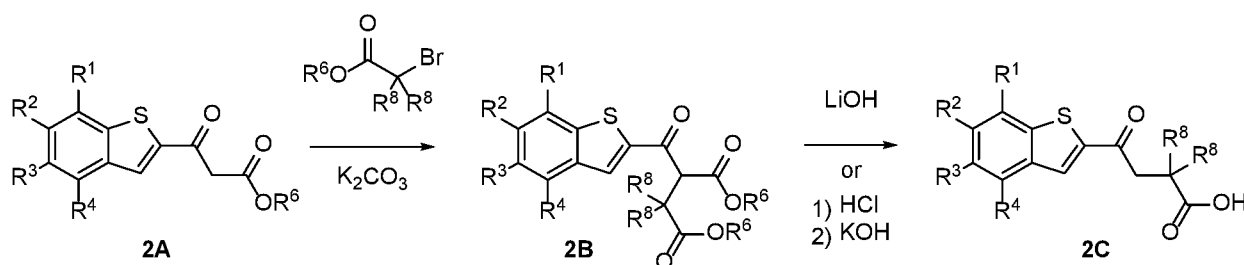
SCHEME 1



Method 2

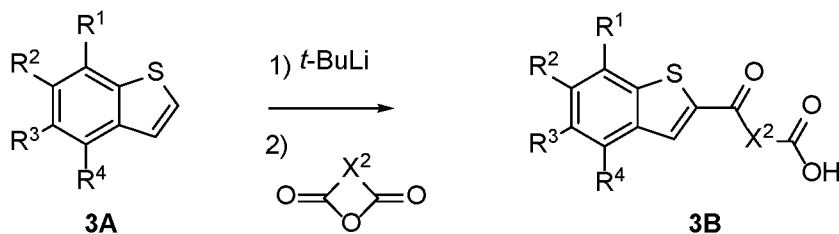
Another method for the preparation of benzo[b]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, is detailed in Scheme 2. The sequence starts with a benzo[b]thiophene substituted at the 2-position with an appropriate 1,3-dicarbonyl group, such as a beta-keto ester. It was reacted with an alpha-halo ester under basic conditions to afford substitution at the 2 position of the alkyl chain. Then, both esters were hydrolyzed using either acidic or basic conditions; upon further exposure to basic conditions, the carboxylic acid corresponding to the ester in the starting material underwent decarboxylation to give the desired benzo[b]thiophene keto acid 2C.

SCHEME 2

Method 3

Another method for the preparation of benzo[b]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, is detailed in Scheme 3. The sequence starts with a benzo[b]thiophene without substitution at the 2 position. It was treated with *tert*-butyllithium followed by a cyclic acid anhydride to give the desired 4-keto carboxylic acid product 3B.

SCHEME 3

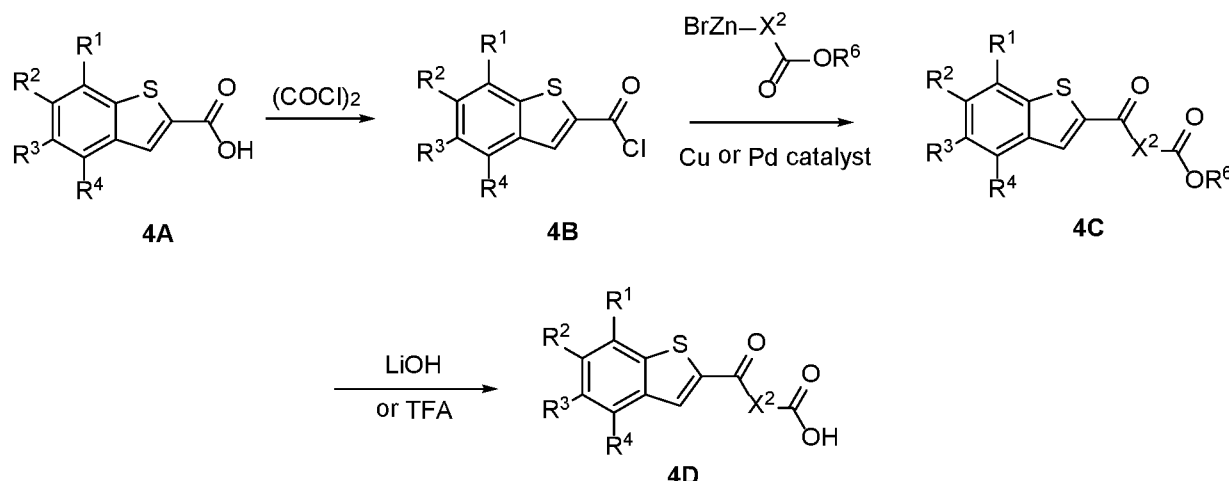
Method 4

Another method for the preparation of benzo[b]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, is detailed in Scheme 4. The sequence starts with a benzo[b]thiophene substituted with a carboxylic acid at the 2 position. It was treated with oxalyl

chloride/dichloromethane. The resulting acid chloride was reacted with an alkyl zinc reagent, typically containing an ester, using a transition metal such as copper or palladium to mediate the coupling. Then, the ester was cleaved under basic or acidic conditions to provide the desired benzo[*b*]thiophene gamma-keto acid 4D.

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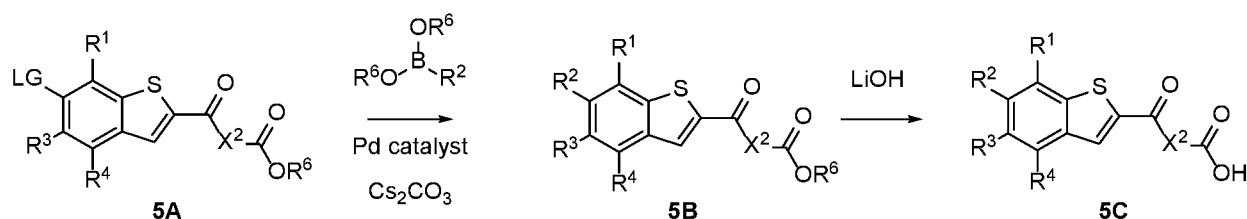
SCHEME 4



Method 5

Another method for the preparation of benzo[*b*]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, is detailed in Scheme 5. The sequence starts with a benzo[*b*]thiophene substituted at the 2 position with a gamma-keto ester and with a halide or triflate on the benzo[*b*]thiophene. It was treated with a boronic ester, acid, or trifluoroborate salt and a palladium catalyst under aqueous basic conditions. Then the ester in the resulting compound was cleaved to the carboxylic acid under basic conditions to provide the desired substituted benzo[*b*]thiophene 5C. The following scheme depicts introduction of the R² substituent, but this same general method couple bring in certain R³ substituents as well when employing a related substrate with an appropriately placed LG.

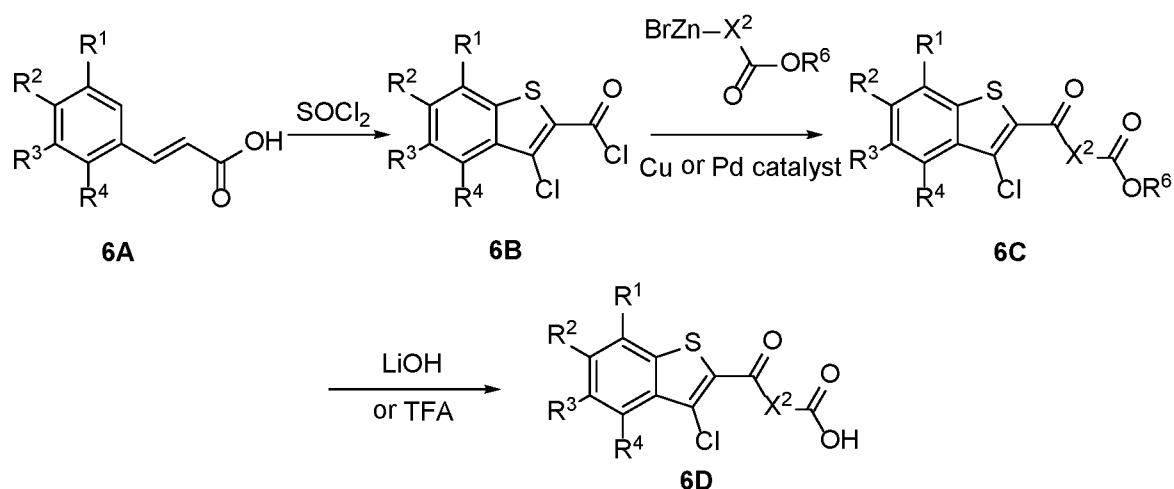
SCHEME 5



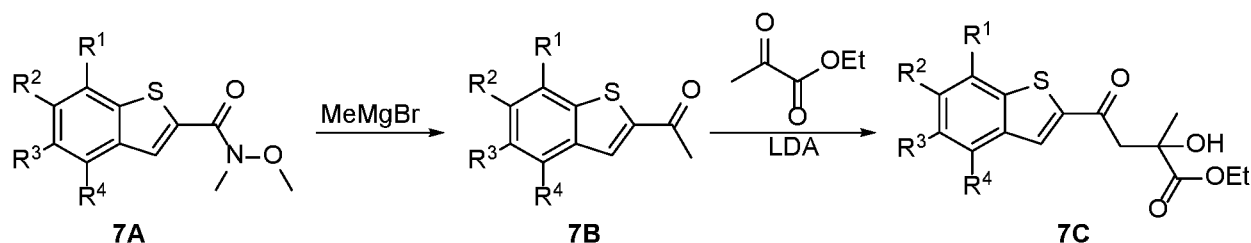
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Method 6

Another method for the preparation of benzo[b]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, involves the cyclization of a cinnamic acid in the presence of thionyl chloride. The resulting acid chloride was reacted with an alkyl zinc reagent, typically containing an ester, using a transition metal such as copper or palladium to mediate the coupling. Then, the ester was cleaved under basic or acidic conditions to provide the desired benzo[b]thiophene gamma-keto acid 6D.

SCHEME 6Method 7

Another method for the preparation of benzo[b]thiophene 2-carboxylic acids, and pharmaceutically acceptable salts thereof, is detailed in Scheme 7. The sequence starts with a Grignard reaction with the Weinreb amide 7A to provide the methyl ketone 7B. Deprotonation of the ketone with LDA followed by the addition of ethyl pyruvate gives 7C.

SCHEME 7Methods of Use

Compounds described herein having therapeutic applications, such as the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of

general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), the compounds of the Examples 1 through 54, and pharmaceutically acceptable salts of the foregoing, may be administered to a patient for the purpose of inducing an immune response, inducing STING-dependent cytokine production and/or inducing anti-tumor activity. The term "administration" and variants thereof (*e.g.*, "administering" a compound) means providing the compound to the individual in need of treatment. When a compound is provided in combination with one or more additional active agents (*e.g.*, antiviral agents useful for treating HCV infection or anti-tumor agents for treating cancers), "administration" and its variants are each understood to include concurrent and sequential provision of the compound or salt and other agents.

The compounds disclosed herein may be STING agonists. These compounds are potentially useful in treating diseases or disorders including, but not limited to, cell proliferation disorders. Cell-proliferation disorders include, but are not limited to, cancers, benign papillomatosis, gestational trophoblastic diseases, and benign neoplastic diseases, such as skin papilloma (warts) and genital papilloma.

In specific embodiments, the disease or disorder to be treated is a cell proliferation disorder. In certain embodiments, the cell proliferation disorder is cancer. In particular embodiments, the cancer is selected from brain and spinal cancers, cancers of the head and neck, leukemia and cancers of the blood, skin cancers, cancers of the reproductive system, cancers of the gastrointestinal system, liver and bile duct cancers, kidney and bladder cancers, bone cancers, lung cancers, malignant mesothelioma, sarcomas, lymphomas, glandular cancers, thyroid cancers, heart tumors, germ cell tumors, malignant neuroendocrine (carcinoid) tumors, midline tract cancers, and cancers of unknown primary (*i.e.*, cancers in which a metastasized cancer is found but the original cancer site is not known). In particular embodiments, the cancer is present in an adult patient; in additional embodiments, the cancer is present in a pediatric patient. In particular embodiments, the cancer is AIDS-related.

In specific embodiments, the cancer is selected from brain and spinal cancers. In particular embodiments, the cancer is selected from the group consisting of anaplastic astrocytomas, glioblastomas, astrocytomas, and esthesioneuroblastomas (also known as olfactory blastomas). In particular embodiments, the brain cancer is selected from the group consisting of astrocytic tumor (*e.g.*, pilocytic astrocytoma, subependymal giant-cell astrocytoma, diffuse astrocytoma, pleomorphic xanthoastrocytoma, anaplastic astrocytoma, astrocytoma, giant cell glioblastoma, glioblastoma, secondary glioblastoma, primary adult glioblastoma, and

primary pediatric glioblastoma), oligodendroglial tumor (*e.g.*, oligodendroglioma, and anaplastic oligodendroglioma), oligoastrocytic tumor (*e.g.*, oligoastrocytoma, and anaplastic oligoastrocytoma), ependymoma (*e.g.*, myxopapillary ependymoma, and anaplastic ependymoma); medulloblastoma, primitive neuroectodermal tumor, schwannoma, meningioma, atypical meningioma, anaplastic meningioma, pituitary adenoma, brain stem glioma, cerebellar astrocytoma, cerebral astrocytoma/malignant glioma, visual pathway and hypothalamic glioma, and primary central nervous system lymphoma. In specific instances of these embodiments, the brain cancer is selected from the group consisting of glioma, glioblastoma multiforme, paraganglioma, and supratentorial primordial neuroectodermal tumors (sPNET).

In specific embodiments, the cancer is selected from cancers of the head and neck, including nasopharyngeal cancers, nasal cavity and paranasal sinus cancers, hypopharyngeal cancers, oral cavity cancers (*e.g.*, squamous cell carcinomas, lymphomas, and sarcomas), lip cancers, oropharyngeal cancers, salivary gland tumors, cancers of the larynx (*e.g.*, laryngeal squamous cell carcinomas, rhabdomyosarcomas), and cancers of the eye or ocular cancers. In particular embodiments, the ocular cancer is selected from the group consisting of intraocular melanoma and retinoblastoma.

In specific embodiments, the cancer is selected from leukemia and cancers of the blood. In particular embodiments, the cancer is selected from the group consisting of myeloproliferative neoplasms, myelodysplastic syndromes, myelodysplastic/myeloproliferative neoplasms, acute myeloid leukemia (AML), myelodysplastic syndrome (MDS), chronic myelogenous leukemia (CML), myeloproliferative neoplasm (MPN), post-MPN AML, post-MDS AML, del(5q)-associated high risk MDS or AML, blast-phase chronic myelogenous leukemia, angioimmunoblastic lymphoma, acute lymphoblastic leukemia, Langerhans cell histiocytosis, hairy cell leukemia, and plasma cell neoplasms including plasmacytomas and multiple myelomas. Leukemias referenced herein may be acute or chronic.

In specific embodiments, the cancer is selected from skin cancers. In particular embodiments, the skin cancer is selected from the group consisting of melanoma, squamous cell cancers, and basal cell cancers.

In specific embodiments, the cancer is selected from cancers of the reproductive system. In particular embodiments, the cancer is selected from the group consisting of breast cancers, cervical cancers, vaginal cancers, ovarian cancers, prostate cancers, penile cancers, and testicular cancers. In specific instances of these embodiments, the cancer is a breast cancer selected from the group consisting of ductal carcinomas and phyllodes tumors. In specific

instances of these embodiments, the breast cancer may be male breast cancer or female breast cancer. In specific instances of these embodiments, the cancer is a cervical cancer selected from the group consisting of squamous cell carcinomas and adenocarcinomas. In specific instances of these embodiments, the cancer is an ovarian cancer selected from the group consisting of
5 epithelial cancers.

In specific embodiments, the cancer is selected from cancers of the gastrointestinal system. In particular embodiments, the cancer is selected from the group consisting of esophageal cancers, gastric cancers (also known as stomach cancers), gastrointestinal carcinoid tumors, pancreatic cancers, gallbladder cancers, colorectal cancers, and
10 anal cancer. In instances of these embodiments, the cancer is selected from the group consisting of esophageal squamous cell carcinomas, esophageal adenocarcinomas, gastric adenocarcinomas, gastrointestinal carcinoid tumors, gastrointestinal stromal tumors, gastric lymphomas, gastrointestinal lymphomas, solid pseudopapillary tumors of the pancreas, pancreatoblastoma, islet cell tumors, pancreatic carcinomas including acinar cell carcinomas and
15 ductal adenocarcinomas, gallbladder adenocarcinomas, colorectal adenocarcinomas, and anal squamous cell carcinomas.

In specific embodiments, the cancer is selected from liver and bile duct cancers. In particular embodiments, the cancer is liver cancer (also known as hepatocellular carcinoma). In particular embodiments, the cancer is bile duct cancer (also known as cholangiocarcinoma); in
20 instances of these embodiments, the bile duct cancer is selected from the group consisting of intrahepatic cholangiocarcinoma and extrahepatic cholangiocarcinoma.

In specific embodiments, the cancer is selected from kidney and bladder cancers. In particular embodiments, the cancer is a kidney cancer selected from the group consisting of renal cell cancer, Wilms tumors, and transitional cell cancers. In particular embodiments, the
25 cancer is a bladder cancer selected from the group consisting of urethelial carcinoma (a transitional cell carcinoma), squamous cell carcinomas, and adenocarcinomas.

In specific embodiments, the cancer is selected from bone cancers. In particular embodiments, the bone cancer is selected from the group consisting of osteosarcoma, malignant fibrous histiocytoma of bone, Ewing sarcoma, chordoma (cancer of the bone along the spine).

30 In specific embodiments, the cancer is selected from lung cancers. In particular embodiments, the lung cancer is selected from the group consisting of non-small cell lung cancer, small cell lung cancers, bronchial tumors, and pleuropulmonary blastomas.

In specific embodiments, the cancer is selected from malignant mesothelioma. In particular embodiments, the cancer is selected from the group consisting of epithelial mesothelioma and sarcomatoids.

5 In specific embodiments, the cancer is selected from sarcomas. In particular embodiments, the sarcoma is selected from the group consisting of central chondrosarcoma, central and periosteal chondroma, fibrosarcoma, clear cell sarcoma of tendon sheaths, and Kaposi's sarcoma.

10 In specific embodiments, the cancer is selected from lymphomas. In particular embodiments, the cancer is selected from the group consisting of Hodgkin lymphoma (*e.g.*, Reed-Sternberg cells), non-Hodgkin lymphoma (*e.g.*, diffuse large B-cell lymphoma, follicular lymphoma, mycosis fungoides, Sezary syndrome, primary central nervous system lymphoma), cutaneous T-cell lymphomas, primary central nervous system lymphomas.

15 In specific embodiments, the cancer is selected from glandular cancers. In particular embodiments, the cancer is selected from the group consisting of adrenocortical cancer (also known as adrenocortical carcinoma or adrenal cortical carcinoma), pheochromocytomas, paragangliomas, pituitary tumors, thymoma, and thymic carcinomas.

In specific embodiments, the cancer is selected from thyroid cancers. In particular embodiments, the thyroid cancer is selected from the group consisting of medullary thyroid carcinomas, papillary thyroid carcinomas, and follicular thyroid carcinomas.

20 In specific embodiments, the cancer is selected from germ cell tumors. In particular embodiments, the cancer is selected from the group consisting of malignant extracranial germ cell tumors and malignant extragonadal germ cell tumors. In specific instances of these embodiments, the malignant extragonadal germ cell tumors are selected from the group consisting of nonseminomas and seminomas.

25 In specific embodiments, the cancer is selected from heart tumors. In particular embodiments, the heart tumor is selected from the group consisting of malignant teratoma, lymphoma, rhabdomyosarcoma, angiosarcoma, chondrosarcoma, infantile fibrosarcoma, and synovial sarcoma.

30 In specific embodiments, the cell-proliferation disorder is selected from benign papillomatosis, benign neoplastic diseases and gestational trophoblastic diseases. In particular embodiments, the benign neoplastic disease is selected from skin papilloma (warts) and genital papilloma. In particular embodiments, the gestational trophoblastic disease is selected from the group consisting of hydatidiform moles, and gestational trophoblastic neoplasia (*e.g.*, invasive

moles, choriocarcinomas, placental-site trophoblastic tumors, and epithelioid trophoblastic tumors).

As used herein, the terms “treatment” and “treating” refer to all processes in which there may be a slowing, interrupting, arresting, controlling, or stopping of the progression of a disease or disorder described herein. The terms do not necessarily indicate a total elimination of all disease or disorder symptoms.

The terms “administration of” and or “administering” a compound should be understood to include providing a compound described herein, or a pharmaceutically acceptable salt thereof, and compositions of the foregoing to a subject.

The amount of a compound administered to a subject is an amount sufficient to induce an immune response and/or to induce STING-dependent type I interferon production in the subject. In an embodiment, the amount of a compound can be an “effective amount” or “therapeutically effective amount,” such that the subject compound is administered in an amount that will elicit, respectively, a biological or medical (*i.e.*, intended to treat) response of a tissue, system, animal, or human that is being sought by a researcher, veterinarian, medical doctor, or other clinician. An effective amount does not necessarily include considerations of toxicity and safety related to the administration of a compound.

An effective amount of a compound will vary with the particular compound chosen (*e.g.*, considering the potency, efficacy, and/or half-life of the compound); the route of administration chosen; the condition being treated; the severity of the condition being treated; the age, size, weight, and physical condition of the subject being treated; the medical history of the subject being treated; the duration of the treatment; the nature of a concurrent therapy; the desired therapeutic effect; and like factors and can be routinely determined by the skilled artisan.

The compounds disclosed herein may be administered by any suitable route including oral and parenteral administration. Parenteral administration is typically by injection or infusion and includes intravenous, intramuscular, and subcutaneous injection or infusion.

The compounds disclosed herein may be administered once or according to a dosing regimen where a number of doses are administered at varying intervals of time for a given period of time. For example, doses may be administered one, two, three, or four times per day. Doses may be administered until the desired therapeutic effect is achieved or indefinitely to maintain the desired therapeutic effect. Suitable dosing regimens for a compound disclosed herein depend on the pharmacokinetic properties of that compound, such as absorption, distribution and half-life, that can be determined by a skilled artisan. In addition, suitable dosing

regimens, including the duration such regimens are administered, for a compound disclosed herein depend on the disease or condition being treated, the severity of the disease or condition, the age and physical condition of the subject being treated, the medical history of the subject being treated, the nature of concurrent therapy, the desired therapeutic effect, and like factors within the knowledge and expertise of the skilled artisan. It will be further understood by such skilled artisans that suitable dosing regimens may require adjustment given an individual subject's response to the dosing regimen or over time as the individual subject needs change. Typical daily dosages may vary depending upon the particular route of administration chosen.

One embodiment of the present disclosure provides for a method of treating a cell proliferation disorder comprising administration of a therapeutically effective amount of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), and pharmaceutically acceptable salts of the foregoing, to a subject in need of treatment thereof. In embodiments, the disease or disorder to be treated is a cell proliferation disorder. In aspects of these embodiments, the cell proliferation disorder is cancer. In further aspects of these embodiments, the cancer is selected from brain and spinal cancers, cancers of the head and neck, leukemia and cancers of the blood, skin cancers, cancers of the reproductive system, cancers of the gastrointestinal system, liver and bile duct cancers, kidney and bladder cancers, bone cancers, lung cancers, malignant mesothelioma, sarcomas, lymphomas, glandular cancers, thyroid cancers, heart tumors, germ cell tumors, malignant neuroendocrine (carcinoid) tumors, midline tract cancers, and cancers of unknown primary.

In one embodiment, disclosed herein is the use of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, in a therapy. The compound may be useful in a method of inducing an immune response and/or inducing STING-dependent type I interferon production in a subject, such as a mammal in need of such inhibition, comprising administering an effective amount of the compound to the subject.

In one embodiment, disclosed herein is a pharmaceutical composition comprising at least one compound of general formula (Ia), at least one compound of general formula (Ia'), at least one compound of general formula (Ib), at least one compound of general formula (Ib'), at least one compound of general formula (I), at least one compound of general formula (I'), or at

least one pharmaceutically acceptable salt of the foregoing, for use in potential treatment to induce an immune response and/or to induce STING-dependent type I interferon production.

One embodiment disclosed herein is the use of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, in the manufacture of a medicament to induce an immune response and/or to induce STING-dependent type I interferon production. In embodiments, the disease or disorder to be treated is a cell proliferation disorder. In aspects of these embodiments, the cell proliferation disorder is cancer. In further aspects of these embodiments, the cancer is selected from brain and spinal cancers, cancers of the head and neck, leukemia and cancers of the blood, skin cancers, cancers of the reproductive system, cancers of the gastrointestinal system, liver and bile duct cancers, kidney and bladder cancers, bone cancers, lung cancers, malignant mesothelioma, sarcomas, lymphomas, glandular cancers, thyroid cancers, heart tumors, germ cell tumors, malignant neuroendocrine (carcinoid) tumors, midline tract cancers, and cancers of unknown primary.

Compositions

The term "composition" as used herein is intended to encompass a dosage form comprising a specified compound in a specified amount, as well as any dosage form that results, directly or indirectly, from combination of a specified compound in a specified amount. Such term is intended to encompass a dosage form comprising a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and one or more pharmaceutically acceptable carriers or excipients. Accordingly, the compositions of the present disclosure encompass any composition made by admixing a compound of the present disclosure and one or more pharmaceutically acceptable carrier or excipients. By "pharmaceutically acceptable", it is meant the carriers or excipients are compatible with the compound disclosed herein and with other ingredients of the composition.

For the purpose of inducing an immune response and/or inducing STING-dependent type I interferon production, the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), or

pharmaceutically acceptable salts of the foregoing, can be administered by means that produces contact of the active agent with the agent's site of action. The compounds can be administered by conventional means available for use in conjunction with pharmaceuticals, either as individual therapeutic agents or in a combination of therapeutic agents. The compounds can be administered alone, but typically are administered with a pharmaceutical carrier selected on the basis of the chosen route of administration and standard pharmaceutical practice.

In one embodiment, disclosed herein is a composition comprising a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and one or more pharmaceutically acceptable carriers or excipients. The composition may be prepared and packaged in bulk form in which a therapeutically effective amount of a compound of the disclosure can be extracted and then given to a subject, such as with powders or syrups. Alternatively, the composition may be prepared and packaged in unit dosage form in which each physically discrete unit contains a therapeutically effective amount of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing.

The compounds disclosed herein and a pharmaceutically acceptable carrier or excipient(s) will typically be formulated into a dosage form adapted for administration to a subject by a desired route of administration. For example, dosage forms include those adapted for (1) oral administration, such as tablets, capsules, caplets, pills, troches, powders, syrups, elixirs, suspensions, solutions, emulsions, sachets, and cachets; and (2) parenteral administration, such as sterile solutions, suspensions, and powders for reconstitution. Suitable pharmaceutically acceptable carriers or excipients will vary depending upon the particular dosage form chosen. In addition, suitable pharmaceutically acceptable carriers or excipients may be chosen for a particular function that they may serve in the composition. For example, certain pharmaceutically acceptable carriers or excipients may be chosen for their ability to facilitate the production of uniform dosage forms. Certain pharmaceutically acceptable carriers or excipients may be chosen for their ability to facilitate the production of stable dosage forms. Certain pharmaceutically acceptable carriers or excipients may be chosen for their ability to facilitate the carrying or transporting of a compound disclosed herein, once administered to the subject, from one organ or portion of the body to another organ or another portion of the body. Certain

pharmaceutically acceptable carriers or excipients may be chosen for their ability to enhance patient compliance.

Suitable pharmaceutically acceptable excipients include the following types of excipients: diluents, lubricants, binders, disintegrants, fillers, glidants, granulating agents, coating agents, wetting agents, solvents, co-solvents, suspending agents, emulsifiers, sweeteners, flavoring agents, flavor masking agents, coloring agents, anti-caking agents, hemectants, chelating agents, plasticizers, viscosity increasing agents, antioxidants, preservatives, stabilizers, surfactants, and buffering agents.

A skilled artisan possesses the knowledge and skill in the art to select suitable pharmaceutically acceptable carriers and excipients in appropriate amounts for the use in the compositions of the disclosure. In addition, there are a number of resources available to the skilled artisan, which describe pharmaceutically acceptable carriers and excipients and may be useful in selecting suitable pharmaceutically acceptable carriers and excipients. Examples include REMINGTON'S PHARMACEUTICAL SCIENCES (Mack Publishing Company), THE HANDBOOK OF PHARMACEUTICAL ADDITIVES (Gower Publishing Limited), and THE HANDBOOK OF PHARMACEUTICAL EXCIPIENTS (the American Pharmaceutical Association and the Pharmaceutical Press).

The compositions of the disclosure are prepared using techniques and methods known to those skilled in the art. Some methods commonly used in the art are described in REMINGTON'S PHARMACEUTICAL SCIENCES (Mack Publishing Company).

In one embodiment, the disclosure is directed to a solid oral dosage form such as a tablet or capsule comprising a therapeutically effective amount of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and a diluent or filler. Suitable diluents and fillers include lactose, sucrose, dextrose, mannitol, sorbitol, starch (*e.g.*, corn starch, potato starch, and pre-gelatinized starch), cellulose and its derivatives, (*e.g.*, microcrystalline cellulose), calcium sulfate, and dibasic calcium phosphate. The solid oral dosage form may further comprise a binder. Suitable binders include starch (*e.g.*, corn starch, potato starch, and pre-gelatinized starch) gelatin, acacia, sodium alginate, alginic acid, tragacanth, guar gum, povidone, and cellulose and its derivatives (*e.g.*, microcrystalline cellulose). The solid oral dosage form may further comprise a disintegrant. Suitable disintegrants include crospovidone, sodium starch glycolate, croscarmellose, alginic acid, and

sodium carboxymethyl cellulose. The solid oral dosage form may further comprise a lubricant. Suitable lubricants include stearic acid, magnesium stearate, calcium stearate, and talc.

Where appropriate, dosage unit formulations for oral administration can be microencapsulated. The composition can also be prepared to prolong or sustain the release as, for example, by coating or embedding particulate material in polymers, wax, or the like.

The compounds disclosed herein may also be coupled with soluble polymers as targetable drug carriers. Such polymers can include polyvinylpyrrolidone, pyranicopolymer, polyhydroxypropylmethacrylamidephenol, polyhydroxyethylaspartamidephenol, or polyethyleneoxidepolylysine substituted with palmitoyl residues. Furthermore, the compounds of the disclosure may be coupled to a class of biodegradable polymers useful in achieving controlled release of a drug, for example polylactic acid, polyepsilon caprolactone, polyhydroxy butyric acid, polyorthoesters, polyacetals, polydihydropyrans, polycyanacrylates, and cross-linked or amphipathic block copolymers of hydrogels.

In one embodiment, the disclosure is directed to a liquid oral dosage form. Oral liquids such as solutions, syrups, and elixirs can be prepared in dosage unit form so that a given quantity contains a predetermined amount of a compound or a pharmaceutically acceptable salt thereof disclosed herein. Syrups can be prepared by dissolving the compound of the disclosure in a suitably flavored aqueous solution; elixirs are prepared through the use of a non-toxic alcoholic vehicle. Suspensions can be formulated by dispersing a compound disclosed herein in a non-toxic vehicle. Solubilizers and emulsifiers such as ethoxylated isostearyl alcohols and polyoxy ethylene sorbitol ethers, preservatives, flavor additives such as peppermint oil, or other natural sweeteners or saccharin or other artificial sweeteners and the like can also be added.

In one embodiment, the disclosure is directed to compositions for parenteral administration. Compositions adapted for parenteral administration include aqueous and non-aqueous sterile injection solutions that may contain anti-oxidants, buffers, bacteriostats, and solutes that render the formulation isotonic with the blood of the intended recipient; and aqueous and non-aqueous sterile suspensions that may include suspending agents and thickening agents. The compositions may be presented in unit-dose or multi-dose containers, for example sealed ampoules and vials, and may be stored in a freeze-dried (lyophilized) condition, requiring only the addition of the sterile liquid carrier, for example water for injections, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules, and tablets.

Combinations

The compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), and/or pharmaceutically acceptable salts of the foregoing, may be administered in combination with one or more additional active agents. In embodiments, one or more compounds of general formula (Ia), one or more compounds of general formula (Ia'), one or more compounds of general formula (Ib), one or more compounds of general formula (Ib'), one or more compounds of general formula (I), one or more compounds of general formula (I'), or one or more pharmaceutically acceptable salts of the foregoing, and the one or more additional active agents may be co-administered. The additional active agent(s) may be administered in a single dosage form with the compound of general formula (Ia), the compound of general formula (Ia'), the compound of general formula (Ib), the compound of general formula (Ib'), the compound of general formula (I), the compound of general formula (I'), or pharmaceutically acceptable salt of the foregoing, or the additional active agent(s) may be administered in separate dosage form(s) from the dosage form containing the compound of general formula (Ia), the compound of general formula (Ia'), the compound of general formula (Ib), the compound of general formula (Ib'), the compound of general formula (I), the compound of general formula (I'), or pharmaceutically acceptable salt of the foregoing.

The additional active agent(s) may be provided as a pharmaceutically acceptable salt, where appropriate.

The additional active agent(s) may be one or more agents selected from the group consisting of STING agonist compounds, anti-viral compounds, antigens, adjuvants, anti-cancer agents, CTLA-4, LAG-3 and PD-1 pathway antagonists, lipids, liposomes, peptides, cytotoxic agents, chemotherapeutic agents, immunomodulatory cell lines, checkpoint inhibitors, vascular endothelial growth factor (VEGF) receptor inhibitors, topoisomerase II inhibitors, smoothen inhibitors, alkylating agents, anti-tumor antibiotics, anti-metabolites, retinoids, and immunomodulatory agents including but not limited to anti-cancer vaccines. It will be understood that such additional active agent(s) may be provided as a pharmaceutically acceptable salt. It will be understood the descriptions of the above additional active agents may be overlapping. It will also be understood that the treatment combinations are subject to optimization, and it is understood that the best combination to use of the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of

general formula (I'), or pharmaceutically acceptable salts of the foregoing, and one or more additional active agents will be determined based on the individual patient needs.

A compound disclosed herein may be used in combination with one or more other active agents, including but not limited to, other anti-cancer agents that are used in the prevention, treatment, control, amelioration, or reduction of risk of a particular disease or condition (*e.g.*, cell proliferation disorders). In one embodiment, a compound disclosed herein is combined with one or more other anti-cancer agents for use in the prevention, treatment, control amelioration, or reduction of risk of a particular disease or condition for which the compounds disclosed herein are useful. Such other active agents may be administered, by a route and in an amount commonly used therefor, contemporaneously or sequentially with a compound of the present disclosure.

When a compound disclosed herein is used contemporaneously with one or more other active agents, a composition containing such other active agents in addition to the compound disclosed herein is contemplated. Accordingly, the compositions of the present disclosure include those that also contain one or more other active ingredients, in addition to a compound disclosed herein. A compound disclosed herein may be administered either simultaneously with, or before or after, one or more other active agent(s). A compound disclosed herein may be administered separately, by the same or different route of administration, or together in the same pharmaceutical composition as the other agent(s).

Products provided as combinations may include a composition comprising a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and one or more other active agent(s) together in the same pharmaceutical composition, or may include a composition comprising a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and a composition comprising one or more other active agent(s) in separate form, *e.g.* in the form of a kit or in any form designed to enable separate administration either concurrently or on separate dosing schedules.

The weight ratio of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically

acceptable salt of the foregoing, to a second active agent may be varied and will depend upon the therapeutically effective dose of each agent. Generally, a therapeutically effective dose of each will be used. Combinations of a compound disclosed herein and other active agents will generally also be within the aforementioned range, but in each case, a therapeutically effective
5 dose of each active agent should be used. In such combinations, the compound disclosed herein and other active agents may be administered separately or in conjunction. In addition, the administration of one element may be prior to, concurrent to, or subsequent to the administration of other agent(s).

In one embodiment, this disclosure provides a composition comprising a
10 compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, and at least one other active agent as a combined preparation for simultaneous, separate or sequential use in therapy. In one embodiment, the therapy is the treatment of a cell proliferation disorder,
15 such as cancer.

In one embodiment, the disclosure provides a kit comprising two or more separate pharmaceutical compositions, at least one of which contains a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or
20 a pharmaceutically acceptable salt of the foregoing. In one embodiment, the kit comprises means for separately retaining said compositions, such as a container, divided bottle, or divided foil packet. An example of such a kit is a blister pack, as typically used for the packaging of tablets, capsules, and the like.

A kit of this disclosure may be used for administration of different dosage forms,
25 for example, oral and parenteral, for administration of the separate compositions at different dosage intervals, or for titration of the separate compositions against one another. To assist with compliance, a kit of the disclosure typically comprises directions for administration.

Disclosed herein is a use of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'),
30 a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, for treating a cell proliferation disorder, where the medicament is prepared for administration with another active agent. The disclosure also provides the use of another active agent for treating a cell proliferation disorder, where the medicament is

administered with a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing.

5 The disclosure also provides the use of a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing, for treating a cell proliferation disorder, where the patient has previously (*e.g.*, within 24 hours) been treated with another active agent. The
10 disclosure also provides the use of another active agent for treating a cell proliferation disorder, where the patient has previously (*e.g.*, within 24 hours) been treated with a compound of general formula (Ia), a compound of general formula (Ia'), a compound of general formula (Ib), a compound of general formula (Ib'), a compound of general formula (I), a compound of general formula (I'), or a pharmaceutically acceptable salt of the foregoing. The second agent may be
15 administered a week, several weeks, a month, or several months after the administration of a compound disclosed herein.

 STING agonist compounds that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the
20 compounds of general formula (I'), or pharmaceutically acceptable salts of the foregoing, disclosed herein include but are not limited to cyclic di-nucleotide compounds.

 Anti-viral compounds that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the
25 compounds of general formula (I'), or pharmaceutically acceptable salts of the foregoing, disclosed herein include hepatitis B virus (HBV) inhibitors, hepatitis C virus (HCV) protease inhibitors, HCV polymerase inhibitors, HCV NS4A inhibitors, HCV NS5A inhibitors, HCV NS5b inhibitors, and human immunodeficiency virus (HIV) inhibitors. Such anti-viral compounds may be provided as a pharmaceutically acceptable salt, where appropriate.

30 Antigens and adjuvants that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), or the pharmaceutically acceptable salts of the foregoing,

include B7 costimulatory molecule, interleukin-2, interferon- γ , GM-CSF, CTLA-4 antagonists, OX-40/OX-40 ligand, CD40/CD40 ligand, sargramostim, levamisole, vaccinia virus, Bacille Calmette-Guerin (BCG), liposomes, alum, Freund's complete or incomplete adjuvant, detoxified endotoxins, mineral oils, surface active substances such as lipolecithin, pluronic polyols, polyanions, peptides, and oil or hydrocarbon emulsions. Adjuvants, such as aluminum hydroxide or aluminum phosphate, can be added to increase the ability of the vaccine to trigger, enhance, or prolong an immune response. Additional materials, such as cytokines, chemokines, and bacterial nucleic acid sequences, like CpG, a toll-like receptor (TLR) 9 agonist as well as additional agonists for TLR 2, TLR 4, TLR 5, TLR 7, TLR 8, TLR9, including lipoprotein, LPS, monophosphoryllipid A, lipoteichoic acid, imiquimod, resiquimod, and in addition retinoic acid-inducible gene I (RIG-I) agonists such as poly I:C, used separately or in combination with the described compositions are also potential adjuvants. Such antigens and adjuvants may be provided as a pharmaceutically acceptable salt, where appropriate.

CTLA-4 and PD-1 pathways are important negative regulators of immune response. Activated T-cells up-regulate CTLA-4, which binds on antigen-presenting cells and inhibits T-cell stimulation, IL-2 gene expression, and T-cell proliferation; these anti-tumor effects have been observed in mouse models of colon carcinoma, metastatic prostate cancer, and metastatic melanoma. PD-1 binds to active T-cells and suppresses T-cell activation; PD-1 antagonists have demonstrated anti-tumor effects as well. CTLA-4 and PD-1 pathway antagonists that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), or the pharmaceutically acceptable salts of the foregoing, disclosed herein, include ipilimumab, tremelimumab, nivolumab, pembrolizumab, CT-011, AMP-224, and MDX-1106.

"PD-1 antagonist" or "PD-1 pathway antagonist" means any chemical compound or biological molecule that blocks binding of PD-L1 expressed on a cancer cell to PD-1 expressed on an immune cell (T-cell, B-cell, or NKT-cell) and preferably also blocks binding of PD-L2 expressed on a cancer cell to the immune-cell expressed PD-1. Alternative names or synonyms for PD-1 and its ligands include: PDCD1, PD1, CD279, and SLEB2 for PD-1; PDCD1L1, PDL1, B7H1, B7-4, CD274, and B7-H for PD-L1; and PDCD1L2, PDL2, B7-DC, Btdc, and CD273 for PD-L2. In any of the treatment method, medicaments and uses of the present disclosure in which a human individual is being treated, the PD-1 antagonist blocks binding of human PD-L1 to human PD-1, and preferably blocks binding of both human PD-L1

and PD-L2 to human PD-1. Human PD-1 amino acid sequences can be found in NCBI Locus No.: NP_005009. Human PD-L1 and PD-L2 amino acid sequences can be found in NCBI Locus No.: NP_054862 and NP_079515, respectively.

PD-1 antagonists useful in any of the treatment method, medicaments and uses of the present disclosure include a monoclonal antibody (mAb), or antigen binding fragment thereof, which specifically binds to PD-1 or PD-L1, and preferably specifically binds to human PD-1 or human PD-L1. The mAb may be a human antibody, a humanized antibody, or a chimeric antibody and may include a human constant region. In some embodiments, the human constant region is selected from the group consisting of IgG1, IgG2, IgG3, and IgG4 constant regions, and in preferred embodiments, the human constant region is an IgG1 or IgG4 constant region. In some embodiments, the antigen binding fragment is selected from the group consisting of Fab, Fab'-SH, F(ab')₂, scFv, and Fv fragments.

Examples of mAbs that bind to human PD-1, and useful in the treatment method, medicaments and uses of the present disclosure, are described in U.S. Patent Nos. US7488802, US7521051, US8008449, US8354509, and US8168757, PCT International Patent Application Publication Nos. WO2004/004771, WO2004/072286, and WO2004/056875, and U.S. Patent Application Publication No. US2011/0271358.

Examples of mAbs that bind to human PD-L1, and useful in the treatment method, medicaments and uses of the present disclosure, are described in PCT International Patent Application Nos. WO2013/019906 and WO2010/077634 A1 and in U.S. Patent No. US8383796. Specific anti-human PD-L1 mAbs useful as the PD-1 antagonist in the treatment method, medicaments and uses of the present disclosure include MPDL3280A, BMS-936559, MEDI4736, MSB0010718C, and an antibody that comprises the heavy chain and light chain variable regions of SEQ ID NO:24 and SEQ ID NO:21, respectively, of WO2013/019906.

Other PD-1 antagonists useful in any of the treatment method, medicaments, and uses of the present disclosure include an immune-adhesion that specifically binds to PD-1 or PD-L1, and preferably specifically binds to human PD-1 or human PD-L1, *e.g.*, a fusion protein containing the extracellular or PD-1 binding portion of PD-L1 or PD-L2 fused to a constant region such as an Fc region of an immunoglobulin molecule. Examples of immune-adhesion molecules that specifically bind to PD-1 are described in PCT International Patent Application Publication Nos. WO2010/027827 and WO2011/066342. Specific fusion proteins useful as the PD-1 antagonist in the treatment method, medicaments, and uses of the present disclosure

include AMP-224 (also known as B7-DCIg), which is a PD-L2-FC fusion protein and binds to human PD-1.

Examples of cytotoxic agents that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), or pharmaceutically acceptable salts of the foregoing, include, but are not limited to, arsenic trioxide (sold under the tradename TRISENOX[®]), asparaginase (also known as L-asparaginase, and Erwinia L-asparaginase, sold under the tradenames ELSPAR[®] and KIDROLASE[®]).

Chemotherapeutic agents that may be used in combination with the compounds of general formula (Ia), the compounds of general formula (Ia'), the compounds of general formula (Ib), the compounds of general formula (Ib'), the compounds of general formula (I), the compounds of general formula (I'), or pharmaceutically acceptable salts of the foregoing, disclosed herein include abiraterone acetate, altretamine, anhydrovinblastine, auristatin, bexarotene, bicalutamide, BMS 184476, 2,3,4,5,6-pentafluoro-N-(3-fluoro-4-methoxyphenyl) benzene sulfonamide, bleomycin, N,N-dimethyl-L-valyl-L-valyl-N-methyl-L-valyl-L-prolyl-1-Lproline-t-butylamide, cachectin, cemadotin, chlorambucil, cyclophosphamide, 3',4'-didehydro-4'-deoxy-8'-norvin-calculeoblastine, docetaxol, doxorubicin (adriamycin), etoposide, 5-fluorouracil, finasteride, flutamide, hydroxyurea and hydroxyurea andtaxanes, ifosfamide, liarozole, lonidamine, lomustine (CCNU), MDV3100, mechlorethamine (nitrogen mustard), melphalan, mivobulin isethionate, rhizoxin, sertenef, streptozocin, mitomycin, methotrexate, taxanes, nilutamide, nivolumab, onapristone, paclitaxel, pembrolizumab, prednimustine, procarbazine, RPR109881, stramustine phosphate, tamoxifen, tasonermin, taxol, tretinoin, vinblastine, vincristine, vindesine sulfate, and vinflunine. Such chemotherapeutic agents may be provided as a pharmaceutically acceptable salt, where appropriate.

Examples of vascular endothelial growth factor (VEGF) receptor inhibitors include, but are not limited to, bevacizumab (sold under the trademark AVASTIN by Genentech/Roche), axitinib (described in PCT International Patent Publication No. WO01/002369), Brivanib Alaninate ((S)-((R)-1-(4-(4-Fluoro-2-methyl-1H-indol-5-yloxy)-5-methylpyrrolo[2,1-f][1,2,4]triazin-6-yloxy)propan-2-yl)2-aminopropanoate, also known as BMS-582664), motesanib (N-(2,3-dihydro-3,3-dimethyl-1H-indol-6-yl)-2-[(4-pyridinylmethyl)amino]-3-

pyridinecarboxamide. and described in PCT International Patent Application Publication No. WO02/068470), pasireotide (also known as SO 230, and described in PCT International Patent Publication No. WO02/010192), and sorafenib (sold under the tradename NEXAVAR). Such inhibitors may be provided as a pharmaceutically acceptable salt, where appropriate.

5 Examples of topoisomerase II inhibitors, include but are not limited to, etoposide (also known as VP-16 and Etoposide phosphate, sold under the tradenames TOPOSAR, VEPESID, and ETOPOPHOS), and teniposide (also known as VM-26, sold under the tradename VUMON). Such inhibitors may be provided as a pharmaceutically acceptable salt, where appropriate.

10 Examples of alkylating agents, include but are not limited to, 5-azacytidine (sold under the trade name VIDAZA), decitabine (sold under the trade name of DECOGEN), temozolomide (sold under the trade names TEMODAR and TEMODAL by Schering-Plough/Merck), dactinomycin (also known as actinomycin-D and sold under the tradename COSMEGEN), melphalan (also known as L-PAM, L-sarcolysin, and phenylalanine mustard, sold under the tradename ALKERAN), altretamine (also known as hexamethylmelamine (HMM), sold under the tradename HEXALEN), carmustine (sold under the tradename BCNU), bendamustine (sold under the tradename TREANDA), busulfan (sold under the tradenames BUSULFEX[®] and MYLERAN[®]), carboplatin (sold under the tradename PARAPLATIN[®]), lomustine (also known as CCNU, sold under the tradename CEENU[®]), cisplatin (also known as CDDP, sold under the tradenames PLATINOL[®] and PLATINOL[®]-AQ), chlorambucil (sold under the tradename LEUKERAN[®]), cyclophosphamide (sold under the tradenames CYTOXAN[®] and NEOSAR[®]), dacarbazine (also known as DTIC, DIC and imidazole carboxamide, sold under the tradename DTIC-DOME[®]), altretamine (also known as hexamethylmelamine (HMM) sold under the tradename HEXALEN[®]), ifosfamide (sold under the tradename IFEX[®]), procarbazine (sold under the tradename MATULANE[®]), mechlorethamine (also known as nitrogen mustard, mustine and mechloroethamine hydrochloride, sold under the tradename MUSTARGEN[®]), streptozocin (sold under the tradename ZANOSAR[®]), thiotepa (also known as thiophosphoamide, TSPA and TSPA, and sold under the tradename THIOPLEX[®]). Such alkylating agents may be provided as a pharmaceutically acceptable salt, where appropriate.

30 Examples of anti-tumor antibiotics include, but are not limited to, doxorubicin (sold under the tradenames ADRIAMYCIN[®] and RUBEX[®]), bleomycin (sold under the tradename LENOXANE[®]), daunorubicin (also known as dauorubicin hydrochloride, daunomycin, and rubidomycin hydrochloride, sold under the tradename CERUBIDINE[®]), daunorubicin liposomal

(daunorubicin citrate liposome, sold under the tradename DAUNOXOME[®]), mitoxantrone (also known as DHAD, sold under the tradename NOVANTRONE[®]), epirubicin (sold under the tradename ELLENCE[™]), idarubicin (sold under the tradenames IDAMYCIN[®], IDAMYCIN PFS[®]), and mitomycin C (sold under the tradename MUTAMYCIN[®]). Such anti-tumor antibiotics may be provided as a pharmaceutically acceptable salt, where appropriate.

Examples of anti-metabolites include, but are not limited to, claribine (2-chlorodeoxyadenosine, sold under the tradename LEUSTATIN[®]), 5-fluorouracil (sold under the tradename ADRUCIL[®]), 6-thioguanine (sold under the tradename PURINETHOL[®]), pemetrexed (sold under the tradename ALIMTA[®]), cytarabine (also known as arabinosylcytosine (Ara-C), sold under the tradename CYTOSAR-U[®]), cytarabine liposomal (also known as Liposomal Ara-C, sold under the tradename DEPOCYT[™]), decitabine (sold under the tradename DACOGEN[®]), hydroxyurea and (sold under the tradenames HYDREA[®], DROXIA[™] and MYLOCEL[™]), fludarabine (sold under the tradename FLUDARA[®]), floxuridine (sold under the tradename FUDR[®]), cladribine (also known as 2-chlorodeoxyadenosine (2-CdA) sold under the tradename LEUSTATIN[™]), methotrexate (also known as amethopterin, methotrexate sodium (MTX), sold under the tradenames RHEUMATREX[®] and TREXALL[™]), and pentostatin (sold under the tradename NIPENT[®]). Such anti-metabolites may be provided as a pharmaceutically acceptable salt, where appropriate.

Examples of retinoids include, but are not limited to, alitretinoin (sold under the tradename PANRETIN[®]), tretinoin (all-trans retinoic acid, also known as ATRA, sold under the tradename VESANOID[®]), Isotretinoin (13-c/s-retinoic acid, sold under the tradenames ACCUTANE[®], AMNESTEEM[®], CLARAVIS[®], CLARUS[®], DECUTAN[®], ISOTANE[®], IZOTECH[®], ORATANE[®], ISOTRET[®], and SOTRET[®]), and bexarotene (sold under the tradename TARGRETIN[®]). Such compounds may be provided as a pharmaceutically acceptable salt, where appropriate.

Activity: STING Biochemical [3H]cGAMP Competition Assay

The individual compounds described in the Examples herein are defined as STING agonists by (i) binding to the STING protein as evidenced by a reduction in binding of tritiated cGAMP ligand to the STING protein by at least 20% at 20uM (concentration of compound being tested) in a STING Biochemical [3H]cGAMP Competition Assay and (ii) demonstrating interferon production with a 6% or greater induction of IFN- β secretion at 30uM in the THP1 cell assay (where induction caused by cGAMP at 30uM was set at 100%).

The ability of compounds to bind STING is quantified by the ability to compete with tritiated cGAMP ligand for human STING receptor membrane using a radioactive filter-binding assay. The binding assay employs STING receptor obtained from Hi-Five cell membranes overexpressing full-length HAQ STING prepared in-house and tritiated cGAMP ligand also purified in-house.

The following experimental procedures detail the preparation of specific examples of the instant disclosure. The compounds of the examples are drawn in their neutral forms in the procedures and tables below. In some cases, the compounds were isolated as salts depending on the method used for their final purification and/or intrinsic molecular properties. The examples are for illustrative purposes only and are not intended to limit the scope of the instant disclosure in any way.

EXAMPLES

ABBREVIATIONS

(COCl) ₂	Oxalyl chloride
¹⁹ F NMR	¹⁹ F nuclear magnetic resonance spectroscopy
¹ H NMR	¹ H (Proton) nuclear magnetic resonance spectroscopy
2',3'-cGAMP, cGAMP	2',3'-cyclic guanosine monophosphate-adenosine monophosphate
ACN, MeCN, CH ₃ CN	Acetonitrile
AcOH, HOAc	Acetic acid
AlCl ₃	Aluminum trichloride
AMP	Adenosine monophosphate
aq	Aqueous
Ar	Argon
ATP	Adenosine 5'-triphosphate
BIIC	Baculovirus Infected Insect Cell
br	Broad
Br ₂	Bromine
cat	Catalog number
CD ₃ OD	Deuterium-enriched methyl alcohol, deuterium-enriched methanol
CDCl ₃	Deuterated trichloromethane
cGAMP	Cyclic GMP-AMP synthase

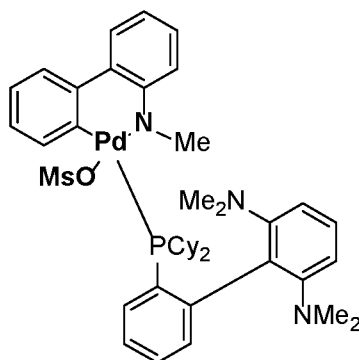
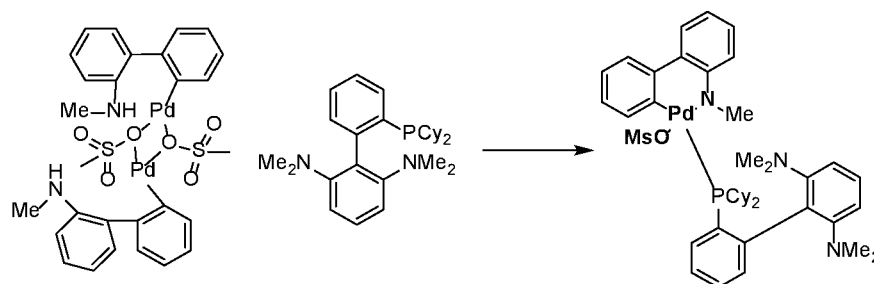
CH ₂ I ₂	Diiodomethane
CH ₃ Cl	Chloromethane, methyl chloride
CHCl ₃	Trichloromethane
Ci	Curie, a non-standard unit of radioactivity; 1Ci = 3.7×10 ¹⁰ Bq, where Bq is Becquerel, the SI unit of radioactivity, equivalent to 1 disintegration per second (dps)
CO ₂	Carbon dioxide
CPhos Pd G4	2-Aminobiphenylpalladium methanesulfonate palladium CPhos precatalyst (4 th generation precatalyst)
Cs ₂ CO ₃	Cesium carbonate
Cu-Cl	Copper(I) chloride
Cu-I	Copper(I) iodide
Cy	Cyclohexyl
d	Doublet
DCE	1,2-Dichloroethane
DCM, CH ₂ Cl ₂	Dichloromethane
ddd	Doublet of doublet of doublet
ddt	Doublet of doublet of triplet
DMAP	4-dimethylaminopyridine
DMEA	N,N-dimethyl ethyl amine
DMF	N,N-dimethylformamide
DMSO	Dimethyl sulfoxide
DMTr	4,4'-dimethoxytrityl
DMTrCl	4,4'-dimethoxytrityl chloride
dq	Doublet of quartet
EC ₅₀	half maximal effective concentration; concentration of a drug, antibody, or toxicant that induces a response halfway between the baseline and maximum after a specified exposure time
EDC	Ethylene dichloride
eq	Equivalents
ES	Electron spray
Et	Ethyl
Et ₂ O	Diethyl ether

Et ₂ Z	Diethyl zinc
EtOAc	Ethyl acetate
EtOH	Ethyl alcohol, ethanol
g	Gram
GMP	Guanosine 5'-monophosphate
GTP	Guanosine 5'-triphosphate
h	Hour
H ₂	Hydrogen (gas)
H ₂ SO ₄	Sulfuric acid
HAQ STING	Common STING variant containing the three mutations R71H-G230A-R293Q (DNA construct used herein: STING(1-379)R71H,G230A,H232R,R293Q-GG-AviTag-GS-HRV3C-HIS8/pBAC1)
HCl	Hydrochloric acid
HEPES	2-[4-(2-hydroxyethyl)piperazin-1-yl]ethanesulfonic acid, a zwitterionic organic chemical buffering agent
hept	Heptet
Hex	Hexanes
HNO ₃	Nitric acid
HPLC	High performance liquid chromatography
Hz	Hertz
IC ₅₀	half maximal inhibitory concentration; concentration of a drug, antibody, or toxicant required for 50% inhibition of response or binding
Inh	Inhibition
<i>J</i>	NMR Coupling constant
K ₂ CO ₃	Potassium carbonate
KCl	Potassium chloride
KOH	Potassium hydroxide
LCMS	Liquid chromatography – mass spectroscopy
LDA	Lithium di-isopropyl amide
LiOH	Lithium hydroxide
LiOH·H ₂ O	Lithium hydroxide monohydrate
m	Multiplet
M	Molar, moles per liter

m/z	Mass-to-charge ratio
M+H	Protonated mass, mass measurement produced by mass spectrometry
mCi	Millicurie
Me	Methyl
MeB(OH) ₂	Methyl boronic acid
MeMgBr	Methyl magnesium bromide
MeOH, CH ₃ OH	Methanol
mg	Milligram
MgCl ₂	Magnesium chloride
MgSO ₄	Magnesium sulfate
MHz	Megahertz
min	Minute(s)
mL, ml	Milliliter
mM	Millimole per liter
mmol	Millimole
MOI	Multiplicity of infection
N ₂	Nitrogen (gas)
Na ₂ CO ₃	Sodium carbonate
Na ₂ SO ₄	Sodium sulfate
NaCl	Sodium chloride
NaHCO ₃	Sodium bicarbonate
NaHSO ₃	Sodium bisulfite
NaHSO ₄	Sodium bisulfate, sodium hydrogen sulfate
NaOH	Sodium hydroxide
ng	Nanogram(s)
NH ₃	Ammonia
NH ₄ Cl	Ammonium chloride
NH ₄ OH	Ammonium hydroxide
nL	Nanoliter
nm	Nanometer
nM	Nanomolar
NMP	N-methyl-2-pyrrolidone
Pd(Ph ₃ P) ₄	Tetrakis(triphenyl phosphine) palladium(0)

Pd/C	Palladium on carbon
Pd ₂ (dba) ₃	Tris(dibenzylidene acetone) dipalladium(0)
PE	Petroleum ether
pfu	Plaque-forming unit
prep-HPLC	Preparative high performance liquid chromatography
prep-TLC	Preparative thin layer liquid chromatography
PSI	Pounds per square inch
Py, py	Pyridine
q	Quartet
RPM, rpm	Revolutions per minute
RT, rt	Room temperature, approximately 25°C
s	Singlet
sat	Saturated
SFC	Supercritical fluid chromatography
SiO ₂	Silica, silicon dioxide
SO ₂ Cl ₂	Sulfuryl chloride
SOCl ₂	Thionyl chloride
t	Triplet
<i>t</i> -BuLi	<i>t</i> -Butyl lithium, <i>tert</i> -butyl lithium
TFA	Trifluoroacetic acid
THF	Tetrahydrofuran
TLC	Thin layer chromatography
TMSCl	Trimethylsilyl chloride
T _R	Retention time
TrisCl	Tris(hydroxymethyl)aminomethane hydrochloride
v/v	Volume/volume
WT STING	The wild type (most abundant) variant of STING in humans (DNA construct used herein: STING(1-379)H232R-gg-AviTag-gs-HRV3C-HIS8/pBAC1)
X-Phos	2-Dicyclohexylphosphino-2',4',6'-triisopropylbiphenyl
λ _{em}	Emission wavelength
λ _{ex}	Excitation wavelength
μg, ug	Microgram

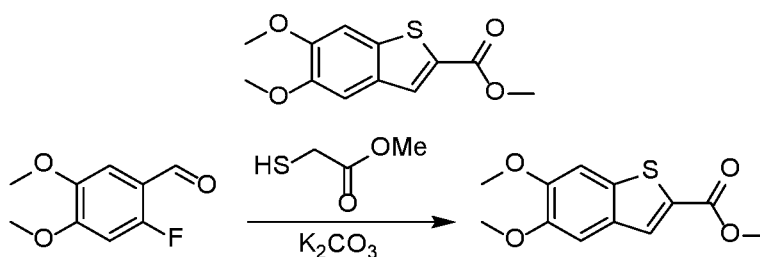
μL , uL , μl , ul	Microliter
μM , uM	Micromolar
μm , um	Micrometer

Preparation 1: CPhos Pd G4Step 1: CPhos Pd G4

5

A mixture of (2'-methylamino-1,1'-biphenyl-2-yl)methanesulfonatopalladium (II) dimer (439mg, 0.573mmol) and 2'-(dicyclohexylphosphino)-*N*2,*N*2,*N*6,*N*6-tetramethyl-[1,1'-biphenyl]-2,6-diamine (500mg, 1.15mmol) in DCM (6mL) was stirred at rt for 2h. The solution was then diluted with Et₂O (30mL). The solution was filtered and concentrated under reduced pressure. The residue was then slurried in pentanes and again concentrated under reduced pressure to afford CPhos Pd G4. See Bruno, N. C.; Niljianskul, N.; Buchwald, S. L. *J. Org. Chem.* **2014**, 79, 4161.

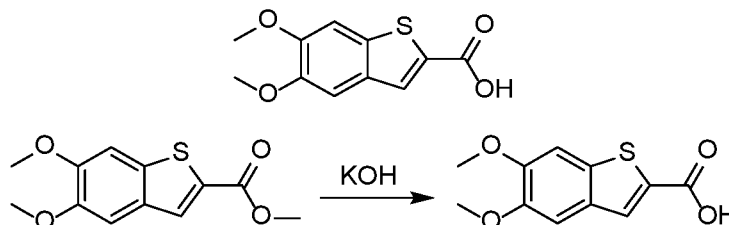
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Preparation 2: Methyl-5,6-dimethoxybenzo[b]thiophene-2-carboxylate

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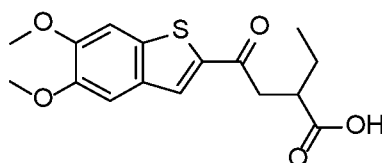
To a stirred solution of 2-fluoro-4,5-dimethoxybenzaldehyde (18.7g, 102mmol) in DMF (600mL) was added methyl 2-mercaptoacetate (11.9g, 112mmol) and K₂CO₃ (42.1g, 305mmol). The resulting mixture was then heated at 60°C for 15h. After cooling to rt, the reaction mixture was concentrated under reduced pressure. The resulting residue was diluted with H₂O (500mL) and extracted with DCM (600mL). The organic phase was dried over Na₂SO₄, filtered, and concentrated under reduced pressure to afford methyl 5,6-dimethoxybenzo[*b*]thiophene-2-carboxylate. LCMS (C₁₂H₁₃O₄S) (ES, m/z): 253 [M+H]⁺. ¹H NMR (400MHz, DMSO-*d*₆): δ 8.03 (s, 1H), 7.60 (s, 1H), 7.49 (s, 1H), 3.85 (s, 6H), 3.82 (s, 3H).

Preparation 3: 5,6-Dimethoxybenzo[*b*]thiophene-2-carboxylic acid

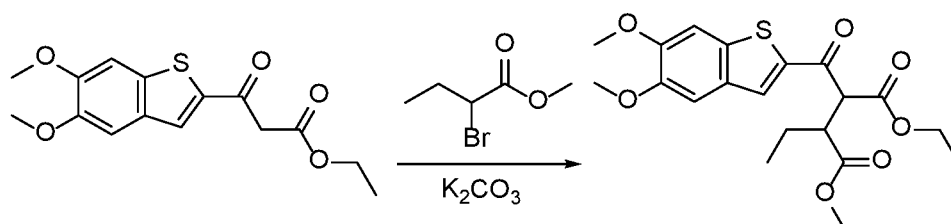


To a suspension of methyl 5,6-dimethoxybenzo[*b*]thiophene-2-carboxylate from Preparation 2 (23g, 91mmol) in MeOH (200mL), THF (200mL) and H₂O (200mL) was added KOH (51g, 910mmol). The resulting suspension was heated to 60°C for 30min. After cooling to rt, the reaction mixture was concentrated under reduced pressure. H₂O (600mL) was added to the resulting residue, and then citric acid was added to the solution to adjust to pH 6. The precipitated material was collected via filtration to afford 5,6-dimethoxybenzo[*b*]thiophene-2-carboxylic acid. ¹H NMR (400MHz, DMSO-*d*₆): δ 7.94 (s, 1H), 7.58 (s, 1H), 7.48 (s, 1H), 3.85 (s, 3H), 3.82 (s, 3H).

Example 1: 4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-ethyl-4-oxobutanoic acid

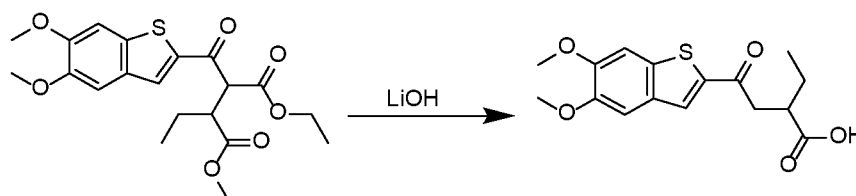


Step 1: 1-Ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-ethylsuccinate



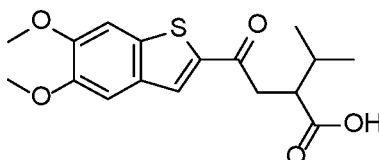
To a stirring solution of 3-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-3-oxopropanoate (commercially available from SPECS, 0.10g, 0.32mmol) in DMF (1.6mL) was added methyl 2-bromobutyrate (37uL, 0.32mmol) and K₂CO₃ (54mg, 0.39mmol) at rt. The reaction mixture was stirred overnight at rt and then diluted with H₂O (3mL) and DCM (6mL). The phases were separated, and the aq layer was washed with additional DCM (3x6mL). The combined organic layers were concentrated under reduced pressure and dried overnight under high vacuum. The resulting residue was purified by silica gel column chromatography (EtOAc in Hex) to give 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-ethylsuccinate, which was used without further purification. LCMS (C₂₀H₂₅O₇S) (ES, m/z): 409 [M+H]⁺.

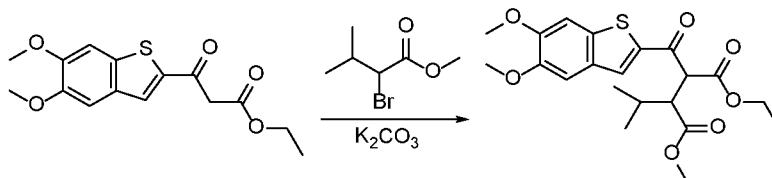
Step 2: 4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-ethyl-4-oxobutanoic acid



To a mixture of 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-ethylsuccinate (83mg, 0.20mmol) in THF (1.8mL) and H₂O (0.18mL) was added LiOH (39mg, 1.6mmol). The reaction mixture was stirred overnight at rt before the mixture was quenched with aq 2M HCl (0.30mL, 0.59mmol) and then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered, and concentrated under reduced pressure. The resulting residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford 4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-ethyl-4-oxobutanoic acid. The racemic mixture was resolved by CHIRAL-SFC (CHIRACEL OJ-H (250mm*21mm), 25% MeOH (+0.25% DMEA) in CO₂), affording two compounds with retention times of 3.65min and 5.26min. Concentration of the first eluting peak afforded the product. LCMS (C₁₆H₁₉O₅S) (ES, m/z): 323 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.15 (s, 1H), 7.52 (s, 1H), 7.40 (s, 1H), 3.79 (s, 3H), 3.77 (s, 3H), 3.35-3.27 (m, 1H), 3.00-2.94 (m, 1H), 2.73-2.67 (m, 1H), 1.58-1.50 (m, 2H), 0.85 (t, *J* = 7.3Hz, 3H).

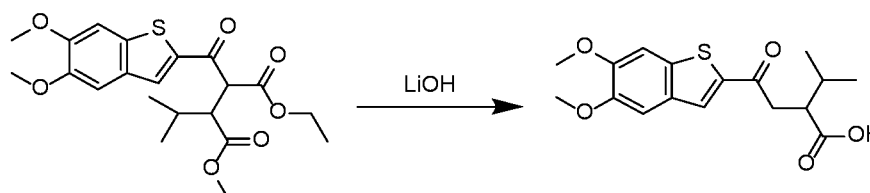
Example 2: 4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-isopropyl-4-oxobutanoic acid



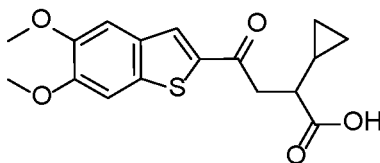
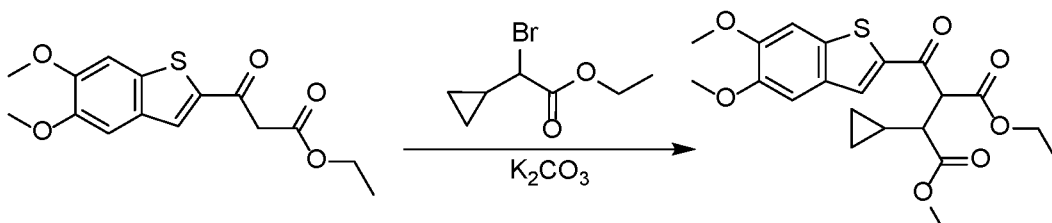
Step 1: 1-Ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-isopropylsuccinate

To a stirring mixture of ethyl 3-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-3-oxopropanoate (SPECS, 0.15g, 0.49mmol) in DMF (2.4mL) was added methyl 2-

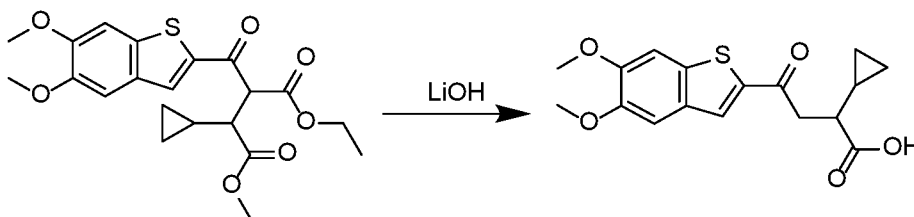
bromoisovalerate (73uL, 0.49mmol) and K₂CO₃ (81mg, 0.58mmol) at rt. The reaction mixture was stirred overnight at rt and then diluted with H₂O (3.0mL) and DCM (6.0ml). The phases were separated, and the aq layer was washed with additional DCM (3x6.0mL). The combined organic layers were concentrated under reduced pressure and dried overnight under high vacuum. The resulting residue was purified by silica gel column chromatography (EtOAc in hexanes) to afford 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-isopropylsuccinate, which was used in the next reaction without further purification. LCMS (C₂₁H₂₇O₇S) (ES, m/z): 423 [M+H]⁺.

Step 2: 4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-isopropyl-4-oxobutanoic acid

To a mixture of 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl)-3-isopropylsuccinate (68mg, 0.16mmol) in THF (0.80mL), MeOH (0.40mL), and H₂O (0.18mL) was added LiOH (19mg, 0.80mmol). The reaction mixture was stirred for 2h at rt before the mixture was quenched with aq 2M HCl (0.40mL, 0.80mmol) and then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered, and concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography (EtOAc in Hex) to afford 4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-isopropyl-4-oxobutanoic acid. The racemic mixture was resolved by CHIRAL-SFC (CHIRALPAK IC (250mm*21mm), 40% MeOH (+0.25% DMEA) in CO₂), affording two compounds with retention times of 5.70min and 7.05min. Concentration of the second eluting peak afforded the product. LCMS (C₁₇H₂₁O₅S) (ES, m/z): 337 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.17 (1H, s), 7.49 (s, 1H), 7.37 (s, 1H), 3.76 (s, 3H), 3.74 (s, 3H), 3.35-3.25 (m, 1H), 3.05-2.85 (m, 1H), 2.67-2.61 (m, 1H), 1.95-1.87 (m, 1H), 0.88-0.82 (m, 6H).

Example 3: 2-Cyclopropyl-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid***Step 1: Diethyl 2-cyclopropyl-3-(5,6-dimethoxybenzo[*b*]thiophen-2-carbonyl)succinate***

5 To a stirring mixture of ethyl 3-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-3-oxopropanoate (SPECS, 0.30g, 0.97mmol) in DMF (4.9mL) was added ethyl 2-bromo-2-cyclopropylacetate (0.20g, 0.97mmol) and then K₂CO₃ (0.16g, 1.2mmol) at rt. The mixture was allowed to stir overnight and then diluted with H₂O (3.0mL) and DCM (6.0mL). The phases were separated, and the aq layer was washed with DCM (3x6mL). The combined organics were concentrated under reduced pressure and dried overnight under high vacuum. The resulting residue was purified by silica gel column chromatography (EtOAc in Hex) to afford diethyl 2-cyclopropyl-3-(5,6-dimethoxybenzo[*b*]thiophen-2-carbonyl)succinate. LCMS (C₂₂H₂₇O₇S) (ES, m/z): 435 [M+H]⁺.

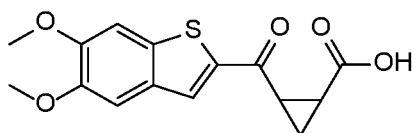
Step 2: 2-Cyclopropyl-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid

15 To a mixture of diethyl 2-cyclopropyl-3-(5,6-dimethoxybenzo[*b*]thiophen-2-carbonyl)succinate (90mg, 0.21mmol) in THF (1.0mL), MeOH (0.50mL) and H₂O (0.50mL) was added LiOH (25mg, 1.0mmol), and the mixture was allowed to stir for 2h at rt. After 2h, the mixture was acidified with 1N HCl (0.50mL, 1.0mmol) and then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography (EtOAc in hexanes) to afford 2-cyclopropyl-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid as a racemic mixture. The racemic mixture was resolved by CHIRAL-SFC (OJ-H column, 25% MeOH (+0.25% DMEA) in CO₂), affording two compounds with retention times of 5.3min and

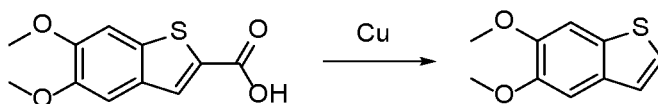
6.9min. Concentration of the first eluting peak afforded the product. LCMS ($C_{17}H_{19}O_5S$) (ES, m/z): 335 $[M+H]^+$. 1H NMR (500MHz, $DMSO-d_6$) δ 8.23 (s, 1H), 7.58 (s, 1H), 7.46 (s, 1H), 3.85 (s, 3H), 3.83 (s, 3H), 3.51-3.43 (m, 2H), 2.13-2.08 (m, 1H), 0.99-0.87 (m, 1H), 0.54-0.34 (m, 4H).

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Example 4: 2-(5,6-Dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane carboxylic acid

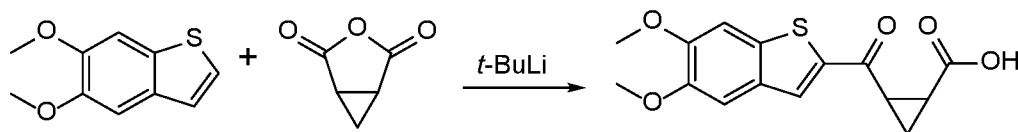


Step 1: 5,6-Dimethoxybenzo[b]thiophene



To a stirring solution of 5, 6-dimethoxybenzo[b]thiophene-2-carboxylic acid (Preparation 3, 2.00g, 8.39mmol) in quinoline (20mL) was added copper (0.907g, 14.3mmol) and then the mixture was heated at 190°C for 2h. Upon cooling to rt, the mixture was diluted with EtOAc and then successively washed with aq HCl (2M), H_2O , sat aq $NaHCO_3$, and brine. The organic layer was dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in Hex) to give 5,6-dimethoxybenzo[b]thiophene. LCMS ($C_{10}H_{11}O_2S$) (ES, m/z): 195 $[M+H]^+$. 1H NMR (500MHz, $DMSO-d_6$): δ 7.54 (s, 1H), 7.51 (d, $J = 5.3Hz$, 1H), 7.38 (s, 1H), 7.29 (d, $J = 5.3Hz$, 1H), 3.81 (s, 3H), 3.80 (s, 3H).

Step 2: 2-(5,6-Dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane carboxylic acid



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To a stirring solution of 5,6-dimethoxybenzo[b]thiophene (500mg, 2.57mmol) in THF (12mL) was added $t-BuLi$ (3.0mL, 3.9mmol) (1.3M in n -pentane) dropwise over 5min at -78°C under N_2 atmosphere. The mixture was stirred at -78°C for 1h, and then 3-oxabicyclo[3.1.0]hexane-2,4-dione (577mg, 5.15mmol) in THF (10mL) was added dropwise over 10min. The mixture was allowed to warm to rt and then stirred at rt for 12h under N_2 atmosphere. H_2O (15mL) was added to the mixture, and the mixture was then extracted with EtOAc (10mL). The aq layer was extracted with additional EtOAc (10mL) and then was adjusted to pH = 5-6 with aq HCl (1.0M) and further extracted with EtOAc (3x30mL). The combined organic layers were

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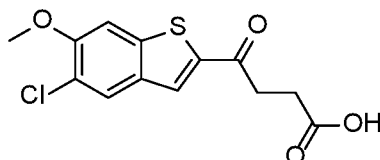
washed with brine (20mL), dried over MgSO₄, filtered, and concentrated under reduced pressure. The resulting residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to give 2-(5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl) cyclopropane carboxylic acid. The racemic mixture was resolved by CHIRAL-SFC (Column AD (250mm*30mm), 40% (1:1 H₂O (+0.1% NH₃) and EtOH) in CO₂), affording two compounds with retention times of 5.61min and 6.22min. Concentration of the first eluting peak afforded the product. LCMS (C₁₅H₁₅O₅S) (ES, m/z): 307 [M+H]⁺. ¹H NMR (400MHz, DMSO-*d*₆): δ 11.35 (s, 1H), 7.37 (s, 1H), 6.74 (s, 1H), 6.67 (s, 1H), 3.01 (s, 3H), 3.00 (s, 3H), 2.20 (m, 1H), 1.46-1.38 (m, 1H), 0.72-0.63 (m, 1H), 0.51-0.43 (m, 1H).

Examples 5 and 6, as shown in Table 1 below, were or may be prepared according to procedures analogous to those outlined in Example 4 above using the appropriate starting materials, described as Preparations or as obtained from commercial sources.

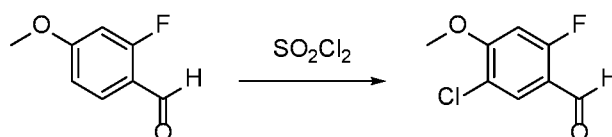
Table 1

Ex.	Structure	Name	Mass [M+H] ⁺
5		2-(5-bromo-6-methoxybenzo[<i>b</i>]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid (Single Enantiomer)	355, 357
6		2-(5-bromo-6-methoxybenzo[<i>b</i>]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid (Single Enantiomer)	355, 357

Example 7: 4-(5-Chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



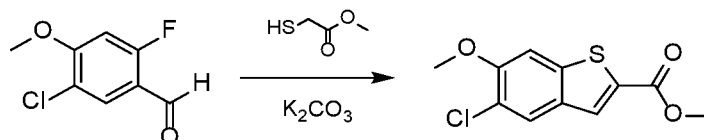
Step 1: 5-Chloro-2-fluoro-4-methoxybenzaldehyde



To a stirring solution of 2-fluoro-4-methoxybenzaldehyde (1.00g, 6.49mmol) in AcOH (2mL) was added SO₂Cl₂ (1.05mL, 13.0mmol). After stirring at rt for 12h, the reaction was complete. The reaction mixture was poured into ice water (50mL). The resulting precipitate

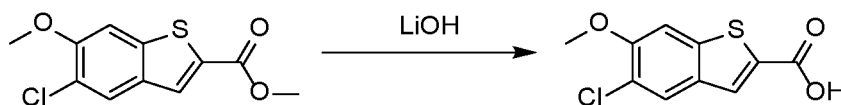
was collected by vacuum filtration, washed with H₂O (3x20mL), and air dried to afford 5-chloro-2-fluoro-4-methoxybenzaldehyde. LCMS (C₈H₇ClFO₂) (ES, m/z): 189 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ 10.18 (s, 1H), 7.88 (d, *J* = 7.28Hz, 1H), 6.72 (d, *J* = 11.69Hz, 1H), 3.99 (s, 3H). ¹⁹F NMR (376MHz, CDCl₃): δ -119.91 (dd, *J* = 7.15, 11.32Hz).

5 Step 2: Methyl 5-chloro-6-methoxybenzo[*b*]thiophene-2-carboxylate



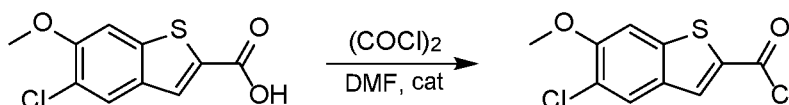
A mixture of 5-chloro-2-fluoro-4-methoxybenzaldehyde (1.04g, 5.51mmol), methyl 2-mercaptoacetate (0.740mL, 8.27mmol), K₂CO₃ (2.29g, 16.5mmol) and DMF (50mL) was stirred for 12h at 80°C. The reaction mixture was cooled to rt and poured into 500mL of ice water. Aq HCl (1M) was added to adjust the mixture to pH 5. The precipitate was collected by filtration, washed with H₂O (3x100mL), and dried under reduced pressure to give methyl 5-chloro-6-methoxybenzo[*b*] thiophene-2-carboxylate, which was used directly in the next step. LCMS (C₁₁H₁₀ClO₃S) (ES, m/z): 257 [M+H]⁺.

15 Step 3: 5-Chloro-6-methoxybenzo[*b*]thiophene-2-carboxylic acid



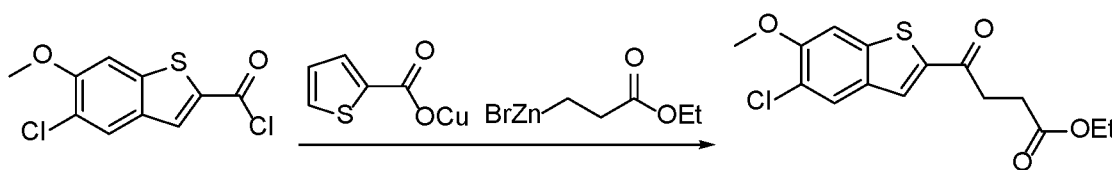
To a stirring suspension of methyl 5-chloro-6-methoxybenzo[*b*]thiophene-2-carboxylate (1.15g, 4.46mmol) in H₂O (10mL), THF (10mL), and MeOH (10mL) was added LiOH·H₂O (0.562g, 13.4mmol). The resulting mixture was heated to 50°C for 3h. The reaction mixture was then cooled to rt, and the organic solvents were removed by distillation under reduced pressure. The residue was diluted with H₂O (20mL) and washed with DCM (3x10mL). The aq layer was acidified with aq 1M HCl to pH 5, and the resulting precipitate was washed with H₂O (3x10mL). The remaining solid was dried under reduced pressure to give 5-chloro-6-methoxybenzo[*b*]thiophene-2-carboxylic acid. LCMS (C₁₀H₈ClO₃S) (ES, m/z): 243 [M+H]⁺. ¹H NMR (400MHz, DMSO-*d*₆): δ 13.43 (br, 1H), 8.10 (s, 1H), 7.99 (s, 1H), 7.83 (s, 1H), 3.94 (s, 3H).

25 Step 4: 5-Chloro-6-methoxybenzo[*b*]thiophene-2-carbonyl chloride



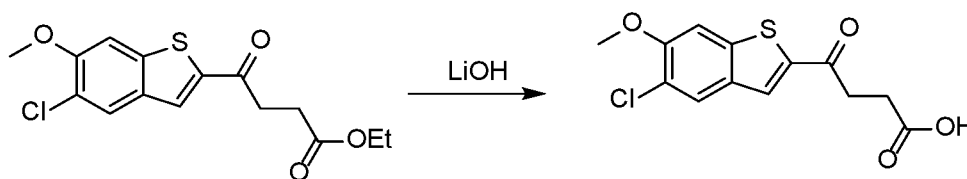
To a mixture of 5-chloro-6-methoxybenzo[*b*]thiophene-2-carboxylic acid (215mg, 0.886mmol) and THF (10mL) was added (COCl)₂ (0.4mL, 4.73mmol) and DMF (4uL, 0.055mmol) at 0°C. The resulting mixture was stirred at 80°C for 16h and then cooled to rt. The mixture was diluted with toluene (20mL) and concentrated under reduced pressure. The concentrated reaction mixture was then twice redissolved in toluene (20mL) and concentrated under reduced pressure. The resulting concentrated reaction mixture was dried *in vacuo* at 50°C-80°C for 1h and then backfilled with Ar gas for storage. The resultant 5-chloro-6-methoxybenzo[*b*] thiophene-2-carbonyl chloride was used in the next step directly.

Step 5: Ethyl 4-(5-chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate



An oven-dried Schlenk flask was charged with stir bar and ((thiophene-2-carbonyl)oxy)copper (500mg, 2.62mmol) under an Ar balloon. The flask was dried while attached to a high vacuum source by heating with a heat gun for 3min. After cooling to 0°C, (3-ethoxy-3-oxopropyl)zinc(II) bromide (5.0mL, 0.5M in THF, 2.5mmol) was added to the flask via syringe to form a mixture. After stirring at 0°C for 40min, a solution of 5-chloro-6-methoxybenzo[*b*]thiophene-2-carbonyl chloride (272mg, 0.885mmol) in THF (5mL) was added to the mixture. The resulting mixture was gradually warmed to rt and stirred for 16h. The reaction mixture was quenched with sat aq NH₄Cl solution (20mL) and extracted with EtOAc (3x30mL). The combined organic layers were washed with sat aq Na₂CO₃ solution (2x15mL) and brine (10mL), dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to give ethyl 4-(5-chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₅H₁₆ClO₄S) (ES, m/z): 327 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ 7.87 (s, 1H), 7.86 (s, 1H), 7.32 (s, 1H), 4.16 (q, *J* = 7.0Hz, 2H), 3.99 (s, 3H), 3.32 (t, *J* = 6.8Hz, 2H), 2.78 (t, *J* = 6.8Hz, 2H), 1.27 (t, *J* = 7.0Hz, 5H).

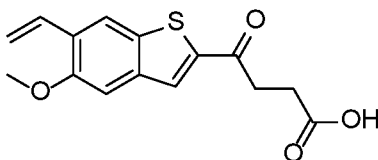
Step 6: 4-(5-Chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



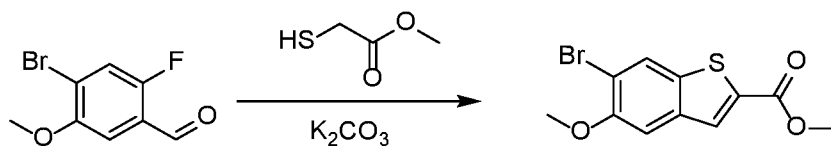
To a stirred solution of ethyl 4-(5-chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate (62mg, 0.19mmol) in MeOH (6mL) and H₂O (3mL) was added LiOH·H₂O (0.12g,

5.0mmol). The mixture was stirred at 45°C for 2h, and the solvent was removed under reduced pressure. The residue was dissolved in H₂O (15mL) and washed with DCM (2x15mL). The aq layer was acidified with concentrated aq HCl to pH~2 and then extracted with DCM (5x10mL). The combined organic phases were dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to give 4-(5-chloro-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₃H₁₂ClO₄S) (ES, m/z): 299 [M+H]⁺. ¹H NMR (400MHz, MeOH-*d*₄): δ 8.10 (s, 1H), 7.98 (s, 1H), 7.60 (s, 1H), 3.98 (s, 3H), 3.37 - 3.33 (m, 2H), 2.73 (t, *J* = 6.5Hz, 2H).

10 **Example 8: 4-(5-Methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid**

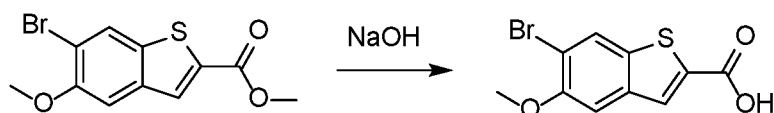


*Step 1: Methyl 6-bromo-5-methoxybenzo[*b*]thiophene-2-carboxylate*



To a stirred solution of 4-bromo-2-fluoro-5-methoxybenzaldehyde (5.00g, 21.5mmol) in DMF (100mL) was added methyl 2-mercaptoacetate (2.51g, 23.6mmol) and K₂CO₃ (8.90g, 64.4mmol). The reaction mixture was degassed with N₂ 3 times. The resulting mixture was then stirred at rt for 15h. EtOAc (500mL) and H₂O (1200mL) were added to the reaction mixture. The organic layer was separated and washed with brine (2x200mL), dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in PE) to give methyl 6-bromo-5-methoxybenzo[*b*]thiophene-2-carboxylate. LCMS (C₁₁H₁₀BrO₃S) (ES, m/z): 301, 303 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ = 8.01 (s, 1H), 7.93 (s, 1H), 7.26 (s, 1H), 3.96 (s, 3H), 3.94 (s, 3H).

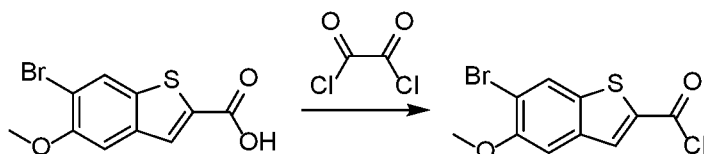
*Step 2: 6-Bromo-5-methoxybenzo[*b*]thiophene-2-carboxylic acid*



To a suspension of methyl 6-bromo-5-methoxybenzo[*b*]thiophene-2-carboxylate (1.45g, 4.81mmol) in MeOH (20mL), THF (20mL), and H₂O (20mL) was added NaOH (1.93g, 48.1mmol). The resulting suspension was heated to 50°C for 0.5h. The reaction mixture was

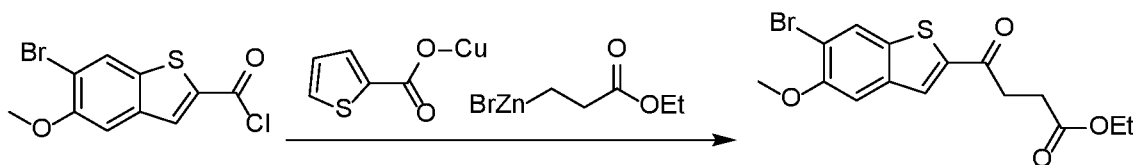
concentrated under reduced pressure to remove the solvent. H₂O (200mL) was added to the residue, and citric acid was added to adjust the solution to pH = 6. The remaining aq suspension was extracted with EtOAc (3x50mL). The combined organic layers were washed with brine (100mL), dried over Na₂SO₄, filtered, and concentrated under reduced pressure to give 6-bromo-5-methoxybenzo[*b*]thiophene-2-carboxylic acid, which was used directly for the next step without further purification. ¹H NMR (400MHz, DMSO-*d*₆): δ = 13.52 (br s, 1H), 8.35 (s, 1H), 8.01 (s, 1H), 7.65 (s, 1H), 3.90 (s, 3H).

Step 3: 6-Bromo-5-methoxybenzo[*b*]thiophene-2-carbonyl chloride



To a stirred solution of 6-bromo-5-methoxybenzo[*b*]thiophene-2-carboxylic acid (800mg, 2.79mmol) in anhydrous THF (6mL) was added (COCl)₂ (1.06g, 8.36mmol) dropwise at 0°C. The mixture was then heated at 75°C for 15h and then cooled to rt. The solvent was removed under reduced pressure to give the crude 6-bromo-5-methoxybenzo[*b*]thiophene-2-carbonyl chloride, which was used directly in the next step without further purification.

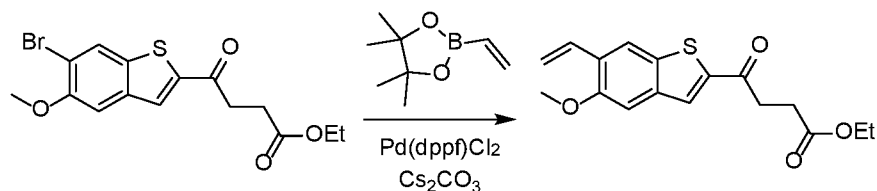
Step 4: Ethyl 4-(6-bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate



A solution of (3-ethoxy-3-oxopropyl)zinc(II) bromide (19.6mL, 0.5M in THF, 9.82mmol) was added to an oven-dried flask containing ((thiophene-2-carbonyl)oxy)copper (1.87g, 9.82mmol) under Ar atmosphere at 0°C. The reaction mixture was stirred for 20min at 0°C under Ar atmosphere. An Ar-degassed solution of 6-bromo-5-methoxybenzo[*b*]thiophene-2-carbonyl chloride (1.00g, 3.27mmol) in THF (20mL) was then added to the reaction mixture at 0°C. The resulting suspension was allowed to warm to rt and was stirred for an additional 3h. The reaction mixture was then cooled to 0°C and quenched with sat aq NH₄Cl solution (50mL). The mixture was allowed to warm to rt and stirred for 10min. The mixture was then filtered to remove any precipitated solid, and the filtrate was diluted with EtOAc (50mL) and brine (20mL). The organic layer was separated, washed with additional brine (50mL), dried over MgSO₄, filtered, and concentrated under reduced pressure to afford the crude product residue. The residue was purified by silica gel column chromatography (DCM in PE) to give ethyl 4-(6-

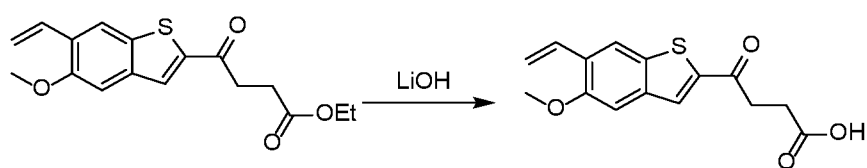
bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS ($C_{15}H_{16}BrO_4S$) (ES, m/z): 371, 373 $[M+H]^+$. 1H NMR (400MHz, $CDCl_3$): δ = 8.05 (s, 1H), 7.92 (s, 1H), 7.30 (s, 1H), 4.18 (q, J = 7.2Hz, 2H), 3.98 (s, 3H), 3.34 (t, J = 6.7Hz, 2H), 2.80 (t, J = 6.7Hz, 2H), 1.28 (t, J = 7.1Hz, 3H).

5 Step 5: Ethyl 4-(5-methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoate

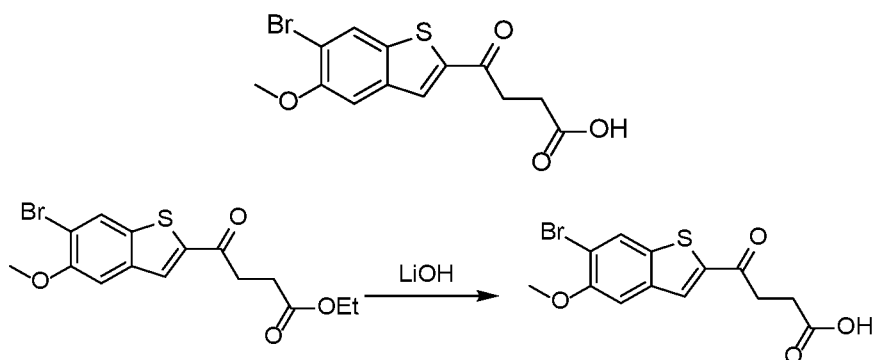


To a stirring mixture of ethyl 4-(6-bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate (40.0mg, 0.108mmol), 4,4,5,5-tetramethyl-2-vinyl-1,3,2-dioxaborolane (33.2mg, 0.215mmol), and CS_2CO_3 (105mg, 0.323mmol) in 1,4-dioxane (1.0mL) and H_2O (0.2mL) was added 1,1'-bis(diphenylphosphino)ferrocene dichloride (12mg, 0.022mmol). The reaction mixture was degassed by placing under reduced pressure and backfilling with N_2 3 times. The reaction mixture was stirred at 90°C under N_2 atmosphere for 2h, cooled to rt, and filtered to remove any solids. The filtrate was diluted with EtOAc (5mL) and brine (5mL). The organic layer was separated, washed with additional brine (5mL), dried over anhydrous Na_2SO_4 , filtered, and concentrated under reduced pressure to give ethyl 4-(5-methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoate, which was used for next step without further purification. LCMS ($C_{17}H_{19}O_4S$) (ES, m/z): 319 $[M+H]^+$.

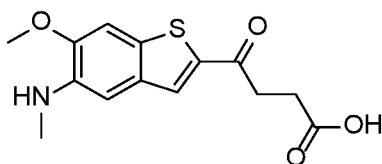
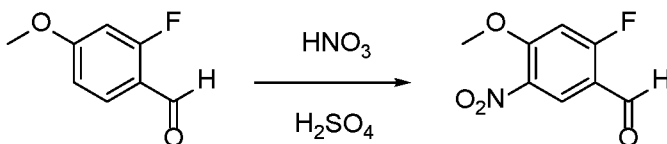
15 Step 6: 4-(5-Methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



20 To a stirred suspension of ethyl 4-(5-methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoate (25mg, 0.079mmol) in MeOH (0.5mL), THF (0.5mL), and H_2O (0.5mL) was added LiOH (18.8mg, 0.785mmol). The resulting suspension was heated to 50°C for 2h and then cooled to rt. The reaction mixture was concentrated under reduced pressure to remove the solvent, and the residue was purified by prep-HPLC (ACN/ H_2O with 0.1% TFA) to give 4-(5-methoxy-6-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid. LCMS ($C_{15}H_{15}O_4S$) (ES, m/z): 291 $[M+H]^+$. 1H NMR (400MHz, $MeOH-d_4$): δ = 8.10 (s, 1H), 7.98 (s, 1H), 7.44 (s, 1H), 7.09 (dd, J = 11.3, 17.8Hz, 1H), 5.87 (br d, J = 17.4Hz, 1H), 5.32 (br d, J = 11.2Hz, 1H), 3.91 (s, 3H), 3.37-3.32 (m, 2H), 2.71 (br t, J = 6.5Hz, 2H).

Example 9: 4-(6-Bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid

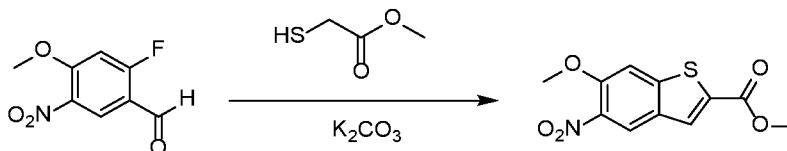
5 To a suspension of ethyl 4-(6-bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate from Example 8, step 4 (20mg, 0.054mmol) in MeOH (0.5mL), THF (0.5mL), and H₂O (0.5mL) was added LiOH (1.3mg, 0.054mmol). The resulting suspension was heated to 50°C for 2h and then cooled to rt. The reaction mixture was concentrated under reduced pressure to remove the solvent, and the residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to give 4-(6-bromo-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₃H₁₂BrO₄S) (ES, m/z): 343, 345 [M+H]⁺. ¹H NMR (400MHz, MeOH-*d*₄): δ = 8.12 (s, 1H), 8.11 (s, 1H), 7.53 (s, 1H), 3.95 (s, 3H), 3.36 (t, *J* = 6.4Hz, 2H), 2.74 (t, *J* = 6.4Hz, 2H).

Example 10: 4-(6-Methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoic acid**Step 1: 2-Fluoro-4-methoxy-5-nitrobenzaldehyde**

15 To a stirred solution of 2-fluoro-4-methoxybenzaldehyde (1.00g, 6.49mmol) in concentrated H₂SO₄ (5.88mL, 110mmol) at -15°C was added concentrated HNO₃ (0.414mL, 6.49mmol) in concentrated H₂SO₄ (0.795mL, 14.9mmol) dropwise over 5min. After 1h of stirring at below -10°C, the reaction mixture was poured into 50mL of ice water. The precipitate was collected by filtration. The filter cake was washed with H₂O (3x100mL) and dried under reduced pressure to give 2-fluoro-4-methoxy-5-nitrobenzaldehyde, which was used directly in

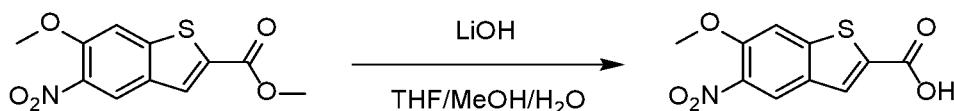
the next step. LCMS ($C_8H_7FNO_4$) (ES, m/z): 200 $[M+H]^+$. 1H NMR (400MHz, $CDCl_3$): δ 10.22 (s, 1H), 8.47 (d, $J = 7.24$ Hz, 1H), 6.88 (d, $J = 11.54$ Hz, 1H), 4.07 (s, 3H).

Step 2: Methyl 6-methoxy-5-nitrobenzo[b]thiophene-2-carboxylate



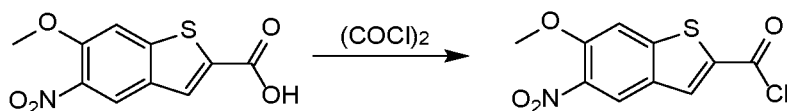
5 A mixture of 2-fluoro-4-methoxy-5-nitrobenzaldehyde (1.14g, 5.72mmol), methyl 2-mercaptoacetate (0.77mL, 8.6mmol), and K_2CO_3 (2.37g, 17.2mmol) in DMF (50mL) was stirred for 12h at $60^\circ C$. The reaction mixture was cooled to rt and then poured into 500mL of ice water. Aq HCl (1M) was added to adjust to pH 5. The precipitate was collected by filtration, washed with H_2O (3x100mL), and dried under reduced pressure to give methyl 6-methoxy-5-nitrobenzo[b]thiophene-2-carboxylate, which was used directly in the next step. LCMS ($C_{11}H_{10}NO_5S$) (ES, m/z): 268 $[M+H]^+$.

Step 3: 6-Methoxy-5-nitrobenzo[b]thiophene-2-carboxylic acid



15 To a suspension of methyl 6-methoxy-5-nitrobenzo[b]thiophene-2-carboxylate (1.50g, 5.61mmol) in H_2O (10mL), THF (10mL), and MeOH (10mL) was added $LiOH \cdot H_2O$ (0.707g, 16.8mmol). The resulting mixture was heated to $50^\circ C$ for 5h and then cooled to rt. The organic solvent was removed under reduced pressure, the residue was diluted with 20mL H_2O , and the mixture was extracted with DCM (3x10mL). The aq layer was acidified with aq HCl solution (1M) to pH 5. The precipitate was collected by filtration and then washed with H_2O (3x10mL). The resulting solid was dried under reduced pressure to give 6-methoxy-5-nitrobenzo[b]thiophene-2-carboxylic acid, which was used directly in the next step. LCMS ($C_{10}H_8NO_5S$) (ES, m/z): 254 $[M+H]^+$. 1H NMR (400MHz, $DMSO-d_6$): δ 13.93-13.26 (s, 1H), 8.58 (s, 1H), 8.12 (s, 1H), 8.05 (s, 1H), 3.98 (s, 3H).

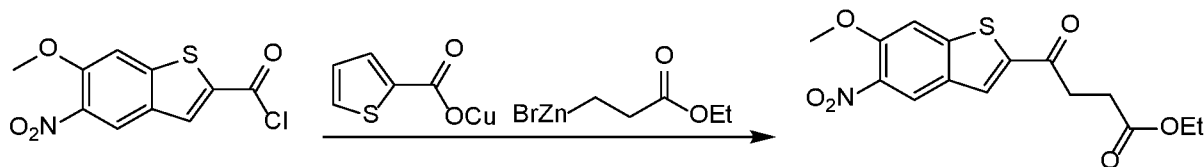
Step 4: 6-Methoxy-5-nitrobenzo[b]thiophene-2-carbonyl chloride



25 To a stirred solution of 6-methoxy-5-nitrobenzo[b]thiophene-2-carboxylic acid (400mg, 1.58mmol) in anhydrous THF (15mL) was added $(COCl)_2$ (1.20g, 9.48mmol) dropwise at $0^\circ C$. The mixture was heated at $75^\circ C$ for 15h and then cooled to rt. The solvent was removed

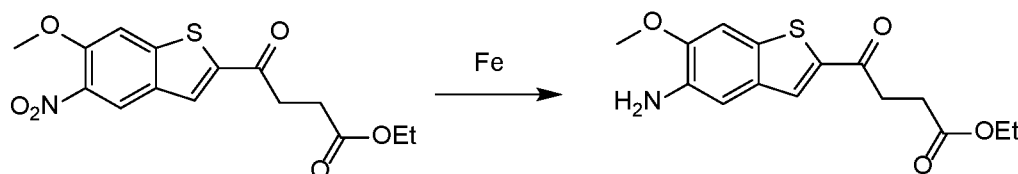
under reduced pressure to give the crude 6-methoxy-5-nitrobenzo[*b*]thiophene-2-carbonyl chloride, which was without further purification in the next step.

Step 5: Ethyl 4-(6-methoxy-5-nitrobenzo[*b*]thiophen-2-yl)-4-oxobutanoate



5 A solution of (3-ethoxy-3-oxopropyl)zinc(II) bromide (17.7mL, 0.5M in THF, 8.83mmol) was added to an oven-dried flask containing ((thiophene-2-carbonyl)oxy)copper (1.69g, 8.83mmol) under Ar atmosphere at 0°C. The reaction mixture was stirred for 20min at 0°C under Ar atmosphere. An Ar-degassed solution of 6-methoxy-5-nitrobenzo[*b*]thiophene-2-carbonyl chloride (800mg, 2.94mmol) in THF (10mL) was then added to the reaction mixture at
10 0°C; the resulting suspension was allowed to warm to rt and was stirred for an additional 8h. The reaction mixture was then cooled to 0°C and quenched with sat aq NH₄Cl solution (30mL). The mixture was allowed to warm to rt and stirred for 10min. The mixture was filtered, and the filtrate was diluted with EtOAc (50mL) and brine (30mL). The organic layer was separated, washed with additional brine (50mL), dried over MgSO₄, filtered, and concentrated under
15 reduced pressure to afford the crude product residue. The residue was purified by prep-TLC (SiO₂, DCM in PE) to give ethyl 4-(6-methoxy-5-nitrobenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₅H₁₆NO₆S) (ES, m/z): 338 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ = 8.36 (s, 1H), 7.99 (s, 1H), 7.47 (s, 1H), 4.24-4.16 (m, 2H), 4.05 (s, 3H), 3.34 (t, *J* = 6.6Hz, 2H), 2.81 (t, *J* = 6.5Hz, 2H), 1.33-1.27 (m, 3H).

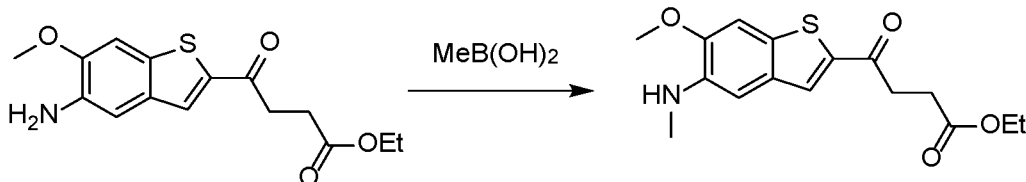
20 Step 6: Ethyl 4-(5-amino-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate



To a solution of ethyl 4-(6-methoxy-5-nitrobenzo[*b*]thiophen-2-yl)-4-oxobutanoate (140mg, 0.415mmol) in EtOH (2mL), THF (2mL), and H₂O (2mL) was added Fe (116mg, 2.08mmol) and NH₄Cl (222mg, 4.15mmol). The mixture was heated to 80°C for 1h,
25 cooled to rt, and filtered. H₂O (10mL) was added to the filtrate, and the aq layer was extracted with EtOAc (3x5mL). The combined organic layers were washed with brine (5mL), dried over MgSO₄, and filtered. The filtrate was concentrated under the reduced pressure to give ethyl 4-(5-

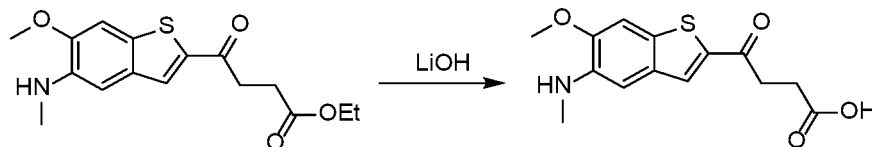
amino-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate, which was used directly for the next step without purification. LCMS ($C_{15}H_{18}NO_4S$) (ES, m/z): 308 $[M+H]^+$.

Step 7: Ethyl 4-(6-methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoate



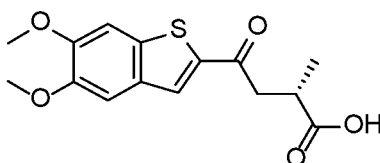
To a stirred solution of ethyl 4-(5-amino-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate (55 mg, 0.18 mmol), $MeB(OH)_2$ (16.1 mg, 0.268 mmol), and py (56.6 mg, 0.716 mmol) in 1,4-dioxane (2.0 mL) was added diacetoxycopper (48.8 mg, 0.268 mmol). The reaction mixture was stirred at 120°C for 2 h and then cooled to rt. The mixture was filtered, and the filtrate was diluted with EtOAc (5.0 mL) and brine (5.0 mL). The organic layer was separated, washed with additional brine (5 mL), dried over anhydrous Na_2SO_4 , and concentrated under reduced pressure to give ethyl 4-(6-methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoate, which was used directly for the next step without purification. LCMS ($C_{16}H_{20}NO_4S$) (ES, m/z): 322 $[M+H]^+$.

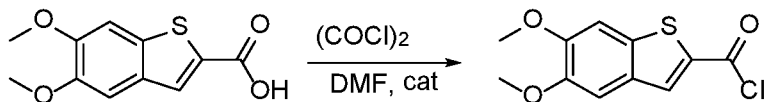
Step 8: 4-(6-Methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



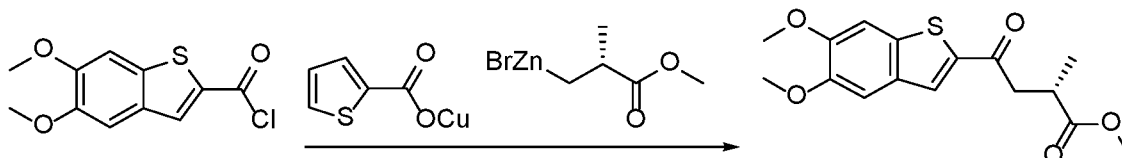
To a suspension of ethyl 4-(6-methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoate (30 mg, 0.093 mmol) in MeOH (0.5 mL), THF (0.5 mL), and H_2O (0.5 mL) was added LiOH (44.7 mg, 1.87 mmol). The resulting suspension was heated to 50°C for 2 h and then cooled to rt. The reaction mixture was concentrated under reduced pressure to remove the solvent, and the residue was purified by prep-HPLC (ACN/ H_2O with 0.1% TFA) to give 4-(6-methoxy-5-(methylamino)benzo[*b*]thiophen-2-yl)-4-oxobutanoic acid. LCMS ($C_{14}H_{16}NO_4S$) (ES, m/z): 294 $[M+H]^+$. 1H NMR (400 MHz, $MeOH-d_4$): δ 8.07 (s, 1H), 7.44 (s, 1H), 7.27 (s, 1H), 3.99 (s, 3H), 3.36-3.33 (m, 2H), 2.94 (s, 3H), 2.73 (t, $J = 6.4$ Hz, 2H).

Example 11: (S)-4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

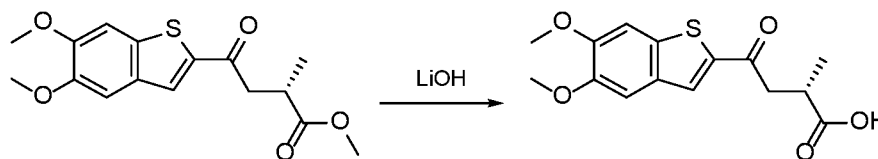


Step 1: 5,6-Dimethoxybenzo[b]thiophene-2-carbonyl chloride

To a stirring solution of 5,6-dimethoxybenzo[b]thiophene-2-carboxylic acid from Preparation 3 (5.0g, 21mmol) in THF (200mL) at 0°C under Ar was added $(\text{COCl})_2$ (5.5ml, 63mmol) followed by DMF (0.1ml, 1.3mmol). The reaction mixture was stirred at 0°C for 1h and then allowed to warm to rt and stirred overnight. The reaction mixture was concentrated under reduced pressure, and the resulting 5,6-dimethoxybenzo[b]thiophene-2-carbonyl chloride was used in the next step without purification. ^1H NMR (600MHz, $\text{CH}_3\text{CN}-d_3$): δ 8.25 (s, 1H), 7.46 (s, 1H), 7.45 (s, 1H), 3.92 (s, 3H), 3.88 (s, 3H).

Step 2: Methyl (S)-4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate

To an oven-dried, Ar-purged, round-bottomed flask containing copper (I) thiophene-2-carboxylate (797mg, 4.2mmol) at 0°C was added (R)-(3-methoxy-2-methyl-3-oxopropyl)zinc(II) bromide (7.8mL, 0.5M in THF, 3.9mmol) dropwise. The reaction mixture was stirred at 0°C for 20min. A suspension of 5,6-dimethoxybenzo[b]thiophene-2-carbonyl chloride (777mg, 3.0mmol) in THF (15mL) was added dropwise to the reaction mixture. The reaction mixture was allowed to warm to rt and stirred for 6h. The reaction mixture was diluted with sat aq NH_4Cl solution (15mL), followed by DCM (30mL). Precipitates were removed by filtration prior to extraction. The layers were separated, and the aq layer was extracted with DCM (3x30mL). The combined organic layers were concentrated under reduced pressure. The residue was purified by silica gel column chromatography ((25% EtOH in EtOAc) in Hex) to afford methyl (S)-4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS ($\text{C}_{16}\text{H}_{19}\text{O}_5\text{S}$) (ES, m/z): 323 $[\text{M}+\text{H}]^+$. ^1H NMR (500MHz, CHCl_3-d): δ 7.89 (s, 1H), 7.26 (s, 2H), 4.00 (s, 3H), 3.97 (s, 3H), 3.72 (s, 3H), 3.48 (dd, $J = 16.9, 7.6\text{Hz}$, 1H), 3.22-3.16 (m, 1H), 3.05 (dd, $J = 16.9, 6.0\text{Hz}$, 1H), 1.31 (d, $J = 7.2\text{Hz}$, 3H).

Step 3: (S)-4-(5,6-Dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

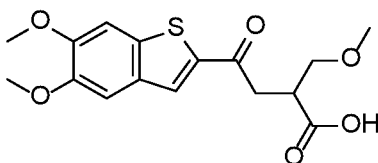
To a solution of methyl (*S*)-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate (200mg, 0.62mmol) in H₂O (1.2mL) and THF (5mL) was added LiOH (59mg, 2.5mmol). The reaction mixture was stirred overnight at rt. The reaction mixture was adjusted to ~pH 2 using additional 1M aq HCl. DCM (15mL) was added to the reaction mixture, and the layers were separated. The organic layer was concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography ((25% EtOH in EtOAc) in Hex) to afford (*S*)-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₅H₁₇O₅S) (ES, m/z): 309 [M+H]⁺. ¹H NMR (600MHz, CH₃OH-d₄): δ 8.06 (s, 1H), 7.41 (s, 2H), 3.90 (s, 3H), 3.88 (s, 3H), 3.46 (dd, *J* = 17.1, 8.3Hz, 1H), 3.08 (dd, *J* = 17.2, 5.3Hz, 1H), 3.04-2.98 (m, 1H), 1.26 (d, *J* = 7.1Hz, 3H).

Examples 12 through 16, as shown in Table 2 below, were or may be prepared according to procedures analogous to those outlined in Example 11 above using the appropriate starting materials, described as Preparations or as obtained from commercial sources.

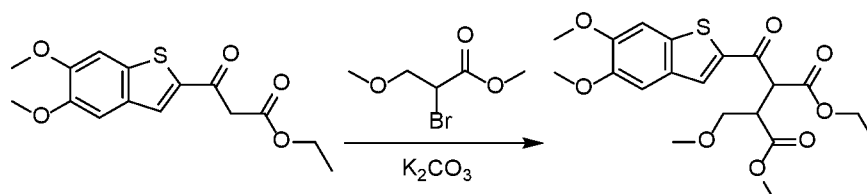
Table 2

Ex.	Structure	Name	Mass [M+H] ⁺
12		tert-butyl 4-(5,6-dimethoxybenzo[<i>b</i>]thiophen-2-yl)-4-oxobutanoate	295 [M – C ₄ H ₈]
13		(<i>S</i>)-4-(4-fluoro-5,6-dimethoxybenzo[<i>b</i>]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	327
14		4-(4-fluoro-5,6-dimethoxybenzo[<i>b</i>]thiophen-2-yl)-4-oxobutanoic acid	313
15		(<i>S</i>)-4-(6-bromo-5-methoxybenzo[<i>b</i>]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	357, 359
16		4-(5,6-dimethoxybenzo[<i>b</i>]thiophen-2-yl)-4-oxobutanoic acid	295

Example 17: 4-(5,6-Dimethoxybenzo[*b*]thiophen-2-yl)-2-(methoxymethyl)-4-oxobutanoic acid

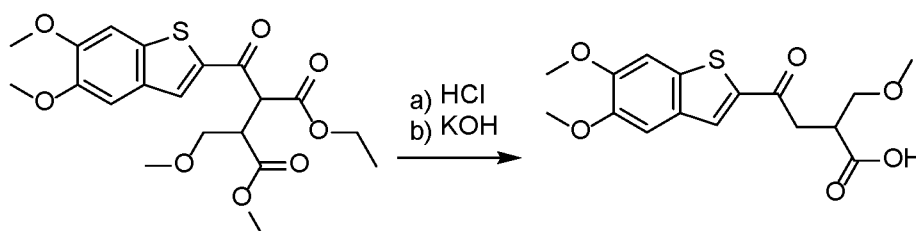


Step 1: 1-Ethyl 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-(methoxymethyl)succinate



5 To a stirring solution of ethyl 3-(5,6-dimethoxybenzo[b]thien-2-yl)-3-oxopropanoate (SPECS, 231mg, 0.75mmol) in DMF (2.5mL) was added methyl 2-bromo-3-methoxypropanoate (125μl, 0.93mmol) at rt. The reaction mixture was stirred overnight at rt. Then, the reaction mixture was diluted with H₂O (3mL) and DCM (6ml). The phases were separated, and the aq layer was washed with DCM (3x6mL). The combined organics were concentrated under reduced pressure and dried overnight *in vacuo*. The product was purified by silica gel column chromatography ((25% EtOH in EtOAc) in Hex) to give 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-(methoxymethyl)succinate, which was used without further purification. LCMS (C₂₀H₂₅O₈S) (ES, m/z): 425 [M+H]⁺.

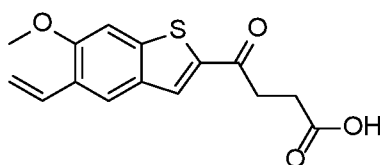
Step 2: 4-(5,6-Dimethoxybenzo[b]thiophen-2-yl)-2-(methoxymethyl)-4-oxobutanoic acid



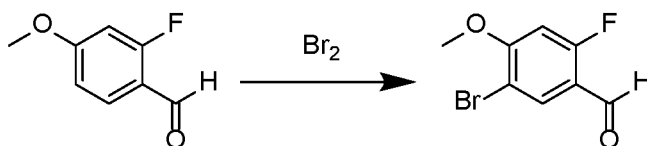
15 To a stirring solution of 1-ethyl 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-(methoxymethyl)succinate (200mg, 0.5mmol) in EtOH (3ml) was added aq HCl solution (490μl, 6M, 2.9mmol) at rt. The reaction mixture was heated to 100°C in a sealed microwave vial for 2h. Upon cooling, aq KOH solution (490μl, 10M, 4.9mmol) was added to the stirring reaction mixture, and the reaction mixture was returned to heat at 100°C for 1h. The pH of the reaction mixture was adjusted to ~2 with aq HCl solution (1M) as indicated by pH test strips. The reaction mixture was concentrated under reduced pressure to remove EtOH, then diluted with DCM (10mL). The layers were separated, and the aq layer was extracted with DCM (3x10mL). The combined organic layers were concentrated under reduced pressure, and the

residue was purified by column chromatography on silica ((25% EtOH in EtOAc) in Hex). Product-containing fractions were concentrated under reduced pressure to give 4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-(methoxymethyl)-4-oxobutanoic acid. The racemic mixture was resolved by Chiral-SFC (CHIRACEL OJ-H (250mm*21mm), 25% MeOH (+0.25% DMEA) in CO₂), affording two compounds with retention times of 3.12min and 3.96min. Concentration of the first eluting peak afforded the product. LCMS (C₁₆H₁₉O₆S) (ES, m/z): 339 [M+H]⁺. ¹H NMR (600MHz, DMSO-*d*₆): δ 12.32 (1H, br s), 8.18 (1H, s), 7.56 (1H, s), 7.44 (1H, s), 3.83 (3H, s), 3.80 (3H, s), 3.58-3.51 (2H, m), 3.46-3.40 (1H, m), 3.22 (3H, s), 3.09-3.07 (2H, m).

10 **Example 18: 4-(6-Methoxy-5-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid**

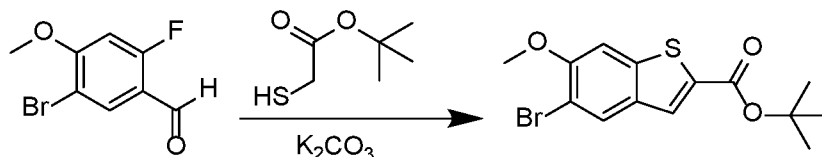


Step 1: 5-Bromo-2-fluoro-4-methoxybenzaldehyde



2-Fluoro-4-methoxybenzaldehyde (9.0g, 58mmol) was added slowly (portion-wise) to a solution of Br₂ (6.0mL, 120mmol) in MeOH (40mL) at 0°C. The reaction mixture was stirred at 0°C for 2h. A solution of NaHSO₃ (24.3g, 234mmol) in H₂O (300mL) was added slowly to the reaction mixture at 0°C. The resulting suspension was then stirred for 30min at 0°C. The reaction mixture was filtered, and the filtrate was washed with additional H₂O (3x25mL). The filtrate was then dried under reduced pressure to afford 5-bromo-2-fluoro-4-methoxybenzaldehyde. The product was used without purification. ¹H NMR (500MHz, DMSO-*d*₆): δ 10.02 (s, 1H), 7.98 (d, *J* = 7.5Hz, 1H), 7.26 (d, *J* = 13.0Hz, 1H), 3.97 (s, 3H).

Step 2: *tert*-Butyl 5-bromo-6-methoxybenzo[*b*]thiophene-2-carboxylate



K₂CO₃ (19.0g, 137mmol) was added slowly (portion-wise) to a solution of 5-bromo-2-fluoro-4-methoxybenzaldehyde (10.7g, 45.8mmol) and *tert*-butyl 2-mercaptoacetate (6.65mL, 45.8mmol) in DMF (50mL) at 20°C under Ar atmosphere. The reaction mixture was

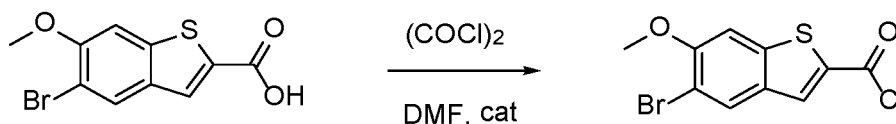
stirred and heated to 100°C for 16h. The reaction mixture was then cooled to rt and diluted with Et₂O (1000mL). The mixture was then washed with H₂O (500mL, then 2x250mL), and the combined aq layers were extracted with Et₂O (2x200mL). The organic layers were then combined and washed with brine (50mL). The organic layer was separated, dried over MgSO₄,
 5 filtered, and concentrated under reduced pressure to afford *tert*-butyl 5-bromo-6-methoxybenzo[*b*]thiophene-2-carboxylate. The product was used without purification. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.26 (s, 1H), 7.96 (s, 1H), 7.78 (s, 1H), 3.92 (s, 3H), 1.55 (s, 9H).

Step 3: 5-Bromo-6-methoxybenzo[*b*]thiophene-2-carboxylic acid



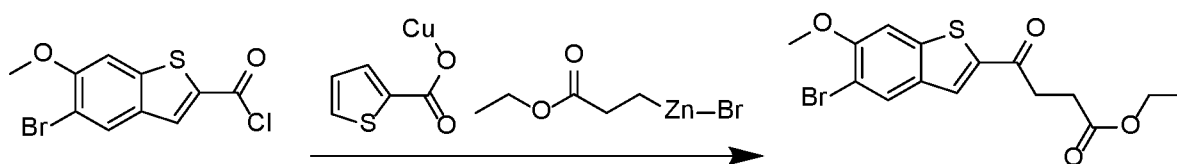
HCl (56mL, 4.0M in 1,4-dioxane, 230mmol) was added to a solution of *tert*-butyl 5-bromo-6-methoxybenzo[*b*]thiophene-2-carboxylate (15.5g, 45.0mmol) in DCM (200mL) at 20°C. The reaction mixture was stirred at 20°C for 3 days. The reaction mixture was then diluted by the dropwise addition of Hex (500mL). The resulting suspension was stirred for an additional 2h post-addition at rt. The reaction mixture was filtered, and the collected solids were washed
 15 with Hex (2x50mL) and dried under reduced pressure to afford 5-bromo-6-methoxybenzo[*b*]thiophene-2-carboxylic acid, which was used without purification. ¹H NMR (500MHz, DMSO-*d*₆): δ 13.42 (s, 1H), 8.26 (s, 1H), 7.98 (s, 1H), 7.80 (s, 1H), 3.93 (s, 3H).

Step 4: 5-Bromo-6-methoxybenzo[*b*]thiophene-2-carbonyl chloride



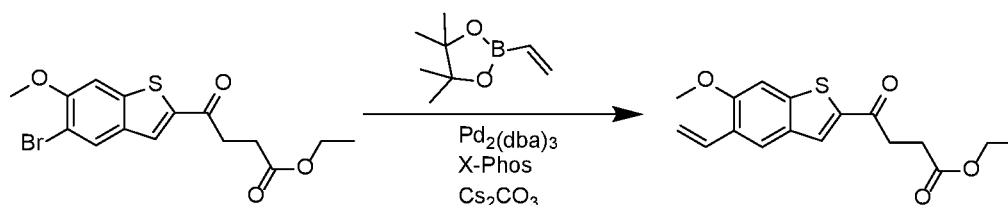
DMF (0.049mL, 0.63mmol) was added slowly (dropwise) to a solution of 5-bromo-6-methoxybenzo[*b*]thiophene-2-carboxylic acid (6.0g, 21mmol) and (COCl)₂ (5.5mL, 63mmol) in THF (100mL) at 0°C under Ar atmosphere. The reaction mixture was stirred at 0°C for 2h and then allowed to warm to rt. The reaction mixture was stirred for 18h at rt. The reaction mixture was then concentrated under reduced pressure to afford 5-bromo-6-methoxybenzo[*b*]thiophene-2-carbonyl chloride. The product was used without purification.
 25

Step 5: Ethyl 4-(5-bromo-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate



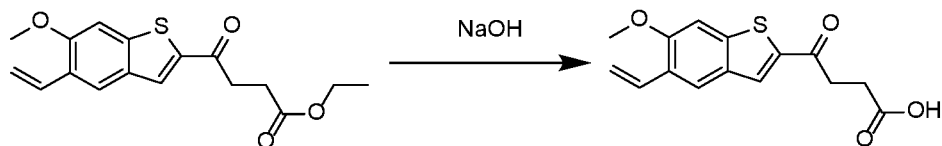
A solution of (3-ethoxy-3-oxopropyl)zinc(II) bromide (13.8mL, 0.50M in THF, 6.9mmol) was added to an oven-dried flask containing ((thiophene-2-carbonyl)oxy)copper (1.31g, 6.87mmol) under Ar atmosphere at 0°C. The reaction mixture was stirred for 20min at 0°C under Ar atmosphere. An Ar-degassed solution of 5-bromo-6-methoxybenzo[*b*]thiophene-2-carbonyl chloride (1.52g, 4.98mmol) in THF (25.0mL) was then added via cannula to the reaction mixture at 0°C; the resulting suspension was allowed to warm to rt and was stirred for an additional 3h. The reaction mixture was cooled to 0°C and quenched with sat aq NH₄Cl (50mL). The mixture was allowed to warm to rt and stirred for an additional 10min. The mixture was filtered, and the filtrate was diluted with EtOAc (500mL) and brine (50mL). The organic layer was separated, washed with additional brine (25mL), dried over MgSO₄, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in DCM) to afford ethyl 4-(5-bromo-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₅H₁₆BrO₄S) (ES, m/z): 371, 373 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.27 (s, 1H), 8.26 (s, 1H), 7.81 (s, 1H), 4.07-4.02 (m, 2H), 3.94 (s, 3H), 3.35-3.25 (m, 2H), 2.68-2.64 (m, 2H), 1.20-1.14 (m, 3H).

Step 6: Ethyl 4-(6-methoxy-5-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoate



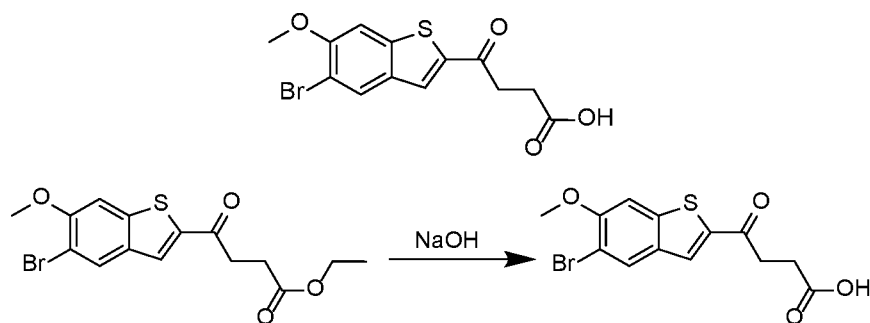
To an Ar-degassed mixture of ethyl 4-(5-bromo-6-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate (100mg, 0.269mmol), 4,4,5,5-tetramethyl-2-vinyl-1,3,2-dioxaborolane (50mg, 0.32mmol), Pd₂(dba)₃ (12mg, 0.013mmol), X-phos (13mg, 0.027mmol), and Cs₂CO₃ (263mg, 0.808mmol) was added 1,4-dioxane (3mL) and H₂O (0.3mL) at rt while degassing with Ar. The reaction mixture was stirred for 5min while degassing with Ar (subsurface sparge), after which the mixture was heated to 90°C under Ar atmosphere for 2h. The reaction mixture was then cooled to rt and diluted with EtOAc (20mL). The resulting suspension was filtered through a frit containing MgSO₄. The organic layer (filtrate) was concentrated under reduced pressure. The crude product residue was purified by silica gel column chromatography (EtOAc in DCM) to afford ethyl 4-(6-methoxy-5-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₇H₁₉O₄S) (ES, m/z): 319 [M+H]⁺.

Step 7: 4-(6-Methoxy-5-vinylbenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



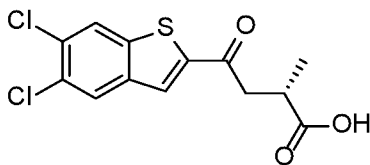
An aq NaOH solution (0.33mL, 1.0M, 0.33mmol) was added to a solution of ethyl 4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-4-oxobutanoate (21mg, 0.066mmol) in MeOH (4.0mL). The reaction mixture was stirred at rt for 18h. The reaction mixture was
 5 quenched with aq HCl solution (0.33mL, 1.0M, 0.33mmol) and then was concentrated under reduced pressure. The crude product residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford 4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₅H₁₅O₄S) (ES, m/z): 291 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.21 (s, 1H), 8.27 (s, 1H), 8.11 (s, 1H), 7.65 (s, 1H), 7.00 (dd, *J* = 17.5, 11.5Hz, 1H), 5.87 (d, *J* = 17.5Hz, 1H), 5.33
 10 (d, *J* = 11.5Hz, 1H), 3.91 (s, 3H), 3.30-3.24 (m, 2H), 2.63-2.56 (m, 2H).

Example 19: 4-(5-Bromo-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid

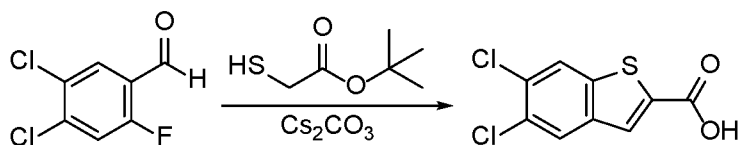


An aq NaOH solution (0.54mL, 1.0M, 0.54mmol) was added to a solution of ethyl 4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate from Example 17, step 5 (40mg, 0.11mmol) in MeOH (2.0mL). The reaction mixture was stirred at 20°C for 24h. The reaction mixture was quenched with aq HCl solution (0.54mL, 1.0M, 0.54mmol). The mixture was then concentrated under reduced pressure to afford the crude product residue. The crude
 15 product residue was purified by prep- HPLC (ACN/H₂O with 0.1% TFA) to afford 4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₃H₁₂BrO₄S) (ES, m/z): 343, 345 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.23 (s, 1H), 8.27 (s, 1H), 8.25 (s, 1H), 7.81 (s, 1H), 3.94 (s, 3H), 3.29-3.24 (m, 2H), 2.62-2.57 (m, 2H).
 20

Example 20: 4-((S)-4-(5,6-Dichlorobenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

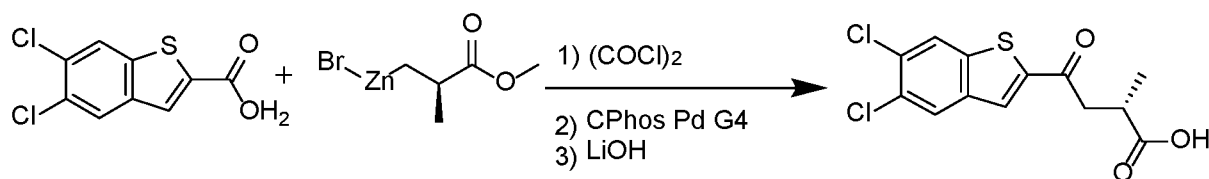


Step 1: 5,6-Dichlorobenzo[b]thiophene-2-carboxylic acid

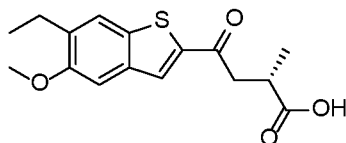
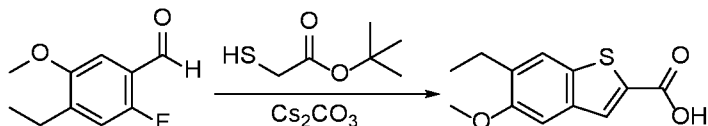


To a solution of 4,5-dichloro-2-fluorobenzaldehyde (V-Pharma, 386mg, 2.00mmol), *tert*-butyl 2-mercaptoacetate (356mg, 2.40mmol) and toluene (5ml) was added Cs₂CO₃ (1.30g, 4.00mmol), and the reaction was heated at reflux for 2h. The reaction mixture was then filtered, and the filtrate was washed with toluene (5mL). TFA (10mL) was then added to the filtrate, and the mixture was stirred for 1h. The reaction mixture was filtered, washed with toluene and hexanes, and dried under reduced pressure to afford 5,6-dichlorobenzo[b]thiophene-2-carboxylic acid. LCMS (C₉H₃Cl₂O₂S) (ES, m/z): 245 [M-H]⁻.

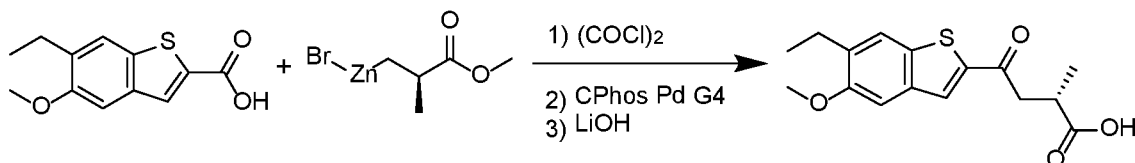
Step 2: (S)-4-(5,6-Dichlorobenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



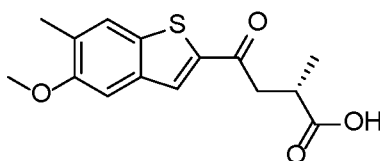
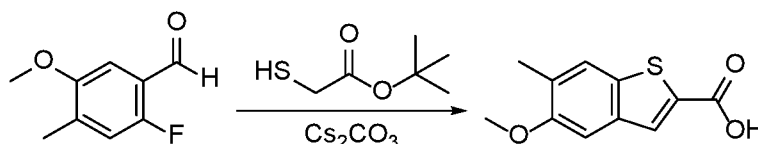
To a mixture of 5,6-dichlorobenzo[b]thiophene-2-carboxylic acid (0.049g, 0.20mmol) and DCM (2ml) was added DMF (4μL, 0.055mmol). (COCl)₂ (0.175ml, 2.00mmol) was then added, and the reaction was stirred at rt for 1h. The solvent was removed under reduced pressure. The residue was redissolved in THF (2.0ml), CPhos Pd G4 from Preparation 1 (0.033g, 0.040mmol) was added, and the mixture was stirred while (*R*)-(3-methoxy-2-methyl-3-oxopropyl)zinc(II) bromide (0.40mL, 0.5M in THF, 0.20mmol) was added all at once. The reaction was stirred for 2h, and then LiOH (0.048g, 2.0mmol), H₂O (1mL), and MeOH (1mL) were added. The reaction mixture was stirred for another 2h, and then the solvent was removed under reduced pressure. The residue was purified via prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (*S*)-4-(5,6-dichlorobenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₃H₁₁Cl₂O₃S) (ES, m/z): 317 [M+H]⁺. ¹H NMR (600MHz, DMSO-*d*₆): δ 8.45 (s, 1 H), 8.31 (s, 1H), 8.28 (s, 1H), 3.38 (dd, *J* = 17.4, 8.5Hz, 1H), 3.10 (dd, *J* = 17.6, 5.0Hz, 1H), 2.90-2.84 (m, 1H), 1.16 (d, 3H).

Example 21: (S)-4-(6-Ethyl-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acidStep 1: 6-Ethyl-5-methoxybenzo[b]thiophene-2-carboxylic acid

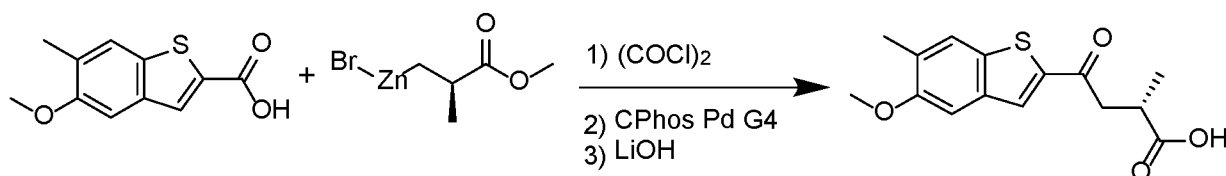
5 To a stirred solution of 4-ethyl-2-fluoro-5-methoxybenzaldehyde (Biogene Organics, 364mg, 2.00mmol), *tert*-butyl 2-mercaptoacetate (356mg, 2.40mmol), and toluene (5ml) was added Cs_2CO_3 (1.30g, 4.00mmol), and the reaction was heated at reflux for 2h. The reaction mixture was then filtered, and the filtrate was washed with toluene (5mL). TFA (10mL) was then added to the filtrate, and the mixture was stirred for 1h. The reaction mixture was
10 filtered, washed with toluene and Hex, and dried under reduced pressure to afford 6-ethyl-5-methoxybenzo[b]thiophene-2-carboxylic acid. LCMS ($\text{C}_{12}\text{H}_{11}\text{O}_3\text{S}$) (ES, m/z): 236 $[\text{M}-\text{H}]^-$.

Step 2: (S)-4-(6-Ethyl-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

To a mixture of 6-ethyl-5-methoxybenzo[b]thiophene-2-carboxylic acid (0.047g,
15 0.20mmol), and DCM (2ml) was added DMF (4uL, 0.055mmol). $(\text{COCl})_2$ (0.175mL, 2.00mmol) was then added, and the reaction was stirred at rt for 1h. The solvent was removed under reduced pressure. The residue was redissolved in THF (2.0ml), CPhos Pd G4 from Preparation 1 (0.033g, 0.040mmol) was added, and the mixture was stirred while (*R*)-(3-methoxy-2-methyl-3-oxopropyl)zinc(II) bromide (0.40ml, 0.5M in THF, 0.20mmol) was added
20 all at once. The reaction was stirred for 2h, and then LiOH (48mg, 2.0mmol), H_2O (1 mL), and MeOH (1 mL) were added. The reaction mixture was stirred for another 2h, and then the solvent was removed under reduced pressure. The residue was then purified via prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford (*S*)-4-(6-ethyl-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS ($\text{C}_{16}\text{H}_{19}\text{O}_4\text{S}$) (ES, m/z): 307 $[\text{M}+\text{H}]^+$. ^1H NMR (600MHz, $\text{DMSO}-d_6$):
25 δ 8.21 (s, 1H), 7.75 (s, 1H), 7.43 (s, 1H), 3.83 (s, 3H), 3.38 (dd, $J = 17.4, 8.5\text{Hz}$, 1H), 3.07 (dd, $J = 17.4, 5.1\text{Hz}$, 1H), 2.87-2.84 (m, 1H), 2.65 (q, $J = 7.5\text{Hz}$, 2H), 1.16-1.14 (m, 6H).

Example 22: (S)-4-(5-methoxy-6-methylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acidStep 1: 5-Methoxy-6-methylbenzo[b]thiophene-2-carboxylic acid

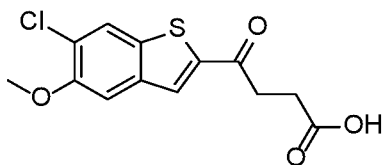
To a stirred solution of 2-fluoro-5-methoxy-4-methylbenzaldehyde (Biogene Organics, 336mg, 2.00mmol), *tert*-butyl 2-mercaptoacetate (356mg, 2.40mmol) and toluene (5ml) was added Cs_2CO_3 (1.30g, 4.00mmol), and the reaction was heated at reflux for 2h. The reaction mixture was filtered, and the filtrate was washed with toluene (5mL). TFA (10mL) was then added to the filtrate, and the mixture was stirred for 1h. The reaction mixture was filtered, washed with toluene and Hex, and dried under reduced pressure to afford 5-methoxy-6-methylbenzo[b]thiophene-2-carboxylic acid. LCMS ($\text{C}_{11}\text{H}_9\text{O}_3\text{S}$) (ES, m/z): 221 $[\text{M}-\text{H}]^-$.

Step 2: (S)-4-(5-methoxy-6-methylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

To a mixture of 5-methoxy-6-methylbenzo[b]thiophene-2-carboxylic acid (0.044g, 0.20mmol) and DCM (2ml) was added DMF (4uL, 0.055mmol). $(\text{COCl})_2$ (0.175mL, 2.00mmol) was then added, and the reaction was stirred at rt for 1h. The solvent was removed under reduced pressure. The residue was redissolved in THF (2.0ml), CPhos Pd G4 (0.033g, 0.040mmol) was added, and the mixture was stirred while (*R*)-(3-methoxy-2-methyl-3-oxopropyl)zinc(II) bromide (0.40ml, 0.5M in THF, 0.20mmol) was added all at once. The reaction was stirred for 2h, and then LiOH (48mg, 2.0mmol), H_2O (1mL), and MeOH (1mL) were added. The reaction mixture was stirred for another 2h, and then the solvent was removed under reduced pressure. The residue was then purified via prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford (*S*)-4-(5-methoxy-6-methylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS ($\text{C}_{15}\text{H}_{17}\text{O}_4\text{S}$) (ES, m/z): 293 $[\text{M}+\text{H}]^+$. ^1H NMR (600MHz, $\text{DMSO}-d_6$): δ 8.21 (s, 1H),

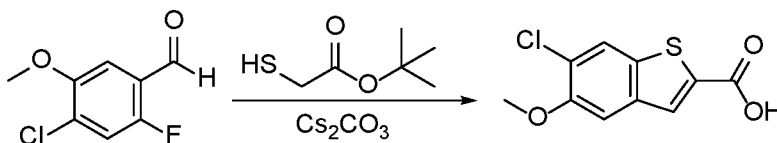
7.75 (s, 1H), 7.42 (s, 1H), 3.83 (s, 3H), 3.38 (dd, $J = 17.4, 8.5\text{Hz}$, 1H), 3.06 (dd, $J = 17.4, 5.2\text{Hz}$, 1H), 2.88-2.83 (m, 1H), 2.24 (s, 3H), 1.15 (d, $J = 7.2\text{Hz}$, 3H).

Example 23: 4-(6-Chloro-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



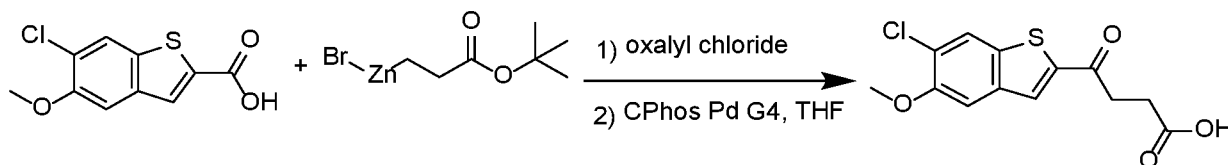
5

Step 1: 6-Chloro-5-methoxybenzo[*b*]thiophene-2-carboxylic acid



To a stirred solution of 4-chloro-2-fluoro-5-methoxybenzaldehyde (38mg, 0.20mmol), *tert*-butyl 2-mercaptoacetate (54mg, 0.30mmol) and 1,4-dioxane (2ml) was added Cs₂CO₃ (326mg, 1.00mmol), and the reaction was heated at reflux for 4h. The reaction mixture was then filtered, washed with 1,4-dioxane (2mL), and concentrated under reduced pressure. The concentrate was slurried in DCM (1mL), and TFA (1mL) was added. Then, the reaction was stirred at rt for 2h. The solvent was removed under reduced pressure to afford 6-chloro-5-methoxybenzo[*b*]thiophene-2-carboxylic acid. LCMS (C₁₀H₆ClO₃S) (ES, *m/z*): 241 [M-H]⁻.

15 Step 2: 4-(6-Chloro-5-methoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid



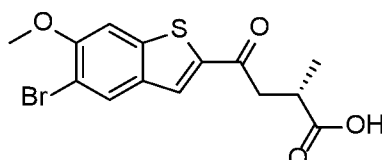
To a mixture of 6-chloro-5-methoxybenzo[*b*]thiophene-2-carboxylic acid (0.045g, 0.20mmol) and DCM (2ml) was added DMF (4uL, 0.055mmol). (COCl)₂ (0.175mL, 2.00mmol) was then added. The reaction was stirred at rt for 1h, and the solvent was removed under reduced pressure. The residue was redissolved in THF (2.0ml), CPhos Pd G4 from Preparation 1 (0.033g, 0.040mmol) was added, and the mixture was stirred while 3-*tert*-butoxy-3-oxopropylzinc bromide (0.40ml, 0.5M in THF, 0.20mmol) was added all at once. The reaction was stirred for 2h, and then the solvent was removed under reduced pressure. Then, DCM (1mL) and TFA (1mL) were added. The reaction mixture was stirred for another 2h, and then the solvent was removed under reduced pressure. The residue was then purified via prep-HPLC (ACN/H₂O with 0.1% TFA) to afford 4-(6-chloro-5-methoxybenzo[*b*]thiophen-2-yl)-4-

20

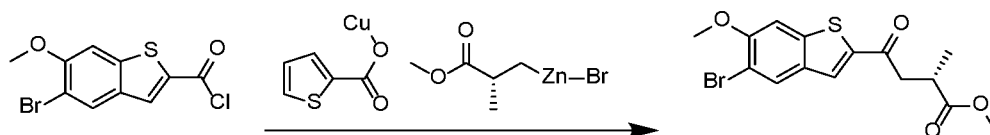
25

oxobutanoic acid. LCMS ($C_{13}H_{12}ClO_4S$) (ES, m/z): 299 $[M+H]^+$. 1H NMR (600MHz, $DMSO-d_6$): δ 8.23 (s, 1 H), 8.18 (s, 1 H), 7.65 (s, 1 H), 3.89 (s, 3 H), 3.23 (t, $J = 6.6$ Hz, 2 H), 2.52 (t, $J = 6.4$ Hz, 2 H).

5 **Example 24: (S)-4-(5-Bromo-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid**



Step 1: Methyl (S)-4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate



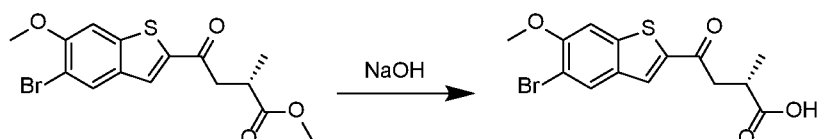
10 A solution of (R)-3-methoxy-2-methyl-3-oxopropylzinc(II) bromide (57.7mL, 0.50M) in THF (28.9mmol) was added to an oven-dried flask containing ((thiophene-2-carbonyl)oxy)copper (5.50g, 28.9mmol) under Ar atmosphere at 0°C. The reaction mixture was stirred for 20min at 0°C under Ar atmosphere. An Ar-degassed solution of 5-bromo-6-methoxybenzo[b]thiophene-2-carbonyl chloride from Example 18, step 4 (6.39g, 20.9mmol) in THF (100mL) was then added via cannula to the reaction mixture at 0°C. The resulting suspension was allowed to warm to rt and was stirred for an additional 3h. The reaction mixture was cooled to 0°C and added via cannula to a stirring mixture of sat aq NH_4Cl (300mL) and EtOAc (500mL). The mixture was allowed to warm to rt and stirred for an additional 16h. The mixture was filtered, and the filtrate was diluted with EtOAc (1000mL) and brine (100mL). The organic layer was separated, washed with additional brine (50mL), dried over $MgSO_4$, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in DCM) to afford methyl (S)-4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS ($C_{15}H_{16}BrO_4S$) (ES, m/z): 371, 373 $[M+H]^+$. 1H NMR (500MHz, $DMSO-d_6$): δ 8.27-8.24 (m, 2H), 7.80 (s, 1H), 3.94 (s, 3H), 3.59 (s, 3H), 3.46-3.39 (m, 1H), 3.23-3.16 (m, 1H), 3.01-2.93 (m, 1H), 1.19 (d, $J = 7.0$ Hz, 3H).

15

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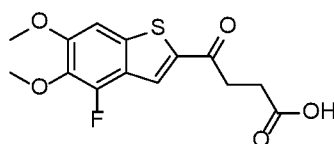
25

Step 2: (S)-4-(5-Bromo-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

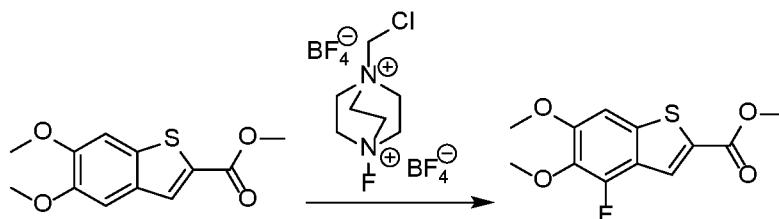


An aq NaOH solution (0.61mL, 1.0M, 0.61mmol) was added to a solution of methyl (*S*)-4-(5-bromo-6-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate (50mg, 0.14mmol) in THF (4.0mL). The reaction mixture was stirred at rt for 18h. The reaction mixture was quenched with aq HCl solution (0.61mL, 1.0M, 0.61mmol). The mixture was then concentrated under reduced pressure to afford the crude product residue, which was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (*S*)-4-(5-bromo-6-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₄H₁₄BrO₄S) (ES, *m/z*): 357, 359 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.22 (s, 1H), 8.27-8.24 (m, 2H), 7.81 (s, 1H), 3.93 (s, 3H), 3.44-3.35 (m, 1H), 3.14-3.06 (m, 1H), 2.94-2.85 (m, 1H), 1.18 (d, *J* = 7.5Hz, 3H).

Example 25: 4-(4-Fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid

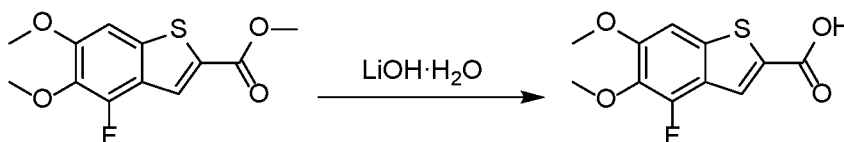


Step 1: Methyl 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carboxylate



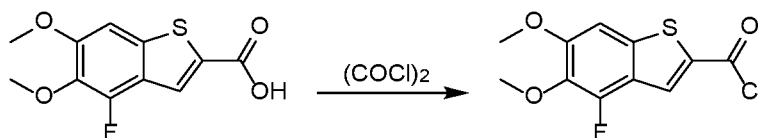
1-Chloromethyl-4-fluoro-1,4-diazoniabicyclo[2.2.2]octane bis(tetrafluoroborate) (SELECTFLUOR™, 77mg, 0.22mmol) was added to a mixture of methyl 5,6-dimethoxybenzo[*b*]thiophene-2-carboxylate from Preparation 2 (50mg, 0.20mmol) in ACN (1ml) at rt. The resulting mixture was stirred at 45°C for 15h. The mixture was cooled to rt, diluted with sat aq NaHCO₃ (10mL), and extracted with EtOAc (3x10mL). The combined organic layers were washed with brine (10mL), dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The residue was purified by prep-TLC (SiO₂, EtOAc in PE) to give methyl 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carboxylate. LCMS (C₁₂H₁₂FO₄S) (ES, *m/z*): 293 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ 8.05 (s, 1H), 7.08 (s, 1H), 3.99 (s, 3H), 3.97 (s, 3H), 3.94 (s, 3H).

Step 2: 4-Fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carboxylic acid



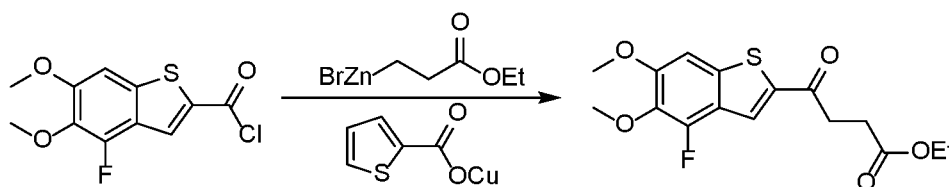
LiOH·H₂O (71.4 mg, 1.70mmol) was added portionwise to a mixture of methyl 4-fluoro-5, 6-dimethoxybenzo[*b*]thiophene-2-carboxylate (46mg, 0.170mmol) in THF (3ml), MeOH (1ml), and H₂O (1ml) at rt. Then, the mixture was stirred for 15h. The mixture was adjusted to pH=5 with 1N HCl and extracted with EtOAc (3x10ml). The combined organic layers were washed with brine (10mL), dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to give 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carboxylic acid. LCMS (C₁₁H₉FO₄S) (ES, *m/z*): 257 [M+H]⁺. ¹H NMR (400MHz, CDCl₃): δ 8.12 (s, 1H), 7.09 (s, 1H), 3.99 (s, 3H), 3.97 (s, 3H).

10 Step 3: 4-Fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl chloride



To a stirred solution of 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carboxylic acid (153mg, 0.60mmol) in anhydrous THF (5mL) was added (COCl)₂ (0.21mL, 2.40mmol) dropwise at 0°C. The mixture was stirred at 0°C for 1h and then at rt for 1h. The solvent was removed under reduced pressure to give 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl chloride, which was used without further purification.

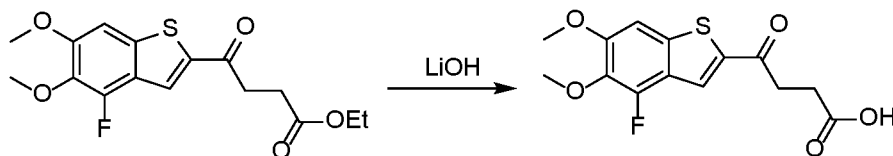
15 Step 4: Ethyl 4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate



A suspension of copper(I) thiophene-2-carboxylate (125mg, 0.65mmol) was sparged with N₂ for 5min and then cooled to 0°C. A solution of (3-ethoxy-3-oxopropyl)zinc(II) bromide (17.7mL, 0.5M in THF, 8.83mmol) was added under N₂ atmosphere at 0°C, and the reaction mixture was stirred for 20min at 0°C. A N₂-sparged solution of 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl chloride (130mg, 0.47mmol) in THF (3mL) was then added to the reaction mixture at 0°C. The resulting suspension was allowed to warm to rt and was stirred for an additional 8h. The reaction mixture was poured into sat aq NH₄Cl (20mL) with stirring. The mixture was extracted with EtOAc (2x20mL). The combined organic layers were washed with H₂O and brine, dried over MgSO₄, filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in Hex) to give

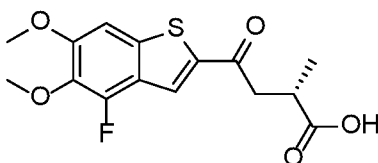
ethyl 4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate. LCMS ($C_{16}H_{18}FO_5S$) (ES, m/z): 341 $[M+H]^+$. 1H NMR (500MHz, $CDCl_3$) δ 8.02 (d, $J = 0.7$ Hz, 1H), 7.10 (t, $J = 1.0$ Hz, 1H), 4.19 (q, $J = 7.2$ Hz, 2H), 4.05-3.97 (m, 6H), 3.36 (t, $J = 6.7$ Hz, 2H), 2.81 (t, $J = 6.7$ Hz, 2H), 1.29 (t, $J = 7.2$ Hz, 3H).

5 Step 5: 4-(4-Fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid

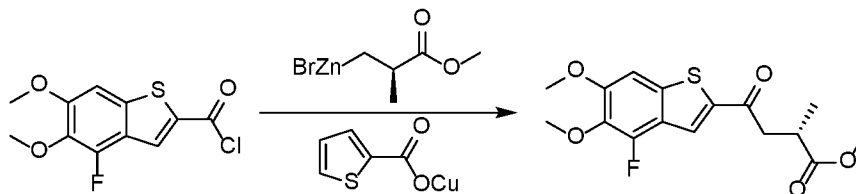


To a solution of ethyl 4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoate (124mg, 0.36mmol) in MeOH (1.5mL) and THF (1.5mL) was added 1N aq LiOH (1.5mL, 1.5mmol). The reaction mixture was stirred at rt for 1h, and then aq 1N HCl (1.5mL, 1.5mmol) was added. The resulting precipitate was collected by suction filtration and purified by prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford 4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid. LCMS ($C_{14}H_{14}FO_5S$) (ES, m/z): 313 $[M+H]^+$. 1H NMR (500MHz, $DMSO-d_6$) δ 12.19 (s, 1H), 8.33 (d, $J = 0.7$ Hz, 1H), 7.59 (d, $J = 1.2$ Hz, 1H), 3.93 (s, 3H), 3.87 (s, 3H), 3.35-3.28 (m, 2H), 2.64-2.57 (m, 2H).

15 Example 26: (S)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



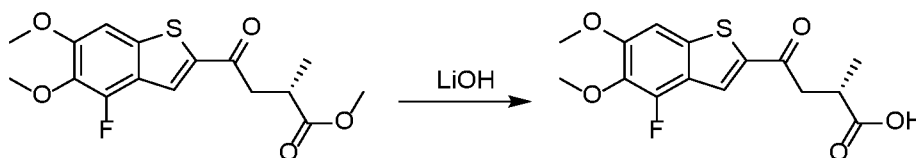
Step 1: Methyl (S)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate



A suspension of copper(I) thiophene-2-carboxylate (125mg, 0.65mmol) was sparged with N_2 for 5min and then cooled to $0^\circ C$. A solution of (R)-3-methoxy-2-methyl-3-oxopropylzinc(II) bromide (1.21mL, 0.5M in THF, 0.606mmol) was added under an N_2 -atmosphere, and the reaction mixture was stirred for 20min at $0^\circ C$. A N_2 -sparged solution of 4-fluoro-5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl chloride from Example 25, step 3 (130mg,

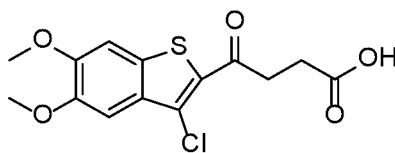
0.47mmol) in THF (3mL) was then added, and the resulting suspension was allowed to warm to rt and was stirred for an additional 8h. The reaction mixture was poured into sat aq NH_4Cl (20mL) with stirring and then extracted with EtOAc (2x20mL). The combined organic layers were washed with H_2O and brine, dried over Na_2SO_4 , filtered, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography (EtOAc in Hex) to give methyl (*S*)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS ($\text{C}_{16}\text{H}_{18}\text{FO}_5\text{S}$) (ES, m/z): 341 $[\text{M}+\text{H}]^+$. ^1H NMR (500MHz, CDCl_3) δ 7.98 (d, $J = 0.7\text{Hz}$, 1H), 7.09 (t, $J = 1.0\text{Hz}$, 1H), 4.04-3.95 (m, 6H), 3.72 (s, 3H), 3.50 (dd, $J = 17.0, 7.9\text{Hz}$, 1H), 3.23-3.12 (m, 1H), 3.06 (dd, $J = 17.0, 5.7\text{Hz}$, 1H), 1.32 (d, $J = 7.2\text{Hz}$, 3H).

10 Step 2: (*S*)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

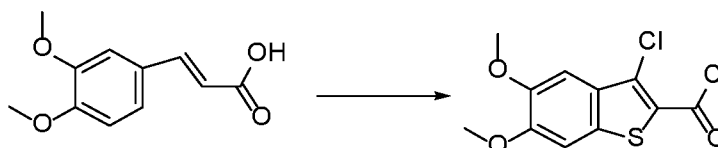


To a solution of methyl (*S*)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate (90mg, 0.26mmol) in MeOH (1.5mL), and THF (1.5mL) was added 1N aq LiOH (1.5mL, 1.5mmol). The reaction mixture was stirred at rt for 1h, and then aq 1N HCl (1.5mL, 1.5mmol) was added. The resulting precipitate was collected by suction filtration and purified by prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford (*S*)-4-(4-fluoro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS ($\text{C}_{15}\text{H}_{16}\text{FO}_5\text{S}$) (ES, m/z): 327 $[\text{M}+\text{H}]^+$. ^1H NMR (500MHz, $\text{DMSO}-d_6$) δ 12.21 (s, 1H), 8.33 (d, $J = 0.7\text{Hz}$, 1H), 7.59 (d, $J = 1.1\text{Hz}$, 1H), 3.93 (s, 3H), 3.87 (s, 3H), 3.48 (dd, $J = 17.6, 8.7\text{Hz}$, 1H), 3.14 (dd, $J = 17.6, 5.0\text{Hz}$, 1H), 2.95-2.84 (m, 1H), 1.19 (d, $J = 7.3\text{Hz}$, 3H).

Example 27: 4-(3-chloro-5,6-dimethoxybenzo[*b*]thiophen-2-yl)-4-oxobutanoic acid

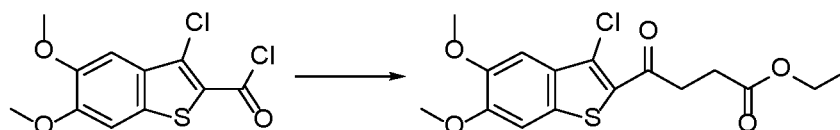


Step 1: 3-chloro-5,6-dimethoxybenzo[*b*]thiophene-2-carbonyl chloride



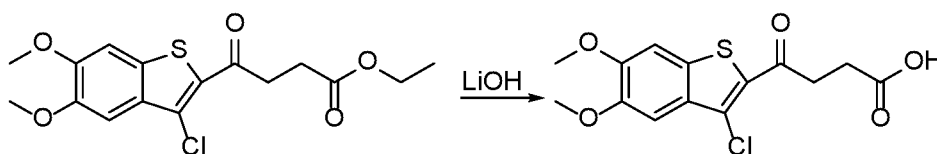
To a reaction mixture of (E)-3-(3,4-dimethoxyphenyl)acrylic acid (5.7g, 27mmol) in chlorobenzene (40mL) was added SOCl₂ (9.0mL, 120mmol) slowly. After 30min at rt, py (0.58mL, 7.1mmol) was added slowly. The mixture was then heated to reflux for 24h. Upon cooling to rt, the mixture was concentrated under reduced pressure to afford 3-chloro-5,6-dimethoxybenzo[b]thiophene-2-carbonylchloride that was taken on to the next step without further purification.

Step 2: ethyl 4-(3-chloro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate



To an oven-dried round bottom flask was added Cu-Cl (510mg, 5.2mmol). The reaction flask was purged with Ar. (3-ethoxy-3-oxopropyl)zinc(II) bromide (0.5M in THF, 12mL, 6.2mmol) was added at rt. After 30min at rt, a mixture of 3-chloro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl chloride (1.5g, 5.2mmol) in THF (10mL) was added. After 30min, the mixture was quenched with sat NH₄Cl (6.0mL) and diluted with EtOAc. The organic layer was separated and then concentrated under reduced pressure to provide a residue that was purified by silica gel column chromatography (EtOAc in Hex) to give ethyl 4-(3-chloro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₆H₁₈ClO₅S) (ES, m/z): 357 [M+H]⁺. ¹H NMR (500MHz, Acetone-*d*₆) δ 7.56 (s, 1H), 7.36 (s, 1H), 4.13 (q, *J* = 7.1Hz, 2H), 3.98 (s, 3H), 3.97 (s, 3H), 3.47 (t, *J* = 6.3Hz, 2H), 2.75 (t, *J* = 6.3Hz, 2H), 1.24 (t, *J* = 7.1Hz, 3H).

Step 3: 4-(3-chloro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid

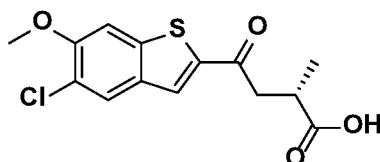


A mixture of ethyl 4-(3-chloro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (58mg, 0.16mmol) and LiOH (23mg, 0.98mmol) in THF (1.5mL), H₂O (0.40mL) and MeOH (1.0mL) was allowed to stir at rt for 1.5h. The reaction mixture was adjusted to a pH between 3 and 4 with HCl (1.0N in H₂O) and then diluted with DCM. The organic layer was separated, and then the H₂O layer was re-extracted with DCM (2X20mL). The combined organic layers were concentrated under reduced pressure to afford the crude product. The crude product was purified by prep HPLC (ACN/H₂O in 0.1% TFA). The liquid fractions containing pure product were combined and then freeze-dried with a lyophilizer to yield 4-(3-chloro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₄H₁₄ClO₅S) (ES, m/z): 329

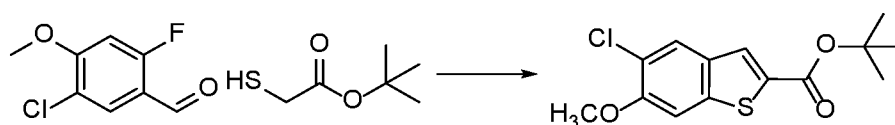
$[M+H]^+$. ^1H NMR (500MHz, $\text{DMSO}-d_6$) δ 12.22 (s, 1H), 7.67 (s, 1H), 7.29 (s, 1H), 3.90 (s, 3H), 3.88 (s, 3H), 3.34 (t, $J = 5.0\text{Hz}$, 2H), 2.62 (t, $J = 6.2\text{Hz}$, 2H).

Example 28: (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

5 **acid**

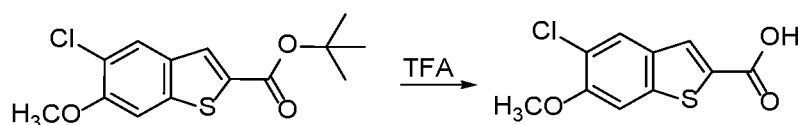


Step 1: tert-butyl 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylate



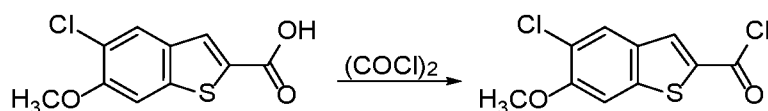
To a mixture of 5-chloro-2-fluoro-4-methoxybenzaldehyde (0.055 g, 0.3 mmol), Cs_2CO_3 (0.49g, 1.5mmol), and dioxane (1.5mL) was added tert-butyl 2-mercaptoacetate (0.053g, 0.36 mmol). The reaction was heated at reflux for 6h. After 6h, the mixture was allowed to cool to rt and then diluted with dioxane (2.0mL). Macroporous polystyrene-bound isocyanate (1.59mmol/g-0.50g) was added, and the reaction was shaken at rt for 1h. After 1h, the mixture was filtered, washed with dioxane and concentrated under reduced pressure to afford a crude mixture containing tert-butyl 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylate that was taken on to the next step without further purification or characterization.

Step 2: 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylic acid



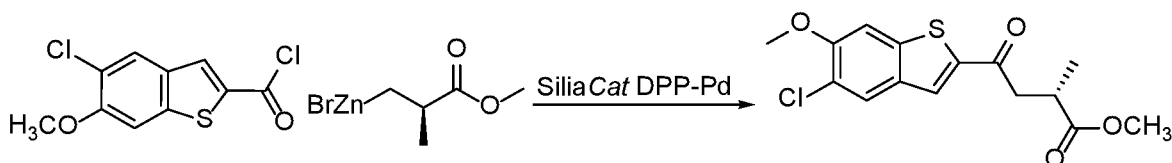
To the crude residue containing tert-butyl 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylate was added DCM (1.0mL) and TFA (1.0mL). After 1h, the mixture was diluted with Hex (2.0mL) and then concentrated under reduced pressure to provide 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylic acid that was taken on to the next step without further purification or characterization.

Step 3: 5-chloro-6-methoxybenzo[b]thiophene-2-carbonyl chloride



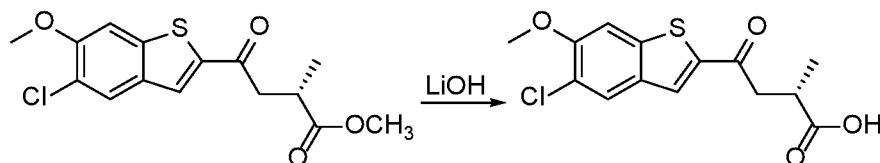
To the crude residue containing 5-chloro-6-methoxybenzo[b]thiophene-2-carboxylic acid was added a mixture of DMF in DCM (0.05M DMF in DCM, 1.5mL). (COCl)₂ (0.13mL, 1.5mmol) was added slowly to the reaction mixture, and the mixture was allowed to stir for 1h. After 1h, the mixture was diluted with Hex and then concentrated under reduced pressure to provide 5-chloro-6-methoxybenzo[b]thiophene-2-carbonyl chloride that was taken on to the next step without further purification or characterization.

Step 4: methyl (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate



To the crude residue containing 5-chloro-6-methoxybenzo[b]thiophene-2-carbonyl chloride and (R)-(3-methoxy-2-methyl-3-oxopropyl)zinc(II) bromide (0.5M in THF, 1.2mL, 0.60mmol) was added a diphenylphosphine-Pd(II) catalyst bound to an organosilica matrix (([O₃Si]_n(CH₂)₃DPP-Pd), commercially available as SILIACAT[®] DPP-Pd R390-100, from Silicycle, 0.25mmol/g, 0.23g, 0.060mmol), and the reaction was stirred at rt for 18h. The mixture was then diluted with THF (4mL) and N,N-diethanolaminomethyl polystyrene (1.6mmol/g, 0.50g) was added. The mixture was allowed to stir for 1h. After 1h, the mixture was filtered, the solids were washed with THF (3.5mL), and the filtrate was concentrated under reduced pressure to afford methyl (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate that was taken on to the next step without further purification or characterization.

Step 5: (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



To the crude reaction mixture containing methyl (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate was added THF (1.0mL), MeOH (0.30mL) and aq LiOH (1.0M in H₂O, 1.0mL, 1.0mmol). After 3h at rt, the mixture was quenched with AcOH (0.20mL), and the mixture was concentrated under reduced pressure. The residue was taken up in DMSO (1.5mL), and the mixture was purified by reverse phase HPLC (ACN/H₂O 0.1% TFA) to provide (S)-4-(5-chloro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₄H₁₃ClO₄S) (ES, m/z): 313 [M+H]⁺. ¹H NMR (500MHz,

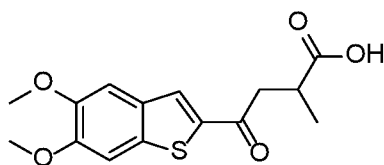
DMSO-*d*₆) δ 8.26 (s, 1H), 8.11 (s, 1H), 7.84 (s, 1H), 3.95 (s, 3H), 3.41 (dd, *J* = 17.2, 8.4Hz, 1H), 3.09 (dd, *J* = 17.4, 5.0Hz, 1H), 2.94 – 2.85 (m, 1H), 1.19 (d, *J* = 7.2Hz, 3H).

- 5 Examples 29 through 34, as shown in Table 3 below, were or may be prepared according to procedures analogous to those outlined in Example 28 above using the appropriate starting materials, described as Preparations or as obtained from commercial sources.

Table 3

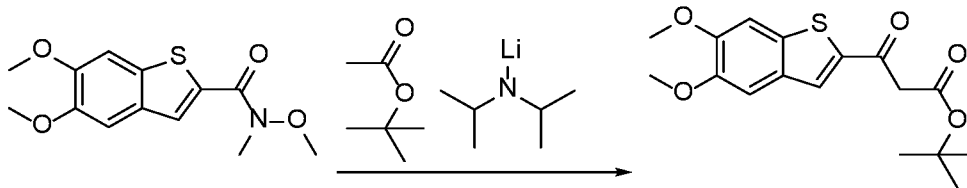
Ex.	Structure	Name	Mass [M+H] ⁺
29		(S)-4-(6-bromo-5-methylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	341, 343
30		(S)-4-(5-fluoro-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	297
31		(S)-4-(5,6-dimethylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	337
32		(S)-4-(6-bromo-5-chlorobenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	361, 363
33		(S)-4-(5-chloro-6-ethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	327
34		(S)-4-(5-bromo-6-methylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid	341, 343

Example 35: 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



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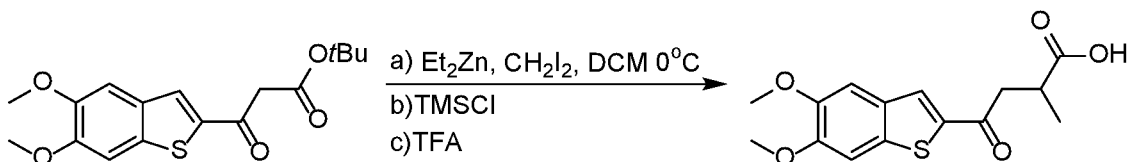
Step 1: tert-butyl 3-(5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate



To a flask containing THF (10mL) at -78°C was added LDA (2.0M in THF/heptane/benzene, 4.2mL, 8.4mmol). Tert-butyl acetate (1.1mL, 8.3mmol) was added dropwise. After the addition was complete, the mixture was allowed to stir at -78°C for 15min.

- 5 A mixture of N,5,6-trimethoxy-N-methylbenzo[b]thiophene-2-carboxamide (1.9g, 6.9mmol) in THF (15mL) was added dropwise. After complete addition, the mixture was allowed to stir at -78°C for 1h. The mixture was then allowed to warm to rt. After warming to rt, the mixture was cooled to 5°C and then quenched with aq HCl (1N) until pH=2. The mixture was extracted with isopropyl acetate (2x20mL). The combined organics were washed with sat aq NaHCO_3 and
- 10 brine, dried over MgSO_4 , filtered and concentrated under reduced pressure. The crude residue was purified by silica gel chromatography (EtOAc in Hex) to afford tert-butyl 3-(5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate. LCMS ($\text{C}_{17}\text{H}_{21}\text{O}_5\text{S} - \text{C}_4\text{H}_8$) (ES, m/z): 281 $[\text{M}+\text{H}]^+$. ^1H NMR (600 MHz, $\text{DMSO}-d_6$) δ 8.12 (s, 1H), 7.57 (s, 1H), 7.44 (s, 1H), 4.00 (s, 2H), 3.82 (s, 3H), 3.79 (s, 3H), 1.36 (s, 9H).

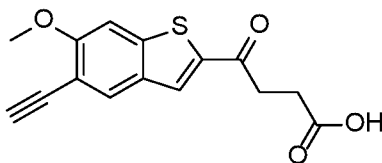
15 Step 2: 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



- Et_2Zn (1.0M in Hex, 6.0mL, 6.0mmol) was added to DCM (20mL) at 0°C under N_2 atmosphere. CH_2I_2 (0.50mL, 6.0mmol) was then added dropwise. After the mixture was allowed to stir at 0°C for 10min, tert-butyl 3-(5,6-dimethoxybenzo[b]thiophen-2-yl)-3-
- 20 oxopropanoate (0.50g, 1.5mmol) was added followed by TMSCl (20 μL , 0.15mmol). The mixture was allowed to warm to rt and then stirred for 18h. The reaction mixture was then quenched with sat aq NH_4Cl and extracted with DCM (3x20mL). The combined organics were concentrated under reduced pressure. The residue was reconstituted in DCM (30mL), and TFA (0.50mL, 6.0mmol) was added. After the reaction mixture was stirred for 20min, the reaction
- 25 mixture was concentrated under reduced pressure. The product was purified by reverse phase Prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS ($\text{C}_{15}\text{H}_{16}\text{O}_5\text{S}$) (ES, m/z): 309 $[\text{M}+\text{H}]^+$. ^1H NMR (CD_3OD ,

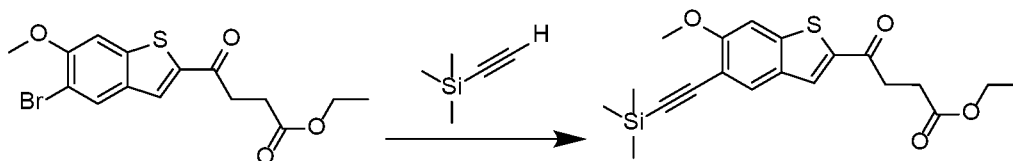
600MHz): δ 8.06 (s, 1H), 7.43-7.40 (m, 2H), 3.90 (s, 3H), 3.88 (s, 3H), 3.46 (dd, $J = 17, 8\text{Hz}$, 1H), 3.08 (dd, $J = 17, 5\text{Hz}$, 1H), 3.02 (sextet, $J = 7.0\text{Hz}$, 1H), 1.26 (d, $J = 7\text{Hz}$, 3H)

Example 36: 4-(5-Ethynyl-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid



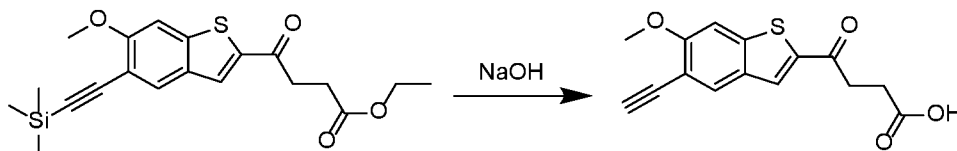
5

Step 1: Ethyl 4-(6-methoxy-5-((trimethylsilyl)ethynyl)benzo[b]thiophen-2-yl)-4-oxobutanoate



To an Ar-degassed mixture of ethyl 4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (100mg, 0.269mmol), $\text{Pd}(\text{Ph}_3\text{P})_4$ (78mg, 0.067mmol), and Cu-I (51mg, 0.27mmol) was added DMF (1.0mL) followed by triethylamine (0.188mL, 1.35mmol) and ethynyltrimethylsilane (0.192 L, 1.35mmol) at rt while degassing with Ar. The mixture was stirred for 5mins while degassing with Ar (subsurface sparge), after which time the mixture was stirred under Ar at 20°C for 18h. The reaction mixture was diluted with EtOAc (50mL) and filtered through CELITE. The filtrate was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by silica gel chromatography (EtOAc in Hex) to afford ethyl 4-(6-methoxy-5-((trimethylsilyl)ethynyl)benzo[b]thiophen-2-yl)-4-oxobutanoate. LCMS ($\text{C}_{20}\text{H}_{25}\text{O}_4\text{SSi}$) (ES, m/z): 389 $[\text{M}+\text{H}]^+$. ^1H NMR (500MHz, $\text{DMSO}-d_6$): δ 8.25 (s, 1H), 8.06 (s, 1H), 7.72 (s, 1H), 4.06 (q, $J = 7.0\text{Hz}$, 2H), 3.90 (s, 3H), 3.34–3.30 (m, 2H), 2.68–2.64 (m, 2H), 1.17 (t, $J = 7.0\text{Hz}$, 3H), 0.24 (s, 9H).

Step 2: 4-(5-Ethynyl-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid



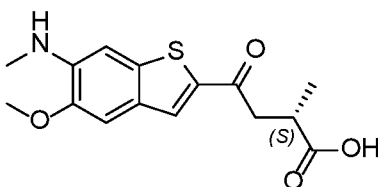
NaOH (1.0M in H_2O , 1.0mL, 1.0mmol) was added to a suspension of ethyl 4-(6-methoxy-5-((trimethylsilyl)ethynyl)benzo[b]thiophen-2-yl)-4-oxobutanoate (61mg, 0.16mmol) in MeOH (5.0mL). The resulting suspension was stirred at 20°C for 2.5h. The reaction mixture was quenched with HCl (37% in H_2O , 0.083mL, 1.0mmol). The mixture was then concentrated under reduced pressure to afford the crude product residue. The crude product residue was by

25

prep-HPLC (ACN/H₂O with 0.1% TFA) to afford 4-(5-ethynyl-6-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₅H₁₃O₄S) (ES, m/z): 289 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.22 (s, 1H), 8.27 (s, 1H), 8.08 (s, 1H), 7.73 (s, 1H), 4.33 (s, 1H), 3.91 (s, 3H), 3.30–3.24 (m, 2H), 2.63–2.57 (m, 2H).

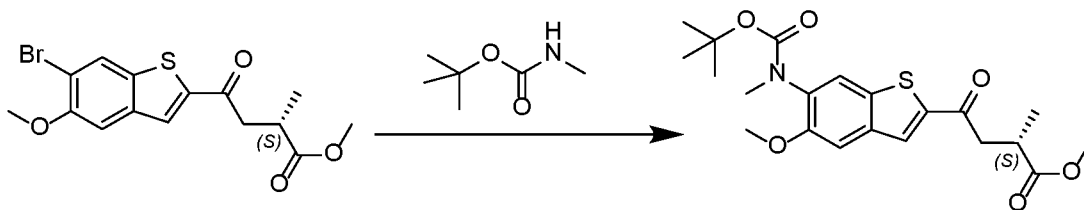
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Example 37: (S)-4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



Step 1: (S)-methyl 4-(6-((tert-butoxycarbonyl)(methyl)amino)-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate

10



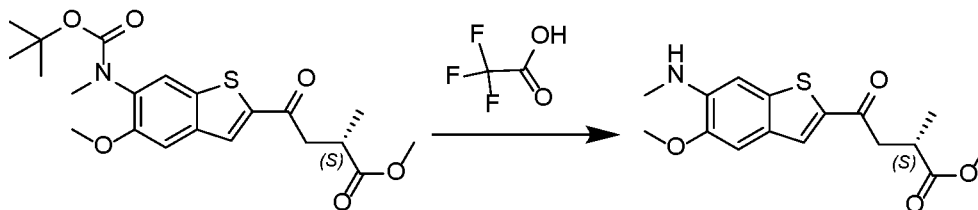
To an Ar-degassed mixture of (S)-methyl 4-(6-bromo-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (40mg, 0.11mmol), tert-butyl methylcarbamate (21mg, 0.16mmol), Pd₂(dba)₃ (5mg, 5μmol), 4,5-bis(diphenylphosphino)-9,9-dimethylxanthene (XANTPHOS, 9mg, 0.02mmol), and Cs₂CO₃ (70mg, 0.22mmol) was added dioxane (0.50mL) at rt while degassing with Ar. The mixture was stirred for 5min while degassing with Ar (subsurface sparge), after which time the mixture was heated to 95°C under Ar atmosphere for 12h. The reaction mixture was cooled to rt and diluted with EtOAc (20mL). The resulting suspension was filtered through a frit containing CELITE. The filtrate was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by silica gel chromatography (EtOAc in Hex) to afford (S)-methyl 4-(6-((tert-butoxycarbonyl)(methyl)amino)-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS (C₂₁H₂₈NO₆S) (ES, m/z): 422 [M+H]⁺.

15

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Step 2: (S)-methyl 4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate

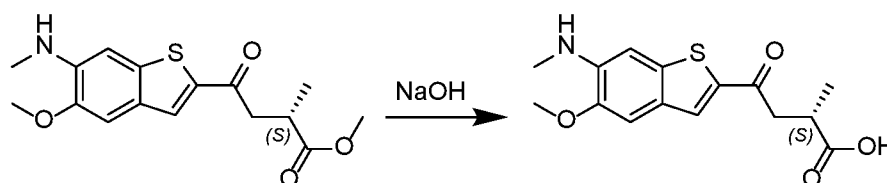
25



TFA (0.34mL, 4.4mmol) was added to a mixture of (S)-methyl 4-(6-((tert-butoxycarbonyl)(methyl)amino)-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (37mg, 0.088mmol) in DCM (2.0mL) at 20°C. The reaction mixture was stirred at 20°C for 2h.

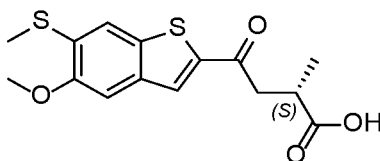
- 5 The reaction mixture was concentrated under reduced pressure to afford (S)-methyl 4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate as the crude product residue. The crude product residue was used without workup or purification in the subsequent step. LCMS ($C_{16}H_{20}NO_4S$) (ES, m/z): 322 $[M+H]^+$.

Step 3: (S)-4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

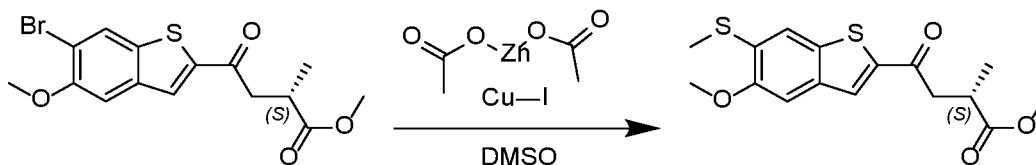


- 10 NaOH (2.0M in H_2O , 0.35mL, 0.70mmol) was added to a mixture of (S)-methyl 4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (28mg, 0.087mmol) in DMSO (0.50mL) and MeOH (2.0mL) at 20°C. The reaction mixture was stirred at 20°C for 18h. The reaction mixture was quenched with HCl (0.057mL, 37% in H_2O , 0.70mmol) and then diluted with additional DMSO (1.0mL). The crude product residue was by reverse phase prep-HPLC (ACN/ H_2O with 0.1% TFA) to afford (S)-4-(5-methoxy-6-(methylamino)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS ($C_{15}H_{18}NO_4S$) (ES, m/z): 308 $[M+H]^+$. 1H NMR (500MHz, $DMSO-d_6$): δ 8.07 (s, 1H), 7.27 (s, 1H), 6.89 (s, 1H), 3.86 (s, 3H), 3.34–3.29 (m, 1H), 3.04–2.96 (m, 1H), 2.90–2.82 (m, 1H), 2.79 (s, 3H), 1.16 (d, J = 7.0Hz, 3H).
- 15
- 20

Example 38: (S)-4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

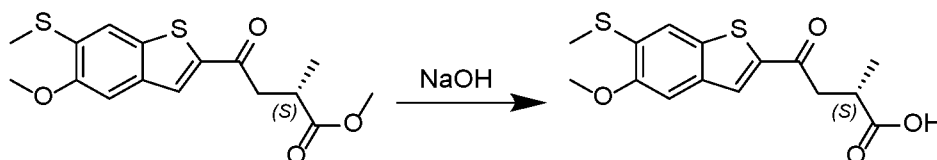


- 25 Step 1: (S)-methyl 4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate



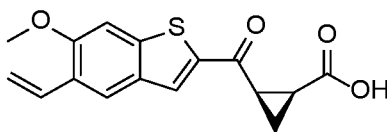
DMSO (1.00mL) was added to a mixture of (S)-methyl 4-(6-bromo-5-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (95mg, 0.26mmol), Cu-I (12mg, 0.064mmol), and zinc acetate (94mg, 0.51mmol). The resulting mixture was heated to 120°C for 20h under N₂. The reaction mixture was cooled to rt and diluted with EtOAc (50mL) and then filtered through CELITE. The filtrate was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by prep- HPLC (ACN/H₂O with 0.1% TFA) to afford (S)-methyl 4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS (C₁₆H₁₉O₄S₂) (ES, m/z): 339 [M+H]⁺.

10 Step 2: (S)-4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

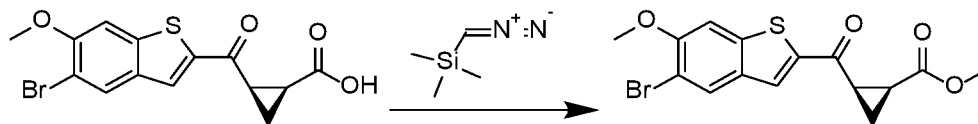


NaOH (2.0M in H₂O, 0.19mL, 0.38mmol) was added to a solution of (S)-methyl 4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (32mg, 0.095mmol) in DMSO (1.00mL) at 20°C. The resulting mixture was stirred at 20°C for 15min under N₂. The reaction mixture was then quenched with HCl (0.035mL, 37% in H₂O, 0.43mmol). The reaction mixture was filtered and purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (S)-4-(5-methoxy-6-(methylthio)benzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₅H₁₇O₄S₂) (ES, m/z): 325 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.23 (s, 1H), 7.75 (s, 1H), 7.47 (s, 1H), 3.89 (s, 3H), 3.45–3.37 (m, 1H), 3.13–3.07 (m, 1H), 2.91–2.88 (m, 1H), 2.47 (s, 3H), 1.18 (d, *J* = 7.0Hz, 3H).

Example 39: (1S,2R)-2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid

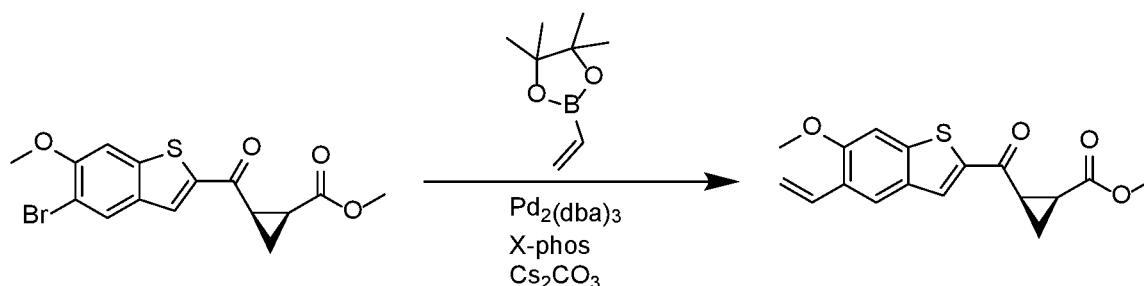


25 Step 1: (1S,2R)-methyl 2-(5-bromo-6-methoxybenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate



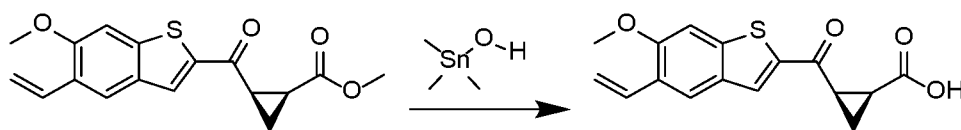
TMS-diazomethane (2.0M in Hex, 1.4mL, 2.8mmol) was added to a mixture of (1S,2R)-2-(5-bromo-6-methoxybenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylic acid (891mg, 2.51mmol) in DCM (20mL) and MeOH (20mL) at 0°C. The reaction mixture was stirred at 0°C for 1h. The reaction mixture was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by silica gel chromatography (EtOAc in Hex) to afford (1S,2R)-methyl 2-(5-bromo-6-methoxybenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate. LCMS (C₁₅H₁₄BrO₄S) (ES, m/z): 369, 371 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.30 (s, 1H), 8.28 (s, 1H), 7.81 (s, 1H), 3.94 (s, 3H), 3.47 (s, 3H), 3.18–3.12 (m, 1H), 2.44–2.39 (m, 1H), 1.60–1.57 (m, 1H), 1.42–1.39 (m, 1H).

Step 2: (1S,2R)-methyl 2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate



To an Ar-degassed mixture of (1S,2R)-methyl 2-(5-bromo-6-methoxybenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate (100mg, 0.271mmol), 4,4,5,5-tetramethyl-2-vinyl-1,3,2-dioxaborolane (50mg, 0.33mmol), Pd₂(dba)₃ (12mg, 0.014mmol), X-Phos (12mg, 0.027mmol), and Cs₂CO₃ (176mg, 0.542mmol) was added dioxane (1.50ml) and H₂O (0.2 ml) at rt while degassing with Ar. The mixture was stirred for 5min while degassing with Ar (subsurface sparge), after which time the mixture was heated to 90°C under Ar atmosphere for 16h. The reaction mixture was cooled to rt and diluted with EtOAc (20mL). The resulting suspension was filtered through a frit containing MgSO₄. The filtrate was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by silica gel chromatography (EtOAc in Hex) to afford (1S,2R)-methyl 2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate. LCMS (C₁₇H₁₇O₄S) (ES, m/z): 317 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.31 (s, 1H), 8.14 (s, 1H), 7.66 (s, 1H), 7.05–6.97 (m, 1H), 5.88 (d, *J* = 17.5Hz, 1H), 5.34 (d, *J* = 11.5Hz, 1H), 3.91 (s, 3H), 3.47 (s, 3H), 3.20–3.13 (m, 1H), 2.46–2.38 (m, 1H), 1.62–1.56 (m, 1H), 1.44–1.36 (m, 1H).

Step 3: (1S,2R)-2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid



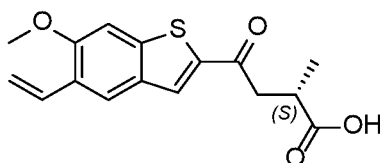
Trimethyltin hydroxide (34mg, 0.19mmol) was added to a mixture of (1S,2R)-methyl 2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropanecarboxylate (30mg, 0.095mmol) in 1,2-dichloroethane (2.0mL) at 20°C. The reaction mixture was stirred and heated to 85°C for 2 days. The reaction mixture was cooled to rt and quenched with NaHSO₄ (2.0M in H₂O, 0.19mL, 0.378mmol) and then diluted with EtOAc (100mL) and H₂O (25mL). The organic layer was separated, washed with brine (10mL), dried over MgSO₄, filtered, and concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (1S,2R)-2-(6-methoxy-5-vinylbenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid. LCMS (C₁₆H₁₅O₄S) (ES, m/z): 303 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.22 (s, 1H), 8.28 (s, 1H), 8.15 (s, 1H), 7.65 (s, 1H), 7.05–6.96 (m, 1H), 5.88 (d, *J* = 17.5Hz, 1H), 5.33 (d, *J* = 11.5Hz, 1H), 3.90 (s, 3H), 3.10–3.02 (m, 1H), 2.30–2.25 (m, 1H), 1.56–1.50 (m, 1H), 1.34–1.30 (m, 1H).

Example 40, as shown in Table 4 below, was or may be prepared according to procedures analogous to those outlined in Example 39 above using the appropriate starting materials, described as Preparations or as obtained from commercial sources.

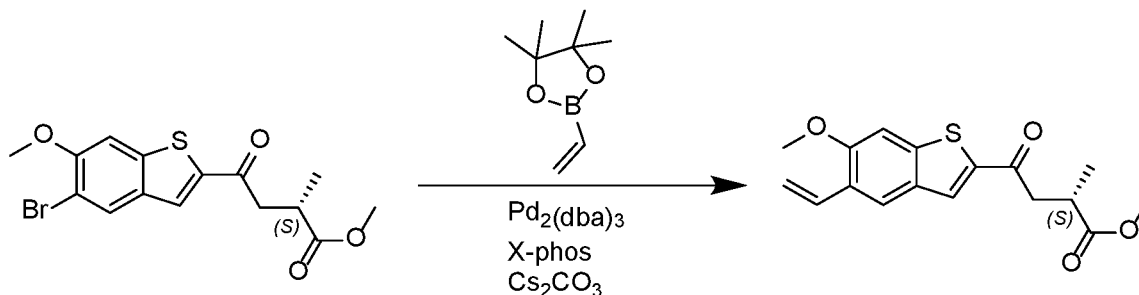
Table 4

Ex.	Structure	Name	Mass [M+H] ⁺
40		2-(6-methoxy-5-(methylthio)benzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid	323

Example 41: (S)-4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

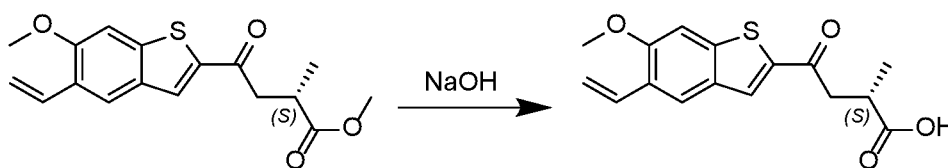


Step 1: (S)-methyl 4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate



To an Ar-degassed mixture of (S)-methyl 4-(5-bromo-6-methoxybenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (122mg, 0.329mmol), 4,4,5,5-tetramethyl-2-vinyl-1,3,2-dioxaborolane (61mg, 0.39mmol), Pd₂(dba)₃ (15mg, 0.016mmol), X-Phos (15mg, 0.033mmol), and Cs₂CO₃ (321mg, 0.986mmol) was added dioxane (3.0mL) and H₂O (0.30mL) at rt while degassing with Ar. The mixture was stirred for 5min while degassing with Ar (subsurface sparge), after which time the mixture was heated to 90°C under Ar atmosphere for 2h. The reaction mixture was cooled to rt and diluted with EtOAc (20mL). The resulting suspension was filtered through a frit containing MgSO₄. The filtrate was concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by silica gel chromatography (EtOAc in Hex) to afford (S)-methyl 4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS (C₁₇H₁₉O₄S) (ES, m/z): 319 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.28 (s, 1H), 8.10 (s, 1H), 7.66 (s, 1H), 7.05–6.96 (m, 1H), 5.86 (d, *J* = 17.5Hz, 1H), 5.34 (d, *J* = 11.5Hz, 1H), 3.91 (s, 3H), 3.59 (s, 3H), 3.47–3.40 (m, 1H), 3.24–3.16 (m, 1H), 3.00–2.93 (m, 1H), 1.19 (d, *J* = 6.5Hz, 3H).

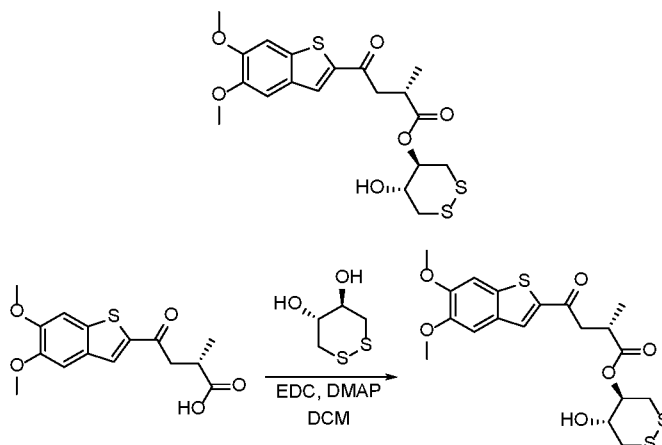
Step 2: (S)-4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid



NaOH (1.0M in H₂O, 0.41mL, 0.41mmol) was added to a solution of (S)-methyl 4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoate (26mg, 0.082mmol) in THF (3.0mL). The resulting suspension was stirred at 20°C for 18h. The reaction mixture was quenched with HCl (1.0M in H₂O, 0.41mL, 0.41mmol). The reaction mixture was then concentrated under reduced pressure to afford the crude product residue. The crude product residue was purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (S)-4-(6-methoxy-5-vinylbenzo[b]thiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₆H₁₇O₄S) (ES, m/z): 305 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.21 (s, 1H), 8.27 (s, 1H), 8.10 (s, 1H), 7.65 (s,

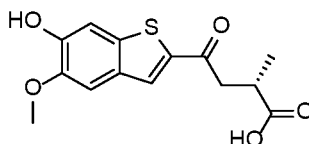
1H), 7.06–6.96 (m, 1H), 5.92–5.81 (m, 1H), 5.38–5.30 (m, 1H), 3.90 (s, 3H), 3.44–3.36 (m, 1H), 3.14–3.05 (m, 1H), 2.93–2.85 (m, 1H), 1.18 (bs, 3H).

Example 42: *(S)*-(4*R*,5*R*)-5-hydroxy-1,2-dithian-4-yl 4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate

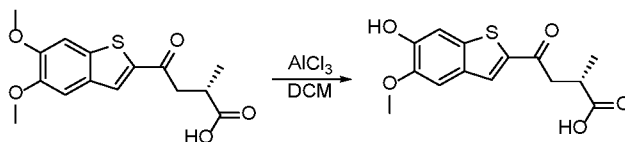


To a stirred solution of *(S)*-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid (81mg, 0.26mmol) and EDC (50mg, 0.26mmol) in DCM (2.0mL) were added
 10 (4*R*,5*R*)-1,2-dithiane-4,5-diol (30mg, 0.20mmol) and DMAP (1.6mg, 0.013mmol). The solution was left to stir for 3 days and purified by silica gel column chromatography (EtOAc in Hex). The desired fractions were combined, concentrated, and re-purified by prep-HPLC (ACN/H₂O with 0.1% TFA) to afford *(S)*-(4*R*,5*R*)-5-hydroxy-1,2-dithian-4-yl 4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoate. LCMS (C₁₉H₂₃O₆S₃) (ES, *m/z*): 443 [M+H]⁺. ¹H NMR
 15 (600 MHz, DMSO-*d*₆) δ 8.22 (s, 1H), 7.60 (s, 1H), 7.46 (s, 1H), 5.49 (d, *J* = 5.6Hz, 1H), 4.66 (m, 1H), 3.86 (s, 3H), 3.83 (s, 3H), 3.60 (m, 1H), 3.40 (dd, *J* = 17.3, 8.3Hz, 1H), 3.22 (dd, *J* = 17.3, 5.1Hz, 1H), 3.15–3.09 (m, 2H), 2.98 (m, 1H), 2.89–2.83 (m, 2H), 1.21 (d, *J* = 7.1Hz, 3H).

Example 43: *(S)*-4-(6-hydroxy-5-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid

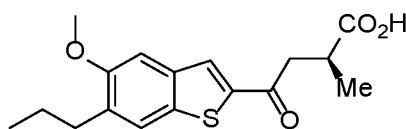


*Step 1: (S)-4-(6-hydroxy-5-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid*

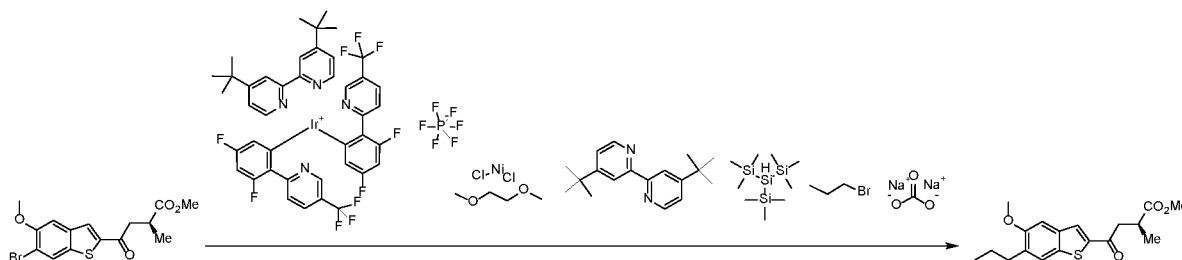


To a stirred solution of (*S*)-4-(5,6-dimethoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid (47mg, 0.15mmol) in DCM (2.0mL) was added AlCl₃ (140mg, 1.10mmol). The reaction mixture was left to stir for 2h, concentrated, and purified by prep-HPLC (ACN/H₂O with 0.1% TFA). The mixture of (*S*)-4-(6-hydroxy-5-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid and (*S*)-4-(5-hydroxy-6-methoxybenzo[*b*]thiophen-2-yl)-2-methyl-4-oxobutanoic acid was re-purified by chiral-SFC (Column AD-H (21x250mm), 40% MeOH with 0.25% DMEA in CO₂) to afford the product (retention time 6.2min) as the DMEA salt. The salt was dissolved in H₂O and acidified with 1N HCl to pH of 2. The precipitate was filtered, washed with H₂O, and dried under high vacuum to afford the product. LCMS (C₁₄H₁₅O₅S) (ES, *m/z*): 295 [M+H]⁺. ¹H NMR (600MHz, DMSO-*d*₆) δ 12.19 (s, 1H), 9.88 (s, 1H), 8.16 (s, 1H), 7.44 (s, 1H), 7.30 (s, 1H), 3.85 (s, 3H), 3.37 (m, 1H), 3.05 (dd, *J* = 17.1, 5.1Hz, 1H), 2.88 (m, 1H), 1.17 (d, *J* = 7.1Hz, 3H).

Example 44: (2*S*)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoic acid



Step 1: methyl (2*S*)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoate

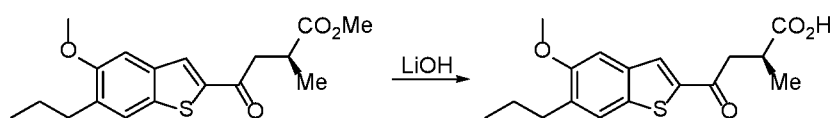


Anhydrous Na₂CO₃ (16mg, 0.15mmol) was heated to 125°C under high vacuum in a capped microwave vial for 1h before use. This vial was moved inside of a glove box. Inside the glove box, degassed dimethoxyethane (7.0mL) was added to a 2-dram vial containing Nickel(II) chloride ethylene glycol dimethyl ether complex (5.8mg) and 4,4'-di-*tert*-butyl-2,2'-bipyridine (8.0mg). The resulting mixture was stirred for 25min at rt to prepare Solution A.

To a second vial, degassed dimethoxyethane (2.4mL) was added to Ir(2-(2,4-difluorophenyl)-5-(trifluoromethyl)pyridine)₂(4,4'-di-*tert*-butyl-2,2'-bipyridine)PF₆ (7.2mg). The resulting mixture was stirred for 10min at rt to prepare Solution B.

To a third vial, degassed dimethoxyethane (0.38mL) was added to a mixture of methyl (2S)-4-(6-bromo-5-methoxy-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoate (28mg, 0.075mmol), and tris(trimethylsilyl)silane (23μL, 0.075mmol). To this vial was added Solution A (101μL), Solution B (280μL), 1-bromopropane (28mg, 0.23mmol), and Na₂CO₃ (16mg, 0.15mmol). The vial was capped and sealed with paraffin film (PARAFILM). The reaction mixture was taken outside of the glovebox, stirred and irradiated with two 34W blue LED lamps for 4h. Note that the lamps were situated at an appropriate distance from the reaction vessel to provide irradiation without heating the reaction mixture significantly above rt. The crude reaction mixture containing methyl (2S)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoate was used in the next step without further purification or characterization.

Step 2: (2S)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoic acid



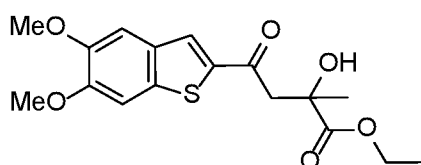
To the crude mixture of methyl (2S)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoate in dimethoxyethane (0.76mL), was added MeOH (0.76mL), H₂O (0.19mL), and LiOH (22mg, 0.91mmol) at rt. The resulting mixture was stirred for 1.5h at rt, and was then adjusted to pH=5 with aq HCl (2.0N) and filtered. The filtrate was purified by reverse phase prep-HPLC (ACN/H₂O with 0.1% TFA) to afford (2S)-4-(5-methoxy-6-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₇H₂₁O₄S) (ES, m/z): 321 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 8.25 (s, 1H), 7.77 (s, 1H), 7.47 (s, 1H), 3.86 (s, 3H), 3.45-3.39 (m, 1H), 3.12-3.07 (m, 1H), 2.92-2.87 (m, 1H), 2.65 (t, *J* = 7.5 Hz, 2H), 1.60 (sextet, *J* = 7.4Hz, 2H), 1.18 (d, *J* = 7.5Hz, 3H), 0.91 (t, *J* = 7.3Hz, 3H).

Examples 45 through 47, as shown in Table 5 below, were or may be prepared according to procedures analogous to those outlined in Example 44 above using the appropriate starting materials, described as Preparations or as obtained from commercial sources.

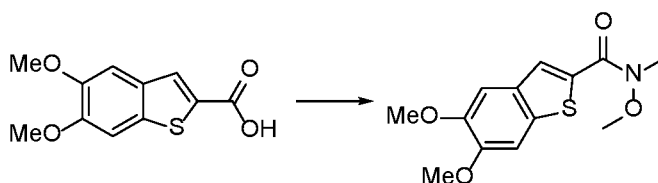
Table 5

Ex.	Structure	Name	Mass [M+H] ⁺
45		4-[6-(2-fluoroethyl)-5-methoxy-1-benzothiophen-2-yl]-4-oxobutanoic acid	311
46		(2S)-4-[6-(2-fluoroethyl)-5-methoxy-1-benzothiophen-2-yl]-2-methyl-4-oxobutanoic acid	325
47		(2S)-4-(6-methoxy-5-propyl-1-benzothiophen-2-yl)-2-methyl-4-oxobutanoic acid	321

Example 48: Ethyl 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-hydroxy-2-methyl-4-oxobutanoate

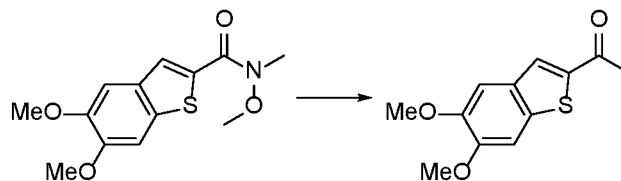


Step 1: N,5,6-trimethoxy-N-methylbenzo[b]thiophene-2-carboxamide



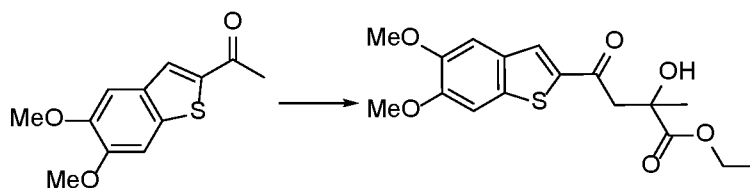
To a mixture of 5,6-dimethoxybenzo[b]thiophene-2-carboxylic acid (2.0g, 8.4mmol) in THF (17mL) at 0°C was added *N*,*O*-dimethylhydroxylamine hydrochloride (1.6g, 17mmol), EDC (3.2g, 17mmol) and then Hunig's Base (5.9mL, 34mmol). The mixture was allowed to warm to rt and was stirred for 18h. The mixture was then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography on silica gel (EtOAc in Hex) to afford the desired product. LCMS (C₁₃H₁₆ NO₄S) (ES, m/z): 282 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 8.05 (s, 1H), 7.55 (s, 1H), 7.49 (s, 1H), 3.84 (s, 3H), 3.81 (s, 3H), 3.80 (s, 3H), 3.30 (s, 3H).

Step 2: 1-(5,6-dimethoxybenzo[b]thiophen-2-yl)ethan-1-one



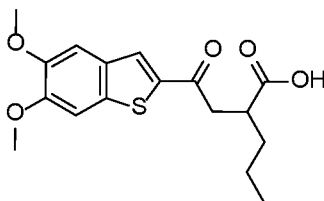
To a mixture of N,5,6-trimethoxy-N-methylbenzo[b]thiophene-2-carboxamide (0.20g, 0.71mmol) in THF (3.6mL) at 0°C was added MeMgBr (3.0M in THF, 0.36mL, 1.1mmol) slowly. After 30min at 0°C, more MeMgBr (3.0M in THF, 0.10mL, 0.28mmol) was added. After 15min at 0°C, more MeMgBr (3.0M in THF, 0.19mL, 0.57mmol) was added. After 45min at 0°C, the mixture was slowly quenched with aq sat NH₄Cl and then diluted with EtOAc. The organic layer was separated, dried over MgSO₄, filtered, and concentrated under reduced pressure. The crude residue was purified by column chromatography on silica gel (EtOAc in Hex) to afford the desired product. LCMS (C₁₂H₁₃O₃S) (ES, m/z): 237 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 8.15 (s, 1H), 7.59 (s, 1H), 7.46 (s, 1H), 3.85 (s, 3H), 3.83 (s, 3H), 2.58 (s, 3H).

Step 3: ethyl 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-hydroxy-2-methyl-4-oxobutanoate

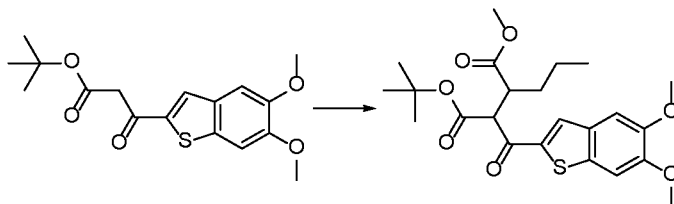


To a mixture of 1-(5,6-dimethoxybenzo[b]thiophen-2-yl)ethanone (50mg, 0.21mmol) in THF (4.2mL) at -78°C was added LDA (2.0M in THF/heptane/benzene, 0.50mL, 1.0mmol). After 45min at -78°C, ethyl pyruvate (78μl, 0.70mmol) was added, and the mixture was stirred for 30min at -78°C. After 30min, the mixture was quenched with sat aq NH₄Cl and allowed to warm to rt. EtOAc was added, and the organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by column chromatography on silica gel (EtOAc in Hex) to afford the desired product as a racemic mixture. The purified racemic mixture was then purified by chiral-SFC (ES Industries, ChromegaChiral CCC, 21x250 mm column, 40% MeOH (+0.25% DMEA) in CO₂), affording two compounds with retention times of 3.9min and 6.3min. Concentration of the first eluting peak afforded the product. LCMS (C₁₇H₂₁O₆S) (ES, m/z): 353 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 8.16 (s, 1H), 7.59 (s, 1H), 7.46 (s, 1H), 5.39 (s, 1H), 4.08 (q, *J* = 6.8Hz, 2H), 3.85 (s, 3H), 3.83 (s, 3H), 3.47 (d, *J* = 16.0Hz, 1H), 3.35 (d, *J* = 15.0Hz, 1H), 1.40 (s, 3H), 1.16 (t, *J* = 7.1Hz, 3H).

Example 49: 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoic acid

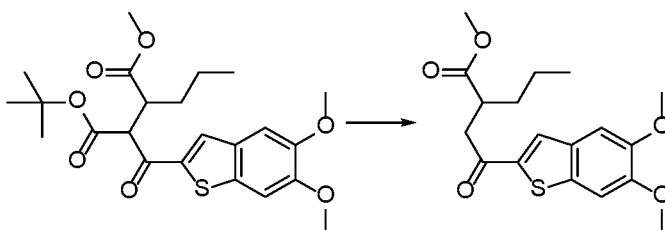


Step 1: 1-(tert-butyl) 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-propylsuccinate



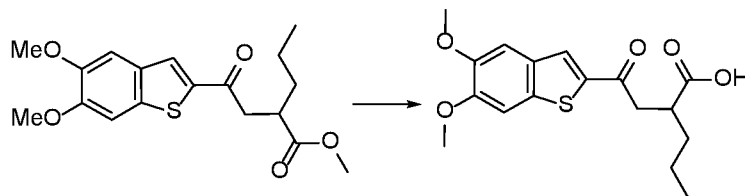
5 To a mixture of *tert*-butyl 3-(5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate (0.15g, 0.45mmol) in DMF (4.5mL) was added Cs₂CO₃ (0.29g, 0.89mmol), and the mixture was stirred for 20min. After 20min, methyl 2-bromopentanoate (0.17g, 0.89mmol) was added, and the mixture was stirred for 30min. After 30min, the mixture was diluted with EtOAc and brine. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography to afford 1-(tert-butyl) 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-propylsuccinate as a mixture of isomers. LCMS (C₂₃H₃₁O₇S) (ES, m/z): 451 [M+H]⁺.

Step 2: methyl 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoate



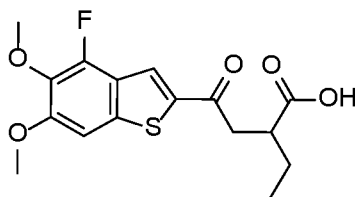
15 To 1-*tert*-butyl 4-methyl 2-(5,6-dimethoxybenzo[b]thiophene-2-carbonyl)-3-propylsuccinate (0.16g, 0.35mmol) in CH₂Cl₂ (0.94mL) was added TFA (0.47mL), and the mixture was stirred overnight at rt. The mixture was diluted with EtOAc and sat NaHCO₃. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by silica gel column chromatography to provide methyl 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoate. LCMS (C₁₈H₂₃O₅S) (ES, m/z): 351 [M+H]⁺.

Step 3: 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoic acid

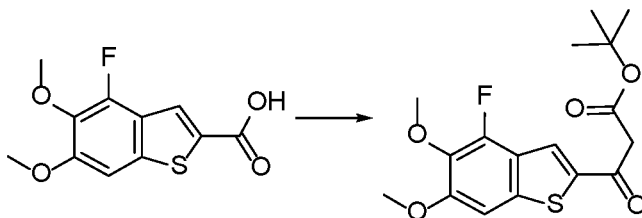


To a mixture of methyl 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoate (69mg, 0.20mmol) in THF (1.0mL), MeOH (0.50mL) and H₂O (0.50mL) was added LiOH (24mg, 0.99mmol), and the mixture was stirred for 2h at rt. After 2h, the mixture was quenched with aq HCl (2.0N, 0.50mL, 1.0mmol) and then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by chiral-SFC (CHIRALCEL, OJ-H, 21X250mm, 20% MeOH (+0.25% DMEA) in CO₂) to provide the separated enantiomers with retention times of 4.2min and 6.7min. The fractions containing the first peak were combined and concentrated under reduced pressure. The residue was then taken up in H₂O and freeze-dried via lyophilization to afford 2-(2-(5,6-dimethoxybenzo[b]thiophen-2-yl)-2-oxoethyl)pentanoic acid. LCMS (C₁₇H₂₁O₅S) (ES, m/z): 337 [M+H]⁺. ¹H NMR (600MHz, DMSO-*d*₆) δ 12.02 (s, 1H), 8.18 (s, 1H), 7.55 (s, 1H), 7.42 (s, 1H), 3.82 (s, 3H), 3.79 (s, 3H), 3.36–3.31 (m, 1H), 3.04 (dd, *J* = 17.2, 4.3Hz, 1H), 2.82–2.76 (m, 1H), 1.59–1.51 (m, 1H), 1.51–1.42 (m, 1H), 1.36–1.26 (m, 2H), 0.85 (t, *J* = 7.2Hz, 3H).

Example 50: 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid



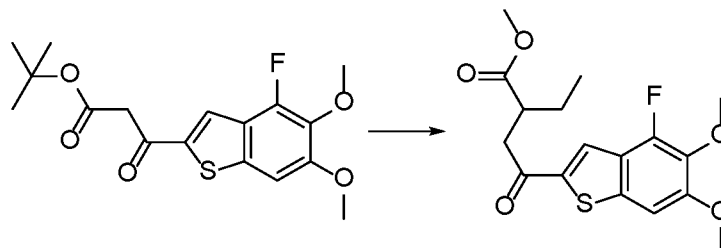
Step 1: tert-butyl 3-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate



To a mixture of 4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carboxylic acid (290mg, 1.1mmol) in 7.5mL of THF was added 1,1'-carbonyldiimidazole (220mg, 1.4mmol). After 2h, magnesium 3-(*tert*-butoxy)-3-oxopropanoate (0.58g, 1.7mmol) was added, and the reaction mixture was allowed to stir for 18h. The mixture was then diluted with EtOAc and

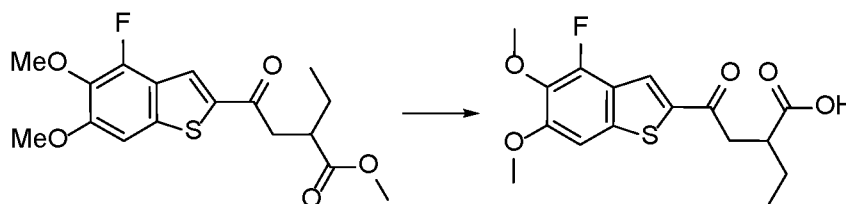
H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The crude residue was purified by silica gel column chromatography (EtOAc in Hex) to afford *tert*-butyl 3-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate. LCMS (C₁₇H₂₀FO₅S-C₄H₈) (ES, m/z): 299 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 8.32 (s, 1H), 7.60 (s, 1H), 4.13 (s, 2H), 3.92 (s, 3H), 3.85 (s, 3H), 1.40 (s, 9H).

Step 2: methyl 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate



To a mixture of *tert*-butyl 3-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-3-oxopropanoate (0.12g, 0.34mmol) in DMF (1.0mL) was added Cs₂CO₃ (0.22g, 0.68mmol), and the mixture was stirred for 20min. Methyl 2-bromobutyrate (78μl, 0.68mmol) was then added, and the mixture was allowed to stir for 3h at rt. After 3h, the mixture was diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. To the crude residue was added CH₂Cl₂ (1.7mL) and TFA (0.85mL), and the mixture was heated to 50°C for 4h. Upon cooling to rt, the mixture was diluted with EtOAc and sat aq NaHCO₃. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The crude residue was purified by silica gel column chromatography (EtOAc in Hex) to afford methyl 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₇H₂₀FO₅S) (ES, m/z): 355 [M+H]⁺.

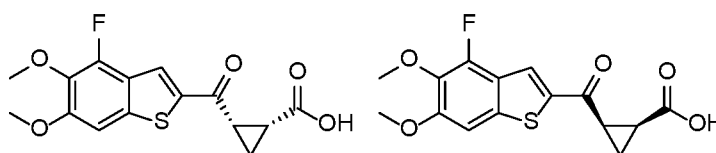
Step 3: 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid



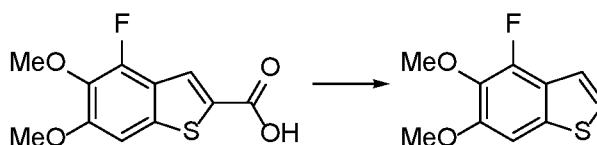
To a mixture of methyl 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (57mg, 0.16mmol) in THF (1.0mL), MeOH (0.50mL), and H₂O (0.50mL) was added LiOH (19mg, 0.80mmol), and the mixture was stirred for 2h at 40°C. After 2h, the mixture was cooled to rt and then quenched with aq HCl (2.0M, 0.40mL, 0.80mmol) and then diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The residue was purified by chiral-SFC (Lux-4,

21x250mm, 45% MeOH (+0.25% DMEA) in CO₂) to provide the separated enantiomers with retention times of 2.8min and 5.3min. The fractions containing the second peak were combined and concentrated. The residue was then taken up in H₂O and freeze-dried via lyophilization to afford 2-ethyl-4-(4-fluoro-5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₆H₁₈FO₅S) (ES, m/z): 341 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 11.97 (s, 1H), 8.35 (s, 1H), 7.57 (s, 1H), 3.91 (s, 3H), 3.85 (s, 3H), 3.52–3.42 (m, 1H), 3.15–3.07 (m, 1H), 2.81–2.71 (m, 1H), 1.68–1.55 (m, 2H), 0.92 (t, *J* = 7.3Hz, 3H).

Example 51 and 52: (1R,2S)-2-(4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid and (1S,2R)-2-(4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid

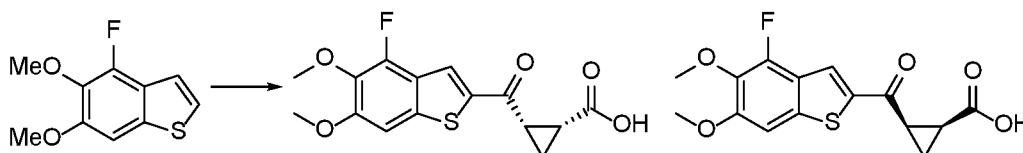


Step 1: 4-fluoro-5,6-dimethoxybenzo[b]thiophene



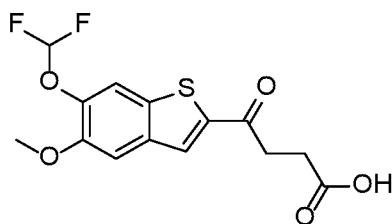
To a mixture of 4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carboxylic acid (0.090g, 0.35mmol) in quinoline (0.83mL, 7.0mmol) was added copper (0.038g, 0.60mmol), and the mixture was heated to 190°C for 2h. After 2h, the mixture was allowed to cool to rt and was then diluted with EtOAc and 2N HCl. The mixture was filtered, and then the organic layer was separated. The organic layer was then washed successively with H₂O, sat aq NaHCO₃ and brine. The organic layer was dried over MgSO₄, filtered and concentrated under reduced pressure. The mixture was purified by column chromatography on silica gel (EtOAc in Hex) to provide 4-fluoro-5,6-dimethoxybenzo[b]thiophene. LCMS (C₁₀H₁₀FO₂S) (ES, m/z): 213 [M+H]⁺. ¹H NMR (500MHz, Chloroform-*d*) δ 7.33 (d, *J* = 5.4Hz, 1H), 7.27 (d, *J* = 5.2Hz, 1H), 7.14 (s, 1H), 3.99 (s, 3H), 3.95 (s, 3H).

Step 2: 2-(4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid

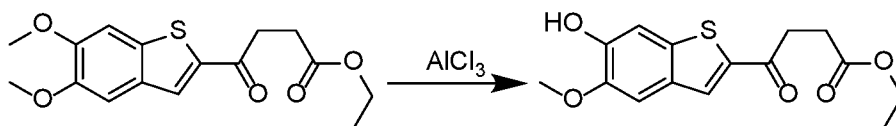


To a mixture of 4-fluoro-5,6-dimethoxybenzo[b]thiophene (45mg, 0.21mmol) in CH₂Cl₂ (2.0mL) at 0°C was added AlCl₃ (37mg, 0.28mmol) and then 3-oxabicyclo[3.1.0]hexane-2,4-dione (48mg, 0.42mmol). The mixture was stirred for 1h at 0°C and then allowed to warm to rt and stirred for 18h. After 18h, the mixture was diluted with EtOAc and H₂O. The organic layer was separated, dried over MgSO₄, filtered and concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography (EtOAc in Hex) to afford a racemic mixture of the desired product. The enantiomers were then separated by chiral-SFC (Lux-4, 21x250mm, 45% MeOH (+0.25% DMEA) in CO₂) to provide (1R,2S)-2-(4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid and (1S,2R)-2-(4-fluoro-5,6-dimethoxybenzo[b]thiophene-2-carbonyl)cyclopropane-1-carboxylic acid with retention times of 4.0min and 4.9min. The fractions containing the first peak (retention time 4.0min) were combined and concentrated. The residue was taken up in H₂O and freeze-dried via lyophilization to afford one of the pure enantiomers. LCMS (C₁₅H₁₄FO₅S) (ES, m/z): 325 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 8.31 (s, 1H), 7.58 (s, 1H), 3.92 (s, 3H), 3.85 (s, 3H), 3.15 (q, *J* = 8.0Hz, 1H), 2.33–2.28 (m, 1H), 1.58–1.48 (m, 1H), 1.34–1.27 (m, 1H). The fractions containing the second peak (retention time 4.9min) were combined and concentrated. The residue was taken up in H₂O and freeze-dried via lyophilization to afford one of the pure enantiomers. LCMS (C₁₅H₁₄FO₅S) (ES, m/z): 325 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆) δ 12.18 (s, 1H), 8.31 (s, 1H), 7.58 (s, 1H), 3.91 (s, 3H), 3.85 (s, 3H), 3.14 (q, *J* = 7.9Hz, 1H), 2.29 (q, *J* = 8.0Hz, 1H), 1.57–1.49 (m, 1H), 1.34–1.27 (m, 1H).

Example 53: 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid



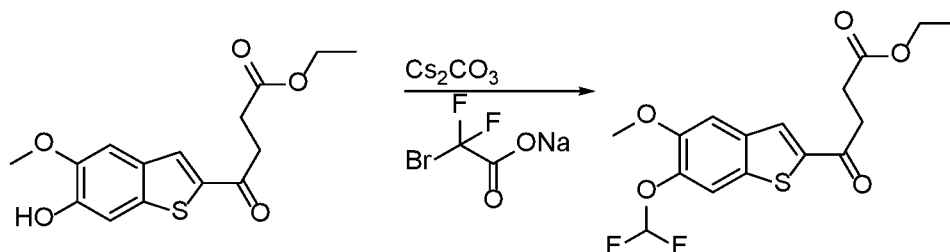
Step 1: ethyl 4-(6-hydroxy-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate



To a mixture of ethyl 4-(5,6-dimethoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (0.45g, 1.4mmol) and DCM (12mL) was added AlCl₃ (0.56g, 4.2mmol) at 25°C. The mixture was stirred at 25°C for 15h. After 15h, more AlCl₃ (1.0g, 7.5mmol) was added to the mixture.

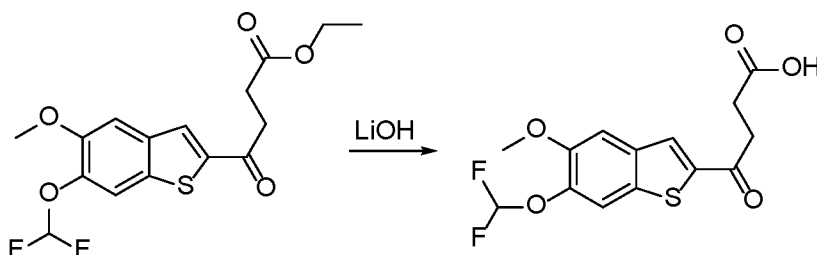
The resulting mixture was stirred at 25°C for 16h. After 16h, the mixture was quenched with aq HCl (1.0N, 20mL, 20mm) and extracted with DCM (3x30mL). The combined organic phases were washed with brine (20 mL), dried over anhydrous Na₂SO₄, filtered and concentrated under reduced pressure. The resulting residue was purified by silica gel column chromatography (EtOAc in PE) to give crude ethyl 4-(6-hydroxy-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate. The crude product was then purified by chiral-SFC to provide ethyl 4-(6-hydroxy-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₅H₁₇O₅S) (ES, m/z): 309. ¹H NMR (400MHz, CDCl₃) δ = 7.88 (s, 1H), 7.34 (s, 1H), 7.24 (s, 1H), 6.08 (s, 1H), 4.17 (q, J = 7.3Hz, 2H), 3.99 (s, 3H), 3.31 (t, J = 6.7Hz, 2H), 2.78 (t, J = 6.8Hz, 2H), 1.27 (t, J = 7.0Hz, 3H).

Step 2: ethyl 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate



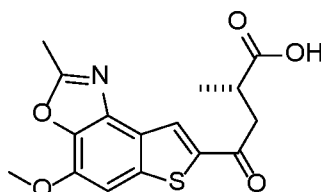
To a mixture of ethyl 4-(6-hydroxy-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (25mg, 0.081mmol) in DMF (1.5ml) was added sodium 2-bromo-2,2-difluoroacetate (48mg, 0.24mmol) and Cs₂CO₃ (79mg, 0.24mmol) at 30°C. The resulting mixture was heated to 100°C for 3h. Upon cooling to rt, the mixture was diluted with H₂O (10mL) and extracted with EtOAc (3x10mL). The combined organic layers were washed with H₂O (20mL) and brine (20mL), dried over anhydrous Na₂SO₄, filtered and concentrated under reduced pressure to give crude product. The crude was purified by reverse phase prep-HPLC (ACN/H₂O with 0.1% TFA) to provide ethyl 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate. LCMS (C₁₆H₁₇F₂O₅S) (ES, m/z): 359 [M+H]⁺. ¹H NMR (400MHz, CDCl₃) δ 7.90 (s, 1H), 7.61 (s, 1H), 7.34 (s, 1H), 6.60 (t, J = 7.4Hz, 1H), 4.15 (q, J = 7.2Hz, 2H), 3.93 (s, 3H), 3.31 (t, J = 6.4Hz, 2H), 2.77 (t, J = 6.4Hz, 2H), 1.25 (t, J = 7.2Hz, 3H).

Step 3: 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid

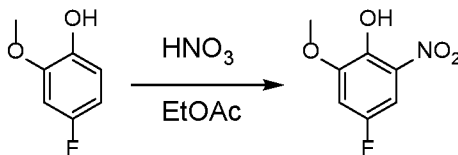


To a mixture of ethyl 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoate (5.0mg, 0.014mmol) in MeOH (0.50mL), THF (0.50mL) and H₂O (0.50mL) was added LiOH (3.3mg, 0.14mmol). The mixture was heated to 50°C for 2h. After 2h, the mixture was allowed to cool to rt and aq HCl (1.0M) was added until the mixture had a pH=6. The mixture was concentrated under reduced pressure. The resulting residue was dissolved in DMF (2mL) and purified by reverse phase prep-HPLC (ACN/H₂O with 0.1% TFA) to provide 4-(6-(difluoromethoxy)-5-methoxybenzo[b]thiophen-2-yl)-4-oxobutanoic acid. LCMS (C₁₄H₁₃F₂O₅S) (ES, m/z): 331 [M+H]⁺. ¹H NMR (400MHz, CDCl₃) δ 8.15 (s, 1H), 7.69 (s, 1H), 7.61 (s, 1H), 6.83 (t, *J* = 75Hz, 1H), 3.96 (s, 3H), 3.36 (t, *J* = 6.0Hz, 2H), 2.73 (t, *J* = 6.0Hz, 2H).

Example 54: (S)-4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoic acid

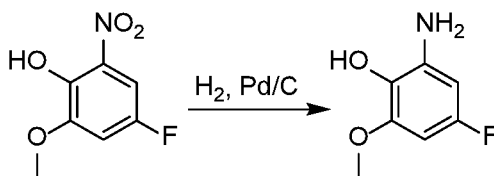


Step 1: 4-fluoro-2-methoxy-6-nitrophenol



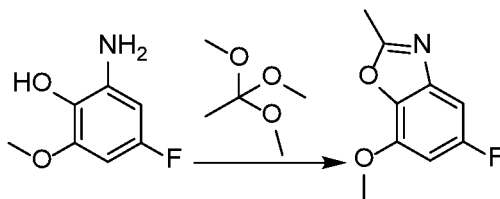
To a 50mL round-bottom flask was added 4-fluoro-2-methoxyphenol (3.7mL, 32mmol) and EtOAc (90mL). The mixture was cooled to 0°C and stirred. To the stirring mixture was added nitric acid (2.1mL, 33mmol) drop wise over 5min. The reaction was stirred at this temperature for 30min. The mixture was diluted with EtOAc (30mL), washed with H₂O (100mL), dried over anhydrous Na₂SO₄, filtered and evaporated under reduced pressure. The resulting residue was purified by column chromatography on silica gel (EtOAc in Hex) to give 4-fluoro-2-methoxy-6-nitrophenol. ¹H NMR (500MHz, CDCl₃): δ 10.60 (s, 1H), 7.41 (dd, *J* = 8.4, 2.7Hz, 1H), 6.94 (dd, *J* = 9.2, 2.4Hz, 1H), 3.97 (s, 3H).

Step 2: 2-amino-4-fluoro-6-methoxyphenol



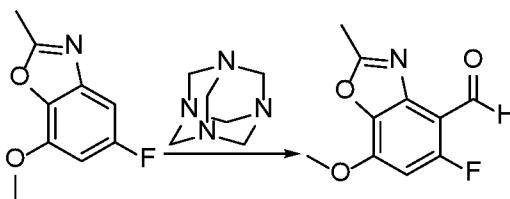
To a 100mL round-bottom flask was added 4-fluoro-2-methoxy-6-nitrophenol (826mg, 4.41mmol), Pd/C (235mg, 0.221mmol), and EtOAc (30mL). The mixture was stirred. The mixture was degassed with N₂ then placed under H₂. After stirring for 16h, the reaction was filtered through CELITE, and the filter cake was washed with EtOAc. The combined filtrates were concentrated under reduced pressure to afford 2-amino-4-fluoro-6-methoxyphenol that was used in the next step without further purification. LCMS (C₇H₉FNO₂) (ES, m/z): 158 [M+H]⁺. ¹H NMR (500MHz, CDCl₃): δ 6.23-6.01 (m, 2H), 3.85 (s, 3H).

Step 3: 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole

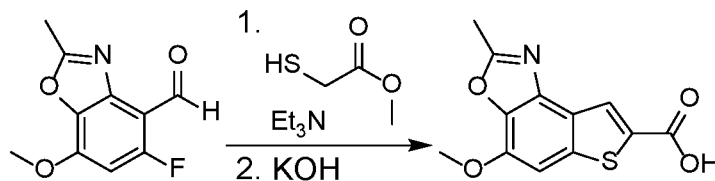


To a 20mL vial was added 2-amino-4-fluoro-6-methoxyphenol (0.58g, 3.7mmol) and 1,1,1-trimethoxyethane (4.0mL, 31mmol). The mixture was stirred and heated to 70°C. After 10min, the mixture was allowed to cool to rt, and the solvents were evaporated under reduced pressure to afford a crude residue that was purified by silica gel chromatography (EtOAc in Hex) to provide 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole. LCMS (C₉H₉FNO₂) (ES, m/z): 182 [M+H]⁺. ¹H NMR (500MHz, CDCl₃): δ 7.05 – 6.90 (m, 1H), 6.61 (d, *J* = 11.1Hz, 1H), 4.01 (s, 3H), 2.66 (s, 3H).

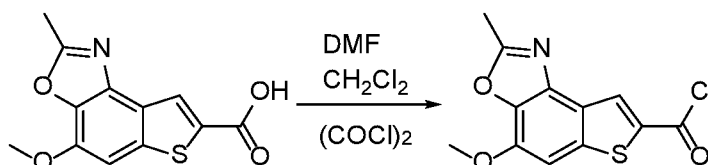
Step 4: 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole-4-carbaldehyde



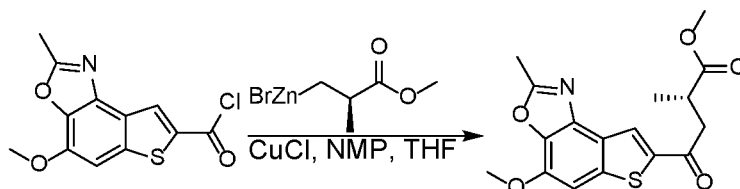
To a 20mL vial was added 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole (423mg, 2.33mmol), 1,3,5,7-tetraazaadamantane (556mg, 3.97mmol), and TFA (0.50mL). The mixture was stirred and heated to 90°C for 3h. The reaction was allowed to cool to rt, diluted with EtOAc (40mL) and partitioned with sat aq NaHCO₃ (100mL). The organic layer was dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure to afford a crude residue that was purified by silica gel chromatography (EtOAc in Hex) to provide 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole-4-carbaldehyde. LCMS (C₁₀H₉FNO₃) (ES, m/z): 210 [M+H]⁺. ¹H NMR (500MHz, CDCl₃): δ 10.42 (s, 1H), 6.60 (d, *J* = 12.7Hz, 1H), 4.05 (s, 3H), 2.68 (s, 3H).

Step 5: 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carboxylic acid

To a 4mL vial was added 5-fluoro-7-methoxy-2-methylbenzo[d]oxazole-4-carbaldehyde (185mg, 0.884mmol) and DMSO (4.0mL). The mixture was stirred. To the mixture was added Et₃N (1.2mL, 8.8mmol) and methyl 2-mercaptoacetate (0.79mL, 8.8mmol). The mixture was heated to 100°C for 15min. The mixture was allowed to cool to rt. Aq KOH (10M, 1.8mL, 18mmol) was added, and the mixture stirred for 10min. The reaction was acidified to pH 3 with aq HCl (6M). The precipitate was collected by filtration, washed with H₂O (2x20mL) and then MeOH (2x2mL), yielding 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carboxylic acid. LCMS (C₁₂H₁₀NO₄S) (ES, m/z): 264 [M+H]⁺. ¹H NMR (500MHz, CDCl₃): δ 8.05 (s, 1H), 7.05 (s, 1H), 3.82 (s, 3H), 2.47 (s, 3H).

Step 6: 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carbonyl chloride

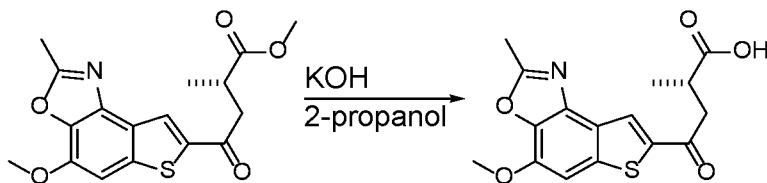
To a 20ml vial was added 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carboxylic acid (106mg, 0.404mmol), CH₂Cl₂ (1.0mL), and DMF (6.3μL, 0.081mmol). The mixture was stirred and cooled to 0°C. (COCl)₂ (0.074mL, 0.85mmol) was added. After 5min, the reaction was warmed to rt and stirred for 35min. The reaction was concentrated under reduced pressure to provide crude 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carbonyl chloride was used in the next step without further purification.

Step 7: methyl (S)-4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoate

To a 20mL vial was added Cu-Cl (14mg, 0.15mmol). The vial was evacuated then refilled with N₂ 3 times. To the vial was added THF (0.25mL). The mixture was cooled to 0°C. To the stirring mixture was added (R)-(3-methoxy-2-methyl-3-oxopropyl)zinc (II) bromide

(0.5M in THF, 1.5mL, 0.73mmol) drop wise over 2min. The mixture was then stirred for 10min. To the mixture was added 4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazole-7-carbonyl chloride (41mg, 0.15mmol) as a solution in NMP (2.0mL) drop wise over 2min. The mixture was stirred for 20min. The reaction was diluted with EtOAc (15mL) and washed with aq
 5 NH₄OH (3M, 30mL, 90mmol). The organic layer was dried over anhydrous Na₂SO₄, filtered, and concentrated under reduced pressure. The resulting residue was purified by silica gel chromatography (EtOAc in Hex) to provide methyl (S)-4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoate. LCMS (C₁₇H₁₈NO₅S) (ES, m/z): 348 [M+H]⁺. ¹H NMR (500MHz, CDCl₃): δ 8.36 (s, 1H), 7.24 (s, 1H), 4.11 (s, 3H), 3.73 (s, 3H),
 10 3.54 (dd, J = 16.6, 7.5Hz, 1H), 3.20-3.09 (m, 2H), 2.78 (s, 3H), 1.32 (d, J = 7.0Hz, 3H).

Step 8: (S)-4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoic acid



To a 4mL vial was added (S)-methyl 4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoate (48mg, 0.14mmol), aq KOH (0.5M, 0.55mL, 0.28mmol), and 2-propanol (1.4mL) at rt. After 30min, the mixture was acidified to pH 3 with aq HCl. The precipitate was collected by filtration and washed with H₂O (2x5mL) and MeOH (2mL). The precipitate was further purified by silica gel chromatography (MeOH in DCM) providing (S)-4-(4-methoxy-2-methylthieno[2',3':5,6]benzo[1,2-d]oxazol-7-yl)-2-methyl-4-oxobutanoic acid. LCMS (C₁₆H₁₆NO₅S) (ES, m/z): 334 [M+H]⁺. ¹H NMR (500MHz, DMSO-*d*₆): δ 12.20 (s, 1H), 8.51 (s, 1H), 7.70 (s, 1H), 4.04 (s, 3H), 3.51 (dd, J = 17.4, 8.6Hz, 1H), 3.18 (dd, J = 17.5, 4.9Hz, 1H), 2.95-2.85 (m, 1H), 2.71 (s, 3H), 1.20 (d, J = 7.2Hz, 3H).

BIOLOGICAL EVALUATION

The individual compounds described in the Examples herein are defined as STING agonists by (i) binding to the STING protein as evidenced by a reduction in binding of tritiated cGAMP ligand to the STING protein by at least 20% at 20uM (concentration of compound being tested) in a STING Biochemical [³H]cGAMP Competition Assay and (ii) demonstrating interferon production with a 6% or greater induction of IFN-β secretion at 30uM in the THP1 cell assay (where induction caused by cGAMP at 30uM was set at 100%).

[³H]-cGAMP Synthesis

2.3mL of buffer solution containing 80mM TrisCl, 200mM MgCl₂, and 20mM NaCl followed by 0.32mL of a 10mM aq solution of GTP was added to a plastic 50mL AMICON tube. A solution of [³H]ATP (21Ci/mmol, 45mCi) in 0.5mL H₂O was then added followed by 1mL of a 1mg/mL solution of DNA (Herring testes activator DNA, Sigma, #D6898) and 53uL of a 47mM solution of cGAS enzyme. Additional H₂O was added to bring the total volume to 10mL.

The reaction was stirred for 2h at 37°C and then added directly to an Amicon Ultra-15 10K centrifuge tube and spun for 1h at 4,000g. The collected solution was then purified on a semi-prep Mono Q column using the following mobile phases:

A: 0.05M TrisCl pH 8.5 adjusted with 1M NaOH

B: 0.05M TrisCl, 0.5M NaCl pH 8.5 adjusted with 1M NaOH

Gradient: 100% A for 5min followed by a linear gradient to 50:50 (A:B) over 25min, 3mL/min, 254nm.

The collected product fractions were pooled and adjusted to a total volume of 30mL with buffer A. A total yield of 15.5mCi of [³H]cGAMP was isolated at a radiochemical purity of 98.0% at a specific activity of 21.5Ci/mmol.

cGAS Enzyme

A recombinant DNA vector was chemically synthesized to express the truncated human cGAS enzyme (residues 161-522). To aid in expression and purification, the amino terminus contains a hexahistidine tag, SUMO tag and TEV cleavage site. The recombinant enzyme was overexpressed in ROSETTA™ 2(DE3) Single Competent Cells (Novagen). Affinity purification was carried out using HIS-Select HF Nickel Affinity Gel (Sigma) followed by size exclusion chromatography using a Hi-Load 26/60 SUPERDEX200 prep grade column (GE Healthcare). Fractions were pooled, concentrated, flash-frozen in liquid nitrogen and stored at -80°C until needed.

Example 55: ³H-cGAMP filtration binding assay (HAQ STING)

The ability of compounds to bind STING is quantified by their ability to compete with tritiated cGAMP ligand for human STING receptor membrane using a radioactive filter-binding assay. The binding assay employs STING receptor obtained from *Trichoplusia ni* cell

membranes (*T.ni*; Expression Systems, cat # 94-002F, www.expressionsystems.com) overexpressing full-length HAQ STING and tritiated cGAMP ligand.

The basic HAQ STING filtration assay protocol is as follows:

The compounds were serially titrated by the Hamilton STARPlus CORE in a 96-well plate (Greiner, # 651201) using a 1:3 ten-point dose response format. After compound preparation, a 2.2ug/ml working concentration of STING membrane (SEQ. ID. No. 1) was prepared by diluting concentrated membrane into assay buffer (1x PBS; Invitrogen # SH30028.02) and douncing 7x using a manual tissue homogenizer (Wheaton, # 357546). 148uL of prepared membrane was then manually added to each well of a 96-well deep-well polypropylene plate (Fisher Scientific, # 12-566-121). Following membrane addition, 2uL of either titrated test compound, DMSO control (Sigma # 276855), or cold cGAMP control was added to the appropriate wells using a BIOMEK FX. Compound and membrane then preincubated for 60min at RT to allow compound binding to equilibrate. Following equilibration, 8nM of [³H] c-GAMP ligand was prepared by diluting into assay buffer, and 50uL of this working stock was then manually added to each well of the assay plate. Plates were then incubated at RT for 60min, and the contents of each assay plate were then filtered through a 96-well GF/B filter plate (PerkinElmer, # 6005250) using a TOMTEC MACH III Cell Harvester equipped with 20mM HEPES buffer (Fisher Scientific, # BP299500). The filter plates were then dried at 55°C for 30min using a pressurized oven before 30uL of ULTIMA GOLD F scintillate was added to each well. Tritium levels for each reaction well were then measured using a PerkinElmer TopCount plate reader.

After normalization to controls, the percent activity for each compound concentration was calculated by measuring the amount of remaining radioactivity. The plot of percent activity versus the log of compound concentration was fit with a 4-parameter dose response equation to calculate EC₅₀ values.

The final reaction conditions were:

Component	Volume (uL)	Final Concentration
STING membrane	148	1.5ug/ml
³ H-cGAMP	50	2.0nM
Low Control (cold cGAMP)	2	10uM
Test compound/DMSO	2	10uM

Compound concentrations tested were 20.000, 637.00, 2.200, 0.740, 0.247, 0.082, 0.027, 0.009, 0.003, and 0.001μM with 1.0% residual DMSO.

Full-Length STING (HAQ) Virus Generation

STING virus was generated using an insect cell baculovirus system. *Spodoptera frugiperda* Sf21 cells (Kempbio, Inc.) were diluted to 5e5 cells/ml in Sf-900II SFM media (LifeTechnologies # 10902088) without antibiotics. The cell suspension was added to each well of a treated 6-well plate (2mL per well, 1e6 cells total), and the cells were allowed to adhere for at least 30min. Meanwhile, a 1mL co-transfection mix was assembled by combining 500ng of HAQ STING [STING(1-379)R71H,G230A,H232R,R293Q-GG-AviTag-GS-HRV3C-HIS8/pBAC1] DNA (Genewiz custom synthesis) with 1mL Sf-900II SFM media containing 10µL Cellfectin® II Reagent (Invitrogen # 10362100) and 100ng viral backbone BestBac 2.0, v-cath/chiA Deleted Linearized Baculovirus DNA (Expression Systems # 91-002). The transfection mixtures were allowed to incubate for 30min. After incubation, media was gently removed from the adhered cells in the 6-well plate, the 1mL transfection mixtures were added (1mL per well), and the plate was placed in a humidified incubator at 27°C. The following day, 1mL Sf-900II SFM media (no antibiotics) was added to each well of the 6-well plate. After media addition, the cells were allowed to incubate with DNA (SEQ. ID. No. 2) at 27°C for 5-7 days to generate the P0 viral stock. To generate P1 viral stocks, 0.5mL of P0 viral supernatant was added to 50mL uninfected Sf21 cells (seeded the day prior to infection at a density of 5x10⁵ cells/mL to allow for one overnight doubling) in Sf-900II SFM media containing 5µg/mL gentamicin (Invitrogen #15710072). The infected cells were then incubated at 27°C for 3days while shaking at 110rpm (ATR Biotech Multitron Infors HT #AJ118). On day 3, P1 cultures were counted using a ViCell XR (Beckman Coulter Life Sciences # 383556) to confirm infection had occurred (cell size ≥3µm larger than uninfected cells and viability approximately 85-95%). Cultures were harvested in 50mL conical tubes and centrifuged at 2000xg for 10min at 4°C. The P1 viral supernatants were poured off into clean 50ml centrifuge tubes, and the remaining P1 cell pellets were used to generate Baculovirus Infected Insect Cells (BIICs). Cryopreservation media containing Sf-900II SFM media with 10% heat inactivated FBS, 10% DMSO (Sigma #D2650), and 5µg/ml gentamicin was prepared and sterilized through 0.22µM filter immediately prior to use. P1 cell pellets were resuspended to a density of 2e7 cells/ml and aliquoted into cryovials (1mL per vial). Cryovials were placed in MR. FROSTY™ cell freezers O/N at -80°C and transferred to liquid nitrogen for long term storage the following day. To generate P2 viral stock, 0.5mL of the P1 viral supernatant was added to 50mL uninfected Sf21 cells (seeded the day prior to infection at a density of 5x10⁵ cells/mL to allow for one overnight doubling) in Sf-

900II SFM media containing 5µg/mL gentamicin. These cells were incubated at 27°C for 3 days while shaking at 110rpm before harvesting P2 stock with centrifugation at 2000xg for 10min at 4°C. The P2 viral supernatants were poured off and discarded, while the P2 cell pellets were used to generate P2 BIICs following the same protocol described above. The baculovirus generation protocol has been validated to consistently produce P1/P2 BIICs with titers of 2e9 pfu/mL (2e7 cells/mLx100 pfu/cell).

Full-Length STING (HAQ) Expression

To generate STING membranes, P1/P2 BIICs were amplified overnight by adding thawed BIICs to *Sf21* cells seeded at a density of 1.0x10⁶ cells/mL. The volume of BIIC used to infect the culture was calculated using an assumed BIIC titer of 2e9 pfu/ml to achieve an MOI of 10 in the overnight amplification. After culturing overnight, the cells were counted on a ViCell XR to confirm infection had occurred (cell size ≥3µm larger than uninfected cells and viability approximately 80-90%). The volume of infected *Sf21* cells from the overnight amplification used to infect the large-scale expression of *Trichoplusia ni* (*T.ni*; Expression Systems, cat # 94-002F, www.expressionsystems.com) seeded at a density of 1.0x10⁶ in cell media (ESF921 SFM containing 5µg/mL gentamicin) at MOI = 2.0 was calculated based on (100 pfu/infected *Sf21* cell). The cells were allowed to express for 48h at 27°C before harvesting the cell pellet, by centrifugation at 3,400xg for 10min at 4°C. *T. ni* cells were counted on a ViCell XR to confirm infection had occurred (cell size ≥3µm larger than uninfected cells and viability approximately 80-90%) prior to harvest.

Full-Length STING (HAQ) Membrane Generation

Buffer stock reagents:

- 1) 1M HEPES pH 7.5, Teknova, Cat#H1035
- 2) 5M NaCl, Sigma Aldrich, Cat#S5150-1L
- 3) KCl, Sigma Aldrich, Cat#319309-500ML
- 4) Complete EDTA-free protease inhibitor tablets, Roche Diagnostics, Cat#11873580001
- 5) Benzonase, Universal Nuclease, Pierce, Cat#88702

Lysis buffer [25mM HEPES pH 7.5, 10mM MgCl₂, 20mM KCl, (Benzonase 1:5000, Complete Protease Inhibitor tab/50mL)] was added to the pellet of cells expressing full-length STING (HAQ) prepared above at 5mL Lysis buffer per g of cell pellet. The pellet was

resuspended and dounced twenty times using a Wheaton Dounce Homogenizer to disrupt the cell membrane. Homogenized lysate was then passed through the EMULSIFLEX-C5 microfluidizer at a pressure close to 5000PSI. The resuspended pellet was centrifuged at 36,000rpm (100,000xg) in a 45Ti rotor ultra-high speed centrifuge for 45min, 4°C. The supernatant was removed. The pellet then was resuspended in wash buffer [(25mM HEPES pH7.5, 1mM MgCl₂, 20mM KCl, 1M NaCl (Complete Protease Inhibitor tab/50mL)] at a volume of 50mL pellet/centrifuge tube. The pellet/wash buffer mixture was then homogenized, using a glass homogenizer on ice (20 strokes), followed by centrifugation at 36,000rpm for 45min at 4°C. The supernatant was removed. The wash step was repeated once more. The resulting membrane was resuspended in 20mM HEPES pH 7.5, 500mM NaCl, 10% glycerol, EDTA-free Protease Inhibitors (1tablet/50mL). The protein concentration was measured by Bradford assay (Bio-Rad Protein Assay, Cat# 500-0006), and protein enrichment was determined by SDS-PAGE and confirmed by Western blot. The resuspended membranes were stored at -80°C.

Full-Length HAQ STING [STING(1-379)R71H,G230A,H232R,R293Q-GG-AviTag-GS-HRV3C-HIS8] Amino Acid Sequence:

MPHSSLHPSIPCPRGHGAQKAALVLLSACLVTWGLGEPPEHTLRYLVHLASLQLGLL
LNGVCSLAEELHHIHSRYRGSYWRTVRACLGCP LRRGALLLLSIYFYYS L PNAVGPPFT
WMLALLGLS QALNILLGLKGLAPAEISAVCEKGNFNV AHGLAWSYYIGYLR LILPELQA
RIRTYNQHYNNLLRGAVSQRLYILLPLDCGVPDNL SMADPNIRFLDKLPQQTADRAGIK
DRVYSNSIYELLENGQRAGTCVLEYATPLQTLFAMSQYSQAGFSREDRLEQAKLFCQTL
EDILADAPESQNNCRLIAYQEPADDSSFSLSQEVLRLRLRQEEKEEVTVGSLKTS AVPSTST
MSQEPPELLISGMEKPLPLRTDFSGGGLNDIFEAQKIEWHEGSLEVL FQGPHHHHHHHH
(SEQ. ID. No. 1)

Full-length HAQ [STING(1-379)R71H,G230A,H232R,R293Q-GG-AviTag-GS-HRV3C-HIS8/pBAC1] Plasmid DNA Sequence:

GGAACGGCTCCGCCCACTATTAATGAAATTAAAAATTCCAATTTTAAAAAACGCAG
CAAGAGAAACATTTGTATGAAAGAATGCGTAGAAGGAAAGAAAAATGTCGTCGAC
ATGCTGAACAACAAGATTAATATGCCTCCGTGTATAAAAAAATATTGAACGATTTG
AAAGAAAACAATGTACCGCGCGGCGGTATGTACAGGAAGAGGTTTATACTAACTG
TTACATTGCAAACGTGGTTTCGTGTGCCAAGTGTGAAAACCGATGTTTAATCAAGGC
TCTGACGCATTTCTACAACCACGACTCCAAGTGTGTGGGTGAAGTCATGCATCTTTT

AATCAAATCCCAAGATGTGTATAAACCACCAAACCTGCCAAAAAATGAAAACCTGTCTG
ACAAGCTCTGTCCGTTTGCTGGCAACTGCAAGGGTCTCAATCCTATTTGTAATTATTG
AATAATAAAACAATTATAAATGCTAAATTTGTTTTTTATTAACGATACAAACCAAAC
GCAACAAGAACATTTGTAGTATTATCTATAATTGAAAACGCGTAGTTATAATCGCTG
5 AGGTAATATTTAAAATCATTTTCAAATGATTCACAGTTAATTTGCGACAATATAATT
TTATTTTTCACATAAACTAGACGCCTTGTCGTCTTCTTCTTCGTATTCCTTCTCTTTTTC
ATTTTTCTCTTCATAAAAATTAACATAGTTATTATCGTATCCATATATGTATCTATCG
TATAGAGTAAATTTTTTGTGTGCATAAATATATATGTCTTTTTTAATGGGGTGTATAG
TACCGCTGCGCATAGTTTTTCTGTAATTTACAACAGTGCTATTTTCTGGTAGTTCTTC
10 GGAGTGTGTTGCTTTAATTATTAAATTTATATAATCAATGAATTTGGGATCGTCGGTT
TTGTACAATATGTTGCCGGCATAGTACGCAGCTTCTTCTAGTTCAATTACACCATTTT
TTAGCAGCACCGGATTAACATAACTTTCCAAAATGTTGTACGAACCGTTAAACAAAA
ACAGTTCACCTCCCTTTTCTATACTATTGTCTGCGAGCAGTTGTTTGTGTGTTAAAAAT
AACAGCCATTGTAATGAGACGCACAACTAATATCACAACTGGAAATGTCTATCA
15 ATATATAGTTGCTGATCAGATCTGATCATGGAGATAATTAAAATGATAACCATCTCG
CAAATAAATAAGTATTTTACTGTTTTTCGTAACAGTTTTGTAATAAAAAAACCTATAA
ATATAGGATCCATGCCCCACTCCAGCCTGCATCCATCCATCCCGTGTCCCAGGGGTC
ACGGGGCCCAGAAGGCAGCCTTGGTTCTGCTGAGTGCCTGCCTGGTGACCCTTTGGG
GGCTAGGAGAGCCACCAGAGCACACTCTCCGGTACCTGGTGCTCCACCTAGCCTCCC
20 TGCAGCTGGGACTGCTGTAAACGGGGTCTGCAGCCTGGCTGAGGAGCTGCACCAC
ATCCACTCCAGGTACCGGGGCAGCTACTGGAGGACTGTGCGGGCCTGCCTGGGCTG
CCCCCTCCGCCGTGGGGCCCTGTTGCTGCTGTCCATCTATTTCTACTACTCCCTCCCA
AATGCGGTGCGCCCGCCCTTCACTTGATGCTTGCCCTCCTGGGCCTCTCGCAGGCA
CTGAACATCCTCCTGGGCCTCAAGGGCCTGGCCCCAGCTGAGATCTCTGCAGTGTGT
25 GAAAAAGGGAATTTCAACGTGGCCCATGGGCTGGCATGGTCATATTACATCGGATA
TCTGCGGCTGATCCTGCCAGAGCTCCAGGCCCGGATTCGAACTTACAATCAGCATTA
CAACAACCTGCTACGGGGTGCAGTGAGCCAGCGGCTGTATATTCTCCTCCCATTGGA
CTGTGGGGTGCCTGATAACCTGAGTATGGCTGACCCCAACATTCGCTTCCTGGATAA
ACTGCCCCAGCAGACCGCTGACCGTGCTGGCATCAAGGATCGGGTTTACAGCAACA
30 GCATCTATGAGCTTCTGGAGAACGGGCAGCGGGCGGGCACCTGTGTCCTGGAGTAC
GCCACCCCCTTGACAGACTTTGTTTGCCATGTCACAATACAGTCAAGCTGGCTTTAGC
CGGGAGGATAGGCTTGAGCAGGCCAACTCTTCTGCCAGACACTTGAGGACATCCT
GGCAGATGCCCTGAGTCTCAGAACAACTGCCGCCTCATTGCCTACCAGGAACCTGC

AGATGACAGCAGCTTCTCGCTGTCCCAGGAGGTTCTCCGGCACCTGCGGCAGGAGG
AAAAGGAAGAGGTTACTGTGGGCAGCTTGAAGACCTCAGCGGTGCCAGTACCTCC
ACGATGTCCCAAGAGCCTGAGCTCCTCATCAGTGGAATGGAAAAGCCCCCTCCCTCTC
CGCACGGATTTCTCTGGCGGTGGCCTGAACGACATCTTCGAAGCCCAGAAAATCGA
5 ATGGCATGAAGGCAGCCTGGAAGTGCTGTTCCAGGGCCCACACCACCATCATCACC
ATCACCATTAATGAGCGGCCGCACTCGAGCACCACCACCACCACCTAACCTAGG
TAGCTGAGCGCATGCAAGCTGATCCGGGTTATTAGTACATTTATTAAGCGCTAGATT
CTGTGCGTTGTTGATTTACAGACAATTGTTGTACGTATTTTAATAATTCATTAAATTT
ATAATCTTTAGGGTGGTATGTTAGAGCGAAAATCAAATGATTTTCAGCGTCTTTATA
10 TCTGAATTTAAATATTAATCCTCAATAGATTTGTAAAATAGGTTTCGATTAGTTTCA
AACAAGGGTTGTTTTTCCGAACCGATGGCTGGACTATCTAATGGATTTTCGCTCAAC
GCCACAAAACCTTGCCAAATCTTGTAGCAGCAATCTAGCTTTGTCGATATTCGTTTGT
GTTTTGTTTTGTAATAAAGGTTTCGACGTCGTTCAAAATATTATGCGCTTTTGTATTTC
TTTCATCACTGTCGTTAGTGTACAATTGACTCGACGTAAACACGTTAAATAGAGCTT
15 GGACATATTTAACATCGGGCGTGTTAGCTTTATTAGGCCGATTATCGTCGTCGTCCTCC
AACCCTCGTCGTTAGAAAGTTGCTTCCGAAGACGATTTTGCCATAGCCACACGACGCC
TATTAATTGTGTCGGCTAACACGTCCGCGATCAAATTTGTAGTTGAGCTTTTTGGAAT
TATTTCTGATTGCGGGCGTTTTTGGGCGGGTTTCAATCTAACTGTGCCCCGATTTTAAT
TCAGACAACACGTTAGAAAGCGATGGTGCAGGCGGTGGTAACATTTTCAGACGGCAA
20 ATCTACTAATGGCGGCGGTGGTGGAGCTGATGATAAATCTACCATCGGTGGAGGCG
CAGGCGGGGCTGGCGGCGGAGGCGGAGGCGGAGGTGGTGGCGGTGATGCAGACGG
CGGTTTAGGCTCAAATGTCTCTTTAGGCAACACAGTCGGCACCTCAACTATTGTACT
GGTTTCGGGCGCCGTTTTTGGTTTGACCGGTCTGAGACGAGTGCGATTTTTTTCGTTT
CTAATAGCTTCCAACAATTGTTGTCTGTCGTCTAAAGGTGCAGCGGGTTGAGGTTCC
25 GTCGGCATTGGTGGAGCGGGCGGCAATTCAGACATCGATGGTGGTGGTGGTGGTGG
AGGCGCTGGAATGTTAGGCACGGGAGAAGGTGGTGGCGGCGGTGCCGCCGGTATAA
TTTGTTCTGGTTTAGTTTTGTTTCGCGCACGATTGTGGGCACCGGCGCAGGCGCCGCTG
GCTGCACAACGGAAGGTCGTCTGCTTCGAGGCAGCGCTTGGGGTGGTGGCAATTCA
ATATTATAATTGGAATACAAATCGTAAAAATCTGCTATAAGCATTGTAATTTTCGCTA
30 TCGTTTACCGTGCCGATATTTAACAACCGCTCAATGTAAGCAATTGTATTGTAAAGA
GATTGTCTCAAGCTCGGATCGATCCCGCACGCCGATAACAAGCCTTTTCATTTTTACT
ACAGCATTGTAGTGGCGAGACACTTCGCTGTCGTCGAGGTTTAAACGCTTCCTCGCT
CACTGACTCGCTGCGCTCGGTCTCGGCTGCGGCGAGCGGTATCAGCTCACTCAAA

GGCGGTAATACGGTTATCCACAGAATCAGGGGATAACGCAGGAAAGAACATGTGAG
CAAAAGGCCAGCAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTTTTTC
CATAGGCTCCGCCCCCTGACGAGCATCACAAAAATCGACGCTCAAGTCAGAGGTG
GCGAAACCCGACAGGACTATAAAGATACCAGGCGTTTCCCCCTGGAAGCTCCCTCG
5 TGCCTCTCCTGTTCCGACCCTGCCGCTTACCGGATACCTGTCCGCTTTCTCCCTTC
GGGAAGCGTGGCGCTTTCTCATAGCTCACGCTGTAGGTATCTCAGTTCGGTGTAGGT
CGTTCGCTCCAAGCTGGGCTGTGTGCACGAACCCCCCGTTCAGCCCGACCGCTGCGC
CTTATCCGGTAACTATCGTCTTGAGTCCAACCCGGTAAGACACGACTTATCGCCACT
GGCAGCAGCCACTGGTAACAGGATTAGCAGAGCGAGGTATGTAGGCGGTGCTACAG
10 AGTTCTTGAAGTGGTGGCCTAACTACGGCTACACTAGAAGGACAGTATTTGGTATCT
GCGCTCTGCTGAAGCCAGTTACCTTCGGAAAAAGAGTTGGTAGCTCTTGATCCGGCA
AACAAACCACCGCTGGTAGCGGTGGTTTTTTTGTGTTGCAAGCAGCAGATTACGCGCA
GAAAAAAAGGATCTCAAGAAGATCCTTTGATCTTTTCTACGGGGTCTGACGCTCAGT
GGAACGAAAACTCACGTTAAGGGATTTTGGTCATGAGATTATCAAAAAGGATCTTC
15 ACCTAGATCCTTTTAAATTA AAAATGAAGTTTTAAATCAATCTAAAGTATATATGAG
TAAACTTGGTCTGACAGTTACCAATGCTTAATCAGTGAGGCACCTATCTCAGCGATC
TGTCTATTTTCGTTTCATCCATAGTTGCCTGACTCCCCGTCGTGTAGATAACTACGATAC
GGGAGGGCTTACCATCTGGCCCCAGTGCTGCAATGATACCGCGAGACCCACGCTCA
CCGGCTCCAGATTTATCAGCAATAAACCAGCCAGCCGGAAGGGCCGAGCGCAGAAG
20 TGGTCCTGCAACTTTATCCGCTCCATCCAGTCTATTAATTGTTGCCGGGAAGCTAG
AGTAAGTAGTTCGCCAGTTAATAGTTTTCGCGCAACGTTGTTGCCATTGCTACAGGCAT
CGTGGTGTACGCTCGTCGTTTGGTATGGCTTCATTCAGCTCCGGTTCCCAACGATCA
AGGCGAGTTACATGATCCCCCATGTTGTGCAAAAAAGCGGTAGCTCCTTCGGTCCT
CCGATCGTTGTCAGAAGTAAGTTGGCCGCAGTGTTATCACTCATGGTTATGGCAGCA
25 CTGCATAATTCTCTTACTGTCATGCCATCCGTAAGATGCTTTTCTGTGACTGGTGAGT
ACTCAACCAAGTCATTCTGAGAATAGTGTATGCGGCGACCGAGTTGCTCTTGCCCGG
CGTCAATACGGGATAATACCGCGCCACATAGCAGAACTTTAAAAGTGCTCATCATTG
GAAAACGTTCTTCGGGGCGAAAACTCTCAAGGATCTTACCGCTGTTGAGATCCAGTT
CGATGTAACCCACTCGTGCACCCAACTGATCTTCAGCATCTTTTACTTTCACCAGCGT
30 TTCTGGGTGAGCAAAAACAGGAAGGC AAAATGCCGCAAAAAAGGGAATAAGGGCG
ACACGGAAATGTTGAATACTCATACTCTTCCTTTTTTCAATATTATTGAAGCATTTATC
AGGGTTATTGTCTCATGAGCGGATACATATTTGAATGTATTTAGAAAAATAAACAAA
TAGGGGTTCGCGCACATTTCCCCGAAAAGTGCCACCTGACGCGCCCTGTAGCGGCG

CATTAAGCGCGGCGGGTGTGGTGGTTACGCGCAGCGTGACCGCTACACTTGCCAGC
 GCCCTAGCGCCCGCTCCTTTTCGCTTTCTTCCCTTCCCTTTCTCGCCACGTTGCGCGGCTT
 TCCCCGTCAAGCTCTAAATCGGGGGCTCCCTTTAGGGTTCCGATTTAGTGCTTTACG
 GCACCTCGACCCCAAAAACTTGATTAGGGTGATGGTTCACGTAGTGGGCCATCGCC
 5 CTGATAGACGGTTTTTTCGCCCTTTGACGTTGGAGTCCACGTTCTTTAATAGTGGACTC
 TTGTTCCAACTGGAACAACACTCAACCCTATCTCGGTCTATTCTTTTGATTATAAG
 GGATTTTGCCGATTTTCGGCCTATTGGTTAAAAAATGAGCTGATTAAACAAAAATTTA
 ACGCGAATTTTAACAAAATATTAACGTTTACAATTTCCCATTCGCCATTCAGGCTGC
 GCAACTGTTGGGAAGGGCGATCGGTGCGGGCCTCTTCGCTATTACGCCA

10 (SEQ. ID. No. 2)

Certain compounds of the disclosure were evaluated in HAQ STING *in vitro* binding assay as described above. The following table tabulates the biological data for these compounds as EC₅₀ values.

15 **Table 6: ³H-cGAMP filtration binding assay for HAQ STING**

Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)
Example 1	3405	Example 19	9705	Example 37	5612
Example 2	9587	Example 20	10720	Example 38	1926
Example 3	10640	Example 21	6341	Example 39	1146
Example 4	1903	Example 22	8808	Example 40	3938
Example 5	1143	Example 23	6054	Example 41	5700
Example 6	703	Example 24	2636	Example 42	759
Example 7	9335	Example 25	4073	Example 43	1197
Example 8	6773	Example 26	1375	Example 44	15740
Example 9	2575	Example 27	13170	Example 45	14670
Example 10	13980	Example 28	1952	Example 46	7454
Example 11	2735	Example 29	13760	Example 47	5056
Example 12	5990	Example 30	5050	Example 48	19250
Example 13	1375	Example 31	5943	Example 49	2718
Example 14	4073	Example 32	3627	Example 50	890
Example 15	894	Example 33	6461	Example 51	17840
Example 16	1720	Example 34	10420	Example 52	599

Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)
Example 17	5865	Example 35	5547	Example 53	13670
Example 18	12500	Example 36	14430	Example 54	531

Example 56: ³H-cGAMP filtration binding assay (WT STING)

The ability of compounds to bind STING is quantified by their ability to compete with tritiated cGAMP ligand for human STING receptor membrane using a radioactive filter-binding assay. The binding assay employs STING receptor obtained from *Trichoplusia ni* cell membranes (*T.ni*; Expression Systems, cat # 94-002F, www.expressionsystems.com) overexpressing full-length WT STING and tritiated cGAMP ligand.

The basic WT STING filtration assay protocol is as follows:

16nM of [³H] c-GAMP ligand was prepared by diluting into assay buffer, and 50uL of this working stock was manually added to each well of the assay plate. After ligand addition, 2uL of either titrated test compound, DMSO control (Sigma # 276855), or cold cGAMP control was added to the appropriate wells using a BIOMEK FX. The serially titrated compound was prepared on a Hamilton STARPlus CORE in a 96-well plate (Greiner, # 651201) using a 1:3 ten-point dose response format. Following compound addition, a 2.2ug/ml working concentration of STING membrane (SEQ. ID. No. 3) was prepared by diluting concentrated membrane into assay buffer (1x PBS; Invitrogen # SH30028.02) and douncing 7x using a manual tissue homogenizer (Wheaton, # 357546). 148uL of this prepared membrane was then manually added to each well of a 96-well deep-well polypropylene plate (Fisher Scientific, # 12-566-121). Compound, ligand, and membrane then incubated for 60min at RT before the contents of each assay plate were filtered through a 96-well GF/B filter plate (PerkinElmer, # 6005250) using a TOMTEC MACH III Cell Harvester equipped with 20mM HEPES buffer (Fisher Scientific, # BP299500). The filter plates were then dried at 55°C for 30min using a pressurized VWR oven before 30uL of ULTIMA GOLD F scintillate was added to each well. Tritium levels for each reaction well were then measured using a PerkinElmer TopCount plate reader.

After normalization to controls, the percent activity for each compound concentration was calculated by measuring the amount of remaining radioactivity. The plot of percent activity versus the log of compound concentration was fit with a 4-parameter dose response equation to calculate EC₅₀ values.

The final reaction conditions were:

Component	Volume (uL)	Final Concentration
STING membrane	148	1.5ug/ml
³ H-cGAMP	50	4.0nM
Low Control (cold cGAMP)	2	10uM
Test compound/DMSO	2	10uM

Compound concentrations tested were 20.000, 637.00, 2.200, 0.740, 0.247, 0.082, 0.027, 0.009, 0.003, and 0.001μM with 1.0% residual DMSO.

Full-Length STING (WT) Virus Generation

5 STING virus was generated using an insect cell baculovirus system. *Spodoptera frugiperda* Sf21 cells (Kempbio, Inc.) were diluted to 5e5 cells/ml in Sf-900II SFM media (LifeTechnologies # 10902088) without antibiotics. The cell suspension was added to each well of a treated 6-well plate (2mL per well, 1e6 cells total), and the cells were allowed to adhere for at least 30min. Meanwhile, a 1mL co-transfection mix was assembled by combining 500ng of

10 WT STING[STING(1-379)H232R-gg-AviTag-gs-HRV3C-HIS8/pBAC1] (Genewiz custom synthesis) with 1mL Sf-900II SFM media containing 10μL CELLFECTIN® II Reagent (Invitrogen # 10362100) and 100ng viral backbone BestBac 2.0, v-cath/chiA Deleted Linearized Baculovirus DNA (Expression Systems # 91-002). The transfection mixtures were allowed to incubate for 30min. After incubation, media was gently removed from the adhered cells in the 6-well plate,

15 the 1mL transfection mixtures were added (1mL per well), and the plate was placed in a humidified incubator at 27°C. The following day, 1mL Sf-900II SFM media (no antibiotics) was added to each well of the 6-well plate. After media addition, the cells were allowed to incubate with DNA [(SEQ. ID. No. 4) and linearized viral backbone BestBac 2.0] at 27°C for 5-7 days to generate the P0 viral stock. To generate P1 viral stocks, 0.5mL of P0 viral supernatant was

20 added to 50mL uninfected Sf21 cells (seeded the day prior to infection at a density of 5x10⁵ cells/mL to allow for one overnight doubling) in Sf-900II SFM media containing 5μg/mL gentamicin (Invitrogen #15710072). The infected cells were then incubated at 27°C for 3days while shaking at 110rpm (ATR Biotech Multitron Infors HT #AJ118). On day 3, P1 cultures were counted using a ViCell XR (Beckman Coulter Life Sciences # 383556) to confirm infection

25 had occurred (cell size ≥3μm larger than uninfected cells and viability approximately 85-95%). Cultures were harvested in 50mL conical tubes and centrifuged at 2000xg for 10min at 4°C. The P1 viral supernatants were poured off into clean 50ml centrifuge tubes, and the remaining P1 cell pellets were used to generate Baculovirus Infected Insect Cells (BIICs). Cryopreservation media

containing Sf-900II SFM media with 10% heat inactivated FBS, 10% DMSO (Sigma #D2650), and 5µg/ml gentamicin was prepared and sterilized through 0.22µM filter immediately prior to use. P1 cell pellets were resuspended to a density of 2e7 cells/ml and aliquoted into cryovials (1mL per vial). Cryovials were placed in MR. FROSTY™ cell freezers O/N at -80°C and transferred to liquid nitrogen for long term storage the following day. To generate P2 viral stock, 0.5mL of the P1 viral supernatant was added to 50mL uninfected *Sf21* cells (seeded the day prior to infection at a density of 5x10⁵ cells/mL to allow for one overnight doubling) in Sf-900II SFM media containing 5µg/mL gentamicin. These cells were incubated at 27°C for 3 days while shaking at 110rpm before harvesting P2 stock with centrifugation at 2000xg for 10min at 4°C. The P2 viral supernatants were poured off and discarded, while the P2 cell pellets were used to generate P2 BIICs following the same protocol described above. The baculovirus generation protocol has been validated to consistently produce P1/P2 BIICs with titers of 2e9 pfu/mL (2e7 cells/mLx100pfu/cell).

15 Full-Length STING (WT) Expression

To generate STING membranes, P1/P2 BIICs were amplified overnight by adding thawed BIICs to *Sf21* cells seeded at a density of 1.0x10⁶ cells/mL. The volume of BIIC used to infect the culture was calculated using an assumed BIIC titer of 2e9 pfu/ml to achieve an MOI of 10 in the overnight amplification. After culturing overnight, the cells were counted on a ViCell XR to confirm infection had occurred (cell size ≥3µm larger than uninfected cells and viability approximately 80-90%). The volume of infected *Sf21* cells from the overnight amplification used to infect the large-scale expression of *Trichoplusia ni* (*T.ni*; Expression Systems, cat # 94-002F, www.expressionsystems.com) seeded at a density of 1.0x10⁶ in cell media (ESF921 SFM containing 5µg/mL gentamicin) at MOI = 2.0 was calculated based on (100pfu/infected *Sf21* cell). The cells were allowed to express for 48h at 27°C before harvesting the cell pellet, by centrifugation at 3,400xg for 10min at 4°C. *T. ni* cells were counted on a ViCell XR to confirm infection had occurred (cell size ≥3µm larger than uninfected cells and viability approximately 80-90%) prior to harvest.

30 Full-Length STING (WT) Membrane Generation

Buffer stock reagents:

- 1) 1 M HEPES pH 7.5, Teknova, Cat#H1035
- 2) 5 M NaCl, Sigma Aldrich, Cat#S5150-1L

- 3) KCl, Sigma Aldrich, Cat#319309-500ML
- 4) Complete EDTA-free protease inhibitor tablets, Roche Diagnostics, Cat#11873580001
- 5) Benzonase, Universal Nuclease, Pierce, Cat#88702

5 Lysis buffer [25mM HEPES pH 7.5, 10mM MgCl₂, 20mM KCl, (Benzonase 1:5000, Complete Protease Inhibitor tab/50mL)] was added to the pellet of cells expressing full-length STING (WT) prepared above at 5mL Lysis buffer per g of cell pellet. The pellet was resuspended and dounced twenty times using a Wheaton Dounce Homogenizer to disrupt the cell membrane. Homogenized lysate was then passed through the emulsiflex-C5 microfluidizer at a pressure close to 5000PSI. The resuspended pellet was centrifuged at 36,000rpm (100,000xg) in 10 a 45Ti rotor ultra-high speed centrifuge for 45min, 4°C. The supernatant was removed. The pellet then was resuspended in wash buffer [(25mM HEPES pH 7.5, 1mM MgCl₂, 20mM KCl, 1M NaCl (Complete Protease Inhibitor tab/50mL)] at a volume of 50mL/pellet/centrifuge tube. The pellet/wash buffer mixture was then homogenized, using a glass homogenizer on ice (20 15 strokes), followed by centrifugation at 36,000rpm for 45min at 4°C. The supernatant was removed. The wash step was repeated once more. The resulting membrane was resuspended in 20mM HEPES pH 7.5, 500mM NaCl, 10% glycerol, EDTA-free Protease Inhibitors (1tablet/50mL). The protein concentration was measured by Bradford assay (Bio-Rad Protein Assay, Cat# 500-0006), and protein enrichment was determined by SDS-PAGE and confirmed 20 by Western blot. The resuspended membranes were stored at -80°C.

Full-Length STING WT [STING(1-379)H232R-gg-AviTag-gs-HRV3C-HIS8] Amino Acid

Sequence:

MPHSSLHPSIPCPRGHGAQKAALVLLSACLVTWGLGEPPEHTLRYLVLHLASLQLGLL
 25 LNGVCSLAEELRHHHSRYRGSYWRTVRACLGCP LRRGALLLLSIYFYSLPNAVGPFFT
 WMLALLGLSQALNILLGLKGLAPAEISAVCEKGNFNVAHGLAWSYYIGYLRLLPELQA
 RIRTYNQHYNNLLRGAVSQRLYILLPLDCGVPDNL SMADPNIRFLDKLPQQTGDRAGIK
 DRVYSNSIYELLENGQRAGTCVLEYATPLQTLFAMSQYSQAGFSREDRLAQAKLFCRTL
 EDILADAPESQNNCRLLIAYQEPADDSSFSLSQEVLRLRLRQEEKEEVTVGSLKTSAPVSTST
 30 MSQPELLISGMEKPLPLRTDFSGGGLNDIFEAQKIEWHEGSLEVLFQGP HHHHHHHHHH
 (SEQ. ID. No. 3)

Full-length WT STING [STING(1-379)H232R-gg-AviTag-gs-HRV3C-HIS8/pBAC1] plasmid sequence:

GGAACGGCTCCGCCCCACTATTAATGAAATTAAAAATTCCAATTTTAAAAAACGCAG
 CAAGAGAAACATTTGTATGAAAGAATGCGTAGAAGGAAAGAAAAATGTCGTCGAC
 5 ATGCTGAACAACAAGATTAATATGCCTCCGTGTATAAAAAAATATTGAACGATTTG
 AAAGAAAACAATGTACCGCGCGGCGGTATGTACAGGAAGAGGTTTATACTAAACTG
 TTACATTGCAAACGTGGTTTCGTGTGCCAAGTGTGAAAACCGATGTTTAATCAAGGC
 TCTGACGCATTTCTACAACCACGACTCCAAGTGTGTGGGTGAAGTCATGCATCTTTT
 AATCAAATCCCAAGATGTGTATAAACCACCAAACCTGCCAAAAAATGAAAACCTGTGC
 10 ACAAGCTCTGTCCGTTTGCTGGCAACTGCAAGGGTCTCAATCCTATTTGTAATTATTG
 AATAATAAAACAATTATAAATGTCAAATTTGTTTTTTATTAACGATACAAACCAAAC
 GCAACAAGAACATTTGTAGTATTATCTATAATTGAAAACGCGTAGTTATAATCGCTG
 AGGTAATATTTAAAATCATTTTCAAATGATTCACAGTTAATTTGCGACAATATAATT
 TTATTTTTCACATAAACTAGACGCCTTGTCGTCTTCTTCTTCGTATTCCTTCTCTTTTTC
 15 ATTTTCTCTTCATAAAAATTAACATAGTTATTATCGTATCCATATATGTATCTATCG
 TATAGAGTAAATTTTTTGTGTGCATAAATATATATGTCTTTTTTAATGGGGTGTATAG
 TACCGCTGCGCATAGTTTTTCTGTAATTTACAACAGTGCTATTTTCTGGTAGTTCTTC
 GGAGTGTGTTGCTTTAATTATTAAATTTATATAATCAATGAATTTGGGATCGTCGGTT
 TTGTACAATATGTTGCCGGCATAGTACGCAGCTTCTTCTAGTTCAATTACACCATTTT
 20 TTAGCAGCACCGGATTAACATAACTTTCCAAAATGTTGTACGAACCGTTAAACAAAA
 ACAGTTCACCTCCCTTTTCTATACTATTGTCTGCGAGCAGTTGTTTGTGTTAAAAAT
 AACAGCCATTGTAATGAGACGCACAACTAATATCACAACTGGAAATGTCTATCA
 ATATATAGTTGCTGATCAGATCTGATCATGGAGATAATTAATGATAACCATCTCG
 CAAATAAATAAGTATTTTACTGTTTTCGTAACAGTTTTGTAATAAAAAAACCTATAA
 25 ATATAGGATCCATGCCCCACTCCAGCCTGCATCCATCCATCCCGTGTCCAGGGGTC
 ACGGGGCCCAGAAGGCAGCCTTGGTTCTGCTGAGTGCCTGCCTGGTGACCCTTTGGG
 GGCTAGGAGAGCCACCAGAGCACACTCTCCGGTACCTGGTGCTCCACCTAGCCTCCC
 TGCAGCTGGGACTGCTGTAAACGGGGTCTGCAGCCTGGCTGAGGAGCTGCGCCAC
 ATCCACTCCAGGTACCGGGGCAGCTACTGGAGGACTGTGCGGGCCTGCCTGGGCTG
 30 CCCCCTCCGCCGTGGGGCCCTGTTGCTGCTGTCCATCTATTTCTACTACTCCCTCCCA
 AATGCGGTTCGGCCCGCCCTTCACTTGGATGCTTGCCCTCCTGGGCCTCTCGCAGGCA
 CTGAACATCCTCCTGGGCCTCAAGGGCCTGGCCCCAGCTGAGATCTCTGCAGTGTGT
 GAAAAAGGGAATTTCAACGTGGCCCATGGGCTGGCATGGTCATATTACATCGGATA

TCTGCGGCTGATCCTGCCAGAGCTCCAGGCCCGGATTTCGAACTTACAATCAGCATTAC
CAACAACCTGCTACGGGGTGCAGTGAGCCAGCGGCTGTATATTCTCCTCCCATTGGA
CTGTGGGGTGCCTGATAACCTGAGTATGGCTGACCCCAACATTTCGCTTCCTGGATAA
ACTGCCCCAGCAGACCGGTGACCGTGCTGGCATCAAGGATCGGGTTTACAGCAACA
5 GCATCTATGAGCTTCTGGAGAACGGGCAGCGGGCGGGCACCTGTGTCCTGGAGTAC
GCCACCCCCTTGCAGACTTTGTTTGCCATGTCACAATACAGTCAAGCTGGCTTTAGC
CGGGAGGATAGGCTTGAGCAGGCCAACTCTTCTGCCGGACACTTGAGGACATCCT
GGCAGATGCCCCTGAGTCTCAGAACAACTGCCGCCTCATTGCCTACCAGGAACCTGC
AGATGACAGCAGCTTCTCGCTGTCCCAGGAGGTTCTCCGGCACCTGCGGCAGGAGG
10 AAAAGGAAGAGGTTACTGTGGGCAGCTTGAAGACCTCAGCGGTGCCCAGTACCTCC
ACGATGTCCAAGAGCCTGAGCTCCTCATCAGTGGAATGGAAAAGCCCCTCCCTCTC
CGCACGGATTTCTCTGGCGGTGGCCTGAACGACATCTTCGAAGCCCAGAAAATCGA
ATGGCATGAAGGCAGCCTGGAAGTGCTGTTCCAGGGCCCACACCACCATCATCACC
ATCACCATTAATGAGCGGCCGCACTCGAGCACCACCACCACCACCCTAACCTAGG
15 TAGCTGAGCGCATGCAAGCTGATCCGGGTTATTAGTACATTTATTAAGCGCTAGATT
CTGTGCGTTGTTGATTTACAGACAATTGTTGTACGTATTTTAATAATTCATTAAATTT
ATAATCTTTAGGGTGGTATGTTAGAGCGAAAATCAAATGATTTTCAGCGTCTTTATA
TCTGAATTTAAATATTAATCCTCAATAGATTTGTAAAATAGGTTTCGATTAGTTTCA
AACAAGGGTTGTTTTTCCGAACCGATGGCTGGACTATCTAATGGATTTTCGCTCAAC
20 GCCACAAAACCTTGCCAAATCTTGTAGCAGCAATCTAGCTTTGTGCATATTCGTTTGT
GTTTTGTTTTGTAATAAAGGTTTCGACGTCGTTCAAAATATTATGCGCTTTTGTATTTT
TTTCATCACTGTCGTTAGTGTACAATTGACTCGACGTAAACACGTAAATAGAGCTT
GGACATATTTAACATCGGGCGTGTTAGCTTTATTAGGCCGATTATCGTCGTCGTCCTCC
AACCTCGTCGTTAGAAAGTTGCTTCCGAAGACGATTTTGCCATAGCCACACGACGCC
25 TATTAATTGTGTCGGCTAACACGTCCGCGATCAAATTTGTAGTTGAGCTTTTTTGAAT
TATTTCTGATTGCGGGCGTTTTTGGGCGGGTTTCAATCTAACTGTGCCCCGATTTTAAT
TCAGACAACACGTTAGAAAGCGATGGTGCAGGCGGTGGTAACATTCAGACGGCAA
ATCTACTAATGGCGGCGGTGGTGGAGCTGATGATAAATCTACCATCGGTGGAGGCG
CAGGCGGGGCTGGCGGCGGAGGCGGAGGCGGAGGTGGTGGCGGTGATGCAGACGG
30 CGGTTTAGGCTCAAATGTCTCTTTAGGCAACACAGTCGGCACCTCAACTATTGTACT
GGTTTCGGGCGCCGTTTTTGGTTTGACCGGTCTGAGACGAGTGCGATTTTTTTTCGTTT
CTAATAGCTTCCAACAATTGTTGTCTGTCGTCTAAAGGTGCAGCGGGTTGAGGTTCC
GTCGGCATTGGTGGAGCGGGCGGCAATTCAGACATCGATGGTGGTGGTGGTGGTGG

AGGCGCTGGAATGTTAGGCACGGGAGAAGGTGGTGGCGGCGGTGCCGCCGGTATAA
TTTGTCTCTGGTTTGTAGTTTGTTCGCGCACGATTGTGGGCACCGGCGCAGGCGCCGCTG
GCTGCACAACGGAAGGTCGTCTGCTTCGAGGCAGCGCTTGGGGTGGTGGCAATTCA
ATATTATAATTGGAATACAAATCGTAAAAATCTGCTATAAGCATTGTAATTTTCGCTA
5 TCGTTTACCGTGCCGATATTTAACAACCGCTCAATGTAAGCAATTGTATTGTAAAGA
GATTGTCTCAAGCTCGGATCGATCCCGCACGCCGATAACAAGCCTTTTCATTTTTACT
ACAGCATTGTAGTGGCGAGACACTTCGCTGTCGTCGAGGTTTAAACGCTTCCTCGCT
CACTGACTCGCTGCGCTCGGTCGTTCGGCTGCGGCGAGCGGTATCAGCTCACTCAAA
GGCGGTAATACGGTTATCCACAGAATCAGGGGATAACGCAGGAAAGAACATGTGAG
10 CAAAAGGCCAGCAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTTTTTC
CATAGGCTCCGCCCCCTGACGAGCATCACAAAAATCGACGCTCAAGTCAGAGGTG
GCGAAACCCGACAGGACTATAAAGATACCAGGCGTTTCCCCCTGGAAGCTCCCTCG
TGCGCTCTCCTGTTCCGACCCTGCCGCTTACCGGATACCTGTCCGCCTTTCTCCCTTC
GGGAAGCGTGGCGCTTTCTCATAGCTCACGCTGTAGGTATCTCAGTTCGGTGTAGGT
15 CGTTCGCTCCAAGCTGGGCTGTGTGCACGAACCCCCCGTTCAGCCCGACCGCTGCGC
CTTATCCGGTAACCTATCGTCTTGAGTCCAACCCGGTAAGACACGACTTATCGCCACT
GGCAGCAGCCACTGGTAACAGGATTAGCAGAGCGAGGTATGTAGGCGGTGCTACAG
AGTTCTTGAAGTGGTGGCCTAACTACGGCTACACTAGAAGGACAGTATTTGGTATCT
GCGCTCTGCTGAAGCCAGTTACCTTCGGAAAAAGAGTTGGTAGCTCTTGATCCGGCA
20 AACAAACCACCGCTGGTAGCGGTGGTTTTTTTTGTTTGCAAGCAGCAGATTACGCGCA
GAAAAAAAGGATCTCAAGAAGATCCTTTGATCTTTTCTACGGGGTCTGACGCTCAGT
GGAACGAAAACCTCACGTTAAGGGATTTTGGTCATGAGATTATCAAAAAGGATCTTC
ACCTAGATCCTTTTAAATTAATAAATGAAGTTTTTAAATCAATCTAAAGTATATATGAG
TAAACTTGGTCTGACAGTTACCAATGCTTAATCAGTGAGGCACCTATCTCAGCGATC
25 TGTCTATTTTCGTTTCATCCATAGTTGCCTGACTCCCCGTCGTGTAGATAACTACGATAC
GGGAGGGCTTACCATCTGGCCCCAGTGCTGCAATGATACCGCGAGACCCACGCTCA
CCGGCTCCAGATTTATCAGCAATAAACCAGCCAGCCGGAAGGGCCGAGCGCAGAAG
TGGTCCTGCAACTTTATCCGCCTCCATCCAGTCTATTAATTGTTGCCGGGAAGCTAG
AGTAAGTAGTTCGCCAGTTAATAGTTTGCGCAACGTTGTTGCCATTGCTACAGGCAT
30 CGTGGTGTACGCTCGTCGTTTGGTATGGCTTCATTCAGCTCCGGTTCCCAACGATCA
AGGCGAGTTACATGATCCCCCATGTTGTGCAAAAAAGCGGTTAGCTCCTTCGGTCCT
CCGATCGTTGTCAGAAGTAAGTTGGCCGCAGTGTTATCACTCATGGTTATGGCAGCA
CTGCATAATTCTCTTACTGTCATGCCATCCGTAAGATGCTTTTCTGTGACTGGTGAGT

ACTCAACCAAGTCATTCTGAGAATAGTGTATGCGGCGACCGAGTTGCTCTTGCCCGG
 CGTCAATACGGGATAATACCGCGCCACATAGCAGAACTTTAAAAGTGCTCATCATTG
 GAAAACGTTCTTCGGGGCGAAAACCTCTCAAGGATCTTACCGCTGTTGAGATCCAGTT
 CGATGTAACCCACTCGTGCACCCAACTGATCTTCAGCATCTTTTACTTTCACCAGCGT
 5 TTCTGGGTGAGCAAAAACAGGAAGGCCAAAATGCCGCAAAAAAGGGAATAAGGGCG
 ACACGGAAATGTTGAATACTCATACTCTTCCTTTTTCAATATTATTGAAGCATTTATC
 AGGGTTATTGTCTCATGAGCGGATACATATTTGAATGTATTTAGAAAAATAAACAAA
 TAGGGGTTCGCGGCACATTTCCCGAAAAGTGCCACCTGACGCGCCCTGTAGCGGCG
 CATTAAGCGCGGCGGGTGTGGTGGTTACGCGCAGCGTGACCGCTACACTTGCCAGC
 10 GCCCTAGCGCCCGCTCCTTTCGCTTCTTCCCTTCCTTCTCGCCACGTTGCGCGGCTT
 TCCCGTCAAGCTCTAAATCGGGGGCTCCCTTTAGGGTTCGATTTAGTGCTTTACG
 GCACCTCGACCCCAAAAACTTGATTAGGGTGATGGTTCACGTAGTGGGCCATCGCC
 CTGATAGACGGTTTTTCGCCCTTGACGTTGGAGTCCACGTTCTTTAATAGTGGACTC
 TTGTTCCAACTGGAACAACACTCAACCCTATCTCGGTCTATTCTTTTGATTTATAAG
 15 GGATTTTGCCGATTTGCGCCTATTGGTTAAAAAATGAGCTGATTTAACAAAAATTTA
 ACGCGAATTTTAACAAAATATTAACGTTTACAATTTCCCATTCGCCATTCAGGCTGC
 GCAACTGTTGGGAAGGGCGATCGGTGCGGGCCTCTTCGCTATTACGCCA
 (SEQ. ID. No. 4)

20 Certain compounds of the disclosure were evaluated in WT STING *in vitro*
 binding assay as described above. The following table tabulates the biological data for these
 compounds as EC₅₀ values.

Table 7: ³H-cGAMP filtration binding assay for WT STING

Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)
Example 1	5172	Example 18	21% Inh @ 20uM	Example 32	17030
Example 2	11210	Example 19	30% Inh @ 20uM	Example 33	30% Inh @ 20μM
Example 3	41% Inh @ 20uM	Example 20	33% Inh @ 20uM	Example 34	18% Inh @ 20μM
Example 4	1145	Example 21	14290	Example 35	7671

Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)	Compound	EC ₅₀ (nM)
Example 7	20% Inh @ 20uM	Example 22	17100	Example 36	9% Inh @ 20μM
Example 8	15520	Example 23	37% Inh @ 20uM	Example 41	14690
Example 9	10890	Example 24	8540	Example 43	4108
Example 10	31% Inh @ 20uM	Example 25	8644	Example 46	24% Inh @ 20μM
Example 11	3873	Example 26	2081	Example 48	23% Inh @ 20μM
Example 13	2081	Example 27	19% Inh @ 20μM	Example 50	2144
Example 14	8644	Example 28	9259	Example 51	3% Inh @ 20μM
Example 15	894	Example 29	16% Inh @ 20μM	Example 52	101% Inh @ 20μM
Example 16	2480	Example 30	18670	Example 53	7% Inh @ 20μM
Example 17	14750	Example 31	10% Inh @ 20μM		

Example 57: IFN-β secretion in THP1 cell culture (5h)

The ability of compounds to stimulate the secretion of interferon-beta from THP1 cells was measured using a human IFN-β AlphaLISA kit (Perkin Elmer, Cat. No. AL265F). The basic protocol is as follows:

A Labcyte Echo 550 acoustic dispenser was used to transfer 120nL of compound dissolved in DMSO into the wells of an empty, sterile 384-well microplate, (Corning, Cat. No. 3712). THP1 cells (American Type Culture Collection, Cat. No. TIB202) previously frozen in Recovery Medium (Life Technologies, Cat. No. 12648-010) were thawed and immediately diluted 10-fold into 37°C assay medium (RPMI 1640 + L-Glutamine & phenol red, Life Technologies, Cat. No. 11875-085; 0.5% heat inactivated fetal bovine serum, Sigma Aldrich, Cat. No. F4135; 1mM Sodium Pyruvate, Life Technologies, Cat. No. 11360-070; 1x non-essential amino acids; Life Technologies, Cat. No. 11140-050). The cell viability and count was

ascertained using a Beckman Coulter V-Cell XR cell counter. The cells suspension was centrifuged at 200xg for 5min at RT. Cells were resuspended to a density of 0.8×10^6 /mL in 37°C assay medium. Subsequent liquid transfers were performed using either a Matrix electronic multichannel pipette or an Agilent Bravo Automated Liquid Handling Platform.

5 The assay was started by dispensing 40μL of the previously prepared cell suspension into the wells of the plate containing compounds. After 5h incubation at 37°C, 5% CO₂ in a humidified atmosphere, the plate of cells and compounds was centrifuged at 200xg for 5min at RT. From each well, 5μL of supernatant was transferred into corresponding wells of a white 384-well plate (Perkin Elmer, Cat. No. 6005620). To these supernatant-containing wells
10 was added 10μL of 5x Anti-Analyte Acceptor beads (50μg/mL of AlphaLISA HiBlock Buffer) and incubated for 30min at RT while shaking on an orbital plate shaker. To each well was added 10μL of 5x Biotinylated Antibody Anti-analyte (5nM in AlphaLISA HiBlock Buffer) and incubated on an orbital plate shaker for 60min at RT or overnight at 4°C. To each well was added 25μL of 2x SA-Donor beads (80μg/mL in AlphaLISA HiBlock Buffer) and incubated for
15 30-45min at RT in the dark while shaking on an orbital plate shaker. The plate was then read on a Perkin Elmer Envision ($\lambda_{ex} = 680\text{nm}$, $\lambda_{em} = 570\text{nm}$). The percent effect of the AlphaLISA signal at each compound concentration was calculated based on 30uM cGAMP positive controls and 0.3% DMSO negative controls. The plot of percent effect versus the log of compound concentration was fit with a 4-parameter concentration response equation to calculate EC₅₀
20 values. The test compounds were tested at concentrations 30000, 10000, 3333, 1111, 370.4, 123.4, 41.2, 13.7, 4.6, and 1.5nM with 0.3% residual DMSO. The control compound, cGAMP was tested at concentrations 100000, 33333, 11111, 3704, 1235, 412, 137, 46, and 15nM with 0.3% residual DMSO.

25 Compounds of the disclosure were evaluated for IFN-β secretion in THP1 cell culture as described above. The following table tabulates the biological data for these compounds as percent activation relative to 2'3'-cGAMP at the 30μM concentration.

Table 8: IFN-β secretion in THP1 cell culture (5h)

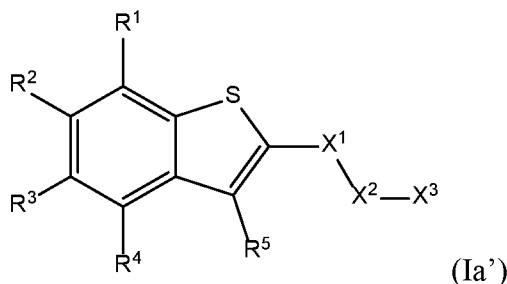
Compound	% Effect at 30μM relative to 2'3'-cGAMP	Compound	% Effect at 30μM relative to 2'3'-cGAMP	Compound	% Effect at 30μM relative to 2'3'-cGAMP
Example 1	144	Example 19	153	Example 37	42
Example 2	149	Example 20	47	Example 38	154

Compound	% Effect at 30μM relative to 2'3'-cGAMP	Compound	% Effect at 30μM relative to 2'3'-cGAMP	Compound	% Effect at 30μM relative to 2'3'-cGAMP
Example 3	59	Example 21	162	Example 39	193
Example 4	34	Example 22	43	Example 40	93
Example 5	77	Example 23	191	Example 41	312
Example 6	130	Example 24	214	Example 42	6
Example 7	290	Example 25	394	Example 43	56
Example 8	260	Example 26	228	Example 44	20
Example 9	298	Example 27	14	Example 45	104
Example 10	182	Example 28	86	Example 46	205
Example 11	132	Example 29	9	Example 47	90
Example 12	16	Example 30	15	Example 48	71
Example 13	228	Example 31	24	Example 49	111
Example 14	394	Example 32	24	Example 50	115
Example 15	115	Example 33	25	Example 51	31
Example 16	129	Example 34	34	Example 52	142
Example 17	21	Example 35	57	Example 53	182
Example 18	273	Example 36	11	Example 54	66

It will be appreciated that various of the above-discussed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. It also will be appreciated that various presently unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art and are also intended to be encompassed by the following claims.

WHAT IS CLAIMED IS:

1. A compound of formula (Ia'):



5 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$;

10 R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

20 R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, C_1-C_6 haloalkyl substituted by OR^6 , C_1-C_6 haloalkyl substituted by SR^6 , and C_1-C_6 haloalkyl substituted by $N(R^6)_2$;

optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, C_1-C_6 haloalkyl substituted by OR^6 , C_1-C_6 haloalkyl substituted by SR^6 , and C_1-C_6 haloalkyl substituted by $N(R^6)_2$;

each R^6 is independently selected from the group consisting of H, C_1-C_6 alkyl, and C_1-C_6 haloalkyl, wherein said C_1-C_6 alkyl, and C_1-C_6 haloalkyl are optionally substituted with OH, $O(C_1-C_3$ alkyl), and $O(C_1-C_3$ haloalkyl);

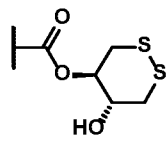
X^1 is $C(O)$;

X^2 is $(C(R^8)_2)_{(1-3)}$;

each R^8 is independently selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3-C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

optionally 2 R^8 on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring;

optionally 2 R^8 on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle;

X^3 is selected from the group consisting of $COOR^6$, , $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and

each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; wherein when $\text{X}^1\text{-X}^2\text{-X}^3$ is $\text{X}^1\text{-CHR}^8\text{-X}^3$ or $\text{X}^1\text{-CHR}^8\text{CH}_2\text{-X}^3$, at least one of R^2 and R^3 is not selected from the group consisting of halogen, OR^6 , $\text{C}_1\text{-C}_6$ alkyl, and $\text{C}_1\text{-C}_6$ haloalkyl.

2. The compound according to claim 1, or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, F, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl;

R^2 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{OC}_1\text{-C}_3$ haloalkyl, OH, $\text{C}_2\text{-C}_3$ alkenyl, $\text{C}_2\text{-C}_3$ alkynyl, $\text{N}(\text{C}_1\text{-C}_3 \text{ alkyl})_2$, $\text{NH}(\text{C}_1\text{-C}_3 \text{ alkyl})$, and $\text{SC}_1\text{-C}_3$ alkyl;

R^3 is selected from the group consisting of halogen, $\text{C}_1\text{-C}_3$ alkyl, $\text{C}_1\text{-C}_3$ haloalkyl, $\text{OC}_1\text{-C}_3$ alkyl, $\text{OC}_1\text{-C}_3$ haloalkyl, OH, $\text{C}_2\text{-C}_3$ alkenyl, $\text{C}_2\text{-C}_3$ alkynyl, $\text{N}(\text{C}_1\text{-C}_3 \text{ alkyl})_2$, $\text{NH}(\text{C}_1\text{-C}_3 \text{ alkyl})$, and $\text{SC}_1\text{-C}_3$ alkyl;

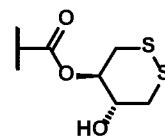
R^4 is selected from the group consisting of H, F, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl;

R^5 is selected from the group consisting of H, F, Cl, $\text{C}_1\text{-C}_3$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl;

each R^6 is independently selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, and $\text{C}_1\text{-C}_4$ haloalkyl;

X^1 is $\text{C}(\text{O})$;

X^2 is CH_2CHR^8 ;



X^3 is selected from the group consisting of COOR^6 , , SO_2R^6 , and $\text{C}(\text{O})\text{N}(\text{R}^9)_2$, where each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; and

R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, $\text{C}_1\text{-C}_4$ alkyl substituted by OH, $\text{C}_1\text{-C}_4$ alkyl substituted by $\text{OC}_1\text{-C}_4$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl.

3. The compound of claim 2 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H and F;

R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^3 is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

R^4 is selected from the group consisting of H and F;

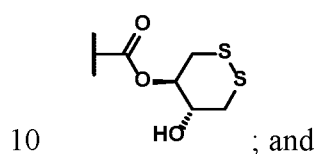
R^5 is selected from the group consisting of H and Cl;

5 each R^6 is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

X^1 is C(O);

X^2 is CH₂CHR⁸;

X^3 is selected from the group consisting of COOH, COOC(CH₃)₃, and



R^8 is selected from the group consisting of H, CH₃, CH₂OH, CH₂CH₃, CH₂CH₂CH₃, CH(CH₃)₂, CH₂OCH₃, and cyclopropyl.

15 4. The compound according to claim 1 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

R^2 is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), SC₁-C₃ alkyl;

20 R^3 is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), SC₁-C₃ alkyl;

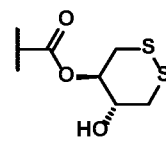
R^4 is selected from the group consisting of H, F, C₁-C₄ alkyl, and C₁-C₃ haloalkyl;

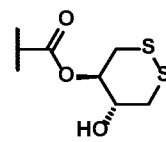
25 R^5 is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

each R^6 is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

X^1 is C(O);

X^2 is CHR⁸CHR⁸;



X^3 is selected from the group consisting of COOR^6 , , SO_2R^6 , and $\text{C(O)N(R}^9)_2$, where each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; and

each R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, $\text{C}_1\text{-C}_4$ alkyl substituted by OH, $\text{C}_1\text{-C}_4$ alkyl substituted by $\text{OC}_1\text{-C}_3$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl, and where optionally 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring.

5. The compound of claim 4 or a pharmaceutically acceptable salt thereof,
10 wherein

R^1 is selected from the group consisting of H and F;

R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^4 is selected from the group consisting of H and F;

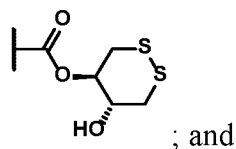
R^5 is selected from the group consisting of H and Cl;

each R^6 is independently selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, and $\text{C}_1\text{-C}_4$ haloalkyl;

20 X^1 is C(O) ;

X^2 is CHR^8CHR^8 ;

X^3 is selected from the group consisting of COOH , $\text{COOC}(\text{CH}_3)_3$, and



; and

each R^8 is selected from the group consisting of H and $\text{C}_1\text{-C}_4$ alkyl.

25

6. The compound of claim 4 or a pharmaceutically acceptable salt thereof,
wherein

R^1 is selected from the group consisting of H and F;

R^2 is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

R^3 is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

5 R^4 is selected from the group consisting of H and F;

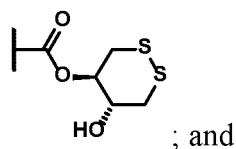
R^5 is selected from the group consisting of H and Cl;

each R^6 is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

X^1 is C(O);

10 X^2 is CHR⁸CHR⁸;

X^3 is selected from the group consisting of COOH, COOC(CH₃)₃, and



the 2 R^8 are taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring.

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7. The compound according to claim 1 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

20 R^2 is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl;

R^3 is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl;

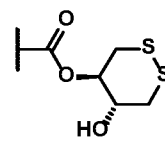
25 R^4 is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

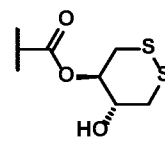
R^5 is selected from the group consisting of H, F, Cl, OR⁶, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

each R^6 is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

30 X^1 is C(O);

X^2 is CH₂C(R⁸)₂;



X^3 is selected from the group consisting of COOR^6 , , SO_2R^6 , and $\text{C(O)N(R}^9)_2$, where each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; and

each R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, $\text{C}_1\text{-C}_4$ alkyl substituted by OH, $\text{C}_1\text{-C}_4$ alkyl substituted by $\text{OC}_1\text{-C}_4$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl, and where optionally 2 R^8 are taken together, along with the atom to which they are attached, to form a 3- to 6-membered spirocycle.

8. The compound of claim 7 or a pharmaceutically acceptable salt thereof,
10 wherein

R^1 is selected from the group consisting of H and F;

R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^3 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$,
15 $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^4 is selected from the group consisting of H and F;

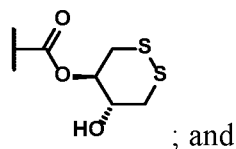
R^5 is selected from the group consisting of H and Cl;

each R^6 is independently selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, and $\text{C}_1\text{-C}_3$ haloalkyl;

20 X^1 is C(O) ;

X^2 is $\text{CH}_2\text{C(R}^8)_2$;

X^3 is selected from the group consisting of COOH , $\text{COOC(CH}_3)_3$, and



; and

each R^8 is selected from the group consisting of H, OH, and CH_3 .

25

9. The compound of claim 7 or a pharmaceutically acceptable salt thereof,
wherein

R^1 is selected from the group consisting of H and F;

R^2 is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

R^3 is selected from the group consisting of Br, Cl, F, CH₃, CH₂CH₃, CH₂CH₂CH₃, CH₂CH₂F, CH=CH₂, C≡CH, OH, OCH₃, OCH₂CH₃, OCHF₂, SCH₃, and NHCH₃;

5 R^4 is selected from the group consisting of H and F;

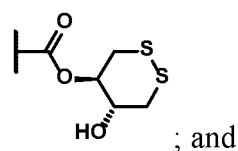
R^5 is selected from the group consisting of H and Cl;

each R^6 is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

X^1 is C(O);

10 X^2 is CH₂C(R⁸)₂;

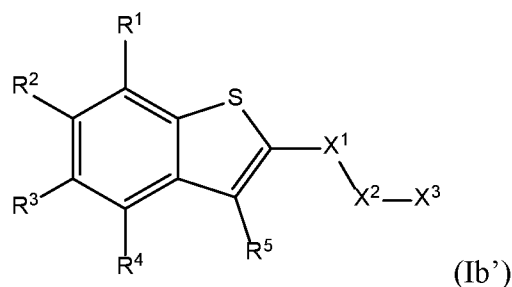
X^3 is selected from the group consisting of COOH, COOC(CH₃)₃, and



the 2 R^8 are taken together, along with the atom to which they are attached, to form a 3- to 6-membered spirocycle.

15

10. A compound of formula (Ib'):



or a pharmaceutically acceptable salt thereof, wherein

20 R^1 is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂;

25 R^2 is selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SR⁶, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆

haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

R³ is selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SR⁶, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

R⁴ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂;

optionally R³ and R⁴ may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶) wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

R⁵ is selected from H, halogen, OR⁶, N(R⁶)₂, CN, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂;

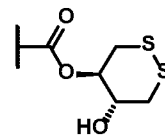
each R⁶ is independently selected from the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl, wherein said C₁-C₆ alkyl, and C₁-C₆ haloalkyl are optionally substituted with OH, O(C₁-C₃ alkyl), and O(C₁-C₃ haloalkyl);

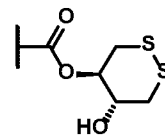
X¹ is C(O);

X² is CH₂CHR⁸;

each R⁸ is independently selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered

heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;



X³ is selected from the group consisting of COOR⁶, , SO₂R⁶, and C(O)N(R⁹)₂, where each R⁹ is independently selected from the group consisting of H, COOR⁶, and SO₂R⁶.

11. The compound according to claim 10 or a pharmaceutically acceptable salt thereof, wherein

R¹ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;
R² is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl;

R³ is selected from the group consisting of halogen, C₁-C₃ alkyl, C₁-C₃ haloalkyl, OC₁-C₃ alkyl, OC₁-C₃ haloalkyl, OH, C₂-C₃ alkenyl, C₂-C₃ alkynyl, N(C₁-C₃ alkyl)₂, NH(C₁-C₃ alkyl), and SC₁-C₃ alkyl;

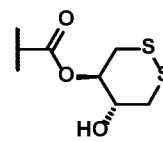
R⁴ is selected from the group consisting of H, F, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

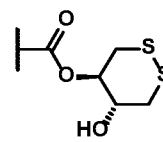
R⁵ is selected from the group consisting of H, F, Cl, C₁-C₃ alkyl, and C₁-C₃ haloalkyl;

each R⁶ is independently selected from the group consisting of H, C₁-C₄ alkyl, and C₁-C₄ haloalkyl;

X¹ is C(O);

X² is CH₂CHR⁸;



X^3 is selected from the group consisting of COOR^6 , , SO_2R^6 , and $\text{C(O)N(R}^9)_2$, where each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 ; and

R^8 is selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, $\text{C}_1\text{-C}_4$ alkyl substituted by OH, $\text{C}_1\text{-C}_4$ alkyl substituted by $\text{OC}_1\text{-C}_4$ alkyl, and $\text{C}_3\text{-C}_6$ cycloalkyl.

12. The compound of claim 11 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H and F;

10 R^2 is selected from the group consisting of Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^3 is selected from the group consisting of halogen, Br, Cl, F, CH_3 , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}_2\text{CH}_2\text{F}$, $\text{CH}=\text{CH}_2$, $\text{C}\equiv\text{CH}$, OH, OCH_3 , OCH_2CH_3 , OCHF_2 , SCH_3 , and NHCH_3 ;

R^4 is selected from the group consisting of H and F;

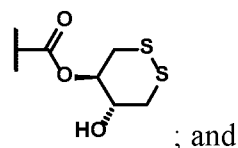
15 R^5 is selected from the group consisting of H and Cl;

each R^6 is independently selected from the group consisting of H, $\text{C}_1\text{-C}_4$ alkyl, and $\text{C}_1\text{-C}_4$ haloalkyl;

X^1 is C(O) ;

X^2 is CH_2CHR^8 ;

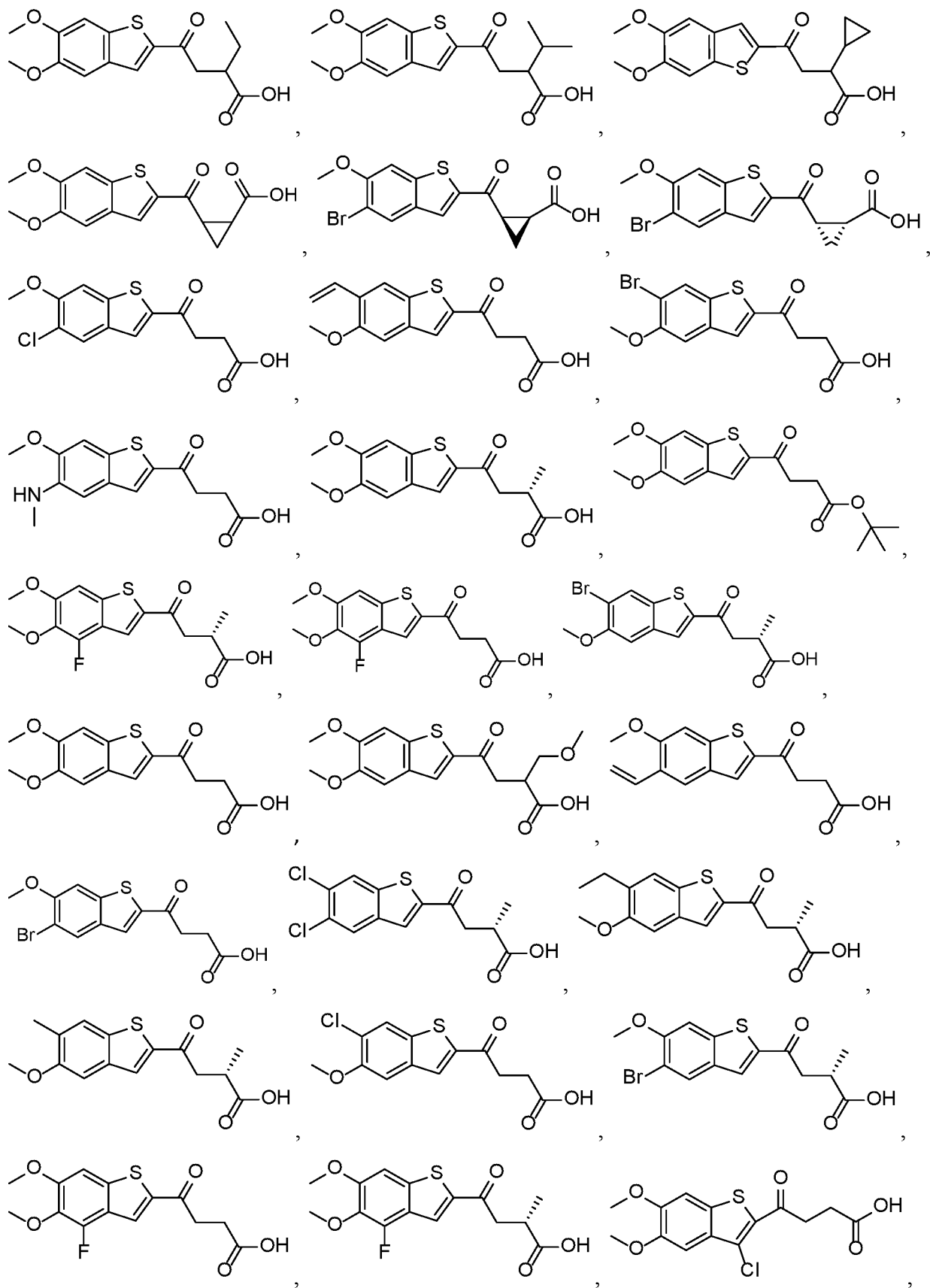
20 X^3 is selected from the group consisting of COOH , $\text{COOC}(\text{CH}_3)_3$, and

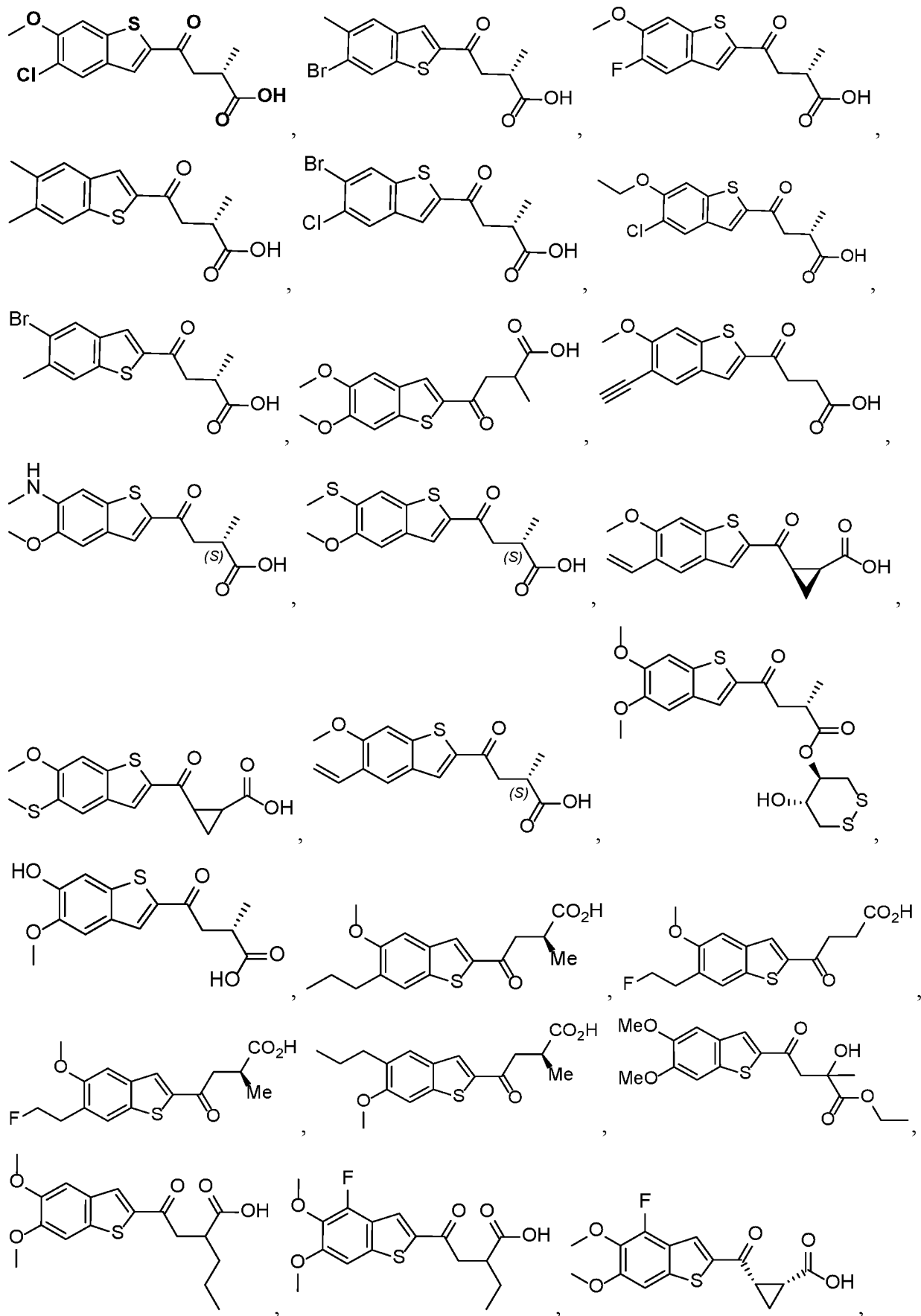


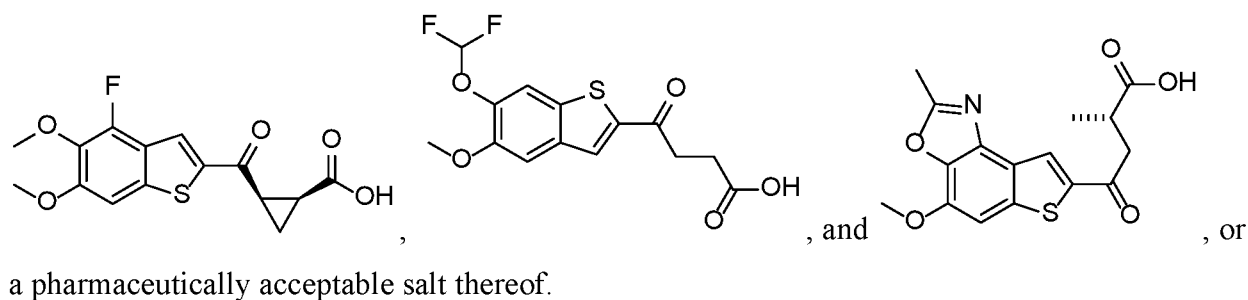
; and

R^8 is selected from the group consisting of H, CH_3 , CH_2OH , CH_2CH_3 , $\text{CH}_2\text{CH}_2\text{CH}_3$, $\text{CH}(\text{CH}_3)_2$, CH_2OCH_3 , and cyclopropyl.

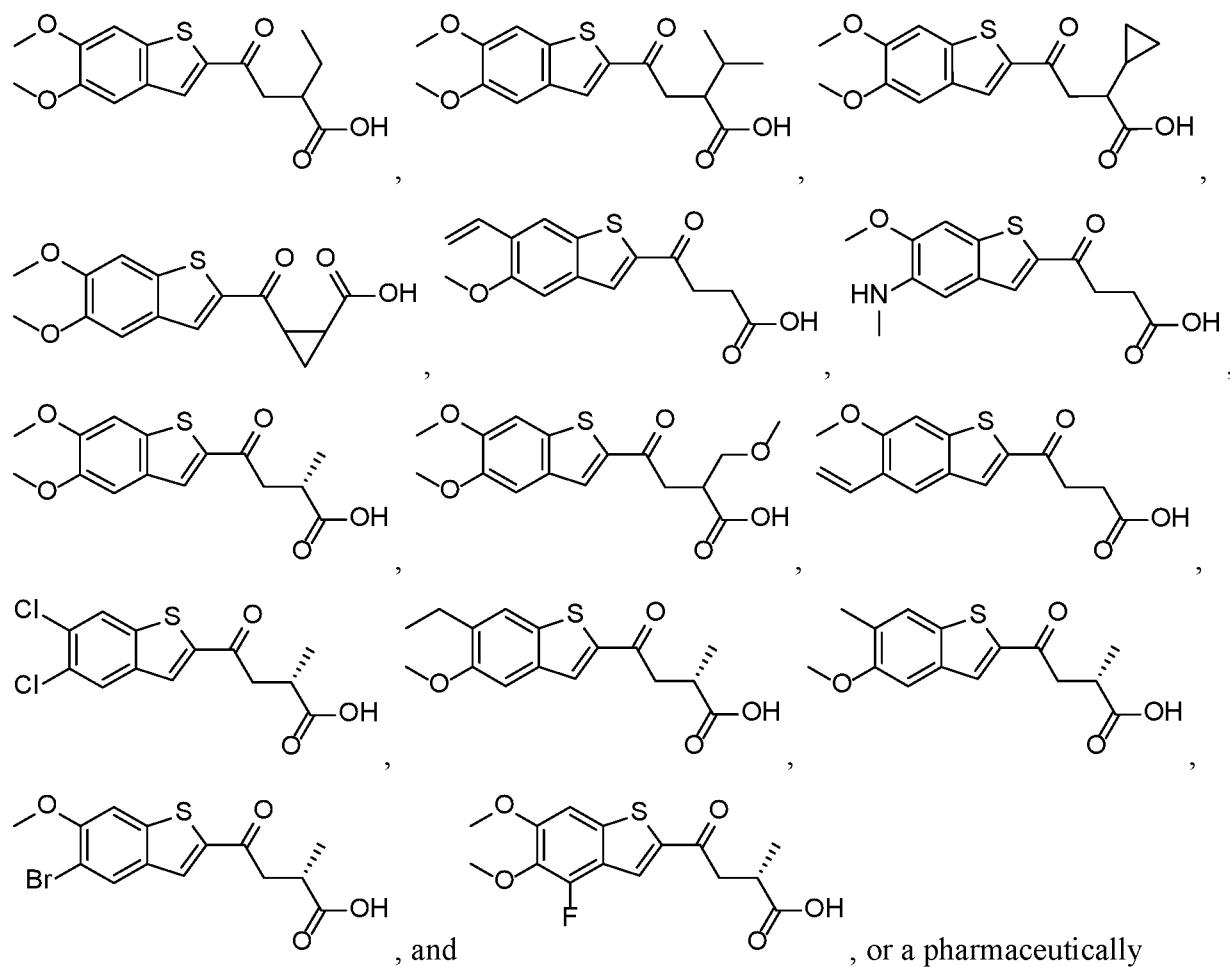
25 13. A compound selected from the group consisting of:





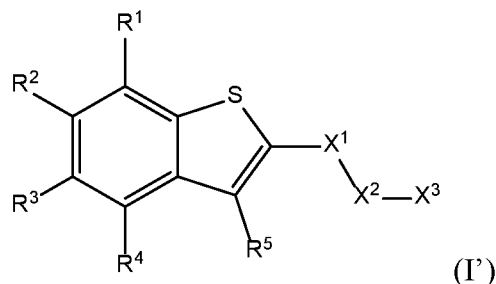


14. The compound according to claim 13, wherein the compound is selected from the group consisting of:



15. A pharmaceutical composition, said pharmaceutical composition comprising a compound according to any one of claims 1 to 14, or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

16. A method of inducing an immune response in a subject, said method comprising administering a therapeutically effective amount of a compound according to formula (I') to the subject, wherein the compound of formula (I') is



5 or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$;

10 R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

20 R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, C_1-C_6 haloalkyl substituted by OR^6 , C_1-C_6 haloalkyl substituted by SR^6 , and C_1-C_6 haloalkyl substituted by $N(R^6)_2$;

optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, C_1-C_6 haloalkyl substituted by OR^6 , C_1-C_6 haloalkyl substituted by SR^6 , and C_1-C_6 haloalkyl substituted by $N(R^6)_2$;

each R^6 is independently selected from the group consisting of H, C_1-C_6 alkyl, and C_1-C_6 haloalkyl, wherein said C_1-C_6 alkyl, and C_1-C_6 haloalkyl are optionally substituted with OH, $O(C_1-C_3$ alkyl), $O(C_1-C_3$ haloalkyl);

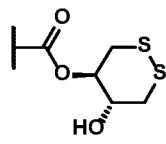
X^1 is $C(O)$;

X^2 is $(C(R^8))_{(1-3)}$;

each R^8 is independently selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3-C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

optionally 2 R^8 on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring;

optionally 2 R^8 on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle;

X^3 is selected from the group consisting of $COOR^6$, , $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and

each R^9 is independently selected from the group consisting of H, COOR^6 , and SO_2R^6 .

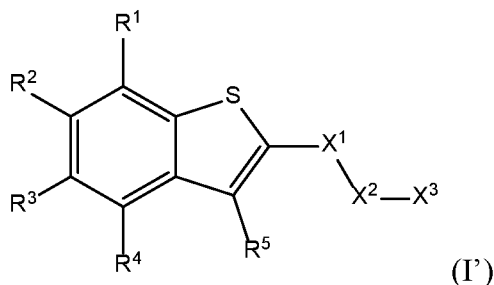
17. A method of inducing an immune response in a subject, said method comprising:

(a) administering a therapeutically effective amount of a compound according to any one of claims 1 through 14, or a pharmaceutically acceptable salt thereof, to the subject.

18. A method of inducing an immune response in a subject, said method comprising:

(a) administering a therapeutically effective amount of a pharmaceutical composition according to claim 15 to the subject.

19. A method of inducing STING-dependent type I interferon production in a subject, said method comprising administering a therapeutically effective amount of a compound according to formula (I') to the subject, wherein the compound of formula (I') is



or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, halogen, OR^6 , $\text{N(R}^6)_2$, SR^6 , $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ alkyl substituted by OR^6 , $\text{C}_1\text{-C}_6$ alkyl substituted by SR^6 , $\text{C}_1\text{-C}_6$ alkyl substituted by $\text{N(R}^6)_2$, $\text{C}_1\text{-C}_6$ haloalkyl substituted by OR^6 , $\text{C}_1\text{-C}_6$ haloalkyl substituted by SR^6 , and $\text{C}_1\text{-C}_6$ haloalkyl substituted by $\text{N(R}^6)_2$;

R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $\text{N(R}^6)_2$, COOR^6 , $\text{C(O)N(R}^6)_2$, SR^6 , SO_2R^6 , $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $\text{N(R}^6)$, wherein said $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ haloalkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_2\text{-C}_6$ haloalkynyl, $\text{C}_3\text{-C}_6$ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally

substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

5 R³ is selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, COOR⁶, C(O)N(R⁶)₂, SR⁶, SO₂R⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶), wherein said C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₂-C₆ alkenyl, C₂-C₆ haloalkenyl, C₂-C₆ alkynyl, C₂-C₆ haloalkynyl, C₃-C₆ cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR⁶, N(R⁶)₂, and SR⁶, and wherein said C₃-C₆ cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

10 R⁴ is selected from the group consisting of H, halogen, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂;

15 optionally R³ and R⁴ may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and N(R⁶) wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C₁-C₃ alkyl and C₁-C₃ haloalkyl;

20 R⁵ is selected from H, halogen, OR⁶, N(R⁶)₂, CN, C₁-C₆ alkyl substituted by OR⁶, C₁-C₆ alkyl substituted by SR⁶, C₁-C₆ alkyl substituted by N(R⁶)₂, C₁-C₆ haloalkyl substituted by OR⁶, C₁-C₆ haloalkyl substituted by SR⁶, and C₁-C₆ haloalkyl substituted by N(R⁶)₂;

25 each R⁶ is independently selected from the group consisting of H, C₁-C₆ alkyl, and C₁-C₆ haloalkyl, wherein said C₁-C₆ alkyl, and C₁-C₆ haloalkyl are optionally substituted with OH, O(C₁-C₃ alkyl), O(C₁-C₃ haloalkyl);

X¹ is C(O);

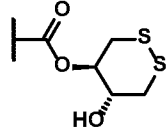
30 X² is (C(R⁸)₂)₍₁₋₃₎;

each R⁸ is independently selected from the group consisting of H, halogen, CN, OR⁶, N(R⁶)₂, SR⁶, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₃-C₆ cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N,

and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN , OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

optionally 2 R^8 on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring;

optionally 2 R^8 on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle;

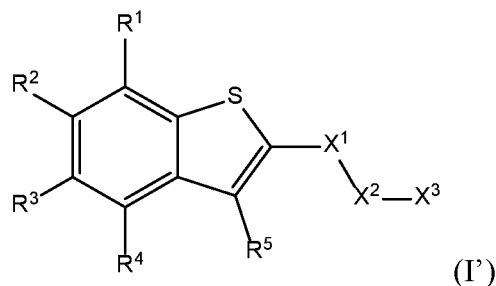
X^3 is selected from the group consisting of $COOR^6$, , $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and

each R^9 is independently selected from the group consisting of H , $COOR^6$, and SO_2R^6 .

20. A method of inducing STING-dependent type I interferon production in a subject, said method comprising administering a therapeutically effective amount of a compound according to any one of claims 1 through 14, or a pharmaceutically acceptable salt thereof, to the subject.

21. A method of inducing STING-dependent type I interferon production in a subject, said method comprising administering a therapeutically effective amount of a pharmaceutical composition according to claim 15 to the subject.

22. A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound according to formula (I') to the subject, wherein the compound of formula (I') is



or a pharmaceutically acceptable salt thereof, wherein

R^1 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6 alkyl substituted by $N(R^6)_2$, C_1-C_6 haloalkyl substituted by OR^6 , C_1-C_6 haloalkyl substituted by SR^6 , and C_1-C_6 haloalkyl substituted by $N(R^6)_2$;

R^2 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3-C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

R^3 is selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, $COOR^6$, $C(O)N(R^6)_2$, SR^6 , SO_2R^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_2-C_6 alkenyl, C_2-C_6 haloalkenyl, C_2-C_6 alkynyl, C_2-C_6 haloalkynyl, C_3-C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3-C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1-C_3 alkyl and C_1-C_3 haloalkyl;

R^4 is selected from the group consisting of H, halogen, OR^6 , $N(R^6)_2$, SR^6 , C_1-C_6 alkyl, C_1-C_6 haloalkyl, C_1-C_6 alkyl substituted by OR^6 , C_1-C_6 alkyl substituted by SR^6 , C_1-C_6

alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$;

optionally R^3 and R^4 may be taken together with the atoms to which they are attached form a 5- or 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$ wherein said heterocyclic ring is optionally substituted with or more members of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

R^5 is selected from H, halogen, OR^6 , $N(R^6)_2$, CN, C_1 - C_6 alkyl substituted by OR^6 , C_1 - C_6 alkyl substituted by SR^6 , C_1 - C_6 alkyl substituted by $N(R^6)_2$, C_1 - C_6 haloalkyl substituted by OR^6 , C_1 - C_6 haloalkyl substituted by SR^6 , and C_1 - C_6 haloalkyl substituted by $N(R^6)_2$;

each R^6 is independently selected from the group consisting of H, C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl, wherein said C_1 - C_6 alkyl, and C_1 - C_6 haloalkyl are optionally substituted with OH, $O(C_1$ - C_3 alkyl), $O(C_1$ - C_3 haloalkyl);

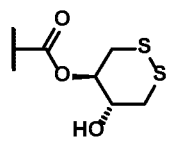
X^1 is $C(O)$;

X^2 is $(C(R^8))_{(1-3)}$;

each R^8 is independently selected from the group consisting of H, halogen, CN, OR^6 , $N(R^6)_2$, SR^6 , C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_3 - C_6 cycloalkyl, and a 3- to 6-membered heterocyclic ring including 1 to 2 ring members selected from the group consisting of O, S, N, and $N(R^6)$, wherein said C_1 - C_6 alkyl, C_1 - C_6 haloalkyl, C_2 - C_6 alkenyl, C_2 - C_6 haloalkenyl, C_2 - C_6 alkynyl, C_2 - C_6 haloalkynyl, C_3 - C_6 cycloalkyl, and 3- to 6-membered heterocyclic ring groups are optionally substituted by one or more substituents independently selected from the group consisting of CN, OR^6 , $N(R^6)_2$, and SR^6 , and wherein said C_3 - C_6 cycloalkyl and 3- to 6-membered heterocyclic ring are each further optionally substituted with a member of the group consisting of C_1 - C_3 alkyl and C_1 - C_3 haloalkyl;

optionally 2 R^8 on different carbon atoms may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered fused ring;

optionally 2 R^8 on a single carbon atom may be taken together, along with the atoms to which they are attached, to form a 3- to 6-membered spirocycle;

X^3 is selected from the group consisting of $COOR^6$, , $C(O)SR^6$, $C(S)OR^6$, SO_2R^6 , and $C(O)N(R^9)_2$; and

each R^9 is independently selected from the group consisting of H, $COOR^6$, and SO_2R^6 .

23. The method of claim 22, wherein the cell proliferation disorder is cancer.

5 24. A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a compound according to any one of claims 1 through 14, or a pharmaceutically acceptable salt thereof, to the subject.

25. The method of claim 24, wherein the cell proliferation disorder is cancer.

10 26. A method of treating a cell proliferation disorder in a subject, said method comprising administering a therapeutically effective amount of a pharmaceutical composition according to claim 15 to the subject.

27. The method of claim 26, wherein the cell proliferation disorder is cancer.

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