Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

CA 2904377 C 2021/07/13

(11)(21) 2 904 377

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(86) Date de dépôt PCT/PCT Filing Date: 2014/03/14
(87) Date publication PCT/PCT Publication Date: 2014/09/25
(45) Date de délivrance/Issue Date: 2021/07/13
(85) Entrée phase nationale/National Entry: 2015/09/04
(86) N° demande PCT/PCT Application No.: US 2014/027058
(87) N° publication PCT/PCT Publication No.: 2014/152195
(30) Priorités/Priorities: 2013/03/15 (US61/787,121); 2013/05/03 (US61/819,029); 2013/12/09 (US61/913,417)

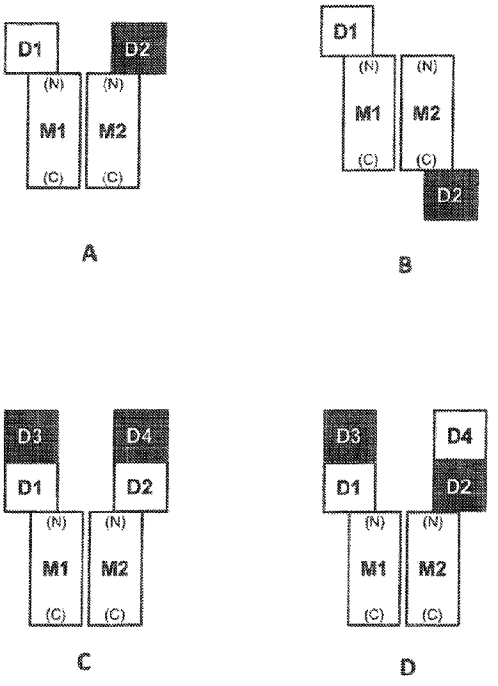
(51) Cl.Int./Int.Cl. *A61K 38/17* (2006.01), *C07K 14/715* (2006.01)

(72) Inventeurs/Inventors:
MURPHY, ANDREW J., US;
PAPADOPOULOS, NICHOLAS J., US;
ORENGO, JAMIE, US

(73) Propriétaire/Owner:
REGENERON PHARMACEUTICALS, INC., US

(74) Agent: BERESKIN & PARR LLP/S.E.N.C.R.L.,S.R.L.

(54) Titre : ANTAGONISTES DE L'IL-33 ET LEURS UTILISATIONS
(54) Title: IL-33 ANTAGONISTS AND USES THEREOF



(57) Abrégé/Abstract:
The present invention provides interleukin-33 (IL-33) antagonists comprising one or more IL-33-binding domains and one or more multimerizing domains and methods of using the same. According to certain embodiments of the invention, the IL-33-binding domains can comprise anIL-33-binding portion of an ST2 protein and/or an extracellular portion of an I L-1 RAcP protein. The IL-33 antagonists of the invention are useful for the treatment of diseases and disorders associated with IL-33 signaling and/or IL-33 cellular expression, such as infectious diseases, inflammatory diseases, allergic diseases and fibrotic diseases.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 September 2014 (25.09.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/152195 A1

(51) International Patent Classification:
A61K 38/17 (2006.01) *C07K 14/715* (2006.01)

(21) International Application Number:
PCT/US2014/027058

(22) International Filing Date:
14 March 2014 (14.03.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

61/787,121	15 March 2013 (15.03.2013)	US
61/819,029	3 May 2013 (03.05.2013)	US
61/913,417	9 December 2013 (09.12.2013)	US

(71) Applicant: **REGENERON PHARMACEUTICALS, INC.** [US/US]; 777 Old Saw Mill River Road, Tarrytown, NY 10591 (US).

(72) Inventors: **MURPHY, Andrew, J.**; 10 Newton Court, Croton-On-Hudson, NY 10520 (US). **PAPADOPOULOS, Nicholas, J.**; 59 Heritage Lane, Lagrangeville, NY 12540 (US). **ORENGO, Jamie**; 17 Maple Moor Lane, Cortlandt Manor, NY 10567 (US).

(74) Agents: **TERMES, Lance, A.** et al.; Alston & Bird LLP, Bank of America Plaza, Suite 4000, 101 South Tryon Street, Charlotte, NC 28280-4000 (US).

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

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,

[Continued on next page]

(54) Title: IL-33 ANTAGONISTS AND USES THEREOF

(57) Abstract: The present invention provides interleukin-33 (IL-33) antagonists comprising one or more IL-33-binding domains and one or more multimerizing domains and methods of using the same. According to certain embodiments of the invention, the IL-33-binding domains can comprise anIL-33-binding portion of an ST2 protein and/or an extracellular portion of an I L-1 RAcP protein. The IL-33 antagonists of the invention are useful for the treatment of diseases and disorders associated with IL-33 signaling and/or IL-33 cellular expression, such as infectious diseases, inflammatory diseases, allergic diseases and fibrotic diseases.

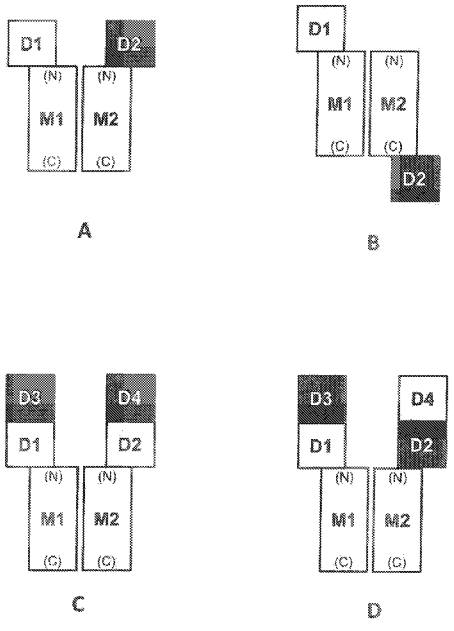


Figure 1

WO 2014/152195 A1

WO 2014/152195 A1

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

— *with sequence listing part of description (Rule 5.2(a))*

IL-33 ANTAGONISTS AND USES THEREOF

FIELD OF THE INVENTION

[0001] The present invention relates to antigen-binding molecules which are capable of antagonizing IL-33, and methods of use thereof.

BACKGROUND

[0002] Interleukin-33 (IL-33) is a ligand for ST2, a toll-like/interleukin-1 receptor super-family member that associates with an accessory protein, IL-1RAcP (for reviews, *see*, *e.g.*, Kakkar and Lee, *Nature Reviews – Drug Discovery 7(10)*:827-840 (2008), Schmitz et al., Immunity 23:479-490 (2005); Liew et al., *Nature Reviews – Immunology 10*:103-110 (2010); US 2010/0260770; US 2009/0041718). Upon activation of ST2/IL-1RAcP by IL-33, a signaling cascade is triggered through downstream molecules such as MyD88 (myeloid differentiation factor 88) and TRAF6 (TNF receptor associated factor 6), leading to activation of NFκB (nuclear factor-κB), among others. IL-33 signaling has been implicated as a factor in a variety of diseases and disorders. (Liew et al., *Nature Reviews – Immunology 10*:103-110 (2010)).

BRIEF SUMMARY OF THE INVENTION

[0003] The present invention provides interleukin-33 (IL-33) antagonists.

[0004] In one aspect, the invention provides an IL-33 antagonist comprising a first IL-33 binding domain (D1) and a multimerizing domain (M).

[0005] In one embodiment, the IL-33 antagonist comprises a first IL-33 binding domain (D1) attached to a multimerizing domain (M), wherein D1 comprises an IL-33-binding portion of an ST2 protein.

[0006] In certain embodiments, the IL-33 antagonist further comprises one or more additional IL-33 binding domains (*e.g.*, D2, D3, D4, etc.).

[0007] According to certain embodiments, the IL-33 binding domain (D1, D2, D3, D4, etc.) comprises an IL-33-binding portion of an ST2 protein, an extracellular domain of an IL-1RAcP protein, or other IL-33 binding domain.

[0008] In one embodiment, the IL-33 antagonist further comprises a second IL-33 binding domain (D2) attached to D1 and/or M, wherein D2 comprises an extracellular portion of an IL-1RAcP protein. In one embodiment, D1 is attached to the N-terminus of M. In one embodiment, D1 is attached to the C-terminus of M. In one embodiment, D2 is attached to the N-terminus of M. In one embodiment, D2 is attached to the C-terminus of M. In one embodiment, D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M.

[0009] The multimerizing domain (M) may be a peptide or polypeptide having a N-terminus and a C-terminus. The IL-33 binding domain components may be attached to either the N-terminus or the C-terminus of M. According to certain embodiments, the D1, D2 and M

components are attached in tandem, such that D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M. Numerous arrangements and configurations of the D1, D2, and M components are contemplated within the scope of the present invention, examples of which are described herein.

[0010] In one embodiment, the IL-33 antagonist binds human interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 80 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 400 pM as measured in a surface plasmon resonance assay at 37°C.

[0011] In one embodiment, the IL-33 antagonist binds human interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 60 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 1.0 pM as measured in a surface plasmon resonance assay at 37°C.

[0012] In one embodiment, the IL-33 antagonist binds monkey interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 60 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 200 pM as measured in a surface plasmon resonance assay at 37°C.

[0013] In one embodiment, the IL-33 antagonist binds monkey interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 1.0 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 1.0 pM as measured in a surface plasmon resonance assay at 37°C.

[0014] In one embodiment, the IL-33 antagonist binds mouse interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 110 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 100 pM as measured in a surface plasmon resonance assay at 37°C.

[0015] In one embodiment, the IL-33 antagonist binds mouse interleukin 33 (IL-33) with a binding dissociation equilibrium constant (K_D) of less than about 10 pM as measured in a surface plasmon resonance assay at 25°C, and/or a binding dissociation equilibrium constant (K_D) of less than about 5 pM as measured in a surface plasmon resonance assay at 37°C.

[0016] In one embodiment, the IL-33 antagonist binds human interleukin 33 (IL-33) with a dissociative half-life ($t_{1/2}$) of greater than or equal to about 9 minutes as measured in a surface plasmon resonance assay at 25°C, and/or a dissociative half-life ($t_{1/2}$) of greater than or equal to about 4 minutes as measured in a surface plasmon resonance assay at 37°C.

[0017] In one embodiment, the IL-33 antagonist binds human interleukin 33 (IL-33) with a dissociative half-life ($t_{1/2}$) of greater than or equal to about 30 minutes as measured in a surface plasmon resonance assay at 25°C, and/or a dissociative half-life ($t_{1/2}$) of greater than or equal to about 1000 minutes as measured in a surface plasmon resonance assay at 37°C.

[0018] In one embodiment, the IL-33 antagonist binds monkey interleukin 33 (IL-33) with a dissociative half-life ($t_{1/2}$) of greater than about 40 minutes as measured in a surface plasmon

resonance assay at 25°C, and/or a dissociative half-life (t½) of greater than or equal to about 10 minutes as measured in a surface plasmon resonance assay at 37°C.

[0019] In one embodiment, the IL-33 antagonist binds monkey interleukin 33 (IL-33) with a dissociative half-life (t½) of greater than about 1000 minutes as measured in a surface plasmon resonance assay at 25°C, and/or a dissociative half-life (t½) of greater than or equal to about 1000 minutes as measured in a surface plasmon resonance assay at 37°C.

[0020] In one embodiment, the IL-33 antagonist binds mouse interleukin 33 (IL-33) with a dissociative half-life (t½) of greater than about 25 minutes as measured in a surface plasmon resonance assay at 25°C, and/or a dissociative half-life (t½) of greater than about 30 minutes as measured in a surface plasmon resonance assay at 37°C.

[0021] In one embodiment, the IL-33 antagonist binds mouse interleukin 33 (IL-33) with a dissociative half-life (t½) of greater than about 500 minutes as measured in a surface plasmon resonance assay at 25°C, and/or a dissociative half-life (t½) of greater than about 1000 minutes as measured in a surface plasmon resonance assay at 37°C.

[0022] In one embodiment, the IL-33 antagonist blocks the interaction of IL-33 and ST2.

[0023] In one embodiment, the IL-33 antagonist blocks the interaction of IL-33 and ST2 with an IC_{50} value of less than about 115 pM as measured in an *in vitro* receptor/ligand binding assay at 25°C.

[0024] In one embodiment, the IL-33 antagonist blocks the interaction of IL-33 and ST2 with an IC_{50} value of less than about 20 pM as measured in an *in vitro* receptor/ligand binding assay at 25°C.

[0025] In one embodiment, D1 comprises the amino acid sequence of SEQ ID NO: 5 or 6, or an amino acid sequence having at least 90% identity thereto.

[0026] In one embodiment, D2 comprises the amino acid sequence of SEQ ID NO: 7 or 8, or an amino acid sequence having at least 90% identity thereto.

[0027] In one embodiment the multimerizing component comprises the amino acid sequence of SEQ ID NO: 9 or 10, or an amino acid sequence having at least 90% identity thereto.

[0028] In one embodiment, the IL-33 antagonist comprises a first IL-33 binding domain (D1) attached to a first multimerizing domain (M1), and a second IL-33 binding domain (D2) attached to a second multimerizing domain (M2), wherein the D1 and/or D2 domains comprise an IL-33-binding portion of a receptor selected from the group consisting of ST2 and IL-1RAcP.

[0029] In one embodiment, the IL-33 antagonist comprises a third IL-33 binding domain (D3), which is attached to either D1 or M1, and wherein D3 comprises an IL-33-binding portion of a receptor selected from the group consisting of ST2 and IL-1RAcP.

[0030] In one embodiment, the IL-33 antagonist comprises a fourth IL-33 binding domain (D4), which is attached to either D2 or M2, and wherein D4 comprises an IL-33-binding portion of a receptor selected from the group consisting of ST2 and IL-1RAcP.

[0031] In one embodiment, D1 is attached to the N-terminus of M1, and D2 is attached to the

N-terminus of M2.

[0032] In one embodiment, D3 is attached to the N-terminus of D1.

[0033] In one embodiment, D3 is attached to the C-terminus of M1.

[0034] In one embodiment, D4 is attached to the N-terminus of D2.

[0035] In one embodiment, D4 is attached to the C-terminus of M2.

[0036] In one embodiment, D3 is attached to the N-terminus of D1, D1 is attached to the N-terminus of M1; D4 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M2.

[0037] In one embodiment, D3 is identical or substantially identical to D4 and D1 is identical or substantially identical to D2.

[0038] In one embodiment D3 and D4 each comprise an IL-33-binding portion of an ST2 protein; and D1 and D2 each comprise an extracellular portion of an IL-1RAcP protein.

[0039] In one embodiment, the IL-33 antagonist comprises an amino acid sequence selected from the group consisting of SEQ ID NOs: 1, 2, 3, 4 and 13.

[0040] A second aspect of the invention provides methods of using the IL-33 antagonists described herein for treating an inflammatory disease or disorder, or at least one symptom associated with the inflammatory disease or disorder, the method comprising administering one or more IL-33 antagonists of the invention, or a pharmaceutical composition containing one or more IL-33 antagonists of the invention, to a patient in need thereof, wherein the inflammatory disease or disorder is alleviated, or reduced in severity, duration or frequency of occurrence, or at least one symptom associated with the inflammatory disease or disorder is alleviated, or reduced in severity, duration, or frequency of occurrence.

[0041] In one embodiment, the inflammatory disease or disorder that may be treated with any one or more IL-33 antagonists of the invention may be selected from the group consisting of asthma, atopic dermatitis, chronic obstructive pulmonary disease (COPD), inflammatory bowel disease, multiple sclerosis, arthritis, allergic rhinitis, eosinophilic esophagitis and psoriasis.

[0042] In one embodiment, the inflammatory disease or disorder that may be treated with any one or more IL-33 antagonists of the invention is asthma. The asthma may be eosinophilic or non-eosinophilic asthma. The asthma may be steroid resistant or steroid sensitive asthma.

[0043] In one embodiment, the inflammatory disease or disorder that may be treated with any one or more IL-33 antagonists of the invention is atopic dermatitis.

[0044] In one embodiment, the inflammatory disease or disorder that may be treated with any one or more IL-33 antagonists of the invention is chronic obstructive pulmonary disease (COPD). In one embodiment, the chronic obstructive pulmonary disease may result from, or may be caused in part by cigarette smoke.

[0045] In a related embodiment, the invention provides a method for treating a patient who demonstrates a sensitivity to an allergen, the method comprising administering an effective amount of one or more of the IL-33 antagonists of the invention, or a pharmaceutical

composition comprising one or more of the IL-33 antagonists of the invention, to a patient in need thereof, wherein the patient demonstrates a reduced sensitivity to, or a diminished allergic reaction against the allergen, or does not experience any sensitivity or allergic reaction to, or anaphylactic response to the allergen following administration of the antibody or a composition comprising the antibody.

[0046] In a related embodiment, the invention provides a pharmaceutical composition comprising one or more of the IL-33 antagonists of the invention for use in treating an inflammatory disease or disorder, wherein the inflammatory disease or disorder is selected from the group consisting of asthma, allergy, anaphylaxis, atopic dermatitis, chronic obstructive pulmonary disease (COPD), inflammatory bowel disease, multiple sclerosis, arthritis, allergic rhinitis, eosinophilic esophagitis and psoriasis.

[0047] In one embodiment, the invention provides a pharmaceutical composition comprising one or more of the IL-33 antagonists of the invention in the manufacture of a medicament for the treatment of an inflammatory disease or disorder, wherein the inflammatory disease or disorder is selected from the group consisting of asthma, allergy, anaphylaxis, atopic dermatitis, chronic obstructive pulmonary disease (COPD), inflammatory bowel disease, multiple sclerosis, arthritis, allergic rhinitis, eosinophilic esophagitis and psoriasis.

[0048] In certain embodiments, the invention provides a method of treating an inflammatory disease or disorder by administering one or more of the IL-33 antagonists of the invention in combination with an effective amount of a second therapeutic agent useful for alleviating the inflammatory disease or disorder, or at least one symptom of the inflammatory disease or disorder, or for diminishing an allergic response to an allergen.

[0049] In one embodiment, the second therapeutic agent may be selected from the group consisting of a non-steroidal anti-inflammatory (NSAID), a corticosteroid, a bronchial dilator, an antihistamine, epinephrine, a decongestant, a thymic stromal lymphopoietin (TSLP) antagonist, an IL-13 antagonist, an IL-4 antagonist, an IL-4/IL-13 dual antagonist, an IL-5 antagonist, an IL-6 antagonist, an IL-12/23 antagonist, an IL-22 antagonist, an IL-25 antagonist, an IL-17 antagonist, an IL-31 antagonist, a PDE4 inhibitor and another IL-33 antagonist or a different antibody to IL-33.

[0050] A third aspect of the invention provides a pharmaceutical composition comprising any one or more of the IL-33 antagonists described herein and a pharmaceutically acceptable carrier or diluent and therapeutic methods comprising administering such pharmaceutical compositions to subjects in need thereof. In certain embodiments, an additional therapeutically active component is formulated with, or administered in combination with an IL-33 antagonist of the present invention.

[0051] Other embodiments will become apparent from a review of the ensuing detailed description.

BRIEF DESCRIPTION OF THE FIGURE

[0052] **Figure 1** shows four exemplary arrangements of the individual components of the IL-33 antagonists relative to one another. **Panel A** shows an arrangement in which a first IL-33-binding domain (D1) is attached to the N-terminus of a first multimerizing domain (M1), and a second IL-33-binding domain (D2) is attached to the N-terminus of a second multimerizing domain (M2). D1 is shown as a white box and D2 is shown as a black box to indicate that D1 and D2 are derived from different IL-33 binding proteins. **Panel B** shows an arrangement in which a first IL-33-binding domain (D1) is attached to the N-terminus of a first multimerizing domain (M1), and a second IL-33-binding domain (D2) is attached to the C-terminus of a second multimerizing domain (M2). D1 is shown as a white box and D2 is shown as a black box to indicate that D1 and D2 are derived from different IL-33 binding proteins. **Panels C** and **D** show arrangements comprising four IL-33-binding domains, D1, D2, D3 and D4. In these arrangements, D3-D1-M1 and D4-D2-M2 are attached in tandem, wherein D3 is attached to the N-terminus of D1, and D1 is attached to the N-terminus of M1; and D4 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M2. In Panel **C**, D3 and D4 are identical or substantially identical to one another, and D1 and D2 are identical or substantially identical to one another. In Panel **D**, D1 and D4 are identical or substantially identical to one another, and D3 and D2 are identical or substantially identical to one another.

DETAILED DESCRIPTION

[0053] Before the present invention is described, it is to be understood that this invention is not limited to particular methods and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0054] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. As used herein, the term "about," when used in reference to a particular recited numerical value, means that the value may vary from the recited value by no more than 1%. For example, as used herein, the expression "about 100" includes 99 and 101 and all values in between (*e.g.*, 99.1, 99.2, 99.3, 99.4, etc.).

[0055] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described.

IL-33 ANTAGONISTS

[0056] The expressions "interleukin-33," "IL-33," and the like, as used herein, refer to a human IL-33 protein having the amino acid sequence as set forth in NCBI accession Nos.

NP_254274.1 (human isoform 1), NP_001186569.1 (human isoform 2), or NP_001186570.1 (human isoform 3). All references to proteins, polypeptides and protein fragments herein are intended to refer to the human version of the respective protein, polypeptide or protein fragment unless explicitly specified as being from a non-human species (*e.g.*, "mouse IL-33," "monkey IL-33," etc.).

[0057] As used herein, the expression "IL-33 antagonist" means any antigen-binding molecule that is capable of binding IL-33 and blocking, attenuating or otherwise interfering with IL-33 signaling and/or the interaction between IL-33 and a cell surface receptor (*e.g.*, ST2).

[0058] The IL-33 antagonists of the present invention comprise a first IL-33 binding domain (D1) attached to a multimerizing domain (M). In certain embodiments, the IL-33 antagonists of the invention comprise a second IL-33 binding domain (D2) attached to D1 and/or M. According to certain embodiments, D1 comprises an IL-33-binding portion of an ST2 protein. According to certain embodiments, D2 comprises an extracellular portion of an IL-1RAcP protein.

[0059] The individual components of the IL-33 antagonists may be arranged relative to one another in a variety of ways that result in functional antagonist molecules capable of binding IL-33. For example, D1 and/or D2 may be attached to the N-terminus of M. In other embodiments D1 and/or D2 is attached to the C-terminus of M. In yet other embodiments, D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M, resulting in an in-line fusion, from N- to C-terminus, of an antagonist molecule represented by the formula D1-D2-M. Other orientations of the individual components are disclosed elsewhere herein.

[0060] Non-limiting examples of IL-33 antagonists of the invention are shown in the working embodiments herein, and include the antagonists designated "hST2-hFc," "hST2-mFc," "hST2-hIL1RAcP-mFc," "hST2-hIL1RAcP-hFc" and "mST2-mIL1RAcP-mFc". hST2-hFc and hST2-mFc may also be referred to as "ST2 receptor proteins". hST2-hIL1RAcP-mFc, hST2-hIL1RAcP-hFc and mST2-mIL1RAcP-mFc may also be referred to herein as "IL-33 Trap proteins".

[0061] As used herein, the term "attached", in the context of a first polypeptide component being "attached" to a second polypeptide component (*e.g.*, "D1 is attached to M," "D2 is attached to M," "D1 is attached to D2," etc.), means that the first component is physically connected to the second component either directly or indirectly. As an example of a direct attachment between two polypeptide components, the C-terminal amino acid of the first component may be connected via a peptide bond to the N-terminal amino acid of the second component, or the N-terminal amino acid of the first component may be connected via a peptide bond to the C-terminal amino acid of the second component. Indirect attachment, on the other hand, means that the first and second components are each connected physically to different parts of an intervening structure which serves as a link between the first and second components. The intervening structure may be, *e.g.*, a single amino acid, a peptide linker, or another polypeptide component (*e.g.*, another IL-33-binding protein, etc.). For example, in the

arrangement D1-D2-M (wherein a first IL-33 binding domain [D1] is attached to a second IL-33 binding domain [D2] which in turn is connected to a multimerizing domain [M]), D1 is regarded as being "attached" to M, even though the attachment is indirect with D2 serving as an intervening structure.

[0062] Standard molecular biological techniques (*e.g.*, recombinant DNA technology) may be used to construct any of the IL-33 antagonists of the invention or variants thereof.

IL-33-BINDING DOMAINS

[0063] The IL-33 antagonists of the present invention comprise at least one IL-33 binding domain (sometimes referred to herein by the designation "D," or "D1," "D2," etc.). In certain embodiments, the IL-33 binding domain comprises an IL-33-binding portion of an ST2 protein. An IL-33-binding portion of an ST2 protein can comprise or consist of all or part of the extracellular domain of an ST2 protein. In certain embodiments, an ST2 protein is a human ST2 protein. A "human ST2 protein," as used herein, refers to an ST2 protein having the amino acid sequence of SEQ ID NO:12. In certain embodiments, the ST2 protein is an ST2 protein from a non-human species (*e.g.*, mouse ST2, monkey ST2, etc). An exemplary IL-33-binding portion of an ST2 protein is set forth herein as the amino acid sequence of SEQ ID NO:5 (corresponding to the extracellular domain of human ST2 [K19-S328 of NCBI Accession No. NP_057316.3]). Another example of an IL-33-binding portion of an ST2 protein is set forth herein as the amino acid sequence of SEQ ID NO:6 (corresponding to the extracellular domain of mouse ST2 [S27-R332 of NCBI Accession No. P14719]).

[0064] In certain embodiments, the IL-33 binding domain comprises an extracellular portion of an IL-1RAcP protein. In certain embodiments, an IL-1RAcP protein is a human IL-1RAcP protein. A "human IL-1RAcP protein," as used herein, refers to an IL-1RAcP protein having the amino acid sequence of SEQ ID NO:13. In certain embodiments, the IL-1RAcP protein is an IL-1RAcP protein from a non-human species (*e.g.*, mouse IL-1RAcP, monkey IL-1RAcP, etc). An exemplary extracellular portion of an IL-1RAcP protein is set forth herein as the amino acid sequence of SEQ ID NO:7 (corresponding to the extracellular domain of human IL-1RAcP [S21-E359 of NCBI Accession No. Q9NPH3]). Another example of an extracellular portion of an IL-1RAcP protein is set forth herein as the amino acid sequence of SEQ ID NO:8 (corresponding to the extracellular domain of mouse IL-1RAcP [S21-E359 of NCBI Accession No. Q61730]).

[0065] The present invention includes IL-33 antagonists comprising D1 and/or D2 components having an amino acid sequence that is at least 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to any of the exemplary IL-33 binding domain component amino acid sequences set forth herein (*e.g.*, SEQ ID NOs:5-8).

MULTIMERIZING DOMAIN

[0066] The IL-33 antagonists of the present invention also comprise at least one multimerizing

domain (sometimes referred to herein by the abbreviation "M," "M1", "M2", etc.). In general terms, the multimerizing domain(s) of the present invention function to connect the various components of the IL-33 antagonists (*e.g.*, the IL-33-binding domain(s)) with one another. As used herein, a "multimerizing domain" is any macromolecule that has the ability to associate (covalently or non-covalently) with a second macromolecule of the same or similar structure or constitution. For example, a multimerizing domain may be a polypeptide comprising an immunoglobulin C_H3 domain. A non-limiting example of a multimerizing domain is an Fc portion of an immunoglobulin, *e.g.*, an Fc domain of an IgG selected from the isotypes IgG1, IgG2, IgG3, and IgG4, as well as any allotype within each isotype group. In certain embodiments, the multimerizing domain is an Fc fragment or an amino acid sequence of 1 to about 200 amino acids in length containing at least one cysteine residues. In other embodiments, the multimerizing domain is a cysteine residue or a short cysteine-containing peptide. Other multimerizing domains include peptides or polypeptides comprising or consisting of a leucine zipper, a helix-loop motif, or a coiled-coil motif.

[0067] Non-limiting exemplary multimerizing domains that can be used in the IL-33 antagonists of the present invention include human IgG1 Fc (SEQ ID NO:9) or mouse IgG2a Fc (SEQ ID NO:10). The present invention includes IL-33 antagonists comprising M components having an amino acid sequence that is at least 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to any of the exemplary M component amino acid sequences set forth herein (*e.g.*, SEQ ID NOs:9 or 10).

[0068] In certain embodiments, the IL-33 antagonists of the present invention comprise two multimerizing domains, M1 and M2, wherein M1 and M2 are identical to one another. For example, M1 can be an Fc domain having a particular amino acid sequence, and M2 is an Fc domain with the same amino acid sequence as M1.

[0069] Alternatively, in certain embodiments, the IL-33 antagonists of the invention comprise two multimerizing domains, M1 and M2, that differ from one another at one or more amino acid position. For example, M1 may comprise a first immunoglobulin (Ig) C_H3 domain and M2 may comprise a second Ig C_H3 domain, wherein the first and second Ig C_H3 domains differ from one another by at least one amino acid, and wherein at least one amino acid difference reduces binding of the targeting construct to Protein A as compared to a reference construct having identical M1 and M2 sequences. In one embodiment, the Ig C_H3 domain of M1 binds Protein A and the Ig C_H3 domain of M2 contains a mutation that reduces or abolishes Protein A binding such as an H95R modification (by IMGT exon numbering; H435R by EU numbering). The C_H3 of M2 may further comprise a Y96F modification (by IMGT; Y436F by EU). Further modifications that may be found within the C_H3 of M2 include: D16E, L18M, N44S, K52N, V57M, and V82I (by IMGT; D356E, L358M, N384S, K392N, V397M, and V422I by EU) in the case of an IgG1 Fc domain; N44S, K52N, and V82I (IMGT; N384S, K392N, and V422I by EU) in the case of an IgG2 Fc domain; and Q15R, N44S, K52N, V57M, R69K, E79Q, and V82I (by IMGT;

Q355R, N384S, K392N, V397M, R409K, E419Q, and V422I by EU) in the case of an IgG4 Fc domain.

ORIENTATION AND ARRANGEMENT OF THE COMPONENTS OF THE IL-33 ANTAGONISTS

[0070] The individual components of the IL-33 antagonists of the present invention (*e.g.*, D1, D2, M, etc.) can be arranged relative to one another in a variety of ways, examples of which are described in detail elsewhere herein. The multimerizing domains (M1 and/or M2) may be a peptide or polypeptide having a N-terminus and a C-terminus. Thus, D1 and D2 components may be attached to the M component at either the N- or C-terminus of the M component. for example, D1 may be attached to the N-terminus of M (represented as "D1-M"). Alternatively, D1 may be attached to the C-terminus of M (represented as "M-D1"). In some embodiments, D2 is attached to the N-terminus of M (represented as "D2-M"), or D2 is attached to the C-terminus of M (represented as "M-D2"). In yet other embodiments, D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M (represented as "D1-D2-M"). Other exemplary arrangements of the individual components, from N- to C-terminus, may thus be represented as follows: D2-D1-M; M-D1; M-D2; M-D1-D2; M-D2-D1; D1-M-D2; D2-M-D1; etc.

[0071] In embodiments comprising two different multimerizing domains (M1 and M2), one or more IL-33 binding domains may be attached to the multimerizing domains in a variety of arrangements. Non-limiting examples of such arrangements are illustrated schematically in Figure 1. For example, the present invention includes IL-33 antagonists comprising a first IL-33 binding domain (D1) attached to a first multimerizing domain (M1), and a second IL-33 binding domain (D2) attached to a second multimerizing domain (M2). The IL-33 antagonists of the invention may also include one or more additional IL-33 binding domains (*e.g.*, D3, D4, etc.). For example, where a third IL-33 binding domain (D3) is included, the D3 component may be attached to either D1 or M1; likewise, where a fourth IL-33 binding domain (D4) is included, the D4 component may be attached to either D2 or M2.

[0072] In embodiments involving multiple IL-33 binding domains, two or more of the IL-33 binding domains may be identical, or substantially identical, to one another. For example, in an embodiment comprising four IL-33 binding domains (D1, D2, D3, and D4), D1 and D2 may be identical, or substantially identical, to one another; and D3 and D4 may be identical, or substantially identical, to one another, etc.

[0073] Non-limiting illustrative examples of IL-33 antagonists of the invention comprising two multimerizing domains (M1 and M2) and four IL-33 binding domains (D1, D2, D3 and D4) are shown in Figure 1, arrangements C and D). In exemplary arrangements of this sort, D1 is attached to the N-terminus of M1, D2 is attached to the N-terminus of M2, D3 is attached to the N-terminus of D1, and D4 is attached to the N-terminus of D2. Panel C depicts the situation wherein D1 and D2 are identical to one another (*e.g.*, each comprising the extracellular domain

of IL-1RAcP), and D3 and D4 are identical to one another (*e.g.*, each comprising the extracellular domain of ST2). Panel C depicts the situation wherein D1 and D2 are non-identical, and D3 and D4 are non-identical. Numerous other arrangements will be apparent to a person of ordinary skill in the art based on the teachings of the present disclosure and are encompassed within the scope of the present invention.

LINKERS

[0074] The individual components of the IL-33 antagonists of the present invention (*e.g.*, D1, D2, M1, M2, etc.) may be attached to one another directly (*e.g.*, D1 and/or D2 may be directly attached to M, etc.); alternatively, the individual components may be attached to one another via a linker component (*e.g.*, D1 and/or D2 may be attached to M via a linker oriented between the individual components; D1 may be attached to D2 via a linker; etc.). In any of the arrangements disclosed herein, wherein one component is described as being "attached" to another component, the attachment may be through a linker (even if not specifically designated as such). As used herein, a "linker" is any molecule that joins two polypeptide components together. For example, a linker may be a peptide comprising from 1 to 20 amino acids connected together via peptide bonds. (A peptide bond *per se*, however, is not considered a "linker" for purposes of the present disclosure). In certain embodiments, the linker comprises sterically unhindered amino acids such as glycine and alanine. In certain embodiments, the linker is a flexible chain of amino acids that is resistant to proteolytic degradation. A linker may comprise two molecular structures that interact with one another. For example, in certain embodiments a linker may comprise a streptavidin component and a biotin component; the association between streptavidin (attached to one component) and biotin (attached to another component) serves as an attachment between individual components of the IL-33 antagonists. The exemplary IL-33 antagonists described herein as hST2-hIL1RAcP-mFc and mST2-mIL1RAcP-mFc include a serine-glycine (SG) linker between the IL-1RAcP component and the Fc multimerizing domain. Other similar linker arrangements and configurations involving linkers are contemplated within the scope of the present invention.

BIOLOGICAL CHARACTERISTICS OF THE IL-33 ANTAGONISTS

[0075] The present invention includes IL-33 antagonists that bind soluble IL-33 molecules with high affinity. For example, the present invention includes IL-33 antagonists (as described elsewhere herein) that bind IL-33 (*e.g.*, at 25°C or 37°C) with a K_D of less than about 400 pM as measured by surface plasmon resonance, *e.g.*, using the assay format as defined in Example 2 herein. In certain embodiments, the IL-33 antagonists of the present invention bind IL-33 with a K_D of less than about 200 pM, less than about 100 pM, less than about 90 pM, less than about 80 pM, less than about 70 pM, less than about 60 pM, less than about 50 pM, less than about 40 pM, less than about 30 pM, less than about 20 pM, less than about 10 pM, less than about 9

pM, less than about 8 pM, less than about 6 pM, or less than about 1 pM as measured by surface plasmon resonance, *e.g.*, using the assay format as defined in Example 2 herein, or a substantially similar assay.

[0076] The present invention also includes IL-33 antagonists that specifically bind IL-33 with a dissociative half-life (t½) of greater than or equal to about 4 minutes as measured by surface plasmon resonance at 25°C or 37°C, *e.g.*, using the assay format as defined in Example 2 herein, or a substantially similar assay. In certain embodiments, the IL-33 antagonists of the present invention bind IL-33 with a t½ of greater than about 10 minutes, greater than about 20 minutes, greater than about 30 minutes, greater than about 40 minutes, greater than about 50 minutes, greater than about 60 minutes, or greater than about 70 minutes, or greater than about 500 minutes, or greater than about 1000 minutes as measured by surface plasmon resonance at 25°C or 37°C, *e.g.*, using the assay format as defined in Example 2 herein, or a substantially similar assay.

[0077] The present invention also includes IL-33 antagonists that block the binding of IL-33 to an IL-33 receptor (*e.g.*, ST2). For example, the present invention includes IL-33 antagonists that block the binding of IL-33 to ST2 *in vitro*, with an IC_{50} value of less than about 115 pM, as measured by an ELISA-based immunoassay, *e.g.*, using the assay format as defined in Example 3 herein, or a substantially similar assay. In certain embodiments, the IL-33 antagonists of the present invention block the binding of IL-33 to ST2 *in vitro* with an IC_{50} value of less than about 120 pM, less than about 90 pM, less than about 80 pM, less than about 70 pM, less than about 60 pM, less than about 50 pM, less than about 40 pM, less than about 30 pM, less than about 20 pM, less than about 18 pM, less than about 16 pM, less than about 14 pM, less than about 12 pM, less than about 10 pM, less than about 9 pM, less than about 8 pM, or less than about 7 pM, as measured by an ELISA-based immunoassay, *e.g.*, using the assay format as defined in Example 3 herein, or a substantially similar assay.

[0078] The present invention also includes IL-33 antagonists that inhibit IL-33-mediated cell signaling. For example, the present invention includes IL-33 antagonists that inhibit IL-33-mediated signaling in cells expressing human ST2, with an IC_{50} value of less than about 500 pM, as measured in a cell-based blocking bioassay, *e.g.*, using the assay format as defined in Example 4 herein, or a substantially similar assay. In certain embodiments, the IL-33 antagonists of the present invention block IL-33-mediated signaling in cells expressing human ST2, with an IC_{50} of less than about 400 pM, less than about 300 pM, less than about 200 pM, less than about 100 pM, less than about 80 pM, less than about 60 pM, less than about 40 pM, less than about 30 pM, less than about 20 pM, less than about 18 pM, less than about 16 pM, less than about 14 pM, less than about 12 pM, less than about 10 pM, less than about 8 pM, less than about 7 pM, less than about 6 pM, less than about 5 pM, less than about 4 pM, less than about 3 pM, less than about 2 pM, or less than about 1.5 pM, as measured in a cell-based blocking bioassay, *e.g.*, using the assay format as defined in Example 4 herein, or a

substantially similar assay.

[0079] The present invention also includes IL-33 antagonists that inhibit IL-33-induced basophil activation and IL-33 antagonists that inhibit IL-33-induced IFN-gamma release from human PBMCs. Basophil activation can be defined as degranulation, cell surface marker expression, cytokine release, and other immune mediator release, such as histamines and leukotrienes.

[0080] The IL-33 antagonists of the present invention may possess one or more of the aforementioned biological characteristics, or any combinations thereof. Other biological characteristics of the antibodies of the present invention will be evident to a person of ordinary skill in the art from a review of the present disclosure including the working Examples herein.

THERAPEUTIC FORMULATION AND ADMINISTRATION

[0081] The invention provides pharmaceutical compositions comprising the IL-33 antagonists of the present invention. The pharmaceutical compositions of the invention may be formulated with suitable carriers, excipients, and other agents that provide improved transfer, delivery, tolerance, and the like. A multitude of appropriate formulations can be found in the formulary known to all pharmaceutical chemists: Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, PA. These formulations include, for example, powders, pastes, ointments, jellies, waxes, oils, lipids, lipid (cationic or anionic) containing vesicles (such as LIPOFECTIN™, Life Technologies, Carlsbad, CA), DNA conjugates, anhydrous absorption pastes, oil-in-water and water-in-oil emulsions, emulsions carbowax (polyethylene glycols of various molecular weights), semi-solid gels, and semi-solid mixtures containing carbowax. See also Powell et al. "Compendium of excipients for parenteral formulations" PDA (1998) J Pharm Sci Technol 52:238-311.

[0082] The dose of IL-33 antagonist administered to a patient may vary depending upon the age and the size of the patient, target disease, conditions, route of administration, and the like. The preferred dose is typically calculated according to body weight or body surface area. When an IL-33 antagonist of the present invention is used for treating a condition or disease associated with IL-33 activity in an adult patient, it may be advantageous to intravenously administer the antagonist of the present invention normally at a single dose of about 0.01 to about 20 mg/kg body weight, more preferably about 0.02 to about 7, about 0.03 to about 5, or about 0.05 to about 3 mg/kg body weight. Depending on the severity of the condition, the frequency and the duration of the treatment can be adjusted. Effective dosages and schedules for administering IL-33 antagonist may be determined empirically; for example, patient progress can be monitored by periodic assessment, and the dose adjusted accordingly. Moreover, interspecies scaling of dosages can be performed using well-known methods in the art (*e.g.*, Mordenti *et al.*, 1991, *Pharmaceut. Res. 8*:1351).

[0083] Various delivery systems are known and can be used to administer the pharmaceutical

composition of the invention, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the mutant viruses, receptor mediated endocytosis (see, e.g., Wu et al., 1987, J. Biol. Chem. 262:4429-4432). Methods of introduction include, but are not limited to, intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, epidural, and oral routes. The composition may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (e.g., oral mucosa, rectal and intestinal mucosa, etc.) and may be administered together with other biologically active agents. Administration can be systemic or local.

[0084] A pharmaceutical composition of the present invention can be delivered subcutaneously or intravenously with a standard needle and syringe. In addition, with respect to subcutaneous delivery, a pen delivery device readily has applications in delivering a pharmaceutical composition of the present invention. Such a pen delivery device can be reusable or disposable. A reusable pen delivery device generally utilizes a replaceable cartridge that contains a pharmaceutical composition. Once all of the pharmaceutical composition within the cartridge has been administered and the cartridge is empty, the empty cartridge can readily be discarded and replaced with a new cartridge that contains the pharmaceutical composition. The pen delivery device can then be reused. In a disposable pen delivery device, there is no replaceable cartridge. Rather, the disposable pen delivery device comes prefilled with the pharmaceutical composition held in a reservoir within the device. Once the reservoir is emptied of the pharmaceutical composition, the entire device is discarded.

[0085] Numerous reusable pen and autoinjector delivery devices have applications in the subcutaneous delivery of a pharmaceutical composition of the present invention. Examples include, but are not limited to AUTOPEN™ (Owen Mumford, Inc., Woodstock, UK), DISETRONIC™ pen (Disetronic Medical Systems, Bergdorf, Switzerland), HUMALOG MIX 75/25™ pen, HUMALOG™ pen, HUMALIN 70/30™ pen (Eli Lilly and Co., Indianapolis, IN), NOVOPEN™ I, II and III (Novo Nordisk, Copenhagen, Denmark), NOVOPEN JUNIOR™ (Novo Nordisk, Copenhagen, Denmark), BD™ pen (Becton Dickinson, Franklin Lakes, NJ), OPTIPEN™, OPTIPEN PRO™, OPTIPEN STARLET™, and OPTICLIK™ (sanofi-aventis, Frankfurt, Germany), to name only a few. Examples of disposable pen delivery devices having applications in subcutaneous delivery of a pharmaceutical composition of the present invention include, but are not limited to the SOLOSTAR™ pen (sanofi-aventis), the FLEXPEN™ (Novo Nordisk), and the KWIKPEN™ (Eli Lilly), the SURECLICK™ Autoinjector (Amgen, Thousand Oaks, CA), the PENLET™ (Haselmeier, Stuttgart, Germany), the EPIPEN (Dey, L.P.), and the HUMIRA™ Pen (Abbott Labs, Abbott Park IL), to name only a few.

[0086] In certain situations, the pharmaceutical composition can be delivered in a controlled release system. In one embodiment, a pump may be used (see Langer, supra; Sefton, 1987, CRC Crit. Ref. Biomed. Eng. 14:201). In another embodiment, polymeric materials can be

used; see, Medical Applications of Controlled Release, Langer and Wise (eds.), 1974, CRC Pres., Boca Raton, Florida. In yet another embodiment, a controlled release system can be placed in proximity of the composition's target, thus requiring only a fraction of the systemic dose (see, *e.g.*, Goodson, 1984, in Medical Applications of Controlled Release, supra, vol. 2, pp. 115-138). Other controlled release systems are discussed in the review by Langer, 1990, Science 249:1527-1533.

[0087] The injectable preparations may include dosage forms for intravenous, subcutaneous, intracutaneous and intramuscular injections, drip infusions, etc. These injectable preparations may be prepared by methods publicly known. For example, the injectable preparations may be prepared, *e.g.*, by dissolving, suspending or emulsifying the antagonist or its salt described above in a sterile aqueous medium or an oily medium conventionally used for injections. As the aqueous medium for injections, there are, for example, physiological saline, an isotonic solution containing glucose and other auxiliary agents, etc., which may be used in combination with an appropriate solubilizing agent such as an alcohol (e.g., ethanol), a polyalcohol (e.g., propylene glycol, polyethylene glycol), a nonionic surfactant [e.g., polysorbate 80, HCO-50 (polyoxyethylene (50 mol) adduct of hydrogenated castor oil)], etc. As the oily medium, there are employed, e.g., sesame oil, soybean oil, etc., which may be used in combination with a solubilizing agent such as benzyl benzoate, benzyl alcohol, etc. The injection thus prepared is preferably filled in an appropriate ampoule.

[0088] Advantageously, the pharmaceutical compositions for oral or parenteral use described above are prepared into dosage forms in a unit dose suited to fit a dose of the active ingredients. Such dosage forms in a unit dose include, for example, tablets, pills, capsules, injections (ampoules), suppositories, etc. The amount of the aforesaid antagonist molecule contained is generally about 5 to about 500 mg per dosage form in a unit dose; especially in the form of injection, it is preferred that the aforesaid antagonist molecule is contained in about 5 to about 100 mg and in about 10 to about 250 mg for the other dosage forms.

THERAPEUTIC USES OF THE IL-33 ANTAGONISTS

[0089] Experiments conducted by the present inventors have contributed to the identification of various diseases and conditions that can be treated, prevented and/or ameliorated by IL-33 antagonism. For example, hydrodynamic delivery of mouse IL-33 DNA resulted in the induction of lung mucus accumulation and increases in total serum IgE in mice. In addition, mIL-33 DNA delivery resulted in up-regulation of ST2 and various downstream cytokines as measured by microarray analysis. Experiments conducted by the present inventors using IL-33 knock-out mice also revealed various potential therapeutic benefits of IL-33 antagonism. For example, macroscopic scoring and skin infiltrates were found to be comparable between wild-type mice and IL-33$^{-/-}$ mice in a model of IMQ-induced psoriasis. Moreover, IL-33$^{-/-}$ mice showed reduced eosinophilia and residual mucus accumulation in an allergen-induced lung inflammation model.

The IL-33 antagonists of the invention are useful, *inter alia*, for the treatment, prevention and/or amelioration of any disease or disorder associated with or mediated by IL-33 expression, signaling, or activity, or treatable by blocking the interaction between IL-33 and a IL-33 ligand (*e.g.*, ST2) or otherwise inhibiting IL-33 activity and/or signaling. For example, the present invention provides methods for treating infectious diseases (*e.g.*, *Leishmania* infection, *Trichuris* infection, *Mycobacterium* infection, *Listeria* infection, *Toxoplasma* infection, *Schistosoma* infection, respiratory syncytial virus infection, influenza virus infection, etc.), asthma (*e.g.*, eosinophilic or non-eosinophilic asthma, steroid resistant or steroid sensitive asthma, allergic asthma, non-allergic asthma, severe refractory asthma, asthma exacerbations [*e.g.*, viral- or allergen-induced], etc.), atopic dermatitis, psoriasis, other inflammatory disorders, allergy, anaphylaxis, cardiovascular disease, central nervous system disease, pain, and arthritis (*e.g.*, rheumatoid arthritis, osteoarthritis, psoriatic arthritis, etc.), giant cell arteritis, inflammatory bowel disease (e.g Crohn's disease or ulcerative colitis), multiple sclerosis, allergic rhinitis, eosinophilic esophagitis vasculitis, and Henoch-schonlein purpura.The IL-33 antagonists of the present invention are also useful for the treatment, prevention and/or amelioration of one or more fibrotic diseases. Exemplary fibrotic diseases that are treatable by administering the IL-33 antagonists of the invention include pulmonary fibrosis (*e.g.*, idiopathic pulmonary fibrosis, bleomycin-induced pulmonary fibrosis, asbestos-induced pulmonary fibrosis, and bronchiolitis obliterans syndrome), chronic asthma, fibrosis associated with acute lung injury and acute respiratory distress (*e.g.*, allergen induced fibrosis, bacterial pneumonia induced fibrosis, trauma induced fibrosis, viral pneumonia induced fibrosis, ventilator induced fibrosis, non-pulmonary sepsis induced fibrosis and aspiration induced fibrosis), silicosis, radiation-induced fibrosis, chronic obstructive pulmonary disease (COPD, including COPD exacerbations, or COPD resulting from, or caused in part by first or second hand cigarette smoke. ocular fibrosis, skin fibrosis (*e.g.*, scleroderma), hepatic fibrosis (*e.g.*, cirrhosis, alcohol-induced liver fibrosis, non-alcoholic steatohepatitis (NASH), bilary duct injury, primary bilary cirrhosis, infection- or viral-induced liver fibrosis [*e.g.*, chronic HCV infection], autoimmune hepatitis), kidney (renal) fibrosis, cardiac fibrosis, atherosclerosis, stent restenosis, and myelofibrosis.

[0090] In the context of the methods of treatment described herein, the IL-33 antagonists may be administered as a monotherapy (*i.e.*, as the only therapeutic agent) or in combination with one or more additional therapeutic agents (examples of which are described elsewhere herein).

COMBINATION THERAPIES AND FORMULATIONS

[0091] The present invention includes compositions and therapeutic formulations comprising any of the IL-33 antagonists described herein in combination with one or more additional therapeutically active components, and methods of treatment comprising administering such combinations to subjects in need thereof. The IL-33 antagonists of the present invention may also be co-formulated with and/or administered in combination with, *e.g.*, cytokine inhibitors or

antagonists, including small-molecule cytokine inhibitors and antibodies that bind to cytokines such as IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, IL-8, IL-9, IL-11, IL-12, IL-13, IL-17, IL-18, IL-21, IL-22, IL-23, IL-25, IL-26, IL-31, an IL-4/IL-13 dual antagonist, an IL-12/IL-23 antagonist, a PDE4 inhibitor (in one embodiment, an oral PDE4 inhibitor), and another IL-33 antagonist or a different antibody to IL-33, thymic stromal lymphopoietin (TSLP), or antagonists of their respective receptors.

[0092] The IL-33 antagonists of the invention may also be administered and/or co-formulated in combination with antivirals, antibiotics, analgesics, corticosteroids, steroids, oxygen, antioxidants, metal chelators, IFN-gamma, and/or NSAIDs,a bronchial dilator, an antihistamine, epinephrine, or a decongestant.

[0093] The additional therapeutically active component(s) may be administered just prior to, concurrent with, or shortly after the administration of an IL-33 antagonist of the present invention; (for purposes of the present disclosure, such administration regimens are considered the administration of an IL-33 antagonist "in combination with" an additional therapeutically active component). The present invention includes pharmaceutical compositions in which an IL-33 antagonist of the present invention is co-formulated with one or more of the additional therapeutically active component(s) as described elsewhere herein.

ADMINISTRATION REGIMENS

[0094] According to certain embodiments of the present invention, multiple doses of an IL-33 antagonist (or a pharmaceutical composition comprising a combination of an IL-33 antagonist and any of the additional therapeutically active agents mentioned herein) may be administered to a subject over a defined time course. The methods according to this aspect of the invention comprise sequentially administering to a subject multiple doses of an IL-33 antagonist of the invention. As used herein, "sequentially administering" means that each dose of IL-33 antagonist is administered to the subject at a different point in time, *e.g.*, on different days separated by a predetermined interval (*e.g.*, hours, days, weeks or months). The present invention includes methods which comprise sequentially administering to the patient a single initial dose of an IL-33 antagonist, followed by one or more secondary doses of the IL-33 antagonist, and optionally followed by one or more tertiary doses of the IL-33 antagonist.

[0095] The terms "initial dose," "secondary doses," and "tertiary doses," refer to the temporal sequence of administration of the IL-33 antagonist of the invention. Thus, the "initial dose" is the dose which is administered at the beginning of the treatment regimen (also referred to as the "baseline dose"); the "secondary doses" are the doses which are administered after the initial dose; and the "tertiary doses" are the doses which are administered after the secondary doses. The initial, secondary, and tertiary doses may all contain the same amount of IL-33 antagonist, but generally may differ from one another in terms of frequency of administration. In certain embodiments, however, the amount of IL-33 antagonist contained in the initial,

secondary and/or tertiary doses varies from one another (*e.g.*, adjusted up or down as appropriate) during the course of treatment. In certain embodiments, two or more (*e.g.*, 2, 3, 4, or 5) doses are administered at the beginning of the treatment regimen as "loading doses" followed by subsequent doses that are administered on a less frequent basis (*e.g.*, "maintenance doses").

[0096] In certain exemplary embodiments of the present invention, each secondary and/or tertiary dose is administered 1 to 26 (*e.g.*, 1, 1½, 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 6½, 7, 7½, 8, 8½, 9, 9½, 10, 10½, 11, 11½, 12, 12½, 13, 13½, 14, 14½, 15, 15½, 16, 16½, 17, 17½, 18, 18½, 19, 19½, 20, 20½, 21, 21½, 22, 22½, 23, 23½, 24, 24½, 25, 25½, 26, 26½, or more) weeks after the immediately preceding dose. The phrase "the immediately preceding dose," as used herein, means, in a sequence of multiple administrations, the dose of IL-33 antagonist which is administered to a patient prior to the administration of the very next dose in the sequence with no intervening doses.

[0097] The methods according to this aspect of the invention may comprise administering to a patient any number of secondary and/or tertiary doses of an IL-33 antagonist. For example, in certain embodiments, only a single secondary dose is administered to the patient. In other embodiments, two or more (*e.g.*, 2, 3, 4, 5, 6, 7, 8, or more) secondary doses are administered to the patient. Likewise, in certain embodiments, only a single tertiary dose is administered to the patient. In other embodiments, two or more (*e.g.*, 2, 3, 4, 5, 6, 7, 8, or more) tertiary doses are administered to the patient.

[0098] In embodiments involving multiple secondary doses, each secondary dose may be administered at the same frequency as the other secondary doses. For example, each secondary dose may be administered to the patient 1 to 2 weeks or 1 to 2 months after the immediately preceding dose. Similarly, in embodiments involving multiple tertiary doses, each tertiary dose may be administered at the same frequency as the other tertiary doses. For example, each tertiary dose may be administered to the patient 2 to 12 weeks after the immediately preceding dose. In certain embodiments of the invention, the frequency at which the secondary and/or tertiary doses are administered to a patient can vary over the course of the treatment regimen. The frequency of administration may also be adjusted during the course of treatment by a physician depending on the needs of the individual patient following clinical examination.

[0099] The present invention includes administration regimens in which 2 to 6 loading doses are administered to a patient a first frequency (*e.g.*, once a week, once every two weeks, once every three weeks, once a month, once every two months, etc.), followed by administration of two or more maintenance doses to the patient on a less frequent basis. For example, according to this aspect of the invention, if the loading doses are administered at a frequency of once a month, then the maintenance doses may be administered to the patient once every six weeks, once every two months, once every three months, etc.).

EXAMPLES

[0100] The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the methods and compositions of the invention, and are not intended to limit the scope of what the inventors regard as their invention. Efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1. Construction of IL-33 Antagonists

[0101] Five different exemplary IL-33 antagonists of the invention were constructed using standard molecular biological techniques. The first IL-33 antagonist (hST2-hFc, SEQ ID NO:1) consists of the soluble extracellular region of human ST2 (SEQ ID NO:5) fused at its C-terminus to the N-terminus of a human IgG1 Fc region (SEQ ID NO:9). The second IL-33 antagonist (hST2-mFc, SEQ ID NO:2) consists of the soluble extracellular region of human ST2 (SEQ ID NO:5) fused at its C-terminus to the N-terminus of a mouse IgG2a Fc region (SEQ ID NO:10). The third IL-33 antagonist (hST2-hIL1RAcP-mFc, SEQ ID NO: 3) consists of an in-line fusion having human ST2 (SEQ ID NO:5) at its N-terminus, followed by the extracellular region of human IL-1RAcP (SEQ ID NO:7), followed by a mouse IgG2a Fc (SEQ ID NO:10) at its C-terminus. The fourth IL-33 antagonist (mST2-mIL1RAcP-mFc, SEQ ID NO: 4) consists of an in-line fusion having mouse ST2 (SEQ ID NO:6) at its N-terminus, followed by the extracellular region of mouse IL-1RAcP (SEQ ID NO:8), followed by a mouse IgG2a Fc (SEQ ID NO:10) at its C-terminus. The fifth IL-33 antagonist (hST2-hIL1RAcP-hFc, SEQ ID NO:13) consists of an in line fusion having human ST2 of SEQ ID NO: 5 at its N-terminus, followed by the extracellular region of human IL-1RAcP (SEQ ID NO: 7) followed by a human IgG1 Fc (SEQ ID NO: 9) at its C terminus. Table 1a sets forth a summary description of the different IL-33 antagonists and their component parts. Table 1b sets forth the amino acid sequences of the IL-33 antagonists and their component parts.

Table 1a: Summary of IL-33 Antagonists

IL-33 Antagonist	Amino Acid Sequence of Full Antagonist Molecule	D1 Component	D2 Component	M Component
hST2-hFc	SEQ ID NO:1	human ST2 extracellular (SEQ ID NO:5)	Absent	human IgG1 Fc (SEQ ID NO:9)
hST2-mFc	SEQ ID NO:2	human ST2 extracellular	Absent	mouse IgG2a Fc

		(SEQ ID NO:5)		(SEQ ID NO:10)
hST2-hIL1RAcP-mFc	SEQ ID NO:3	human ST2 extracellular (SEQ ID NO:5)	human IL-1RAcP extracellular (SEQ ID NO:7)	mouse IgG2a Fc (SEQ ID NO:10)
mST2-mIL1RAcP-mFc	SEQ ID NO:4	mouse ST2 extracellular (SEQ ID NO:6)	mouse IL-1RAcP extracellular (SEQ ID NO:8)	mouse IgG2a Fc (SEQ ID NO:10)
hST2-hIL1RAcP-hFc	SEQ ID NO: 13	human ST2 extracellular (SEQ ID NO:5)	human IL-1RAcP extracellular (SEQ ID NO:7)	human IgG1 Fc (SEQ ID NO:9)

Table 1b: Amino Acid Sequences

Identifier	Sequence
SEQ ID NO:1 (hST2-hFc)	KFSKQSWGLENEALIVRCPRQGKPSYTVDWYYSQTNKSIPTQERNRVFASGQL LKFLPAAVADSGIYTCIVRSPTFNRTGYANVTIYKKQSDCNVPDYLMYSTVSGSE KNSKIYCPTIDLYNWTAPLEWFKNCQALQGSRYRAHKSFLVIDNVMTEDAGDYT CKFIHNENGANYSVTATRSFTVKDEQGFSLFPVIGAPAQNEIKEVEIGKNANLTC SACFGKGTQFLAAVLWQLNGTKITDFGEPRIQQEEGQNQSFSNGLACLDMVLRI ADVKEEDLLLQYDCLALNLHGLRRHTVRLSRKNPIDHHSDKTHTCPPCPAPELL GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAK TKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQ PREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPP VLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK
SEQ ID NO:2 (hST2-mFc)	KFSKQSWGLENEALIVRCPRQGKPSYTVDWYYSQTNKSIPTQERNRVFASGQL LKFLPAAVADSGIYTCIVRSPTFNRTGYANVTIYKKQSDCNVPDYLMYSTVSGSE KNSKIYCPTIDLYNWTAPLEWFKNCQALQGSRYRAHKSFLVIDNVMTEDAGDYT CKFIHNENGANYSVTATRSFTVKDEQGFSLFPVIGAPAQNEIKEVEIGKNANLTC SACFGKGTQFLAAVLWQLNGTKITDFGEPRIQQEEGQNQSFSNGLACLDMVLRI ADVKEEDLLLQYDCLALNLHGLRRHTVRLSRKNPIDHHSEPRGPTIKPCPPCKCP APNLLGGPSVFIFPPKIKDVLMISLSPIVTCVVVDVSEDDPDVQISWFVNNVEVHT AQTQTHREDYNSTLRVVSALPIQHQDWMSGKEFKCKVNNKDLPAPIERTISKPK GSVRAPQVYVLPPPEEEMTKKQVTLTCMVTDFMPEDIYVEWTNNGKTELNYKN TEPVLDSDGSYFMYSKLRVEKKNWVERNSYSCSVVHEGLHNHHTTKSFSRTPG K
SEQ ID NO:3 (hST2-hIL1RAcP-mFc)	KFSKQSWGLENEALIVRCPRQGKPSYTVDWYYSQTNKSIPTQERNRVFASGQL LKFLPAAVADSGIYTCIVRSPTFNRTGYANVTIYKKQSDCNVPDYLMYSTVSGSE KNSKIYCPTIDLYNWTAPLEWFKNCQALQGSRYRAHKSFLVIDNVMTEDAGDYT CKFIHNENGANYSVTATRSFTVKDEQGFSLFPVIGAPAQNEIKEVEIGKNANLTC SACFGKGTQFLAAVLWQLNGTKITDFGEPRIQQEEGQNQSFSNGLACLDMVLRI ADVKEEDLLLQYDCLALNLHGLRRHTVRLSRKNPIDHHSSERCDDWGLDTMRQI QVFEDEPARIKCPLFEHFLKFNYSTAHSAGLTLIWYWTRQDRDLEEPINFRLPEN RISKEKDVLWFRPTLLNDTGNYTCMLRNTTYCSKVAFPLEVVQKDSCFNSPMKL PVHKLYIEYGIQRITCPNVDGYFPSSVKPTITWYMGCYKIQNFNNVIPEGMNLSFL IALISNNGNYTCVVTYPENGRTFHLTRTLTVKVVGSPKNAVPPVIHSPNDHVVYE KEPGEELLIPCTVYFSFLMDSRNEVWWTIDGKKPDDITIDVTINESISHSRTEDET RTQILSIKKVTSEDLKRSYVCHARSAKGEVAKAAKVKQKVPAPRYTVE**SG**EPRG PTIKPCPPCKCPAPNLLGGPSVFIFPPKIKDVLMISLSPIVTCVVVDVSEDDPDVQI SWFVNNVEVHTAQTQTHREDYNSTLRVVSALPIQHQDWMSGKEFKCKVNNKD LPAPIERTISKPKGSVRAPQVYVLPPPEEEMTKKQVTLTCMVTDFMPEDIYVEWT NNGKTELNYKNTEPVLDSDGSYFMYSKLRVEKKNWVERNSYSCSVVHEGLHN HHTTKSFSRTPGK
SEQ ID NO:4	SKSSWGLENEALIVRCPQRGRSTYPVEWYYSDTNESIPTQKRNRIFVSRDRLKF

Identifier	Sequence
(mST2-mIL1RAcP-mFc)	LPARVEDSGIYACVIRSPNLNKTGYLNVTIHKKPPSCNIPDYLMYSTVRGSDKNF KITCPTIDLYNWTAPVQWFKNCKALQEPRFRAHRSYLFIDNVTHDDEGDYTCQF THAENGTNYIVTATRSFTVEEKGFSMFPVITNPPYNHTMEVEIGKPASIACSACF GKGSHFLADVLWQINKTVVGNFGEARIQEEEGRNESSSNDMDCLTSVLRITGVT EKDLSLEYDCLALNLHGMIRHTIRLRRKQPIDHRSERCDDWGLDTMRQIQVFED EPARIKCPLFEHFLKYNYSTAHSSGLTLIWYWTRQDRDLEEPINFRLPENRISKEK DVLWFRPTLLNDTGNYTCMLRNTTYCSKVAFPLEVVQKDSCFNSAMRFPVHKM YIEHGIHKITCPNVDGYFPSSVKPSVTWYKGCTEIVDFHNVLPEGMNLSFFIPLVS NNGNYTCVVTYPENGRLFHLTRTVTVKVVGSPKDALPPQIYSPNDRVVYEKEPG EELVIPCKVYFSFIMDSHNEVWWTIDGKKPDDVTVDITINESVSYSSTEDETRTQI LSIKKVTPEDLRRNYVCHARNTKGEAEQAAKVKQKVIPPRYTVE**SG**EPRGPTIKP CPPCKCPAPNLLGGPSVFIFPPKIKDVLMISLSPIVTCVVVDVSEDDPDVQISWFV NNVEVHTAQTQTHREDYNSTLRVVSALPIQHQDWMSGKEFKCKVNNKDLPAPI ERTISKPKGSVRAPQVYVLPPPEEEMTKKQVTLTCMVTDFMPEDIYVEWTNNGK TELNYKNTEPVLDSDGSYFMYSKLRVEKKNWVERNSYSCSVVHEGLHNHHTTK SFSRTPGK
SEQ ID NO:5 (human ST2 extracellular domain)	KFSKQSWGLENEALIVRCPRQGKPSYTVDWYYSQTNKSIPTQERNRVFASGQL LKFLPAAVADSGIYTCIVRSPTFNRTGYANVTIYKKQSDCNVPDYLMYSTVSGSE KNSKIYCPTIDLYNWTAPLEWFKNCQALQGSRYRAHKSFLVIDNVMTEDAGDYT CKFIHNENGANYSVTATRSFTVKDEQGFSLFPVIGAPAQNEIKEVEIGKNANLTC SACFGKGTQFLAAVLWQLNGTKITDFGEPRIQQEEGQNQSFSNGLACLDMVLRI ADVKEEDLLLQYDCLALNLHGLRRHTVRLSRKNPIDHHS
SEQ ID NO:6 (mouse ST2 extracellular domain)	SKSSWGLENEALIVRCPQRGRSTYPVEWYYSDTNESIPTQKRNRIFVSRDRLKF LPARVEDSGIYACVIRSPNLNKTGYLNVTIHKKPPSCNIPDYLMYSTVRGSDKNF KITCPTIDLYNWTAPVQWFKNCKALQEPRFRAHRSYLFIDNVTHDDEGDYTCQF THAENGTNYIVTATRSFTVEEKGFSMFPVITNPPYNHTMEVEIGKPASIACSACF GKGSHFLADVLWQINKTVVGNFGEARIQEEEGRNESSSNDMDCLTSVLRITGVT EKDLSLEYDCLALNLHGMIRHTIRLRRKQPIDHR
SEQ ID NO:7 (human IL1RAcP extracellular domain)	SERCDDWGLDTMRQIQVFEDEPARIKCPLFEHFLKFNYSTAHSAGLTLIWYWTR QDRDLEEPINFRLPENRISKEKDVLWFRPTLLNDTGNYTCMLRNTTYCSKVAFPL EVVQKDSCFNSPMKLPVHKLYIEYGIQRITCPNVDGYFPSSVKPTITWYMGCYKI QNFNNVIPEGMNLSFLIALISNNGNYTCVVTYPENGRTFHLTRTLTVKVVGSPKN AVPPVIHSPNDHVVYEKEPGEELLIPCTVYFSFLMDSRNEVWWTIDGKKPDDITI DVTINESISHSRTEDETRTQILSIKKVTSEDLKRSYVCHARSAKGEVAKAAKVKQK VPAPRYTVE
SEQ ID NO:8 (mouse IL1RAcP extracellular domain)	SERCDDWGLDTMRQIQVFEDEPARIKCPLFEHFLKYNYSTAHSSGLTLIWYWTR QDRDLEEPINFRLPENRISKEKDVLWFRPTLLNDTGNYTCMLRNTTYCSKVAFPL EVVQKDSCFNSAMRFPVHKMYIEHGIHKITCPNVDGYFPSSVKPSVTWYKGCTE IVDFHNVLPEGMNLSFFIPLVSNNGNYTCVVTYPENGRLFHLTRTVTVKVVGSPK DALPPQIYSPNDRVVYEKEPGEELVIPCKVYFSFIMDSHNEVWWTIDGKKPDDV TVDITINESVSYSSTEDETRTQILSIKKVTPEDLRRNYVCHARNTKGEAEQAAKVK QKVIPPRYTVE
SEQ ID NO:9 (human IgG1 Fc)	DKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVK FNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNK ALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEW ESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALH NHYTQKSLSLSPGK
SEQ ID NO:10 (mouse IgG2a Fc)	EPRGPTIKPCPPCKCPAPNLLGGPSVFIFPPKIKDVLMISLSPIVTCVVVDVSEDD PDVQISWFVNNVEVHTAQTQTHREDYNSTLRVVSALPIQHQDWMSGKEFKCKV NNKDLPAPIERTISKPKGSVRAPQVYVLPPPEEEMTKKQVTLTCMVTDFMPEDIY VEWTNNGKTELNYKNTEPVLDSDGSYFMYSKLRVEKKNWVERNSYSCSVVHE GLHNHHTTKSFSRTPGK
SEQ ID NO:11 (*M. fascicularis*	SITGISPITESLASLSTYNDQSITFALEDESYEIYVEDLKKDKKKDKVLLSYYESQH PSSESGDGVDGKMLMVTLSPTKDFWLQANNKEHSVELHKCEKPLPDQAFFVLH

Identifier	Sequence
IL-33-6His)	NRSFNCVSFECKTDPGVFIGVKDNHLALIKVDYSENLGSENILFKLSEILEHHHHH H
SEQ ID NO:13 (hST2-hIL1RAcP-hFc)	KFSKQSWGLENEALIVRCPRQGKPSYTVDWYYSQTNKSIPTQERNRVFA SGQLLKFLPAAVADSGIYTCIVRSPTFNRTGYANVTIYKKQSDCNVPDYL MYSTVSGSEKNSKIYCPTIDLYNWTAPLEWFKNCQALQGSRYRAHKSFL VIDNVMTEDAGDYTCKFIHNENGANYSVTATRSFTVKDEQGFSLFPVIGA PAQNEIKEVEIGKNANLTCSACFGKGTQFLAAVLWQLNGTKITDFGEPRI QQEEGQNQSFSNGLACLDMVLRIADVKEEDLLLQYDCLALNLHGLRRHT VRLSRKNPIDHHSSERCDDWGLDTMRQIQVFEDEPARIKCPLFEHFLKFN YSTAHSAGLTLIWYWTRQDRDLEEPINFRLPENRISKEKDVLWFRPTLLN DTGNYTCMLRNTTYCSKVAFPLEVVQKDSCFNSPMKLPVHKLYIEYGIQR ITCPNVDGYFPSSVKPTITWYMGCYKIQNFNNVIPEGMNLSFLIALISNNG NYTCVVTYPENGRTFHLTRTLTVKVVGSPKNAVPPVIHSPNDHVVYEKEP GEELLIPCTVYFSFLMDSRNEVWWTIDGKKPDDITIDVTINESISHSRTEDE TRTQILSIKKVTSEDLKRSYVCHARSAKGEVAKAAKVKQKVPAPRYTVED KTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDP EVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEY KCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVK GFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSKLTVDKSRWQQ GNVFSCSVMHEALHNHYTQKSLSLSPGK

[0102] Certain biological properties of the exemplary IL-33 antagonists generated in accordance with this Example are described in detail in the Examples set forth below.

Example 2. Binding of IL-33 Antagonists to Human, Mouse and Monkey IL-33 as Determined by Surface Plasmon Resonance

[0103] Equilibrium dissociation constants (K_D values) for human IL-33 (R&D Systems, # 3625-IL-010/CF), mouse IL-33 (R&D Systems, # 3626-ML-010/CF) and monkey IL-33 expressed with C-terminal hexahistidine tag (MfIL-33-6His; SEQ ID NO:12) binding to purified IL-33 Trap proteins and ST2 receptor proteins were determined using a real-time surface plasmon resonance biosensor using Biacore T-200 instrument at 25°C and/or at 37°C. The Biacore sensor surface was first derivatized by amine coupling a polyclonal rabbit anti-mouse antibody (GE, # BR-1008-38) or with a monoclonal mouse anti-human Fc antibody (GE, # BR-1008-39) to capture IL-33 Trap and receptor proteins with a C-terminal mouse IgG2a Fc tag or a C-terminal human IgG1 Fc tag, respectively. Kinetic experiments were carried out in 0.01 M HEPES pH 7.4, 0.15 M NaCl, 3 mM EDTA, and 0.005% v/v Surfactant Tween-20 (HBST running buffer). Different concentrations of human IL-33, mouse IL-33 or MfIL-33-6His prepared in HBST running buffer (ranging from 60nM to 27.4pM, 3-fold dilutions, for Trap proteins and ranging from 60nM to 0.25nM, 3-fold dilutions, for ST2 receptor proteins) were injected over the captured IL-33 Trap and receptor protein surfaces at a flow rate of 50μL/minute.

Association of different IL-33 proteins to the different capture surfaces was monitored for 7 minutes for Trap proteins or 4 minutes for ST2 receptor proteins and their dissociation in HBST running buffer was monitored for 14 minutes for Trap proteins or 8 minutes for ST2 receptor proteins. Kinetic association (k_a) and dissociation (k_d) rate constants were determined by fitting the real-time binding sensorgrams to a 1:1 binding model using Scrubber 2.0c curve-fitting software. Binding dissociation equilibrium constants (K_D) and dissociative half-lives (t½) were calculated from the kinetic rate constants as:

[0104] K_D (M) = k_d/k_a and $t_{1/2}$ (min) = ln(2)/(60*k_d)

[0105] The kinetic parameters for the IL-33 Trap proteins binding to human, monkey and mouse IL-33 at 25°C and 37°C are shown in Tables 2 through 7, while the binding kinetics for the ST2 receptor proteins binding to human and mouse IL-33 at 25°C are shown in Tables 2 and 6. As shown in Table 2, the IL-33 Trap and receptor proteins bound human IL-33 with K_D values ranging from approximately 0.53pM to 54pM at 25°C. As shown in Table 3, the IL-33 Trap proteins bound human IL-33 with K_D values ranging from approximately 0.569pM to 353pM at 37°C. As shown in Table 4, the IL-33 Trap proteins bound MfIL-33-6HIs with K_D values ranging from approximately 0.596pM to 53.5pM at 25°C. As shown in Table 5, the IL-33 Trap proteins bound MfIL-33-6HIs with K_D values ranging from approximately 0.551pM to 190pM at 37°C. As shown in Table 6, the IL-33 Trap and receptor proteins bound mouse IL-33 with K_D values ranging from approximately 6.1pM to 102pM at 25°C. As shown in Table 7, the IL-33 Trap proteins bound mouse IL-33 with K_D values ranging from approximately 2.78pM to 93.3pM at 37°C.

Table 2: Binding kinetic parameters of human IL-33 binding to human IL-33 Trap, mouse IL-33 Trap, and human ST2 receptor proteins at 25°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Human IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	276 ± 0.7	19	1.89E+07	1.00E-05*	5.30E-13*	1155*
hST2-hIL1RAcP-mFc	256 ± 2.9	28	1.92E+07	6.32E-05	3.29E-12	183
mST2-mIL1RAcP-	233 ± 3.0	22	1.82E+07	1.29E-03	7.09E-11	9

mFc						
hST2-hFc	230 ± 7.7	25	5.90E+06	3.20E-04	5.40E-11	36
hST2-mFc	255 ± 6.6	24	5.72E+06	3.07E-04	5.36E-11	38

*Under the experimental conditions, no dissociation of IL-33 from the captured monoclonal antibody was observed; therefore, the value of k_d was fixed to 1.00E-05, and the derived $t_{1/2}$ and K_D values represent lower and upper limits, respectively.

Table 3: Binding kinetics parameters of human IL-33 binding to human and mouse IL-33 Trap at 37°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Human IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	339 ± 10.7	26	1.76E+07	1.00E-05*	5.69E-13*	1155*
hST2-hIL1RAcP-mFc	258 ± 4.3	28	1.82E+07	2.02E-05	1.11E-12	573
mST2-mIL1RAcP-mFc	222 ± 5.2	20	9.11E+06	3.22E-03	3.53E-10	4

*Under the experimental conditions, no dissociation of IL-33 from the captured monoclonal antibody was observed; therefore, the value of k_d was fixed to 1.00E-05, and the derived $t_{1/2}$ and K_D values represent lower and upper limits, respectively.

Table 4: Binding kinetic parameters of monkey IL-33 binding to human and mouse IL-33 Trap at 25°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Monkey IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	274 ± 0.9	20	1.68E+07	1.00E-05*	5.96E-13*	1155*
hST2-hIL1RAcP-mFc	247 ± 4.1	28	1.31E+07	4.09E-05	3.13E-12	282
mST2-mIL1RAcP-mFc	225 ± 3.6	23	4.55E+06	2.44E-04	5.35E-11	47

*Under the experimental conditions, no dissociation of IL-33 from the captured monoclonal antibody was observed; therefore, the value of k_d was fixed to 1.00E-05, and the derived $t_{1/2}$ and K_D values represent lower and upper limits, respectively.

Table 5: Binding kinetic parameters of monkey IL-33 binding to human and mouse IL-33 Trap at 37°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Monkey IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	308 ± 8.2	25	1.82E+07	1.00E-05*	5.51E-13*	1155*
hST2-hIL1RAcP-mFc	247 ± 3	27	1.45E+07	4.79E-05	3.29E-12	241
mST2-mIL1RAcP-mFc	209 ± 3.1	21	6.16E+06	1.17E-03	1.90E-10	10

*Under the experimental conditions, no dissociation of IL-33 from the captured monoclonal antibody was observed; therefore, the value of k_d was fixed to 1.00E-05, and the derived $t_{1/2}$ and K_D values represent lower and upper limits, respectively.

Table 6: Binding kinetic parameters of mouse IL-33 binding to human IL-33 Trap, mouse IL-33 Trap, and human ST2 receptor proteins at 25°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Mouse IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	272 ± 0.9	17	3.66E+06	2.23E-05	6.10E-12	517
hST2-hIL1RAcP-mFc	237 ± 2.7	22	4.67E+06	8.97E-05	1.92E-11	129
mST2-mIL1RAcP-mFc	217 ± 1.9	22	4.73E+06	4.94E-05	1.05E-11	234
hST2-hFc	211 ± 4.4	18	4.10E+06	4.23E-04	1.02E-10	27
hST2-mFc	238 ± 4.1	18	3.97E+06	3.50E-04	8.82E-11	33

Table 7: Binding kinetic parameters of mouse IL-33 binding to human and mouse IL-33 Trap at 37°C.

Captured Analyte	Amount of Analyte Captured (RU)	60nM Mouse IL-33 Bound (RU)	k_a (1/Ms)	k_d (1/s)	K_D (M)	$t_{½}$ (min)
hST2-hIL1RAcP-hFc	280 ± 7.7	18	3.60E+06	1.00E-05*	2.78E-12*	1155*

hST2-hIL1RAcP-mFc	236 ± 3.2	21	3.39E+06	3.17E-04	9.33E-11	36
mST2-mIL1RAcP-mFc	199 ± 2.8	20	6.00E+06	1.28E-04	2.13E-11	90

*Under the experimental conditions, no dissociation of IL-33 from the captured monoclonal antibody was observed; therefore, the value of k_d was fixed to 1.00E-05, and the derived $t_{1/2}$ and K_D values represent lower and upper limits, respectively.

Example 3. IL-33 Antagonists Block Binding of IL-33 to the Human ST2 Receptor

[0106] The ability of exemplary IL-33 antagonists of the invention to block human IL-33 (hIL-33) binding to the human ST2 receptor was measured using a competition sandwich ELISA. A portion of human ST2 protein ecto domain that was expressed with a C-terminal mouse Fc tag (SEQ ID NO:2) was coated at a concentration of 1 µg/mL in PBS buffer on a 96-well microtiter plate overnight at 4°C. Nonspecific binding sites were subsequently blocked with a 0.5% (w/v) BSA solution in PBS. Biotinylated hIL-33 protein (R&D systems, #3625-IL/CF) (biot-hIL-33) was added to achieve a constant final concentration of 20 pM to serial dilutions of IL-33 antagonists ranging from 0 to 100 nM. The mixture was incubated for 1 hour at room temperature (RT) before transfer to the hST2-hFc coated microtiter plates. After incubation for 1 hour at RT, the wells were then washed, and plate-bound biot-hIL-33 was detected with HRP-conjugated streptavidin (Thermo Scientific, # N200). All samples were developed with a TMB solution (BD biosciences, # 51-2607KC) to produce a colorimetric reaction and then quenched by acidification with 1M sulfuric acid before measuring absorbance at 450 nm on a Victor X5 plate reader (PerkinElmer). Data analysis was performed using a sigmoidal dose-response model within Prism™ software. The calculated IC_{50} value, defined as the concentration of antagonist molecule required to block 50% of biot-hIL-33 binding to hST2-mFc, was used as an indicator of blocking potency. Maximum blocking values represent the ability of the antagonists to block IL-33 binding relative to baseline. The absorbance measured at the constant amount of hIL-33 on the dose curve was defined as 0% blocking and the absorbance with no added IL-33 was defined as 100% blocking. The absorbance values of the wells containing the highest concentration tested for each antagonist were used to determine the maximum blocking percent.

Table 8: ELISA Blocking of Biotin-hIL-33 to hST2-hFc by IL-33 Antagonists

IL-33 Antagonist	Blocking 20pM biotin-hIL-33 on hST2-hFc, IC_{50} (M)	% Maximum blocking
hST2-hFc	1.92E-11	99
hST2-mFc	1.69E-11	100
hST2-hIL1RAcP-mFc	6.34E-12	97

mST2-mIL1RAcP-mFc	1.12E-10	97

[0107] The four IL-33 antagonists tested blocked biotin-hIL-33 binding to hST2-mFc with IC_{50} values ranging from 112 pM to 6.34 pM with maximum blocking percent ranging from 97% to 100%, as shown in Table 8.

Example 4. Inhibition of IL-33-Mediated Receptor Signaling by IL-33 Antagonists

[0108] Interleukin-33 (IL-33) is a ligand for ST2, a toll-like/interleukin-1 receptor super-family member that associates with an accessory protein, IL-1RAcP (for review, see Kakkar and Lee, (2008), Nat Rev Drug Discovery, Oct; 7(10): 827-840). Upon activation of ST2/IL-1RAcP by IL-33, a signaling cascade is triggered through downstream molecules such as MyD88 (myeloid differentiation factor 88) and TRAF6 (TNF receptor associated factor 6), leading to activation of NFκB (nuclear factor –κB) among others. To develop a biologically relevant bioassay system to test IL-33 antagonists, human embryonic kidney cells (HEK293) were stably transfected to express human ST2 (amino acids 1-556 of accession number NP_057316) along with a luciferase reporter [NF□B response element (5x)-luciferase-IRES-GFP] (HEK293/hST2/NFkB-luciferase cell line). The HEK293 cell line expresses IL-1RAcP endogenously, and NFκB activation by IL-33 in HEK293 cells has been shown previously (Schmitz *et al.*, (2005), Immunity 23:479-490). The stable cell line was isolated and maintained in 10% FBS, DMEM, NEAA, penicillin/streptomycin, and G418.

[0109] For the bioassay, HEK293/hST2/ NFκB-luciferase cells were seeded onto 96-well assay plates at 10,000 cells per well in low serum media containing 0.1%FBS and OPTIMEM (Invitrogen, #31985-070) and then incubated at 37°C in 5% CO_2 overnight. The next day, to determine the dose response of IL-33, either human IL-33 (hIL-33; R&D Systems, #3625-IL), cynomolgus monkey IL-33 expressed with a C-terminal hexahistidine tag (MfIL-33-6His; SEQ ID:11), or mouse IL33 (mIL-33; R&D Systems, #3626-IL) were serially diluted at 1:3 (hIL33: 15nM – 0.3pM or 10nM – 0.2pM, mfIL33: 1.5nM – 0.03pM or 1nM – 0.05pM , mIL33: 15nM – 0.3pM or 10nM – 0.2pM) and added to the cells. A control containing dilution buffer but no IL-33 was also added to one sample of cells. To measure inhibition, IL-33 Trap and soluble receptor proteins were serially diluted and added to the cells followed by addition of constant concentrations of IL-33 (5pM or 20pM for hIL-33, 5pM or 3pM for MfIL-33-6His and 30pM for mIL-33). The dilution series of the soluble receptor and Traps before adding to cells was 1:3, starting at ~15, 150, 100, or 200nM and ranging down to ~0.3, 3, or 2pM, plus a control sample containing no Trap or soluble receptor protein control. A human Fc protein (Control Protein) was also serially diluted at 1:3 ranging from 798nM to 0.01nM or 100nM to 0.002nM and tested with hIL-33, MfIL-33-6His, and mIL-33 in the same manner as the Trap and receptor proteins. Luciferase activity was measured after 5.5 hours of incubation at 37°C in 5% CO_2 using a Victor X (Perkin Elmer) plate reader, and the results were analyzed using nonlinear regression (4-

parameter logistics) with Prism 5 software. Results are shown in Table 9.

Table 9: Inhibition of human IL-33, monkey IL-33, and mouse IL-33 activation of HEK293/hST2/NFkB-luciferase cells by IL-33 Trap proteins and soluble human ST2 receptor

IL-33	Human	Monkey	Mouse	Human	Monkey	Mouse
EC_{50} (M)	1.9E-12	1.7E-12	1.0E-11	2.5E-11	1.3E-12	8.8E-11
Constant IL33	5pM	5pM	30pM	20pM	3pM	30pM
Description	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)
mST2-mIL1RAcP-mFc	4.8E-10	6.4E-11	8.7E-12	Not Tested	Not Tested	Not Tested
hST2-hIL1RAcP-mFc	1.3E-12	1.3E-12	1.3E-11	1.3E-11	4.7E-11	1.9E-10
hST2-hIL1RAcP-hFc	Not Tested	Not Tested	Not Tested	3.0E-11	1.0E-10	3.7E-10
hST2-mFc	1.2E-11	5.5E-12	1.4E-10	Not Tested	Not Tested	Not Tested
hST2-hFc	1.0E-11	4.6E-12	1.1E-10	Not Tested	Not Tested	Not Tested
Control Protein	NB	NB	NB	NB	NB	NB

NB=non-blocker

[0110] As shown in Table 9, all five of the tested IL-33 antagonists potently blocked (IC_{50} < 1nM) stimulation of human, cynomolgus monkey, and mouse IL-33 in this cell-based assay.

Example 5. An IL-33 Antagonist Inhibits IL-33-Mediated Basophil Activation

[0111] To further assess the *in vitro* characteristics of the IL-33 antagonists hST2-hIL1RAcP-mFc and hST2-hIL1RAcP-hFc, their ability to block IL-33-induced basophil activation was measured.

[0112] Peripheral blood mononuclear cells (PBMC) were purified from fresh whole blood from four different human donors by density gradient centrifugation. K2 EDTA whole blood was diluted 1:1 in RPMI 1640, carefully layered over Ficoll-Paque (GE Healthcare, # 17-1440-03) and centrifuged to separate PBMC. The interphase layer containing the PBMC was aspirated, transferred to a new tube, and washed twice with MACS buffer that was comprised of a 1:20 dilution of the MACS BSA solution (Militenyi Biotec, #130-091-376) in MACS rinsing solution (Militenyi Biotec, #130-091-222). The purified PBMC were then plated (100 µL per well) in a v-bottom, polypropylene 96-well plate at a final concentration of ~$3.0x10^6$ cells/mL in MACS buffer. To prime the basophils contained within the PBMC population, 1 ng of IL-3 (Sigma, # H7166-10UG) in 50 µL Dulbecco's Phosphate-Buffered Saline without Ca^{++} or Mg^{++} (DPBS) was

added to the cell suspension, and then incubated at 37°C for 10 minutes. Serial dilutions (1:3 for donors 655675 and 655676 and 1:4 for donors 655685, 655686, 698846 and 698847) of the human IL-33 antagonists (hST2-hIL1RAcP-mFc or hST2-hIL1RAcP-hFc) or an irrelevant control protein were made, ranging from 10 nM to 4.6 pM for donors 655675 and 655676 and from 5 nM to 0.3 pM for donors 655685, 655686, 698846 and 698847. Additionally, a control with no IL-33 antagonist or irrelevant control protein was included. The solutions were mixed with a fixed concentration of 100 pM (final concentration) of human IL-33 (R&D Systems, # 6325-IL/CF) or no IL-33 negative control prior to adding to the PBMC. All samples were tested in duplicate.

[0113] After addition of the human IL-33 and the human IL-33 antagonist to the cells, they were incubated at 37°C for 20 minutes to facilitate basophil activation. Activation was then stopped by cooling the assay plates on wet ice for 5 minutes. To enable analysis of the basophil population used to measure activation, 20 µL each (as per the manufacturer's instructions) of anti-HLA-DR-FITC (Beckman Coulter, # IM0463U), anti-CD123-APC (BD, # 560087), and anti-CD203c-PE (Beckman Coulter, # IM3575) were added to each sample, and the samples were held at 4°C for 20 minutes in the dark. The cells were then centrifuged, washed with DPBS, and then resuspended in 2% formaldehyde (fixation buffer) at 4°C. The next day, fixed cells were analyzed on a BD FACSCanto II to determine levels of basophil activation. Basophils are identified according the following flow cytometric parameters: lymphocyte gate/$CD123^{+}$/$HLA\text{-}DR2^{-}$. Basophil activation is defined as an increase in the cell surface expression marker, CD203c on stimulated basophils. Activation is defined as frequency of CD203c positive basophils (%). Results are summarized in Tables 10 and 11 ("NB" = non-blocking; "ND" = not determined in the individual experiments). Data are shown as mean of 3 biological replicates for each donor.

Table 10. Percent Activation of Human Basophils Induced by Human IL-33 Challenge

Donor	100pM IL-33		No IL-33	
	Mean	SD	Mean	SD
655675	39.00	0.28	9.43	0.02
655676	29.75	0.21	9.36	2.18
655685	42.30	3.39	10.9	0.42
655686	52.60	2.69	10.59	0.86
698846	26.25	0.78	9.79	0.18
698847	22.10	1.98	8.83	0.44

Table 11. Blocking of IL-33 Induced Activation of Human Basophil by IL-33 Antagonist

	Donor 655675	Donor 655676	Donor 655685	Donor 655686	Donor 698846	Donor 698847
Antagonist	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)
hST2-hIL1RAcP-mFc	1.90E-11	1.51E-11	2.30E-11	2.09E-11	3.60E-11	1.11E-11
hST2-hIL1RAcP-hFc	ND	ND	ND	ND	1.97E-11	9.79E-12
Irrelevant control protein	NB	NB	NB	NB	NB	NB

[0114] As shown in Table 10, at 100 pM, human IL-33 induced basophil activation in six different donors with a mean percent activation ranging from 22.1% to 52.60%.

[0115] As shown in Table 11, the IL-33 antagonist hST2-hIL1RAcP-mFc blocked basophil activation induced by 100 pM human IL-33 challenge with an IC_{50} value of 19 pM for donor 655675, an IC_{50} value of 15.1 pM for donor 655676, an IC_{50} value of 23 pM for donor 655685, an IC_{50} value of 20.9 pM for donor 655686, an IC_{50} value of 36 pM for donor 698846 and an IC_{50} value of 11.1 pM for donor 698847. The IL-33 antagonist hST2-hIL1RAcP-hFc blocked basophil activation induced by 100 pM human IL-33 challenge with an IC_{50} value of 19.7 pM for donor 698846 and an IC_{50} value of 9.79 pM for donor 698847. The irrelevant control protein did not block basophil activation from any of the tested donors.

Example 6. An IL-33 Antagonist Inhibits IL-33-Mediated Cell Activation

[0116] To further test the blocking properties of the human IL-33 antagonists hST2-hIL1RAcP-mFc and hST2-hIL1RAcP-hFc, a primary cell based assay using peripheral blood mononuclear cells (PBMCs) was used (*see, e.g.*., Smithgall *et al., International Immunology*, 2008, vol. 20 (8) pp. 1019-1030).

[0117] PBMCs were purified from fresh whole human blood from six different donors by density gradient centrifugation. Briefly, K2 EDTA whole blood was diluted two-fold in RPMI 1640, carefully layered over Ficoll-Paque (GE Healthcare, #17-1440-03) and centrifuged for 20 minutes. The interphase layer containing the PBMCs was aspirated, transferred to a new tube, and washed twice with PBS. The isolated PBMCs were plated (200 µL per well) in round-bottom 96-well plates at a final concentration of $5x10^5$ cells/mL in RPMI 1640 supplemented with 10% FBS, 2 mM L-glutamine, 100 U/mL penicillin, and 100 µg/mL streptomycin. Cells were then incubated with 50 ng/mL of human IL-12 (hIL-12; R&D Systems, #219-IL-025/CF) and a serial dilution of human IL-33 (hIL-33; R&D Systems, #3625-IL-010/CF) alone from 10 nM to 0.64 pM, or with 260 pM of hIL-33 in combination with serial dilutions from 20 nM to 0.43 pM of human IL-33 antagonist or an irrelevant mIgG containing control protein. The final volume was 200 µL per well. Each sample was tested in triplicate. When the IL-33 antagonist or irrelevant mIgG containing control protein was present, it was first pre-incubated with hIL-33 for 30 minutes and then added to the cells.

[0118] The cells were incubated overnight at 37°C in a humidified incubator with 5% CO_2, and then IFNγ levels in the culture supernatant were measured by ELISA (R&D Systems, #DY285). For the ELISA, 96-well flat-bottom plates were coated with the capture antibody, according to the manufacturer's instructions. After washing and blocking, 100 µL of undiluted culture supernatant was added to the plates and incubated for 2 hours. Subsequent washes and detection were done following the manufacturer's instructions. Results are summarized in Tables 12 and 13 ("NB" = non-blocking, "ND" = not determined).

Table 12: IL-33 Induced IFNγ Release From Human PBMC from four Donors.

[IL-33]	Donor 698843	Donor 698842	Donor 655684	Donor 634966	Donor 655681	Donor 655682	Donor 727054	Donor 727055
EC_{50} (M)	ND	ND	2.11E-10	3.15E-10	2.04E-10	3.04E-10	ND	ND

Table 13: Blocking of IL-33 Induced IFN-γ Release from Human PBMC by IL-33 Antagonist

	Donor 698843	Donor 698842	Donor 655684	Donor 634966	Donor 655681	Donor 655682	Donor 727054	Donor 727055
Antagonist	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)	IC_{50} (M)
hST2-hIL1RAcP-mFc	1.73E-11	7.39E-11	6.79E-11	2.13E-12	4.59E-11	3.97E-12	3.34E-10	1.23E-10
hST2-hIL1RAcP-hFc	ND	ND	ND	ND	ND	ND	1.52E-10	4.07E-10
Irrelevant mIgG containing control protein	NB	NB	NB	NB	NB	NB	NB	NB

[0119] As shown in this Example, Human IL-33, in the presence of hIL-12, induced the release of IFNγ from human total PBMC from the four different donors tested, with EC_{50} values between 204 pM to 315 pM as shown in Table 12. The human IL-33 antagonist hST2-hIL1RAcP-mFc blocked the release of IFNγ from human PBMC induced by 260 pM IL-33, with IC_{50} values ranging from 2.13 pM to 334 pM, as shown in Table 13. The irrelevant mIgG containing control protein did not demonstrate any measurable blockade of IFNγ release in any of the donors tested.

Example 7. Efficacy of mST2-mIL1RacP-mFc in a Model of Inflammatory Joint Pain

[0120] To determine the effect of mST2-mIL1RacP-mFc in a relevant *in vivo* model a unilateral inflammatory joint pain model was conducted in 12 week old, male C57BL/6 mice obtained from The Jackson Laboratory (Bar Harbor, ME). On day 0 of the experiment, separate cohorts of mice were subcutaneously administered either 50 mg/kg of mST2-mIL1RacP-mFc (n=15-16) or 50 mg/kg of an isotype control antibody (n=15-16). Twenty-four

hours after the initial treatment dosing, half of the mice received a 30µL intrarticular and a 50µL periarticular injection of Complete Freund's Adjuvant (IA-CFA; Sigma, # F5881) (n=7-8) and the other half of the mice received control saline injections in the same locations (n=7-8). One week after the initiation of joint inflammation and continuing for the following four weeks, all mice received subcutaneous boost injections of 50 mg/kg of mST2-mIL1RacP-mFc or 50 mg/kg of an isotype control antibody 24 hours prior to testing in a dynamic weight-bearing assay (BioSeb, Vitrolles, FR). The percent of weight borne on the affected limb and the percent of time spent on the affected limb were recorded from all mice. The results of this experiment, expressed as the average percent of the total body weight or average percent time spent on the affected limb over the test period of 5 minutes, are shown in Table 14 and Table 15 (all data are represented as group mean ± SEM). The cohorts of mice that received IA-CFA all displayed significantly less ($p<0.05$ by ANOVA) weight bearing on the affected limb. The mice that received mST2-mIL1RacP-mFc after IA-CFA administration demonstrated higher percent weight bearing and time spent on affected limb scores at all time points tested compared to the isotype control treated mice after IA-CFA administration as shown in Tables 14 and 15.

[0121] Following week four, all animals were euthanized and the affected joints were dissected, paraffin embedded, sectioned, and stained with hemotoxylin and eosin for histological analysis. Sections were digitized and scored in a blinded manner using a subjective rating scale of inflammatory activity (including joint destruction, synovial thickening, bone erosion, and immune cell infiltrate) graded from 0 – 5 (0=normal, 1=minimal, 2=mild, 3=moderate, 4= marked, 5=severe) following a method similar to that outlined in Choe *et. al.* (Choe, JY *et. al.*, (2003), J. Exp. Med. Feb 17; 197(4):537-542). As shown in Table 16, mice treated with mST2-mIL1RacP-mFc after IA-CFA administration demonstrated more "moderate" and less "severe" knee joints compared to the isotype control treated mice after IA-CFA administration. This example therefore indicates that the IL-33 antagonists of the invention are useful in alleviating inflammatory joint pain.

Table 14: Percent of body weight borne on affected limb

Treatment	Week 1	Week 2	Week 3	Week 4
Saline Control + Isotype control	43.1 ± 1.6	42.2 ± 1.0	41.1 ± 1.7	41.1 ± 0.9
Saline Control + mST2-mIL1RacP-mFc	41.5 ± 1.9	43.3 ± 0.6	42.2 ± 1.2	38.7 ± 1.4
IA-CFA + Isotype control	24.9 ± 1.4	24.2 ± 1.5	23.8 ± 1.0	23.6 ± 2.0
IA-CFA + mST2-mIL1RacP-mFc	30.1 ± 2.1	24.4 ± 1.0	28.3 ± 2.6	29.8 ± 2.9

Table 15: Percent of time spent on affected limb

Treatment	Week 1	Week 2	Week 3	Week 4
Saline Control + Isotype control	96.6 ± 1.0	96.6 ± 0.6	96.2 ± 0.9	96.4 ± 0.6
Saline Control + mST2-mIL1RacP-mFc	95.5 ± 0.8	97.2 ± 0.3	94.3 ± 1.7	97.0 ± 0.5
IA-CFA + Isotype control	68.4 ± 1.6	64.8 ± 2.1	72.8 ± 3.5	80.9 ± 2.7
IA-CFA + mST2-mIL1RacP-mFc	78.9 ± 3.6	68.5 ± 3.1	80.9 ± 4.2	88.0 ± 2.7

Table 16: Histological severity scores for affected knee joints (% of animals)

Treatment	Minimal	Mild	Moderate	Severe
IA-CFA + Isotype control	0	0	12%	88%
IA-CFA + mST2-mIL1RacP-mFc	0	0	38%	62%

[0122] The present invention is not to be limited in scope by the specific embodiments described herein. Indeed, various modifications of the invention in addition to those described herein will become apparent to those skilled in the art from the foregoing description and the accompanying figures. Such modifications are intended to fall within the scope of the appended claims

CLAIMS:

1. An IL-33 antagonist comprising a first IL-33 binding domain (D1), a second IL-33 binding domain (D2), and a multimerizing domain (M), wherein D1 comprises an extracellular portion of a human ST2 protein, D2 comprises an extracellular portion of a human IL-1RAcP protein, and M comprises an Fc portion of an immunoglobulin, and wherein:

(i) D2 is attached to the N-terminus of D1, and D1 is attached to the N-terminus of M;

(ii) D1 is attached to the N-terminus of M, and D2 is attached to the C-terminus of M;

(iii) D1 is attached to the C-terminus of M, and D2 is attached to the C-terminus of D1;

(iv) D2 is attached to the N-terminus of M, and D1 is attached to the C-terminus of M;

(v) D2 is attached to the C-terminus of M, and D1 is attached to the C-terminus of D2; or

(vi) D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M.

2. The IL-33 antagonist of claim 1, wherein D2 is attached to the N-terminus of D1, and D1 is attached to the N-terminus of M.

3. The IL-33 antagonist of claim 1, wherein D1 is attached to the N-terminus of M, and D2 is attached to the C-terminus of M.

4. The IL-33 antagonist of claim 1, wherein D1 is attached to the C-terminus of M, and D2 is attached to the C-terminus of D1.

5. The IL-33 antagonist of claim 1, wherein D2 is attached to the N-terminus of M, and D1 is attached to the C-terminus of M.

6. The IL-33 antagonist of claim 1, wherein D2 is attached to the C-terminus of M, and D1 is attached to the C-terminus of D2.

Date Reçue/Date Received 2020-05-20

7. The IL-33 antagonist of claim 1, wherein D1 is attached to the N-terminus of D2, and D2 is attached to the N-terminus of M.

8. The IL-33 antagonist of any one of claims 1 to 7, wherein D1 comprises the amino acid sequence of SEQ ID NO: 5.

9. The IL-33 antagonist of any one of claims 1 to 7, wherein D2 comprises the amino acid sequence of SEQ ID NO: 7.

10. The IL-33 antagonist of claim 1, comprising the amino acid sequence of SEQ ID NO: 3.

11. The IL-33 antagonist of claim 1, comprising the amino acid sequence of SEQ ID NO: 13.

12. A pharmaceutical composition comprising the IL-33 antagonist of any one of claims 1 to 11, and a pharmaceutically acceptable carrier or diluent.

13. Use of an IL-33 antagonist of any one of claims 1 to 11, or the pharmaceutical composition of claim 12, for treating an IL-33-mediated inflammatory disease or disorder, or at least one symptom associated with the inflammatory disease or disorder in a patient in need thereof.

14. Use of an IL-33 antagonist of any one of claims 1 to 11, or the pharmaceutical composition of claim 12, in the manufacture of a medicament for treating an IL-33-mediated inflammatory disease or disorder, or at least one symptom associated with the inflammatory disease or disorder in a patient in need thereof.

15. The use of claim 13 or 14, wherein the inflammatory disease or disorder is selected from the group consisting of asthma, atopic dermatitis, chronic obstructive pulmonary disease (COPD), inflammatory bowel disease, multiple sclerosis, arthritis, allergic rhinitis, eosinophilic esophagitis and psoriasis.

16. The use of claim 13 or 14, wherein the inflammatory disease or disorder is asthma.

Date Reçue/Date Received 2020-05-20

17. The use of claim 16, wherein the asthma is eosinophilic or non-eosinophilic asthma.

18. The use of claim 16 or 17, wherein the asthma is steroid resistant or steroid sensitive asthma.

19. The use of claim 13 or 14, wherein the inflammatory disease or disorder is atopic dermatitis.

20. The use of claim 13 or 14, wherein the inflammatory disease or disorder is chronic obstructive pulmonary disease (COPD).

21. The use of claim 20, wherein the chronic obstructive pulmonary disease results from, or is caused in part by cigarette smoke.

22. Use of an IL-33 antagonist of any one of claims 1-11, or the pharmaceutical composition of claim 12, for treating a patient who demonstrates a sensitivity to an allergen.

23. Use of an IL-33 antagonist of any one of claims 1-11, or the pharmaceutical composition of claim 12, in the manufacture of a medicament for treating a patient who demonstrates a sensitivity to an allergen.

24. The use of any one of claims 13 to 23, wherein the IL-33 antagonist or the pharmaceutical composition is for use in combination with a second therapeutic agent useful for alleviating the inflammatory disease or disorder, or at least one symptom of the inflammatory disease or disorder, or for diminishing an allergic response to an allergen.

25. The use of claim 24, wherein the second therapeutic agent is selected from the group consisting of a non-steroidal anti-inflammatory (NSAID), a corticosteroid, a bronchial dilator, an antihistamine, epinephrine, a decongestant, a thymic stromal lymphopoietin (TSLP) antagonist, an IL-13 antagonist, an IL-4 antagonist, an IL-4/IL-13 dual antagonist, an IL-5 antagonist, an IL-6 antagonist, an IL-12/23 antagonist, an IL-22 antagonist, an IL-25 antagonist, an IL-17 antagonist, an IL-31 antagonist, an oral PDE4 inhibitor, another IL-33 antagonist, and an antibody to IL-33.

Date Reçue/Date Received 2020-05-20

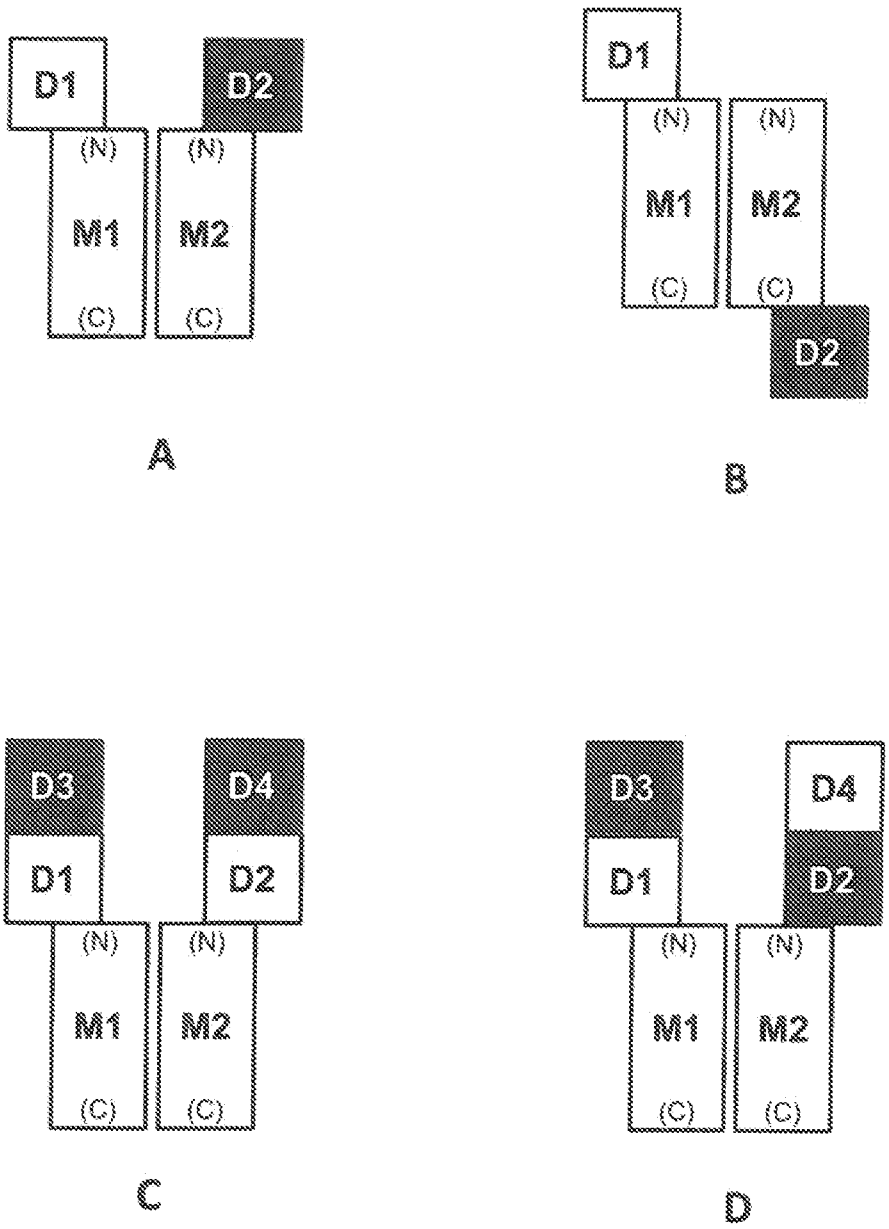
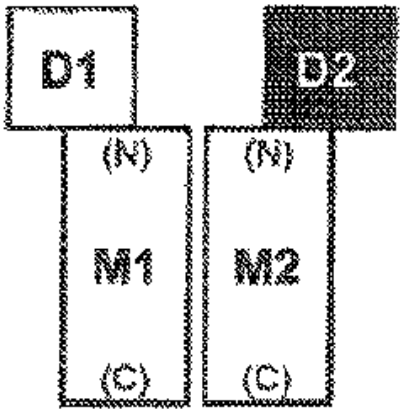
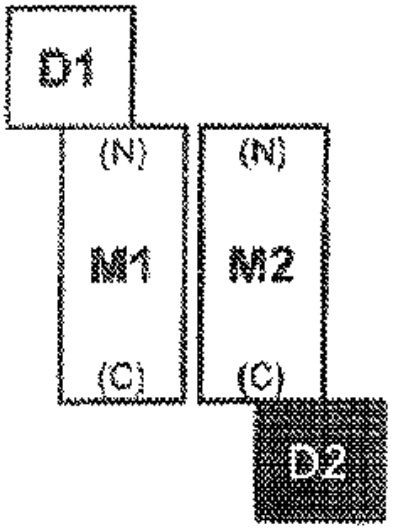

D1
D2
(N)
(N)
M1
M2
(C)
(C)
A
D1
(N)
(N)
M1
M2
(C)
(C)
D2
B
D3
D4
D1
D2
(N)
(N)
M1
M2
(C)
(C)
C
D3
D4
D1
D2
(N)
(N)
M1
M2
(C)
(C)
D

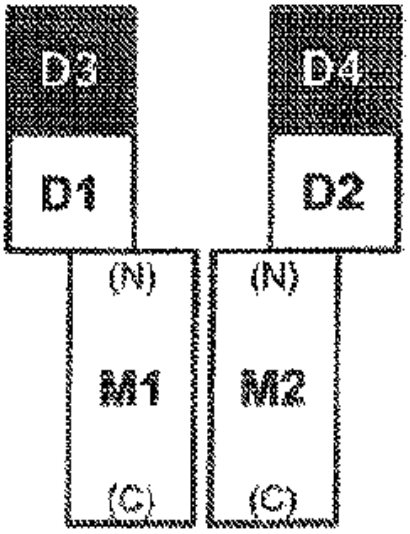
Figure 1


D1
D2
(N)
(N)
M1
M2
(C)
(C)

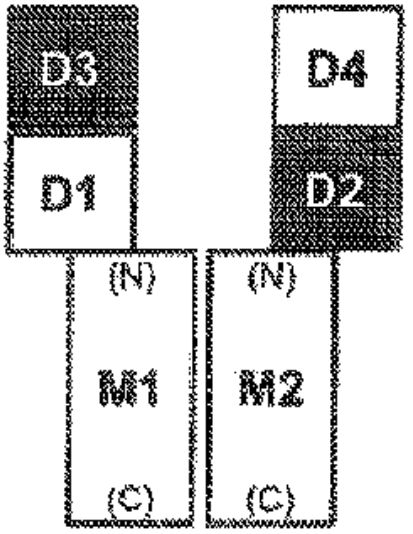
A


D1
(N)
(N)
M1
M2
(C)
(C)
D2

B


D3
D4
D1
D2
(N)
(N)
M1
M2
(C)
(C)

C


D3
D4
D1
D2
(N)
(N)
M1
M2
(C)
(C)

D