



(43) International Publication Date
19 May 2016 (19.05.2016)

(10) International Publication Number
WO 2016/077381 A1

(51) International Patent Classification:
C07K 16/24 (2006.01)

(21) International Application Number:
PCT/US2015/060008

(22) International Filing Date:
10 November 2015 (10.11.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/077,876 10 November 2014 (10.11.2014) US
62/165,732 22 May 2015 (22.05.2015) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, 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, 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, ST, SZ, TZ, 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))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
- with sequence listing part of description (Rule 5.2(a))

(54) Title: ANTI-INTERLEUKIN-33 ANTIBODIES AND USES THEREOF

(57) Abstract: The invention provides interleukin-33 (IL-33) antibodies and methods of using the same.



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ANTI-INTERLEUKIN-33 ANTIBODIES AND USES THEREOF

FIELD OF THE INVENTION

The invention relates to anti-interleukin-33 (IL-33) antibodies, and methods of using the same, including for treatment of IL-33-mediated disorders.

BACKGROUND

Interleukin-33 (IL-33) is a member of the interleukin-1 (IL-1) cytokine family that is encoded by the *IL33* gene, and is constitutively expressed in structural cells, such as smooth muscle, epithelial, and endothelial cells. IL-33 can be induced by inflammatory factors in macrophages and dendritic cells. Cellular stress caused by environmental triggers, such as allergens, toxins, and pathogens, can lead to IL-33 release. Bioavailable IL-33 associates with a heterodimeric IL-33 receptor complex composed of suppression of tumorigenicity 2 (ST2) protein and interleukin-1 receptor accessory protein (IL-1RAcP) to activate the AP-1 and NF- κ B pathways through the adaptor protein myeloid differentiation primary response 88 (MyD88) and possibly MyD88-adaptor-like (Mal) protein. IL-33 stimulates a number of cell types, including innate type II (ILC2) cells, mast cells, basophils, eosinophils, and dendritic cells, to promote Type 2 immunity.

The IL-33 pathway has been suggested to be involved in various diseases, including allergy-related diseases for which there remains a need to develop improved compositions, including therapeutic anti-IL-33 antagonists, and methods for treatment.

SUMMARY

The present invention relates to anti-IL-33 antibodies, including bispecific anti-IL-33/anti-IL-13 antibodies, and methods of using the same.

In one aspect, the invention features an isolated antibody that specifically binds both human and cynomolgus monkey (cyno) interleukin-33 (IL-33) with a K_D of about 500 pM or lower. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 100 fM and about 500 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 1 pM and about 200 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 15 pM and about 180 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 15 and about 140 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 100 fM and about 500 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 1 pM and about 500 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 100 and about 500 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 125 and about 500 pM. In some embodiments, the antibody the antibody specifically binds both human and cyno IL-33 with a K_D of between about 1 pM and about 500 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 200 pM.

In some embodiments, any one of the preceding antibodies is capable of inhibiting the binding of IL-33 to an IL-33 receptor (e.g., ST2 and/or IL-1RAcP). In some embodiments, the inhibiting is measured using a cell-based blocking assay. In some embodiments, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 90% inhibitory concentration (IC90) of between about 0.001 µg/ml and about 0.5 µg/ml. In some embodiments, the IC90 is between about 0.002 µg/ml and about 0.25 µg/ml. In some embodiments, the IC90 is about 0.17 µg/ml. In some embodiments, the IC90 is about 0.004 µg/ml. In some embodiments, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 50% inhibitory concentration (IC50) of between about 800 fM and about 10 pM. In some embodiments, the IC50 is between about 1 pM and about 5 pM. In some embodiments, the IC50 is about 2.5 pM. In some embodiments, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC50 of between about 1 nM and about 5 nM. In some embodiments, IC50 is about 4 nM. In some embodiments, HEK-BLUE™ IL-33/IL-1β cells are used in the cell-based blocking assay. In some embodiments, the HEK-BLUE™ IL-33/IL-1β cells comprise a nucleic acid comprising the sequence of SEQ ID NO: 311. In some embodiments, the assay comprises treating HEK-BLUE™ IL-33/IL-1β cells with IL-33. In some embodiments, the IL-33 comprises the amino acid sequence of any one of SEQ ID NOs: 313-318. In some embodiments, sST2-LZ is used as a positive control in the cell-based blocking assay. In some embodiments, the sST2-LZ comprises the amino acid sequence of SEQ ID NO: 310.

In some embodiments of the above aspect, the antibody comprises a binding domain comprising: (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); and (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 15). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of DVNLVESGGGSVKPGGSLKLSCVASGFTFS (SEQ ID NO: 16); (b) an FR-H2 comprising the amino acid sequence of WVRQTPEKRLEWVA (SEQ ID NO: 17); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDAKNTLYLQMSSLESEDAMYYCTR (SEQ ID NO: 18); and (d) an FR-H4 comprising the amino acid sequence of WGAGTTVAVSS (SEQ ID NO: 19). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12) or EVQLVESGGGLVKPGGSLRLSCAASGFTFS (SEQ ID NO: 20); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13) or WVRQAPGKGLEWVS (SEQ ID NO: 21); (c) an FR-H3 comprising the amino acid sequence of RFTISRDNKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 22), RFTISRDDAKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 23), RFTISRDNKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 24), or RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and (d) an FR-H4 comprising the

amino acid sequence of WGQGT LVT VSS (SEQ ID NO: 15). In some embodiments, the binding domain further comprises: (a) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (b) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (c) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6). In some embodiments,

5 the binding domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLIF (SEQ ID NO: 26); (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTSSLEPEDFAVYYC (SEQ ID NO: 27); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28). In some embodiments, the binding domain further

10 comprises: (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPGFLVSLGQRATISC (SEQ ID NO: 29); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 30); (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFTLSNIHPMEEDDTAMYFC (SEQ ID NO: 31); and (d) an FR-L4 comprising the amino acid sequence of FGSGTKLEIK (SEQ ID NO: 32). In some embodiments, the binding domain

15 further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLIF (SEQ ID NO: 26); (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTSSLEPEDFAVYYC (SEQ ID NO: 27), GVPARFSGSGSGTDFTLTSSLEPEDFAVYFC (SEQ ID NO: 33),

20 GVPARFSGSGSGTDFTLTSSLEPEDFAVYYC (SEQ ID NO: 34), or GIPARFSGSGSGTDFTLTSSLEPEDFAVYFC (SEQ ID NO: 35); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28).

In some embodiments of the above aspect, the antibody comprises a binding domain comprising:

25 (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPSLKS (SEQ ID NO: 66) or SIYYSGRTYYNPALKS (SEQ ID NO: 67); and (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72); (b) an FR-H2 comprising the amino acid

30 sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and (d) an FR-H4 comprising the amino acid sequence of WGQGT T V T VSS (SEQ ID NO: 75). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76); (b) an FR-H2 comprising the amino acid

35 sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and (d) an FR-H4 comprising the amino acid sequence of WGNGTTVT VSS (SEQ ID NO: 78). In some embodiments, the binding domain further comprises: (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72),

QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76) or QVQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 77); (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and (d) an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75) or WGNGTTVTVSS (SEQ ID NO: 78). In some embodiments, the binding domain further comprises: (a) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (b) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (c) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71). In some embodiments, the binding domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSPGERATLSC (SEQ ID NO: 79); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80); (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and (d) an FR-L4 comprising the amino acid sequence of FGSGTKVEIK (SEQ ID NO: 82).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SFSX₁S (SEQ ID NO: 62), wherein X₁ is Met, Leu, or Val; (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDX₁VKG (SEQ ID NO: 63), wherein X₁ is Ser or Ala; (c) an HVR-H3 comprising the amino acid sequence of ANYGX₁X₂FFEY (SEQ ID NO: 64), wherein X₁ is Asn or Asp, and X₂ is Trp or Phe; (d) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); (d) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 36; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 37; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and (d) an FR-H4 comprising the amino acid sequence of WGQGTTLTVSS (SEQ ID NO: 15). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 36. In some

embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLLIF (SEQ ID NO: 26); (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTISLPEPDAVYYC (SEQ ID NO: 27); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 37. In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of DVNLVESGGGSVKPGGSLKLSVASGFTFS (SEQ ID NO: 16); (b) an FR-H2 comprising the amino acid sequence of WVRQTPEKRLEWVA (SEQ ID NO: 17); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDAKNTLYQMSSLESEDAMYYCTR (SEQ ID NO: 18); and (d) an FR-H4 comprising the amino acid sequence of WGAGTTVAVSS (SEQ ID NO: 19). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 38. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPGFLVVS LGQRATISC (SEQ ID NO: 29); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 30); (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPMEEDDTAMYFC (SEQ ID NO: 31); and (d) an FR-L4 comprising the amino acid sequence of FGSGTKLEIK (SEQ ID NO: 32). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 39. In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQP GGSRLRLSCAASGFTFS (SEQ ID NO: 12) or EVQLVESGGGLVKP GGSRLRLSCAASGFTFS (SEQ ID NO: 20); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13) or WVRQAPGKGLEWVS (SEQ ID NO: 21); (c) an FR-H3 comprising the amino acid sequence of RFTISRDN SKNTLYQMNSLRAEDTAVYYCTR (SEQ ID NO: 22), RFTISRDDAKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 23), RFTISRDN AKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 24), or RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and (d) an FR-H4 comprising the amino acid sequence of WGQGT LVT VSS (SEQ ID NO: 15). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 40. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLLIF (SEQ ID NO: 26); (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTISLPEPDAVYYC (SEQ ID NO: 27), GVPARFSGSGSGTDFTLTISLPEPDAVYYC (SEQ ID NO: 33), GVPARFSGSGSGTDFTLTISLPEPDAVYYC (SEQ ID NO: 34), or GIPARFSGSGSGTDFTLTISLPEPDAVYYC (SEQ ID NO: 35); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 41.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a

VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 38 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 39.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 40 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 41.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPX₁LKS (SEQ ID NO: 90), wherein X₁ is Ser or Ala; (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFYMDV (SEQ ID NO: 68); (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPALKS (SEQ ID NO: 66); (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFYMDV (SEQ ID NO: 68); (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPALKS (SEQ ID NO: 67); (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFYMDV (SEQ ID NO: 68); (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 84; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 85; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72); (b) an FR-H2

comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and (d) an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 84. In some

5 embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSSLSPGERATLSC (SEQ ID NO: 79); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80); (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82). In some embodiments, the VL domain comprises the

10 amino acid sequence of SEQ ID NO: 85. In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 86. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSSLSPGERATLSC (SEQ ID NO: 79); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80); (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81);

15 and (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 87. In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76); (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); (c) an FR-H3 comprising the amino acid sequence

20 of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and (d) an FR-H4 comprising the amino acid sequence of WGNGTTVTVSS (SEQ ID NO: 78). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 88. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSSLSPGERATLSC (SEQ ID NO: 79); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO:

25 80); (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 89.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid

30 sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 84 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 85.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid

35 sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 86 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 87.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid

sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 88 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 89.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of NYX₁MN (SEQ ID NO: 97), wherein X₁ is Trp, Phe, or Tyr; (b) an HVR-H2 comprising the amino acid sequence of EITLKFNX₁YX₂THYAESVKG (SEQ ID NO: 98), wherein X₁ is Asn, Asp, Ser, or Ala, and X₂ is Ser or Ala; (c) an HVR-H3 comprising the amino acid sequence of RNYGX₁X₂YINV (SEQ ID NO: 99), wherein X₁ is Asp or Asn, and X₂ is Trp or Phe; (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGX₁SFLN (SEQ ID NO: 100), wherein X₁ is Met, Val, or Leu; (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101); (b) an HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104); (c) an HVR-H3 comprising the amino acid sequence of RNYGDWYINV (SEQ ID NO: 109); (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112); (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101); (b) an HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104); (c) an HVR-H3 comprising the amino acid sequence of RNYGNWYINV (SEQ ID NO: 110); (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112); (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101); (b) an HVR-H2 comprising the amino acid sequence of EITLKFNDYSTHYAESVKG (SEQ ID NO: 105); (c) an HVR-H3 comprising the amino acid sequence of RNYGNWYINV (SEQ ID NO: 110); (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGVSFLN (SEQ ID NO: 115); (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 134; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 135; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFS (SEQ ID NO: 117); (b) an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWMA (SEQ ID NO: 119); (c) an

FR-H3 comprising the amino acid sequence of RFSISRDDSKSTVYLQMNNLRAEDTGIYYCAR (SEQ ID NO: 121); and (d) an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 124). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 134. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of
 5 DIVLTQSPTSLAVSLGQRATISC (SEQ ID NO: 126); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 128); (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPVEEDDTAMYFC (SEQ ID NO: 130); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 132). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 135.

10 In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 136; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 137; or (c) a VH domain as in (a)
 15 and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 118); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWMA (SEQ ID NO: 120); (c) an FR-H3 comprising the amino acid sequence of RFTISRDN SKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 122) or RFTISRDDSKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 123); and (d) an FR-H4
 20 comprising the amino acid sequence of WGQGTTLTVSS (SEQ ID NO: 125). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 138. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIVMTQSPDSLAVSLGERATINC (SEQ ID NO: 127); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQPPKLLIF (SEQ ID NO: 129); (c) an FR-L3 comprising the amino acid sequence of GVPDRFSGSGSGTDFTLTISSLQAEDVAVYYC (SEQ ID NO: 131); and (d) an FR-L4 comprising the
 25 amino acid sequence of FGQGTKVEIK (SEQ ID NO: 133). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 139.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid
 30 sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 134 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 135.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid
 35 sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 136 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 137.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid

sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 138 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 139.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) an HVR-H2 comprising the amino acid sequence of EIRLX₁X₂IN YVKDYAESVKG (SEQ ID NO: 161), wherein X₁ is Asn or Ser, and X₂ is Ser or Ala; (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) an HVR-H2 comprising the amino acid sequence of EIRLNSIN YVKDYAESVKG (SEQ ID NO: 159); (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) an HVR-H2 comprising the amino acid sequence of EIRLSSIN YVKDYAESVKG (SEQ ID NO: 162); (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) an HVR-H2 comprising the amino acid sequence of EIRLNAIN YVKDYAESVKG (SEQ ID NO: 163); (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 183; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 184; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQP GGSMKLSCVASGFTFN (SEQ ID NO: 167); (b) an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWVA (SEQ ID NO: 168); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKNSVYLQMNNLRAEDTGIYYCIR (SEQ ID

NO: 169); and (d) an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 170). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 183. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPASLAVSLGQRATISC (SEQ ID NO: 175); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQSPKLLIY (SEQ ID NO: 176); (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPLEEDDAAMYFC (SEQ ID NO: 177); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 178). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 184.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 185; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 186; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFN (SEQ ID NO: 171); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 172); (c) an FR-H3 comprising the amino acid sequence of RFTISRDNKNSVYLQMNSLRAEDTAVYYCIR (SEQ ID NO: 173); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 174). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 185. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 179); (b) an FR-L2 comprising the amino acid sequence of WFQQKPGKAPKLLIY (SEQ ID NO: 180); (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFSLTISSLQPEDFATYYC (SEQ ID NO: 181); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 182). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 186. In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 187. In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 188. In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 189. In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 190.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 183 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 184.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 185 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 186.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 187 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 188.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 189 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 190.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) an HVR-H2 comprising the amino acid sequence of DINPKX₁X₂DTFYNQNFKD (SEQ ID NO: 192), wherein X₁ is Asn or Ser, and X₂ is Gly or Ala; (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) an HVR-H2 comprising the amino acid sequence of DINPKNGDTFYNQNFKD (SEQ ID NO: 193); (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) an HVR-H2 comprising the amino acid sequence of DINPKSGDTFYNQNFKD (SEQ ID NO: 194) or DINPKNADTFYQNFKD (SEQ ID NO: 195); (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 216; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 217; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVLLQQSGPELVKPGASVKISCNASGYTFS (SEQ ID NO: 200); (b) an FR-H2 comprising the amino acid sequence of WVKQSHGKSLESIG (SEQ ID NO: 201); (c) an FR-

H3 comprising the amino acid sequence of KATLTIDKSSSTVYMELRSLTSEDAMYYCAR (SEQ ID NO: 202); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVAA (SEQ ID NO: 203). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 216. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 208); (b) an FR-L2 comprising the amino acid sequence of WYQQKAGNNPKLLIY (SEQ ID NO: 209); (c) an FR-L3 comprising the amino acid sequence of GVPSRFTGSGSGTLFTLTISLQPEDATYYC (SEQ ID NO: 210); and (d) an FR-L4 comprising the amino acid sequence of FGSGTNLELK (SEQ ID NO: 211). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 217.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 218; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 219; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVQSGAEVKKPGASVKVSCKASGYTFS (SEQ ID NO: 204); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGQGLESIG (SEQ ID NO: 205); (c) an FR-H3 comprising the amino acid sequence of RATLTIDKSTSTAYLELSSLRSEDATVYYCAR (SEQ ID NO: 206); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 207). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 218. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 212); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKNPCKLLIY (SEQ ID NO: 213); (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 214); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 215). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 219.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 216 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 217. In another embodiment, the VH domain comprises the amino acid sequence of SEQ ID NO: 220. In another embodiment, the VL domain comprises the amino acid sequence of SEQ ID NO: 219.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 218 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 219.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 220 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 219.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SYWIN (SEQ ID NO: 222); (b) an HVR-H2 comprising the amino acid sequence of RIAPGSGFISYNELFKD (SEQ ID NO: 223); (c) an HVR-H3 comprising the amino acid sequence of EFYYGSFYGGFAY (SEQ ID NO: 224); (d) an HVR-L1 comprising the amino acid sequence of HASQNIHVWLS (SEQ ID NO: 225); (e) an HVR-L2 comprising the amino acid sequence of KASTLHT (SEQ ID NO: 226); and (f) an HVR-L3 comprising the amino acid sequence of QQGQSSPLT (SEQ ID NO: 227).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 236; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 237; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of QVQLQQSGNDLVKPGASVKLSCKASGYTFT (SEQ ID NO: 228); (b) an FR-H2 comprising the amino acid sequence of WIKQRPGQGLEWIG (SEQ ID NO: 229); (c) an FR-H3 comprising the amino acid sequence of KATLTVDTSSTAYIQLGSLSEDSAVYFCAR (SEQ ID NO: 230); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSA (SEQ ID NO: 231). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 236. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 232); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGNIPKLLIY (SEQ ID NO: 233); (c) an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTGFTLTISLQPEDATYYC (SEQ ID NO: 234); and (d) an FR-L4 comprising the amino acid sequence of FGAGTKLEVK (SEQ ID NO: 235). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 237.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 246; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 247; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVQSGAEVKKPGASVKVSKASGYTFT (SEQ ID NO: 238); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGQGLEWIG (SEQ ID NO: 239); (c) an FR-H3 comprising the amino acid sequence of RVTITRDTSTSTAYLELSSLRSEDTAVYYCAR (SEQ ID

NO: 240); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 241). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 246. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 242); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKLLIY (SEQ ID NO: 243); (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 244); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 245). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 247.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 236 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 237.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 246 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 247.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of GSAX₁H (SEQ ID NO: 248), wherein X₁ is Met or Ile; (b) an HVR-H2 comprising the amino acid sequence of RIRSX₁X₂NX₃YATX₄YX₅ASVKG (SEQ ID NO: 249), wherein X₁ is Arg or Lys, X₂ is Asn, Thr, or Gly, X₃ is Asn or Ser, X₄ is Ala or Glu, and X₅ is Ala or Asp; (c) an HVR-H3 comprising the amino acid sequence of X₁X₂X₃X₄PFDY (SEQ ID NO: 250), wherein X₁ is Leu or Gln, X₂ is Gln, Gly, or Phe, X₃ is Gln or Gly, and X₄ is Pro or Asp; (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) an HVR-L3 comprising the amino acid sequence of LQHX₁X₂YPX₃T (SEQ ID NO: 253), wherein X₁ is Asp or Ser, X₂ is Ser or Ile, and X₃ is Leu or Pro. In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254); (b) an HVR-H2 comprising the amino acid sequence of RIRSRNNNYATAYAASVKG (SEQ ID NO: 255); (c) an HVR-H3 comprising the amino acid sequence of LQQPPFDY (SEQ ID NO: 256); (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) an HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of GSAIH (SEQ ID NO: 258); (b) an HVR-H2 comprising the amino acid sequence of RIRSRTNNYATEYDASVKG (SEQ ID NO: 259); (c) an HVR-H3 comprising the amino acid sequence of LGQPPFDY (SEQ ID NO: 260); (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) an HVR-L2 comprising the amino acid sequence of AASSLQS

(SEQ ID NO: 252); and (f) an HVR-L3 comprising the amino acid sequence of LQHSIYPPT (SEQ ID NO: 261). In some embodiments, the binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254); (b) an HVR-H2 comprising the amino acid sequence of RIRSKGNSYATAYAASVKG (SEQ ID NO: 262); (c) an HVR-H3 comprising the amino acid sequence of QFGDPFDY (SEQ ID NO: 263); (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) an HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257).

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 282; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 283; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of QVQLVQSGGGLVQPGGSLKLSCAASGFTFS (SEQ ID NO: 264); (b) an FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKRTTYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 269); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 282. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 273); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276); (c) an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTEFTLTISLQPEDFATYYC (SEQ ID NO: 277); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 283.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 284; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 285; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGDLVQPGGSLKLSCAASGFTFS (SEQ ID NO: 265); (b) an FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267); (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKRTAYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 270); and (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 284. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of AIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 274); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276); (c) an FR-L3 comprising the amino acid sequence of

GVPSRFSGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 278); and (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 281). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 285.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 286; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 287; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain further comprises: (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLKLSAASGFTFS (SEQ ID NO: 266); (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVG (SEQ ID NO: 268); (c) an FR-H3 comprising the amino acid sequence of RFSISRDDSKRTAYLQMSSLKTEDSAVYYCAR (SEQ ID NO: 271); and (d) an FR-H4 comprising the amino acid sequence of WGQGTTLTVSS (SEQ ID NO: 272). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 286. In some embodiments, the VL domain further comprises: (a) an FR-L1 comprising the amino acid sequence of AIRITQSPSSLSASVGDRVTITC (SEQ ID NO: 275); (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276); (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 279); and (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280). In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 287.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 282 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 283.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 284 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 285.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 286 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 287.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 288 and (b) a light chain comprising

an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 289.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 290 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 291.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 292 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 293.

In another aspect, the invention features an isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 294 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 295.

In some embodiments of any of the preceding aspects, the antibody specifically binds human or cyno IL-33. In some embodiments, the antibody specifically binds both human and cyno IL-33. In some embodiments, the antibody specifically binds both human and cyno IL-33 with a K_D of about 1 nM or lower. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 100 fM and about 1 nM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 1 pM and about 200 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 75 pM and about 180 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D between about 75 and about 140 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 100 fM and about 1 nM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 1 pM and about 500 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 200 and about 500 pM. In some embodiments, the antibody specifically binds cyno IL-33 with a K_D between about 250 and about 500 pM. In some embodiments, the antibody specifically binds both human and cyno IL-33 with a K_D of between about 1 pM and about 500 pM. In some embodiments, the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 200 pM.

In some embodiments of any of the preceding aspects, the antibody is capable of inhibiting the binding of IL-33 to an IL-33 receptor. In some embodiments, the inhibiting is measured using a cell-based blocking assay. In some embodiments, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 90% inhibitory concentration (IC90) of between about 0.001 μ g/ml and about 0.5 μ g/ml. In some embodiments, the IC90 is between about 0.002 μ g/ml and about 0.25 μ g/ml. In some embodiments, the IC90 is about 0.17 μ g/ml. In some embodiments, the IC90 is about 0.004 μ g/ml.

In some embodiments of any of the preceding aspects, the antibody comprises an aglycosylation site mutation.

In some embodiments of any of the preceding aspects, the antibody is monoclonal, human, humanized, or chimeric.

5 In some embodiments of any of the preceding aspects, the antibody is an antibody fragment that binds IL-33. In some embodiments, antibody fragment is selected from the group consisting of Fab, Fab'-SH, Fv, scFv, and (Fab')₂ fragments.

In some embodiments of any of the preceding aspects, the antibody is a full-length antibody. In some embodiments, the antibody is an IgG antibody. In some embodiments, the IgG antibody is an IgG1 antibody. In some embodiments, the IgG antibody is an IgG4 antibody. In some embodiments, the IgG4 antibody comprises a mutation in the hinge region. In some embodiments, the mutation is a substitution mutation. In some embodiments, the substitution mutation is at amino acid residue S228 (EU numbering). In some embodiments, the substitution mutation is an S228P mutation.

In some embodiments of any of the preceding aspects, the antibody is a monospecific antibody.

15 In some embodiments of any of the preceding aspects, the antibody is a multispecific antibody. In some embodiments, the antibody is a bispecific antibody. In some embodiments, the bispecific antibody comprises a second binding domain that binds to a second biological molecule, wherein the second biological molecule is selected from the group consisting of interleukin-13 (IL-13), interleukin-4 (IL-4), interleukin-5 (IL-5), interleukin-17 (IL-17), Factor D, HtrA1, VEGF, and a VEGF receptor. In some
20 embodiments, the second biological molecule is Factor D. In some embodiments, the second biological molecule is HtrA1. In some embodiments, the second biological molecule is VEGF. In some embodiments, the second biological molecule is IL-13. In some embodiments, the second binding domain comprises the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ
25 ID NO: 297); (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In some embodiments, the second binding domain comprises (a) a VH domain comprising an amino acid sequence having at least
30 95% sequence identity to the amino acid sequence of SEQ ID NO: 302; (b) a VL domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 303; or (c) a VH domain as in (a) and a VL domain as in (b). In some embodiments, the VH domain comprises the amino acid sequence of SEQ ID NO: 302. In some embodiments, the VL domain comprises the amino acid sequence of SEQ ID NO: 303.

35 In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEV (SEQ ID NO: 3); (d) an HVR-L1

comprising the amino acid sequence of RASESVAKYGLSLN (SEQ ID NO: 4); (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and a second binding domain that specifically binds IL-13 comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301).

In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPSLKS (SEQ ID NO: 66); (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68); (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71); and a second binding domain that specifically binds IL-13 comprising the following six HVRs: (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301).

In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303.

In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 84 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 85, and a second binding

domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303.

5 In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 306 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 307, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305.

15 In another aspect, the invention features an isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305.

20 In some embodiments of any of the preceding aspects, the antibody is an antigen-binding antibody fragment. In some embodiments, the antigen-binding antibody fragment is selected from the group consisting of Fab, Fab'-SH, Fv, scFv, and (Fab')₂ fragments. In some embodiments, the antigen-binding antibody fragment is an Fab.

25 In another aspect, the invention features an isolated nucleic acid encoding any of the antibodies described herein. In another aspect, the invention features a vector (e.g., an expression vector) comprising the isolated nucleic acid for expressing the antibody. In another aspect, the invention features host cells comprising the preceding nucleic acids and/or vectors. In some embodiments, the host cell is a mammalian cell. In some embodiments, the mammalian cell is a Chinese hamster ovary (CHO) cell. In some embodiments, the host cell is a prokaryotic cell. In some embodiments, the prokaryotic cell is *E. coli*.

30 In another aspect, the invention features a method of producing any of the antibodies described herein, the method comprising culturing a host cell that comprises any of the preceding vectors (e.g., expression vectors) in a culture medium. In some embodiments, the method further comprises recovering the antibody from the host cell or the culture medium.

In another aspect, the invention features a composition comprising any one of the preceding antibodies. In some embodiments, the composition further comprises a pharmaceutically acceptable

carrier, excipient, or diluent. In some embodiments, the composition is a pharmaceutical composition. In some embodiments, the pharmaceutical composition further comprises an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist. In some embodiments, the pharmaceutical composition comprises a Factor D binding antagonist. In some embodiments, the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof. In some embodiments, the pharmaceutical composition comprises an HtrA1 antagonist. In some embodiments, the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof. In some embodiments, the pharmaceutical composition comprises a VEGF antagonist. In some embodiments, the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

In some aspects, any one of the preceding antibodies can be used as a medicament.

In some aspects, any one of the preceding antibodies can be used in treating an IL-33-mediated disorder. In some embodiments, the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder. In some embodiments, the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD). In some embodiments, the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease. In some embodiments, the fibrotic disease is idiopathic pulmonary fibrosis (IPF). In some embodiments, the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID). In some embodiments, the EGID is eosinophilic esophagitis. In some embodiments, the infection is a helminth infection, a protozoan infection, or a viral infection. In some embodiments, the protozoan infection is a *Leishmania major* infection. In some embodiments, the viral infection is a respiratory syncytial virus (RSV) infection or an influenza infection. In some embodiments, the pain is inflammatory pain. In some embodiments, the central nervous system disorder is Alzheimer's disease. In some embodiments, the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor. In some embodiments, the ophthalmologic disorder is selected from the group consisting of age-related macular degeneration (AMD), retinopathy of the eye, polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis. In some embodiments, the AMD is wet AMD, dry AMD, or geographic atrophy (GA). In some embodiments, the AMD is intermediate AMD or advanced AMD. In some embodiments, the retinopathy of the eye is diabetic retinopathy (DR) or retinopathy of prematurity (ROP). In some embodiments, the retinopathy of the eye is high-altitude DR. In some embodiments, the

conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis. In some embodiments, the conjunctivitis is allergic conjunctivitis.

In some aspects, any one of the preceding antibodies can be used in the manufacture of a medicament for treating an IL-33-mediated disorder. In some embodiments, the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder. In some embodiments, the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD). In some embodiments, the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease. In some embodiments, the fibrotic disease is idiopathic pulmonary fibrosis (IPF). In some embodiments, the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID). In some embodiments, the EGID is eosinophilic esophagitis. In some embodiments, the infection is a helminth infection, a protozoan infection, or a viral infection. In some embodiments, the protozoan infection is a *Leishmania major* infection. In some embodiments, the viral infection is a respiratory syncytial virus (RSV) infection or an influenza infection. In some embodiments, the pain is inflammatory pain. In some embodiments, the central nervous system disorder is Alzheimer's disease. In some embodiments, the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor. In some embodiments, the ophthalmologic disorder is selected from the group consisting of age-related macular degeneration (AMD), retinopathy of the eye, polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis. In some embodiments, the AMD is wet AMD, dry AMD, or geographic atrophy (GA). In some embodiments, the AMD is intermediate AMD or advanced AMD. In some embodiments, the retinopathy of the eye is diabetic retinopathy (DR) or retinopathy of prematurity (ROP). In some embodiments, the retinopathy of the eye is high-altitude DR. In some embodiments, the conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis. In some embodiments, the conjunctivitis is allergic conjunctivitis. In some embodiments, the medicament is formulated for use in combination with an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist. In some embodiments, the medicament is formulated for use in combination with a Factor D binding antagonist. In some embodiments, the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof. In some embodiments, the medicament is formulated for use in combination with an HtrA1 binding antagonist. In some embodiments, the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof. In some embodiments, the medicament is formulated for use in combination with a VEGF

antagonist. In some embodiments, the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and Factor D or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating geographic atrophy (GA). In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, any one of the preceding antibodies can be used in the manufacture of a medicament for treating geographic atrophy (GA), wherein the medicament is formulated for use in combination with a Factor D binding antagonist. In some embodiments, the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.

In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and HtrA1 or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, any one of the preceding antibodies can be used in the manufacture of a medicament for treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP, wherein the medicament is formulated for use in combination with an HtrA1 binding antagonist. In some embodiments, the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.

In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating wet AMD. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, any one of the preceding antibodies can be used in the manufacture of a medicament for treating wet AMD, wherein the medicament is formulated for use in combination with a VEGF antagonist. In some embodiments, the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

In another aspect, the invention features a method of treating an IL-33-mediated disorder in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of any one of the preceding antibodies. In some embodiments, the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder. In some embodiments, the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD). In some embodiments, the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease. In some embodiments, the fibrotic disease is idiopathic pulmonary fibrosis (IPF). In some embodiments, the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID). In some embodiments, the EGID is eosinophilic esophagitis.

In some embodiments, the infection is a helminth infection, a protozoan infection, or a viral infection. In some embodiments, the protozoan infection is a *Leishmania major* infection. In some embodiments, the viral infection is a respiratory syncytial virus (RSV) infection or an influenza infection. In some embodiments, the pain is inflammatory pain. In some embodiments, the central nervous system disorder is Alzheimer's disease. In some embodiments, the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor. In some embodiments, the ophthalmologic disorder is selected from the group consisting of age-related macular degeneration (AMD), retinopathy of the eye, polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis. In some embodiments, the AMD is wet AMD, dry AMD, or geographic atrophy (GA). In some embodiments, the AMD is intermediate AMD or advanced AMD. In some embodiments, the retinopathy of the eye is diabetic retinopathy (DR) or retinopathy of prematurity (ROP). In some embodiments, the retinopathy of the eye is high-altitude DR. In some embodiments, the conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis. In some embodiments, the conjunctivitis is allergic conjunctivitis. In some embodiments, the method further comprises administering to the subject an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist. In some embodiments, the method further comprises administering to the subject a Factor D binding antagonist. In some embodiments, the Factor D binding antagonist is anti-Factor D antibody or an antigen-binding fragment thereof. In some embodiments, the method further comprises administering to the subject an HtrA1 binding antagonist. In some embodiments, the HtrA1 binding antagonist is anti-HtrA1 antibody or an antigen-binding fragment thereof. In some embodiments, the method further comprises administering to the subject a VEGF antagonist. In some embodiments, the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

In another aspect, the invention features a method of treating geographic atrophy (GA) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and Factor D or an antigen-binding antibody fragment thereof. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention features a method of treating geographic atrophy (GA) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of any one of the preceding antibodies and a therapeutically effective amount of a Factor D binding antagonist. In some embodiments, the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.

In another aspect, the invention features a method of treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and HtrA1 or an antigen-binding antibody fragment thereof. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention features a method of treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of any one of the preceding antibodies and a therapeutically effective amount of a HtrA1 binding antagonist. In some embodiments, the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.

In another aspect, the invention features a method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention features a method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of any one of the preceding antibodies and a therapeutically effective amount of a VEGF antagonist. In some embodiments, the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

In some embodiments of any of the preceding methods, the antibody is administered subcutaneously, intravenously, intramuscularly, topically, orally, transdermally, intraperitoneally, intraorbitally, by implantation, by inhalation, intrathecally, intraventricularly, intranasally, intravitreally, intraocularly, periocularly, conjunctivally, subconjunctivally, subtenonally, intracamerally, subretinally, retrobulbarly, or intracranially. In some embodiments, the subject is a human.

Brief Description of the Drawings

FIGURE 1A is a diagram showing a schematic of a cell-based IL-33 blocking assay. SEAP is used as a reporter gene for NF-κB/AP-1 secreted alkaline phosphatase. Soluble ST2 (sST2) is used as a positive control.

FIGURE 1B is a graph showing the results of a cell-based IL-33 blocking assay for human IL-33.

FIGURE 1C is a graph showing the results of a cell-based IL-33 blocking assay for cynomolgus monkey (cyno) IL-33.

FIGURE 2 is a graph showing the results of a cell-based IL-33 blocking assay for the indicated anti-IL-33 antibody clones.

FIGURE 3 is a table showing the results of cell-based IL-33 blocking assays (IC₅₀ and IC₉₀) for the indicated parental and humanized anti-IL-33 antibodies.

FIGURE 4A is an image showing the macular and peripheral retina dissected for RNA-seq analysis. The macular area between the superior and inferior temporal vascular arcades was separated from the peripheral fundus using dissecting scissors. RNA was isolated from both macular and peripheral retina tissues for RNA-seq. The dashed outline indicates the area of the macula, and the solid circle

indicates the area of the fovea. The arrow indicates the location of the optic disc.

FIGURE 4B is a graph showing expression of IL-1 α , IL-1 β , IL-33, and IL-18 in macular and peripheral retina of healthy donor eyes. Macula (n=14) and peripheral (n=22) retina of normal donor eyes were isolated and RNA was analyzed by RNA-seq. The data are presented as reads per kilobase per million total reads (RPKM). Horizontal bars represent means. **, P<0.01; ****, P<0.0001; unpaired two-tailed Student's t test.

FIGURE 5A is an image showing a representative cross-section of an eye with central and peripheral areas studied by quantitative analysis (see Figure 5B) indicated by the solid and dashed lines, respectively. Arrows indicate the fovea and the ciliary bodies. Bar, 5 mm.

FIGURES 5B and 5C are images showing immunohistochemical triple staining of IL-33 (green), vimentin (red), and GFAP (yellow) in the central (Figure 5B) and peripheral (Figure 5C) retina of a control eye from an 84-year-old male donor. 4',6-Diamidino-2-Phenylindole (DAPI) staining is shown in blue. Arrows indicate IL-33⁺ Müller cells in the inner nuclear layer (INL); closed arrowheads indicate IL-33⁺ cells in the retinal pigment epithelium (RPE); open arrowheads indicate IL-33⁺ cells in the choroidal vasculature; and angle brackets indicate IL-33⁺ astrocytes in the ganglion cell layer (GCL). Bars, 50 μ m.

FIGURE 5D is a graph showing quantification of IL-33⁺ cells in each retinal layer of central and peripheral areas. IL-33⁺ cells were quantified along an approximately 500 μ m section within the central and peripheral areas from 7 eyes from normal human donors whose ages ranged from 67-89 years (median age 84, 5 males and 2 females). The number of IL-33⁺ cells in the inner nuclear layer (INL) and retinal pigment epithelium (RPE) were higher in the central retina compared to the peripheral retina. GCL, ganglion cell layer; ONL, outer nuclear layer. *, P<0.05; ****, P<0.0001; ns, non-significant; unpaired two-tailed Student's t test.

FIGURE 5E is a series of representative high-magnification images of IL-33⁺ cells in GCL, INL, RPE, and choroid in the central area of a control donor eye. IL-33 (green), vimentin (red), and GFAP (yellow) co-staining showed IL-33⁺ astrocytes (GFAP⁺, angle brackets) and IL-33⁺ Müller cells (vimentin⁺, arrows). IL-33⁺ endothelial cells (open arrowheads) of the choroid vasculature are shown by IL-33 (red) and PLVAP (green) co-staining. Closed arrowheads, IL-33⁺ RPE. DAPI staining is shown in blue. Bars, 10 μ m.

FIGURE 6A is a series of representative images showing fluorescence immunohistochemical triple staining for IL-33 (green), Iba1 (red), and GFAP (yellow) in the central retina of a control human donor eye from an 84-year-old male with no history of ocular diseases, and from an eye of an 82-year-old female donor diagnosed with AMD. Numbers of IL-33⁺ Müller cells and mononuclear phagocytic cells (Iba1⁺ cells) were significantly increased in areas of retina degeneration (AMD: Lesion) compared with adjacent areas of the same donors that did not exhibit retina degeneration (AMD: Non-lesion), or compared with the central retina of control donor eyes (Control: Central). Arrows, IL-33⁺ Müller cells; arrowheads, Iba1⁺ cells in the subretinal space. DAPI (blue), nuclear stain. Bars, 100 μ m.

FIGURE 6B is a series of representative high-magnification images showing immunohistochemistry of IL-33 (green), Iba1 (red), and GFAP (yellow) in the central retina of a control

eye and lesion and non-lesion areas of an AMD eye. The bright field (BF) images show RPE loss in the AMD lesion site. Bars, 50 μm .

FIGURES 6C-6E are graphs showing quantification of IL-33⁺ Müller cells in the INL (Figure 6C), IL-33⁺ cells in the choroid (Figure 6D), and Iba1⁺ cells in the retina (Figure 6E) counted along an approximately 500 μm -long section within the central retina of 7 control human donors aged 67-89 years (median age 84) and lesion and non-lesion areas of eyes from 7 AMD donors aged 82-92 years (median age 86). **, $P < 0.01$; ***, $P < 0.001$, ****, $P < 0.0001$; one-way ANOVA with Tukey's post-test. Horizontal bars represent means.

FIGURE 6F is a graph showing increased IL-33 levels in the vitreous from human AMD patients. IL-33 concentration was determined in vitreous samples obtained from AMD patients ($n=6$, 1 male and 5 females, age 68-91, median age 79), control patients with macular pucker ($n=12$, 3 males and 9 females, age 56-79, median age 72), and control patients with macular hole ($n=21$, 5 males and 16 females, age 46-75, median age 65) by ELISA. ****, $P < 0.0001$; one-way ANOVA with Tukey's post-test. Horizontal bars represent means.

FIGURE 7A shows the results of immunohistochemical staining of IL-33 (brown) and vimentin (red) in Sprague-Dawley (SD) rat retina. Arrows in the images in the left panel indicate IL-33⁺ Müller cells. The inset in the left panel shows an IL-33⁺ Müller cell (vimentin⁺). IL-33⁺ cells in INL, RPE, GCL, and choroid in the central and peripheral retina were counted along a ~500 μm long section. The results of this quantification are shown in the right panel. Bar, 10 μm . ND, not detected.

FIGURE 7B shows the results of immunohistochemical staining of IL-33 (brown) in BALB/c mice. Arrows in the images in the left panel indicate IL-33⁺ Müller cells. IL-33⁺ cells in INL, RPE, GCL, and choroid in the central and peripheral retina were counted along a ~500 μm long section. The results of this quantification are shown in the right panel. Bar, 10 μm .

FIGURE 7C is a graph showing expression of IL-1 family genes (IL-1 α , IL-1 β , IL-33, and IL-18) in the retina of BALB/c mice as determined by ELISA. Each data point represents an individual mouse ($n=5$). The data represent at least two experiments with similar results.

FIGURE 7D is a series of graphs showing expression of GFAP and vimentin in rMC-1 cells measured by intracellular staining using GFAP- and vimentin-specific antibodies or control antibodies followed by flow cytometry. Activated Müller cells are GFAP⁺.

FIGURE 7E is a Western blot showing IL-33 expression in the nuclear ("nucl") and cytoplasmic ("cyto") fractions of rMC-1 cells. Full-length (IL-33p30) and a processed form (IL-33p19) of IL-33 were detected in the nucleus, but only IL-33p19 was present in the cytoplasm. The data represent at least two experiments with similar results.

FIGURE 7F is a graph showing results of a time course analysis of GFAP expression in rMC-1 cells cultured in high-glucose medium ("HG") by qPCR. GFAP mRNA was normalized to β -actin mRNA. GFAP expression at 0 h was set as 1. Data represents mean \pm SEM of triplicate experiments. ***, $P < 0.001$; ****, $P < 0.0001$; one-way ANOVA followed by Dunnett's post-test.

FIGURE 7G shows ELISA (left panel) and Western blot (right panel) analysis of IL-33 secretion in rMC-1 cells cultured in high-glucose (HG) and low-glucose (LG)-containing medium. IL-33p19 was

present in both rat vitreous and rMC-1 culture supernatant. Data shown are mean \pm SEM of triplicate wells and represent three independent experiments. ***, $P < 0.001$; ****, $P < 0.0001$.

two-way ANOVA with Bonferroni's post-test. The data represent at least two experiments with similar results.

5 FIGURE 7H is a graph showing that increased IL-33p19 secretion in rMC-1 cells cultured in HG medium (see Figure 7G) was not associated with increased cell death. Cell viability was assessed by flow cytometry analysis of annexin V and propidium iodide (PI) staining. Live cells were gated as annexin V⁻ PI⁻. Data shown are mean \pm SEM of triplicate wells. The data represent at least two experiments with similar results.

10 FIGURE 7I is a series of images showing terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL) staining (brown) of retina sections to detect photoreceptor cell death. Sprague-Dawley (SD) rats were exposed to light (1200 lux) for days as indicated. Arrows indicate TUNEL+ photoreceptors. Bars, 50 μ m.

15 FIGURE 7J is a series of graphs showing quantification of rods (left panel) and cones (right panel) by flow cytometry. Each data point represents an individual rat ($n=8$ /time point). *, $P < 0.05$; ***, $P < 0.001$; ****, $P < 0.0001$.

20 FIGURE 7K shows that CLE increases expression and secretion of IL-33p19 in rat vitreous (left panels) and retina (right panels). SD rats were exposed to bright light for up to 10 days (see schematic diagram). IL-33 expression in the vitreous and retina was analyzed by ELISA and Western blot (WB). The ratio of IL-33p19 to IL-33p30 in the retina was quantitated with ImageJ software. A recombinant rat IL-33 protein (rrIL-33) (a.a. 109-264; approximately 18 kDa) was used as the positive control for the detection antibody. Each data point in ELISA represents an individual rat ($n=8$ /time point) from one of two independent experiments. ****, $P < 0.0001$; ns, non-significant; one-way ANOVA with Dunnett's post-test. The data represent at least two experiments with similar results.

25 FIGURE 7L is an image showing RT-PCR analysis of IL-33 transcripts in activated rMC-1 cells and light-injured retina (CLE). FL, full-length.

30 FIGURE 7M shows that IL33^{tm2/tm2} mice with the IL-33 cytokine domain replaced by dsRed and an intact nuclear localization sequence (NLS) and chromatin binding domain (CBD) show localization of IL-33 N-term-dsRed in nuclei of Müller cells in the INL. Images (left panel) are Z-section views of confocal microscopic imaging of IL33^{tm2/tm2} retina flat-mount. dsRed signal is shown in red; DAPI signal is shown in blue. Arrows indicate IL-33⁺ Müller cells. Flow cytometry analysis of IL33^{tm2/tm2} retina (middle panels) confirmed the expression of IL-33 in Müller cells (MC) but not in rods, ganglion cells (RGC), or microglia (MGL). IL-33 N-term-dsRed was processed after CLE. dsRed mean fluorescent intensity (MFI) of IL33^{tm2/tm2} Müller cells as well as cell numbers at d0 and d7 of CLE were measured by flow cytometry (right panel). Data represent the MFI of dsRed in IL33^{tm2/tm2} mice normalized by that of IL33^{+/+} mice. Each data point represents an individual mouse ($n=6-7$ /group) pooled from two experiments. Rho, rhodopsin; FCS, forward scatter. ****, $P < 0.0001$; unpaired two-tailed Student's t test. The data represent at least two experiments with similar results.

FIGURE 8A is a series of graphs showing increased expression of membrane-bound (ST2L, left panel) and soluble ST2 (sST2, right panel) following CLE. Retinal RNA from BALB/c mice exposed to light for various days was analyzed by qPCR using probes specific for ST2L and sST2, and normalized by 18s rRNA expression. The fold change of ST2 expression is shown relative to ST2 expression in non-exposed mice (d0). Each data point represents an individual mouse (n=5-6/time point). Data represent two independent experiments. *, P<0.05; ****, P<0.0001; ns, non-significant; one-way ANOVA with Dunnett's post-test.

FIGURE 8B is a series of graphs showing flow cytometry analysis of ST2 expression on various retinal cell populations. The results indicated exclusive expression of ST2 on activated Müller cells (MC) following 7 days light exposure. ST2 was only expressed on activated Müller cells (GFAP⁺ vimentin⁺ MC), but not on resting Müller cells (GFAP⁺ vimentin⁺ MC), microglia (CD11b⁺ CD45^{lo} MGL), or photoreceptor cells. ST2^{-/-} mice were used as the negative control in addition to an isotype control antibody.

FIGURE 8C shows optical coherence tomography (OCT) analysis of retina thickness at baseline (d0) and after 7 days exposure to light in ST2^{+/+} and ST2^{-/-} mice. Representative cross-sectional OCT images are shown. Change (delta) in retina thickness was calculated by subtracting retina thickness of d0 by that of d7 for each mouse (n=10/genotype). Data shown represent three independent experiments. Bars, 100 μ m. ***, P<0.001; ****, P<0.0001; unpaired two-tailed Student's t test.

FIGURE 8D is a series of graphs showing lack of retina protection in IL-1R1^{-/-} and IL-18R1^{-/-} mice following CLE. ST2^{-/-}, IL-1R1^{-/-}, and IL-18R1^{-/-} mice as well as the corresponding wild-type (+/+) mice were exposed to light for 14 days. Retina thickness was measured by OCT. Delta retina thickness was calculated by subtracting retina thickness of d0 by that of d14 for individual mouse. Each data point represents an individual mouse (n=10-15/genotype). ****, P<0.0001.

FIGURE 8E is a series of graphs showing that rods and cones are protected in ST2^{-/-} mice. Retinal cells in ST2^{+/+} and ST2^{-/-} mice at baseline (d0) and at various time points following CLE were quantified by flow cytometry. Flow cytometry plots (top left panel) indicate the gating strategy and percentage as well as absolute numbers (between parentheses) of rods and cones ($\times 10^5$) in ST2^{+/+} and ST2^{-/-} mice at baseline and CLE d7. Each data point in the graphs in the lower panel represents an individual mouse (n=5-6/genotype). Data represent two independent experiments with similar results. Rho, rhodopsin; CAR, cone arrestin. *, P<0.05; **, P<0.01; ***, P<0.001; ****, P<0.0001; ns, non-significant; unpaired two-tailed Student's t test.

FIGURE 8F is a graph showing morphometric analysis of ONL thickness of ST2^{+/+} and ST2^{-/-} mice at baseline (d0) and after 14 days exposure to light plotted as a function of distance from the optic nerve head (ONH). Significant protection of retina ONL in ST2^{-/-} mice was observed in both superior and inferior quadrants. Data shown are means \pm SEM (n=5-7/genotype). *, P<0.05; **, P<0.01; two-way ANOVA with Tukey's post-test.

FIGURE 8G is a series of graphs showing electroretinography (ERG) analysis of ST2^{+/+} and ST2^{-/-} mice at baseline (d0) and after 7 days CLE. Representative ERG recordings at 25 cd·s/m² flash intensity of baseline and after 7 days CLE are shown. Mean dark-adapted a- and b-wave amplitudes at

flash intensities of 1 and 25 cd·s/m² were significantly greater in ST2^{-/-} compared to ST2^{+/+} mice after 7 days CLE. Data shown are means ± SEM (n=10/genotype). *, P<0.05; **, P<0.01; ***, P<0.001; two-way ANOVA with Tukey's post-test.

FIGURE 9A is a series of graphs showing in vitro activity of soluble ST2. Bone marrow derived mast cells (BMMCs) were stimulated with 1 ng/ml recombinant mouse IL-33 in the absence or presence of 20 µg/ml of soluble ST2-His (sST2) or a control His-tagged protein for 24 h. IL-13 and IL-6 secretion in the supernatant were quantified by ELISA. Data represent means ± SEM of triplicate experiments from two independent experiments.

FIGURE 9B shows expression of AAV-sST2. HEK293 cells were infected with an AAV vector expressing sST2-His (sST2) or empty vector (EV). Six days after infection, sST2 expression in the culture supernatant was determined by ELISA (left panel) and Western blot (right panel). Data represents means ± SEM (n=8) of two experiments. ND, not detected; rsST2, recombinant soluble ST2-His.

FIGURE 9C shows expression of AAV-sST2. BALB/c mice were injected subretinally with an AAV expressing soluble ST2 (AAV-sST2) or AAV empty vector (AAV-EV), which served as a negative control. Expression of sST2 in the retina (left panel) and RPE/choroid (right panel) was analyzed three weeks post-infection by ELISA and Western blotting (WB). Western blotting of ST2 and GAPDH was performed on 10 µg of retina lysates and 3 µg of RPE/choroid lysates. rsST2, recombinant soluble ST2-His.

FIGURE 10 is a series of graphs showing that administration of soluble ST2 protects photoreceptors from phototoxic stress. Mice were injected subretinally with an AAV expressing soluble ST2 (AAV-sST2) and exposed to light 21 days post-infection (schematic in top panel). Mice injected with AAV empty vector (AAV-EV) served as controls. Rods and cones were quantified by flow cytometry before (d0) and after 7 days (d7) light exposure. Each data point represents an individual mouse (n=10/group). ***, P<0.001; ****, P<0.0001; unpaired two-tailed Student's t tests. Data represent two independent experiments with similar results.

FIGURE 11A shows the top 22 light exposure-inducible genes that were decreased in ST2^{-/-} mice compared to ST2^{+/+} mice following CLE for 3 days. The left panel is a heatmap showing the results of gene expression in the retina before (d0) and after (d3) CLE as analyzed by microarray. N=5. The right panel is a table showing the gene symbol, the log₂ fold change in expression, and the P value.

FIGURE 11B is a table showing Gene Ontology (GO) analysis of genes with decreased expression in ST2^{-/-} mice compared to ST2^{+/+} mice (see Figure 11A). The top 17 enriched GO terms are shown.

FIGURE 11C is a series of graphs showing expression of CCL2, IL-6, and IL-1β. The top panel shows a time course qPCR analysis of CCL2, IL-6, and IL-1β expression in the retina following CLE. The results showed reduced expression in ST2^{-/-} compared to ST2^{+/+} mice (n=5-6/genotype). Gene expression in d0 ST2^{+/+} mice was set as 1. CCL2 protein expression in the retina was measured by ELISA (bottom panel). Data represent two independent experiments with similar results. *, P<0.05; **, P<0.01; ***, P<0.001; ****, P<0.0001; one-way ANOVA with Tukey's post-test.

FIGURE 11D is a series of graphs showing that addition of IL-33 induced CCL2 secretion from rMC-1 cells. ST2 expression on the surface of rMC-1 cells was detected by flow cytometry (left panel). Stimulation of rMC-1 cells with IL-33 induced CCL2 secretion in a dose-dependent manner, and stimulation was abrogated in the presence of IL-33 TRAP but not a control protein (right panel). CCL2 levels in 24 h culture supernatants were measured by ELISA. Data shown are means \pm SEM of triplicate wells and represent two independent experiments with similar results. *, $P < 0.05$; **, $P < 0.01$; ****, $P < 0.0001$; two-way ANOVA with Tukey's post-test.

FIGURE 11E is a series of graphs showing that autocrine induction and release of CCL2 from rMC-1 cells was blocked by addition of IL-33 TRAP. rMC-1 cells were cultured in HG containing medium in the presence of IL-33 TRAP or a control protein for up to 72 h. CCL2 mRNA expression (left panel) and secretion (right panel) were measured by qPCR and ELISA, respectively. Data shown are mean \pm SEM of triplicate experiments. ***, $P < 0.001$; ****, $P < 0.0001$; two-way ANOVA with Tukey's post-test.

FIGURE 12A is a series of graphs showing CCR2, Ly6C, and CD115 expression on retinal CD11b⁺CD45^{lo} myeloid cells before (d0) and after CLE (d7) as determined by flow cytometry. The data represent at least two independent experiments with similar results.

FIGURES 12B and 12C show reduced Iba1⁺ cells in ONL, OS, and GCL in ST2^{-/-} mice compared with ST2^{+/+} mice upon light exposure. Images (Figure 12B) show representative immunohistochemistry of Iba1 staining (red). Total Iba1⁺ cells (arrows) within each retinal layer of the entire superior and inferior retina before (d0) and after CLE (d14) were quantified. The results of the quantification are shown in Figure 12C. Each data point represents an individual mouse ($n=10$ /genotype). Bars, 40 μ m. *, $P < 0.05$; **, $P < 0.01$; ****, $P < 0.0001$; one-way ANOVA with Tukey's post-test.

FIGURE 12D shows flow cytometry gating strategy to quantify blood monocyte subsets in clodronate depletion during CLE treatment. ST2^{+/+} and ST2^{-/-} mice were treated with clodronate-liposomes (Clod) or control liposomes (Ctrl) daily during CLE. Seven days after CLE, peripheral blood monocytes were quantified by flow cytometry. Representative flow cytometry plots to identify CD115⁺Ly6C^{hi} monocytes and CD115⁺Ly6C^{lo/-} monocytes are shown (left panel). The results are shown in the graphs in the right panel. $n=4-6$ /group.

FIGURE 12E shows IL-33/ST2-mediated photoreceptor cell loss in CLE is dependent on circulating monocytes. ST2^{+/+} and ST2^{-/-} mice were treated intravenously with clodronate-liposomes (Clod) daily starting 2 days prior to CLE as shown in the diagram in the left panel. Treatment with control liposomes (Ctrl) served as a control. Retinal cells were quantified by flow cytometry 7 days after CLE (see Figure 12D). $n=4-6$ /group. *, $P < 0.05$; ****, $P < 0.0001$; ns, non-significant; one-way ANOVA with Tukey's post-test. Data represent at least two independent experiments with similar results.

FIGURE 12F shows that IL33^{tm1/tm1} mice in which the N-terminal nuclear localization sequence and chromatin binding domain are replaced with dsRed (shown in diagram in left panel) but retaining the C-terminal cytokine domain showed localization of dsRed-IL-33-C-term in the cytoplasm of Müller cells. Images (left panel) are Z-section views of confocal microscopic imaging of IL33^{tm1/tm1} retina flat-mount. dsRed signal is shown in red; DAPI signal is shown in blue. Arrows indicate IL-33⁺ Müller cells. Expression of dsRed-IL-33-C-term in Müller cells was verified by flow cytometry (bottom right panel).

While IL-33 mRNA measured by qPCR in IL33^{tm1/-} and IL33^{tm1/tm1} retina was comparable to wild-type (WT) retina, IL-33 protein levels measured by ELISA in the retina and serum in IL33^{tm1/-} and IL33^{tm1/tm1} mice were significantly higher than those in WT mice, indicating that IL-33 lacking the N-terminus was released from cells. Each data point represents an individual mouse (n=6/genotype). Data are representative of two independent experiments with similar results. **, P<0.01; ***, P<0.001; ****, P<0.0001; one way ANOVA with Tukey's post-test.

FIGURE 12G is a series of graphs showing an ST2-dependent increase of CCL2 and IL-6 expression and loss of cones and RGC in IL33^{tm1/tm1} mice. Retinas from IL33^{+/+}, IL33^{tm1/+}, and IL33^{tm1/tm1} mice bred on either a ST2^{+/-} or ST2^{-/-} background were analyzed by qPCR and flow cytometry. A significant increase of CCL2 and IL-6 expression, as well as loss of cones and RGC, were observed in IL33^{tm1/+} and IL33^{tm1/tm1} mice in the ST2^{+/-} background, but not in the ST2^{-/-} background compared to IL33^{+/+} control mice. Each data point represents an individual mouse (n=3-7/genotype). Data represent two independent experiments with similar results. **, P<0.01; ***, P<0.001; ****, P<0.0001; ns, non-significant; one-way ANOVA with Tukey's post-test.

FIGURE 13A is a series of images showing Müller cell activation in mice treated with NaIO₃. Immunohistochemistry of GFAP expression (red) in mice treated with NaIO₃ showed increased GFAP⁺ Müller cells (arrows) compared to saline treated mice. Bar, 100 μm.

FIGURE 13B shows increased IL-33 processing in the retina of mice treated with NaIO₃. IL-33 expression in the retina was analyzed by Western blotting (left panel). The ratio of IL-33p19 to IL-33p30 was quantitated with ImageJ software (right panel). The 19-kDa processed form of IL-33 peaked at day 3 following NaIO₃ treatment. Data represent two independent experiments.

FIGURE 13C is a graph showing reduced CCL2 induction in the retina in NaIO₃-treated ST2^{-/-} mice compared with ST2^{+/+} mice. CCL2 expression in the retina was determined by ELISA. n=5-7/genotype. ****, P<0.0001; ns, non-significant; one-way ANOVA with Tukey's post-test.

FIGURE 13D is a series of graphs showing reduced macrophage infiltration in the retina in NaIO₃-treated ST2^{-/-} mice compared with ST2^{+/+} mice. Macrophages (CD11b⁺CD45^{hi}) in the retina were quantified by flow cytometry (top left panel). Retina macrophages express higher level of CCR2 compared to microglia (CD11b⁺CD45^{lo}) (bottom left panel) n=6-7/genotype. Data represent three independent experiments. MΦ, macrophage; MGL, microglia. ****, P<0.0001; ns, non-significant; one-way ANOVA with Tukey's post-test.

FIGURE 13E is a series of graphs showing reduced Iba1⁺ cells in OS and ONL in NaIO₃-treated ST2^{-/-} mice compared with ST2^{+/+} mice. Retina sections were stained for Iba1 by immunohistochemistry. Iba1⁺ cells in OS and ONL of the entire superior and inferior retina in saline- or NaIO₃-treated mice (d3) were quantified. n=6/genotype. *, P<0.05; **, P<0.01; ***, P<0.001; ****, P<0.0001; one way ANOVA with Tukey's post-test.

FIGURE 13F shows protection of photoreceptors in ST2^{-/-} mice. Retina thickness of ST2^{+/+} and ST2^{-/-} mice before (d0) and after NaIO₃ treatment (d7) was measured by OCT (middle panel). Representative cross-sectional OCT images are shown (top panel). Delta retina thickness was calculated by subtracting retina thickness of d0 by that of d7 for individual mouse. Bars, 100 μm. Retinal cells of

ST2^{+/+} and ST2^{-/-} mice treated with saline or NaIO₃ (d3 and d7) were quantified by flow cytometry (bottom panel). Each data point represents an individual mouse (n=6-8/genotype). Data represent at least two independent experiments with similar results. *, P<0.05; **, P<0.01; ***, P<0.001; ****, P<0.0001; unpaired two-tailed Student's t test.

5 FIGURE 13G is a series of graphs showing the lack of retinal protection in IL-1R1^{-/-} and IL-18^{-/-} mice in RPE damage-induced retinal degeneration. IL-1R1^{-/-} and IL-18^{-/-} mice were treated with 20 mg NaIO₃. Retina thickness at baseline (d0) and d7 was measured by OCT. Delta retina thickness was calculated by subtracting retina thickness of d0 by that of d7 for individual mouse. Each data point represents an individual mouse (n=10-13/genotype).

10 FIGURE 13H is a series of graphs showing clodronate depletion of blood monocytes. ST2^{+/+} and ST2^{-/-} mice were treated with clodronate-liposomes ("Clod") or control liposomes ("Ctrl") daily starting 1 day prior to NaIO₃ treatment. Three days after NaIO₃ treatment, when the mice were euthanized for retinal cell quantification, peripheral blood monocytes were quantified by flow cytometry. Representative flow cytometry plots to identify CD115⁺Ly6C^{hi} monocytes and CD115⁺Ly6C^{lo/-} monocytes are shown.

15 Each data point represents an individual mouse (n=5/group).

FIGURE 13I is a series of graphs showing that IL-33/ST2-mediated photoreceptor cell loss is dependent on circulating monocytes. ST2^{+/+} and ST2^{-/-} mice were treated intravenously with clodronate-liposomes (Clod) daily starting 1 day prior to NaIO₃ treatment as shown in the schematic diagram. Treatment with control liposomes (Ctrl) served as a control. Retinal cells were quantified by flow

20 cytometry 3 days after saline or NaIO₃ treatment. Each data point represents individual mouse (n=5/group). *, P<0.05; ****, P<0.0001; ns, non-significant; one way ANOVA with Tukey's post-test.

FIGURE 14A shows a schematic diagram of the *Nippostrongylus brasiliensis* infection model of Type 2 (Th2) lung inflammation.

FIGURE 14B shows eosinophil (eos) numbers in lung tissue (left panel) and BALF (right panel)

25 derived from ST2^{+/+} and ST2^{-/-} (ST2 KO) mice following infection with *N. brasiliensis*. Mice having the indicated genotypes were treated with control anti-ragweed or anti-IL-13 (α-IL-13) antibodies as described in Section A of Example 4. Naïve ST2^{+/+} mice served as a control. The bottom panel is a table showing the raw data from the study. *, P<0.05; ns, non-significant.

FIGURE 14C shows the results of BALF cytokine analysis from the *N. brasiliensis* infection model

30 of Th2 lung inflammation described in Example 4. The levels of IL-4, IL-5, and IL-13 are shown for mice having the indicated genotypes treated with control anti-ragweed, anti-IL-13 (α-IL-13), and/or anti-IL-4 (α-IL-4) antibodies as described in Section A of Example 4. Naïve mice served as a control. The bottom panel is a table showing the raw data from the study. *, P<0.05; ns, non-significant.

FIGURE 15A shows eosinophil numbers in lung tissue (top left panel) and BALF (top right panel)

35 derived from ST2^{+/+} and ST2^{-/-} mice following sensitization/challenge with TNP-OVA antigen. The table in the bottom panel shows the raw data from the study. Mice having the indicated genotypes were treated with control anti-ragweed or anti-IL-13 (α-IL-13) antibodies as described in Section B of Example 4. Naïve mice served as a control. *, P<0.05.

FIGURE 15B is a series of graphs showing the cell viability (left panel) and cytokine secretion in an antigen recall assay (IL-5, middle panel; IL-13, right panel) from the TNP-OVA model described in Section B of Example 4. An anti-GP120 (α -GP120) antibody served as a control.

FIGURE 16A shows augmentation of mast cell degranulation by IL-33. The top panel shows a schematic diagram of the mast cell degranulation assay, and the bottom panel shows graphs of results from the mast cell degranulation assay for β -hexaminodase (left), tryptase (middle), and histamine (right).

FIGURE 16B is a schematic diagram showing the systemic anaphylaxis assay described in Example 5.

FIGURES 16C and 16D are graphs showing the results from the passive systemic anaphylaxis assay (see, e.g., Figure 16B). Figure 16C shows the results from ST2^{+/+} (WT) or ST2^{-/-} (KO) mice treated with IgE and IL-33 without DNP-HSA addition. Figure 16D shows the results from ST2^{+/+} (WT) or ST2^{-/-} (KO) mice treated with IgE and DNP-HSA without IL-33 addition.

FIGURE 16E shows a series of graphs showing the results from the passive systemic anaphylaxis assay. The graph in the left panel shows body temperature ($^{\circ}$ F) as a function of time (min) for ST2^{+/+} (WT) or ST2^{-/-} (KO) mice treated with IgE, DNP-HSA, and IL-33. The graph in the right panel shows the area under the curve (AUC) from 45 to 60 min for the indicated genotype and challenge.

FIGURE 16F shows that IL-33 enhances IgE crosslinking-dependent cytokine secretion by human mast cells in vitro. The top panel shows a schematic diagram of the experiment. The graphs in the bottom panel show the results from the mast cell cytokine measurements following stimulation with IL-33 and IgE crosslinking for IL-5 (left), IL-13 (middle), and IL-8 (right).

FIGURE 16G shows that IL-33 directly stimulates mast cell cytokine secretion independent of IgE or antigen in vitro. The top panel shows a schematic diagram of the experiment. The graphs in the bottom panel show the results of ELISA experiments to determine the expression level of the indicated cytokine (TNF- α , IL-10, IL-13, IL-5, or IL-8) in the absence of IL-33 (0 ng/ml) or in the presence of 10 ng/mL IL-33.

FIGURE 16H is a series of graphs showing the relative expression of the indicated genes in mast cells following IL-33 stimulation as determined by microarray analysis. The left panel shows examples of genes that were upregulated following IL-33 stimulation, which included genes involved in smooth muscle growth/migration (e.g., CCL1, IL-3, and IL-8); genes involved in smooth muscle contraction (e.g., TNF α , IL-10, IL-6, IL13, and IL-3); and genes involved in hyperreactivity (e.g., TNF α , IL-10, and TNFSF14).

FIGURE 17A is a graph showing the arthritic scores from a K/BxN serum transfer experiment as described in Example 6 in IL33^{-/-} mice as compared to an IL33^{+/+} mice. The data represent averages from groups of ST2^{-/-} or ST2^{+/+} mice.

FIGURE 17B is a graph showing the arthritic scores from a K/BxN serum transfer experiment as described in Example 6 in ST2^{-/-} mice as compared to wild-type (ST2^{+/+}) mice (C57Bl/6 background). The data represent averages from groups of ST2^{-/-} or ST2^{+/+} mice. Similar results were obtained using the ST2^{-/-} genotype in the Balb/C background.

FIGURES 17C-17D are graphs showing the arthritic scores from the K/BxN serum transfer studies in ST2^{-/-} mice compared to wild-type (ST2^{+/+}) mice. Figure 17C shows the average daily clinical score across the entire experiment, while Figure 17D shows the clinical score at day 7 for individual mice.

FIGURE 18A is schematic diagram of an experiment to determine whether IL-33-induced macrophage recruitment depends on IL-4, IL-5, and IL-13, as described in Example 7.

FIGURES 18B and 18C are graphs showing that IL-33-induced macrophage recruitment into the lung is independent of IL-4, IL-5, and IL-13.

FIGURE 19A is a graph showing the results of a cell-based IL-33 blocking assay for human IL-33 using HEK-BLUE™ IL-33 cells as described in Example 8. The concentration of human IL-33 N-His was 15 pM. The cells were stimulated for 20 h. The tables below the graph show the IC90 and IC50 for 10C12.38.H6.87Y.58I IgG4, the anti-IL-33/anti-IL-13 bispecific clone 10C12.38.H6.87Y.58I/IL-13 IgG4 (abbreviated as "10C12-IL-13 KIH IgG4"), a control IgG4 antibody, and ST2-LZ. The values inside parentheses for the IC90 table are the IC90 values in units of µg/ml.

FIGURE 19B is a schematic diagram of the basophil IL-33 phospho-p38 assay described in Example 8.

FIGURE 19C is a series of graphs showing results from the basophil IL-33 phospho-p38 assay as described in Example 8. The graphs show the percentage of maximum fluorescence intensity as a function of phospho-p38 fluorescence intensity.

FIGURE 19D is a graph showing that the monospecific anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and the bispecific antibody 10C12.38.H6.87Y.58I/IL-13 IgG4 ("10C12-IL13 KIH IgG4") caused a dose-dependent inhibition in IL-33-induced phospho-p38 levels in basophils, as described in Example 8. The graph plots mean fluorescence intensity (MFI) (average from two donors) as a function of antibody concentration. A control IgG4 antibody did not inhibit phospho-p38 levels. The graph also shows the results from control experiments in which no antibody was added ("No Ab") or in which no IL-33 was added ("No IL-33").

FIGURE 20 is a table showing the binding kinetics of the 10C12.38.H6.87Y.58I/IL-13 IgG4 bispecific antibody (10C12-IL-13 KIH IgG4) to human IL-33, cyno IL-33, and human IL-13 as assessed by BIACORE® 3000 SPR analysis. The table shows results from three independent antibody preparations (lots).

FIGURE 21A is a graph showing results of a cell-based human IL-33 blocking using HEK-BLUE™ IL-33/IL-1β reporter cells. Dose-response curves were used to determine the inhibition of 10 pM human IL-33 activity (measured by OD 620) by the indicated anti-IL-33 antibodies (RG1-20 and 10C12.38.H6.87Y.58I IgG4), sST2-LZ, and the isotype control antibody (IgG4). The graph also shows the results from control experiments in which no antibody was added ("No Ab") or in which no IL-33 was added ("No IL-33").

FIGURE 21B is a graph showing dose-response of HEK-BLUE™ IL-33/IL-1β reporter cells to human IL-33.

FIGURE 21C is a table showing inhibition of human and cynomolgus monkey IL-33 activation of HEK-BLUE™ IL-33/IL-1β reporter cells by the indicated anti-IL-33 antibodies.

FIGURE 21D is a graph showing dose-response curves of the five anti-IL-33 RG antibodies with the highest human IL-33 blocking activity compared to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ. The graph also shows the results from control experiments in which no antibody was added ("No Ab") or in which no IL-33 was added ("No IL-33").

5 FIGURE 22A is a graph showing results of a cell-based cyno IL-33 blocking assay using HEK-BLUE™ IL-33/IL-1 β reporter cells. Dose-response curves were used to determine the inhibition of 5 pM cynomolgus monkey IL-33 activity by the indicated anti-IL-33 antibodies (RG1-20 and 10C12.38.H6.87Y.58I IgG4), sST2-LZ, and the isotype control antibody (IgG4).

10 FIGURE 22B is a graph showing dose-response of HEK-BLUE™ IL-33/IL-1 β reporter cells to cyno IL-33.

FIGURE 22C is a graph showing dose-response curves of the five anti-IL-33 RG antibodies with the highest cynomolgus monkey IL-33 blocking activity relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ. The graph also shows the results from control experiments in which no antibody was added ("No Ab") or in which no IL-33 was added ("No IL-33").

15 FIGURE 22D is a graph showing dose-response curves of anti-IL-33 RG antibodies that were non-blocking for cyno IL-33.

FIGURE 23A is a series of graphs showing flow cytometry analysis of the purity of enriched NK cells (CD56⁺ CD3⁻) from human PBMCs.

20 FIGURE 23B is a graph showing the results of ELISA analysis of human IFN- γ secretion from primary NK cells in response to human IL-33. Dose-response curves were generated from IFN- γ ELISA OD 450 values.

FIGURE 23C is a graph showing inhibition of human IL-33 activation of primary NK cells by the indicated anti-IL-33 antibodies. Dose-response curves were used to determine the inhibition of human IL-33 activity in NK cells by the indicated anti-IL-33 antibodies (RG1-RG20 and 10C12.38.H6.87Y.58I IgG4), sST2-LZ, and the isotype control antibody (IgG4).

FIGURE 23D is a table showing the inhibition of human IL-33 activation of primary NK cells by the indicated anti-IL-33 antibodies.

FIGURE 23E is a graph showing dose-response curves of the five anti-IL-33 RG antibodies with the highest human IL-33 blocking activity relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

30 FIGURE 23F is a graph showing dose-response curves of anti-IL-33 antibodies RG1-RG5 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 23G is a graph showing dose-response curves of anti-IL-33 antibodies RG6-RG10 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 23H is a graph showing dose-response curves of anti-IL-33 antibodies RG11-RG15 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 23I is a graph showing dose-response curves of anti-IL-33 antibodies RG16-RG20 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 24A is a schematic diagram showing the flow cytometry analysis of IL-33-induced p38 MAPK (Thr180/Tyr182) phosphorylation in primary basophils (CD123⁺) from human PBMCs.

FIGURE 24B is a graph showing the mean fluorescence intensity (MFI) of p38 MAPK (Thr180/Tyr182) phosphorylation (ph-p38) from primary basophils in response to increasing doses of human IL-33.

FIGURE 24C is a graph showing inhibition of human IL-33 activity in primary basophils by the indicated anti-IL-33 antibodies. Dose-response curves were used to determine the inhibition of human IL-33 activity in basophils by the indicated anti-IL-33 antibodies (RG1-RG20 and 10C12.38.H6.87Y.58I IgG4), sST2-LZ, and the isotype control antibody (IgG4).

FIGURE 24D is a table showing inhibition of human IL-33 activation of primary basophils by anti-IL-33 antibodies. "Partial blocking" indicates dose-dependent blocking activity that fails to reach baseline levels at the highest antibody concentrations.

FIGURE 24E is a graph showing dose-response curves of the five anti-IL-33 RG antibodies with highest human IL-33 blocking activity relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 24F is a graph showing inhibition of human IL-33 activity in primary basophils. The graph plots dose-response curves of anti-IL-33 antibodies RG1-RG5 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 24G is a graph showing inhibition of human IL-33 activity in primary basophils. The graph plots dose-response curves of anti-IL-33 antibodies RG6-RG10 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 24H is a graph showing inhibition of human IL-33 activity in primary basophils. The graph plots dose-response curves of anti-IL-33 antibodies RG11-RG15 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURE 24I is a graph showing inhibition of human IL-33 activity in primary basophils. The graph plots dose-response curves of anti-IL-33 antibodies RG16-RG20 relative to 10C12.38.H6.87Y.58I IgG4 and sST2-LZ.

FIGURES 24J and 24K are graphs showing mean fluorescence intensity (MFI) values of p38 MAPK (Thr180/Tyr182) phosphorylation (Ph-p38) used to determine the extent of inhibition of 500 pM human IL-33 activity in basophils by 0.4 nM (Figure 24J) or 2 nM (Figure 24K) anti-IL-33 antibodies (RG1-RG20 and 10C12.38.H6.87Y.58I IgG4), sST2-LZ, and the isotype control antibody (IgG4). The table to the left of each graph summarizes the results for the indicated antibodies.

FIGURES 25A and 25B are graphs showing the results of competitive binding ELISA experiments to measure blocking activity of anti-IL-33 antibodies to human (Figure 25A) or cyno (Figure 25B) IL-33, as described in Example 9, Section F. The graphs plot % IL-33 binding as a function of anti-IL-33 antibody concentration (M).

Detailed Description of Embodiments of the Invention

I. Definitions

The term “about” as used herein refers to the usual error range for the respective value readily known to the skilled person in this technical field. Reference to “about” a value or parameter herein includes (and describes) embodiments that are directed to that value or parameter *per se*.

An “acceptor human framework” for the purposes herein is a framework comprising the amino acid sequence of a light chain variable domain (VL) framework or a heavy chain variable domain (VH) framework derived from a human immunoglobulin framework or a human consensus framework, as defined below. An acceptor human framework “derived from” a human immunoglobulin framework or a human consensus framework may comprise the same amino acid sequence thereof, or it may contain amino acid sequence changes. In some embodiments, the number of amino acid changes are 10 or less, 9 or less, 8 or less, 7 or less, 6 or less, 5 or less, 4 or less, 3 or less, or 2 or less. In some embodiments, the VL acceptor human framework is identical in sequence to the VL human immunoglobulin framework sequence or human consensus framework sequence.

“Affinity” refers to the strength of the sum total of noncovalent interactions between a single binding site of a molecule (e.g., an antibody) and its binding partner (e.g., an antigen). Unless indicated otherwise, as used herein, “binding affinity” refers to intrinsic binding affinity which reflects a 1:1 interaction between members of a binding pair (e.g., antibody and antigen). The affinity of a molecule X for its partner Y can generally be represented by the dissociation constant (K_D). Affinity can be measured by common methods known in the art, including those described herein. Specific illustrative and exemplary embodiments for measuring binding affinity are described in the following.

An “affinity-matured” antibody is one with one or more alterations in one or more HVRs and/or framework regions which result in an improvement in the affinity of the antibody for antigen, compared to a parent antibody which does not possess those alteration(s). Preferred affinity-matured antibodies will have nanomolar or even picomolar affinities for the target antigen. Affinity-matured antibodies are produced by procedures known in the art. For example, Marks et al. *Bio/Technology* 10:779-783, 1992 describes affinity maturation by VH and VL domain shuffling. Random mutagenesis of HVR and/or framework residues is described by: Barbas et al. *Proc. Natl. Acad. Sci. USA* 91:3809-3813, 1994; Schier et al. *Gene* 169:147-155, 1995; Yelton et al. *J. Immunol.* 155:1994-2004, 1995; Jackson et al. *J. Immunol.* 154(7):3310-3319, 1995; and Hawkins et al. *J. Mol. Biol.* 226:889-896, 1992.

The term “antibody” herein is used in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies, including anti-IL-33/anti-IL-13 bispecific antibodies), and antibody fragments so long as they exhibit the desired antigen-binding activity.

The term “interleukin-33 (IL-33),” as used herein, refers to any native IL-33 from any vertebrate source, including mammals such as primates (e.g., humans and cynomolgus monkeys) and rodents (e.g., mice and rats), unless otherwise indicated. IL-33 is also referred to in the art as nuclear factor of high endothelial venules (NF-HEV; see, e.g., Baekkevold et al. *Am. J. Pathol.* 163(1): 69-79, 2003), DVS27,

C9orf26, and interleukin-1 family member 11 (IL-1F11). The term encompasses “full-length,” unprocessed IL-33, as well as any form of IL-33 that results from processing in the cell. Human full-length, unprocessed IL-33 contains 270 amino acids (a.a.) and may also be referred to as IL-33₁₋₂₇₀. Processed forms of human IL-33 include, for example, IL-33₉₅₋₂₇₀, IL-33₉₉₋₂₇₀, IL-33₁₀₉₋₂₇₀, IL-33₁₁₂₋₂₇₀, IL-33₁₋₁₇₈, and IL-33₁₇₉₋₂₇₀ (Lefrançois et al. *Proc. Natl. Acad. Sci.* 109(5):1673-1678, 2012 and Martin, *Semin. Immunol.* 25: 449-457, 2013). In some embodiments, processed forms of human IL-33, e.g., IL-33₉₅₋₂₇₀, IL-33₉₉₋₂₇₀, IL-33₁₀₉₋₂₇₀, or other forms processed by proteases such as calpain, proteinase 3, neutrophil elastase, and cathepsin G may have increased biological activity compared to full-length IL-33. The term also encompasses naturally occurring variants of IL-33, for example, splice variants (e.g., the constitutively active splice variant splIL-33 which lacks exon 3, Hong et al. *J. Biol. Chem.* 286(22):20078-20086, 2011) or allelic variants. IL-33 may be present within a cell (e.g., within the nucleus) or as a secreted cytokine form. Full-length IL-33 protein contains a helix-turn-helix DNA-binding motif including nuclear localization sequence (a.a.1-75 of human IL-33), which includes a chromatin binding motif (a.a. 40-58 of human IL-33). Forms of IL-33 that are processed and secreted lack these N-terminal motifs. The amino acid sequence of an exemplary human IL-33 can be found, for example, under UniProtKB accession number O95760.

By “IL-33 axis” is meant a nucleic acid (e.g., a gene or mRNA transcribed from the gene) or polypeptide that is involved in IL-33 signal transduction. For example, the IL-33 axis may include the ligand IL-33, a receptor (e.g., ST2 and/or IL-1RAcP), adaptor molecules (e.g., MyD88), or proteins that associate with receptor molecules and/or adaptor molecules (e.g., kinases, such as interleukin-1 receptor-associated kinase 1 (IRAK1) and interleukin-1 receptor-associated kinase 4 (IRAK4), or E3 ubiquitin ligases, such as TNF receptor associated factor 6 (TRAF6)).

The terms “interleukin 1 receptor-like 1 (IL1RL1)” and “ST2,” used interchangeably herein, refer to any native ST2 from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated. ST2 is also referred to in the art as DER4, T1, and FIT-1. The term encompasses “full-length,” unprocessed ST2, as well as any form of ST2 that results from processing in the cell. At least four isoforms of ST2 are known in the art, including soluble (sST2, also known as IL1RL1-a) and transmembrane (ST2L, also known as IL1RL1-b), which arise from differential mRNA expression from a dual promoter system, and ST2V and ST2LV, which arise from alternative splicing, as described below. The domain structure of ST2L includes three extracellular immunoglobulin-like C2 domains, a transmembrane domain, and a cytoplasmic Toll/Interleukin-1 receptor (TIR) domain. sST2 lacks the transmembrane and cytoplasmic domains contained within ST2L and includes a unique 9 amino acid (a.a.) C-terminal sequence (see, e.g., Kakkar et al. *Nat. Rev. Drug Disc.* 7: 827-840, 2008). sST2 can function as a decoy receptor to inhibit soluble IL-33. The term also encompasses naturally occurring variants of ST2, e.g., splice variants (e.g., ST2V, which lacks the third immunoglobulin motif and has a unique hydrophobic tail, and ST2LV, which lacks the transmembrane domain of ST2L) or allelic variants (e.g., variants that are protective against asthma risk or that confer asthma risk as described herein). The amino acid sequence of an exemplary human ST2 can be found, for example, under UniProtKB accession number Q01638. ST2 is a part of the IL-33 receptor along with

the co-receptor protein IL-1RAcP. Binding of IL-33 to ST2 and the co-receptor interleukin-1 receptor accessory protein (IL-1RAcP) forms a 1:1:1 ternary signaling complex to promote downstream signal transduction, as depicted in Figure 1A (see, e.g., Lingel et al. *Structure* 17(10): 1398-1410, 2009, and Liu et al. *Proc. Natl. Acad. Sci.* 110(37): 14918-14924, 2013).

The terms "anti-IL-33 antibody," an "antibody that binds to IL-33," and "antibody that specifically binds IL-33" refer to an antibody that is capable of binding IL-33 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting IL-33. In one embodiment, the extent of binding of an anti-IL-33 antibody to an unrelated, non-IL-33 protein is less than about 10% of the binding of the antibody to IL-33 as measured, e.g., by a radioimmunoassay (RIA). In certain embodiments, an antibody that binds to IL-33 has a dissociation constant (K_D) of $\leq 1 \mu\text{M}$, $\leq 100 \text{ nM}$, $\leq 10 \text{ nM}$, $\leq 1 \text{ nM}$, $\leq 0.1 \text{ nM}$, $\leq 0.01 \text{ nM}$, or $\leq 0.001 \text{ nM}$ (e.g., 10^{-8} M or less, e.g. from 10^{-8} M to 10^{-13} M , e.g., from 10^{-9} M to 10^{-13} M). In certain embodiments, an anti-IL-33 antibody binds to an epitope of IL-33 that is conserved among IL-33 from different species.

An "antibody that binds to the same epitope" as a reference antibody refers to an antibody that blocks binding of the reference antibody to its antigen in a competition assay by 50% or more, and conversely, the reference antibody blocks binding of the antibody to its antigen in a competition assay by 50% or more. An exemplary competition assay is provided herein.

"Antibody fragments" comprise a portion of an intact antibody, preferably the antigen binding or variable region of the intact antibody. Examples of antibody fragments include Fab, Fab', F(ab')₂, and Fv fragments; diabodies; linear antibodies (see U.S. Patent No. 5,641,870, Example 2; Zapata et al. *Protein Eng.* 8(10):1057-1062, 1995); single-chain antibody molecules; and multispecific antibodies formed from antibody fragments.

Papain digestion of antibodies produces two identical antigen-binding fragments, called "Fab" fragments, and a residual "Fc" fragment, a designation reflecting the ability to crystallize readily. The Fab fragment consists of an entire L chain along with the variable region domain of the H chain (VH), and the first constant domain of one heavy chain (C_H1). Pepsin treatment of an antibody yields a single large F(ab')₂ fragment which roughly corresponds to two disulfide linked Fab fragments having divalent antigen-binding activity and is still capable of cross-linking antigen. Fab' fragments differ from Fab fragments by having an additional few residues at the carboxy terminus of the C_H1 domain including one or more cysteines from the antibody hinge region. Fab'-SH is the designation herein for Fab' in which the cysteine residue(s) of the constant domains bear a free thiol group. F(ab')₂ antibody fragments originally were produced as pairs of Fab' fragments which have hinge cysteines between them. Other chemical couplings of antibody fragments are also known.

The term "Fc region" herein is used to define a C-terminal region of an immunoglobulin heavy chain that contains at least a portion of the constant region. The term includes native sequence Fc regions and variant Fc regions. In one embodiment, a human IgG heavy chain Fc region extends from Cys226, or from Pro230, to the carboxyl-terminus of the heavy chain. However, the C-terminal lysine (Lys447) of the Fc region may or may not be present. Unless otherwise specified herein, numbering of amino acid residues in the Fc region or constant region is according to the EU numbering system, also

called the EU index, as described in Kabat et al. *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD, 1991.

“Fv” consists of a dimer of one heavy- and one light-chain variable region domain in tight, non-covalent association. From the folding of these two domains emanate six hypervariable loops (3 loops each from the H and L chain) that contribute the amino acid residues for antigen binding and confer antigen binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three Hs specific for an antigen) has the ability to recognize and bind antigen, although often at a lower affinity than the entire binding site.

“Single-chain Fv” also abbreviated as “sFv” or “scFv” are antibody fragments that comprise the VH and VL antibody domains connected into a single polypeptide chain. Preferably, the sFv polypeptide further comprises a polypeptide linker between the VH and VL domains which enables the sFv to form the desired structure for antigen binding. For a review of sFv, see Pluckthun in *The Pharmacology of Monoclonal Antibodies*, vol. 113, Rosenberg and Moore eds., Springer-Verlag, New York, pp. 269-315, 1994.

The term “diabodies” refers to small antibody fragments prepared by constructing sFv fragments (see preceding paragraph) with short linkers (about 5-10 residues) between the VH and VL domains such that inter-chain but not intra-chain pairing of the V domains is achieved, resulting in a bivalent fragment, i.e., fragment having two antigen-binding sites. Bispecific diabodies are heterodimers of two “crossover” sFv fragments in which the VH and VL domains of the two antibodies are present on different polypeptide chains. Diabodies are described more fully in, for example, EP 404,097; WO 93/11161; and Hollinger et al. *Proc. Natl. Acad. Sci. USA* 90:6444-6448, 1993.

By “binding domain” is meant a part of a compound or a molecule that specifically binds to a target epitope, antigen, ligand, or receptor. Binding domains include but are not limited to antibodies (e.g., monoclonal, polyclonal, recombinant, humanized, and chimeric antibodies), antibody fragments or portions thereof (e.g., Fab fragments, Fab’2, scFv antibodies, SMIP, domain antibodies, diabodies, minibodies, scFv-Fc, affibodies, nanobodies, and VH and/or VL domains of antibodies), receptors, ligands, aptamers, and other molecules having an identified binding partner.

A “blocking” antibody or an “antagonist” antibody is one which inhibits or reduces biological activity of the antigen it binds. Certain blocking antibodies or antagonist antibodies substantially or completely inhibit the biological activity of the antigen.

A “cell-based blocking assay” refers to an assay in which the ability of an antibody to inhibit or reduce the biological activity of the antigen it binds can be measured. For example, a cell-based assay can be used to measure the concentration of antibody required to inhibit a specific biological or biochemical function. In some embodiments, the half maximal inhibitory concentration (IC₅₀) and/or 90% inhibitory concentration (IC₉₀) of an antibody (e.g., an anti-IL-33 antibody of the invention) is measured using a cell-based blocking assay. In some embodiments, the cell-based blocking assay is used to determine whether an antibody blocks the interaction between a ligand (e.g., IL-33) and its receptor (e.g., ST2 and/or the coreceptor IL-1RAcP). An exemplary cell-based blocking assay for IL-33 is provided

herein in Example 2B. Additional exemplary cell-based blocking assays for IL-33 are provided herein, for example, in Example 8, including primary natural killer (NK) cell assays and primary basophil cell assays.

The “class” of an antibody refers to the type of constant domain or constant region possessed by its heavy chain. There are five major classes of antibodies: IgA, IgD, IgE, IgG, and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG₁, IgG₂, IgG₃, IgG₄, IgA₁, and IgA₂. The heavy chain constant domains that correspond to the different classes of immunoglobulins are called α , δ , ϵ , γ , and μ , respectively.

Antibody “effector functions” refer to those biological activities attributable to the Fc region (a native sequence Fc region or amino acid sequence variant Fc region) of an antibody, and vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity; Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (e.g., B cell receptor); and B cell activation.

“Antibody-dependent cell-mediated cytotoxicity” or “ADCC” refers to a form of cytotoxicity in which secreted Ig bound onto Fc receptors (FcRs) present on certain cytotoxic cells (e.g., Natural Killer (NK) cells, neutrophils, and macrophages) enable these cytotoxic effector cells to bind specifically to an antigen-bearing target cell and subsequently kill the target cell with cytotoxins. The antibodies “arm” the cytotoxic cells and are absolutely required for such killing. The primary cells for mediating ADCC, NK cells, express Fc γ RIII only, whereas monocytes express Fc γ RI, Fc γ RII, and Fc γ RIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch et al. *Annu. Rev. Immunol.* 9:457-492, 1991. To assess ADCC activity of a molecule of interest, an *in vitro* ADCC assay, such as that described in US Patent No. 5,500,362 or 5,821,337 can be performed. Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest can be assessed *in vivo*, e.g., in a animal model such as that disclosed in Clynes et al. *Proc. Natl. Acad. Sci. USA* 95:652-656, 1998.

“Fc receptor” or “FcR” describes a receptor that binds to the Fc region of an antibody. The preferred FcR is a native sequence human FcR. Moreover, a preferred FcR is one which binds an IgG antibody (a gamma receptor) and includes receptors of the Fc γ RI, Fc γ RII, and Fc γ RIII subclasses, including allelic variants and alternatively spliced forms of these receptors. Fc γ RII receptors include Fc γ RIIA (an “activating receptor”) and Fc γ RIIB (an “inhibiting receptor”), which have similar amino acid sequences that differ primarily in the cytoplasmic domains thereof. Activating receptor Fc γ RIIA contains an immunoreceptor tyrosine-based activation motif (ITAM) in its cytoplasmic domain. Inhibiting receptor Fc γ RIIB contains an immunoreceptor tyrosine-based inhibition motif (ITIM) in its cytoplasmic domain (see review M. in Daëron, *Annu. Rev. Immunol.* 15:203-234, 1997). FcRs are reviewed, for example, in Ravetch et al. *Annu. Rev. Immunol.* 9:457-492, 1991; Capel et al. *Immunomethods* 4:25-34, 1994; and de Haas et al. *J. Lab. Clin. Med.* 126:330-41, 1995. Other FcRs, including those to be identified in the future, are encompassed by the term “FcR” herein. The term also includes the neonatal receptor, FcRn, which is responsible for the transfer of maternal IgGs to the fetus (see, e.g., Guyer et al. *J. Immunol.* 117:587, 1976; and Kim et al. *J. Immunol.* 24:249, 1994).

"Human effector cells" are leukocytes which express one or more FcRs and perform effector functions. Preferably, the cells express at least FcγRIII and perform ADCC effector function. Examples of human leukocytes which mediate ADCC include peripheral blood mononuclear cells (PBMC), natural killer (NK) cells, monocytes, cytotoxic T cells, and neutrophils; with PBMCs and NK cells being preferred.

5 The effector cells can be isolated from a native source, e.g., from blood.

"Complement dependent cytotoxicity" or "CDC" refers to the lysis of a target cell in the presence of complement. Activation of the classical complement pathway is initiated by the binding of the first component of the complement system (C1q) to antibodies (of the appropriate subclass) which are bound to their cognate antigen. To assess complement activation, a CDC assay, e.g., as described in Gazzano-Santoro et al. *J. Immunol. Methods* 202:163, 1996, can be performed.

10 An "epitope" is the portion of the antigen to which the antibody selectively binds. For a polypeptide antigen, the epitope is generally a peptide portion of about 4-15 amino acid residues.

The terms "full-length antibody," "intact antibody," and "whole antibody" are used herein interchangeably to refer to an antibody having a structure substantially similar to a native antibody structure or having heavy chains that contain an Fc region as defined herein.

15 A "human antibody" is one which possesses an amino acid sequence which corresponds to that of an antibody produced by a human and/or has been made using any of the techniques for making human antibodies. This definition of a human antibody specifically excludes a humanized antibody comprising non-human antigen-binding residues.

20 A "human consensus framework" is a framework which represents the most commonly occurring amino acid residues in a selection of human immunoglobulin VL or VH framework sequences. Generally, the selection of human immunoglobulin VL or VH sequences is from a subgroup of variable domain sequences. Generally, the subgroup of sequences is a subgroup as in Kabat et al. *Sequences of Proteins of Immunological Interest*, Fifth Edition, NIH Publication 91-3242, Bethesda MD, vols. 1-3, 1991. In one embodiment, for the VL, the subgroup is subgroup kappa III or kappa IV as in Kabat et al. *supra*. In one embodiment, for the VH, the subgroup is subgroup III as in Kabat et al. *supra*.

25 "Humanized" forms of non-human (e.g., rodent) antibodies are chimeric antibodies that contain minimal sequence derived from the non-human antibody. For the most part, humanized antibodies are human immunoglobulins (recipient antibody) in which residues from a hypervariable region of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit or non-human primate having the desired antibody specificity, affinity, and capability. In some instances, framework region (FR) residues of the human immunoglobulin are replaced by corresponding non-human residues. Furthermore, humanized antibodies can comprise residues that are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance. In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable loops correspond to those of a non-human immunoglobulin and all or substantially all of the FRs are those of a human immunoglobulin sequence. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human

immunoglobulin. For further details, see Jones et al. *Nature* 321:522-525, 1986; Riechmann et al. *Nature* 332:323-329, 1988; and Presta, *Curr. Op. Struct. Biol.* 2:593-596, 1992.

An "immunoconjugate" is an antibody conjugated to one or more heterologous molecule(s), including but not limited to a cytotoxic agent.

5 The term "isolated" when used to describe the various antibodies disclosed herein, means an antibody that has been identified and separated and/or recovered from a cell or cell culture from which it was expressed. Contaminant components of its natural environment are materials that would typically interfere with diagnostic or therapeutic uses for the polypeptide, and can include enzymes, hormones, and other proteinaceous or non-proteinaceous solutes. In some embodiments, an antibody is purified to
10 greater than 95% or 99% purity as determined by, for example, electrophoretic (e.g., sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE), isoelectric focusing (IEF), capillary electrophoresis) or chromatographic (e.g., ion exchange or reverse phase HPLC) methods. For a review of methods for assessment of antibody purity, see, for example, Flatman et al. *J. Chromatogr. B* 848:79-87, 2007. In preferred embodiments, the antibody will be purified (1) to a degree sufficient to obtain at
15 least 15 residues of N-terminal or internal amino acid sequence by use of a spinning cup sequenator, or (2) to homogeneity by SDS-PAGE under non-reducing or reducing conditions using Coomassie blue or, preferably, silver stain. Isolated antibody includes antibodies *in situ* within recombinant cells, because at least one component of the polypeptide natural environment will not be present. Ordinarily, however, isolated polypeptide will be prepared by at least one purification step.

20 The term "monoclonal antibody" as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical and/or bind the same epitope, except for possible variant antibodies, e.g., containing naturally occurring mutations or arising during production of a monoclonal antibody preparation, such variants generally being present in minor amounts. In contrast to polyclonal antibody preparations, which typically
25 include different antibodies directed against different determinants (epitopes), each monoclonal antibody of a monoclonal antibody preparation is directed against a single determinant on an antigen. Thus, the modifier "monoclonal" indicates the character of the antibody as being obtained from a substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the
30 present invention may be made by a variety of techniques, including but not limited to the hybridoma method, recombinant DNA methods, phage-display methods, and methods utilizing transgenic animals containing all or part of the human immunoglobulin loci, such methods and other exemplary methods for making monoclonal antibodies being described herein.

35 The term "multispecific antibody" is used in the broadest sense and specifically covers an antibody comprising a heavy chain variable domain (VH) and a light chain variable domain (VL), where the VHVL unit has polyepitopic specificity (i.e., is capable of binding to two different epitopes on one biological molecule or each epitope on a different biological molecule). Such multispecific antibodies include, but are not limited to, full-length antibodies, antibodies having two or more VL and VH domains, antibody fragments such as Fab, Fv, dsFv, scFv, diabodies, bispecific diabodies and triabodies, antibody

fragments that have been linked covalently or non-covalently. "Polyepitopic specificity" refers to the ability to specifically bind to two or more different epitopes on the same or different target(s). "Dual specificity" or "bispecificity" refers to the ability to specifically bind to two different epitopes on the same or different target(s). However, in contrast to bispecific antibodies, dual-specific antibodies have two
5 antigen-binding arms that are identical in amino acid sequence and each Fab arm is capable of recognizing two antigens. Dual-specificity allows the antibodies to interact with high affinity with two different antigens as a single Fab or IgG molecule. According to one embodiment, the multispecific antibody in an IgG1 form binds to each epitope with an affinity of 5 μ M to 0.001pM, 3 μ M to 0.001pM, 1 μ M to 0.001pM, 0.5 μ M to 0.001pM or 0.1 μ M to 0.001pM. "Monospecific" refers to the ability to bind only one
10 epitope.

The term "knob-into-hole" or "KnH" technology as used herein refers to the technology directing the pairing of two polypeptides together in vitro or in vivo by introducing a protuberance (knob) into one polypeptide and a cavity (hole) into the other polypeptide at an interface in which they interact. For example, KnHs have been introduced in the Fc:Fc binding interfaces, CL:CH1 interfaces, or VH/VL
15 interfaces of antibodies (see, e.g., US 2011/0287009, US2007/0178552, WO 96/027011, WO 98/050431, and Zhu et al. *Protein Science* 6:781-788, 1997). In some embodiments, KnHs drive the pairing of two different heavy chains together during the manufacture of multispecific antibodies. For example, multispecific antibodies having KnH in their Fc regions can further comprise single variable domains linked to each Fc region, or further comprise different heavy chain variable domains that pair with similar
20 or different light chain variable domains. KnH technology can also be used to pair two different receptor extracellular domains together or any other polypeptide sequences that comprises different target recognition sequences (e.g., including affibodies, peptibodies, and other Fc fusions).

The term "knob mutation," as used herein, refers to a mutation that introduces a protuberance (knob) into a polypeptide at an interface in which the polypeptide interacts with another polypeptide. In
25 some embodiments, the other polypeptide has a hole mutation (see e.g., U.S. Patent Nos. 5,731,168; 5,807,706; 5,821,333; 7,695,936; and 8,216,805, which are each incorporated herein by reference in their entirety).

The term "hole mutation," as used herein, refers to a mutation that introduces a cavity (hole) into a polypeptide at an interface in which the polypeptide interacts with another polypeptide. In some
30 embodiments, the other polypeptide has a knob mutation (see e.g., U.S. Patent Nos. 5,731,168; 5,807,706; 5,821,333; 7,695,936; and 8,216,805, which are each incorporated herein by reference in their entirety).

A "naked antibody" refers to an antibody that is not conjugated to a heterologous moiety (e.g., a cytotoxic moiety) or radiolabel. The naked antibody may be present in a pharmaceutical composition.

With regard to the binding of a antibody to a target molecule, the term "specific binding" or
35 "specifically binds" or is "specific for" a particular polypeptide or an epitope on a particular polypeptide target means binding that is measurably different from a non-specific interaction. Specific binding can be measured, for example, by determining binding of a molecule compared to binding of a control molecule. For example, specific binding can be determined by competition with a control molecule that is similar to

the target, for example, an excess of non-labeled target. In this case, specific binding is indicated if the binding of the labeled target to a probe is competitively inhibited by excess unlabeled target. The term “specific binding” or “specifically binds to” or is “specific for” a particular polypeptide or an epitope on a particular polypeptide target as used herein can be exhibited, for example, by a molecule having a K_D for the target of 10^{-4} M or lower, alternatively 10^{-5} M or lower, alternatively 10^{-6} M or lower, alternatively 10^{-7} M or lower, alternatively 10^{-8} M or lower, alternatively 10^{-9} M or lower, alternatively 10^{-10} M or lower, alternatively 10^{-11} M or lower, alternatively 10^{-12} M or lower or a K_D in the range of 10^{-4} M to 10^{-6} M or 10^{-6} M to 10^{-10} M or 10^{-7} M to 10^{-9} M. As will be appreciated by the skilled artisan, affinity and K_D values are inversely related. A high affinity for an antigen is measured by a low K_D value. In one embodiment, the term “specific binding” refers to binding where a molecule binds to a particular polypeptide or epitope on a particular polypeptide without substantially binding to any other polypeptide or polypeptide epitope.

The term “variable” refers to the fact that certain segments of the variable domains differ extensively in sequence among antibodies. The variable or “V” domain mediates antigen binding and defines specificity of a particular antibody for its particular antigen. However, the variability is not evenly distributed across the 110-amino acid span of the variable domains. Instead, the V regions consist of relatively invariant stretches called framework regions (FRs) of 15-30 amino acids separated by shorter regions of extreme variability called “hypervariable regions” that are each 9-12 amino acids long. The term “hypervariable region” or “HVR” when used herein refers to the amino acid residues of an antibody which are responsible for antigen-binding. The hypervariable region generally comprises amino acid residues from e.g., around about residues 24-34 (L1), 50-56 (L2) and 89-97 (L3) in the VL, and around about residues 26-35 (H1), 49-65 (H2) and 95-102 (H3) in the VH (in one embodiment, H1 is around about residues 31-35); Kabat et al. *supra*) and/or those residues from a “hypervariable loop” (e.g., residues 26-32 (L1), 50-52 (L2), and 91-96 (L3) in the VL, and 26-32 (H1), 53-55 (H2), and 96-101 (H3) in the VH; Chothia et al. *J. Mol. Biol.* 196:901-917, 1987. The variable domains of native heavy and light chains each comprise four FRs, largely adopting a beta-sheet configuration, connected by three hypervariable regions, which form loops connecting, and in some cases forming part of, the beta-sheet structure. The hypervariable regions in each chain are held together in close proximity by the FRs and, with the hypervariable regions from the other chain, contribute to the formation of the antigen-binding site of antibodies (see Kabat et al. *supra*). Accordingly, the HVR and FR sequences generally appear in the following sequence in VH (or VL): FR1-H1(L1)-FR2-H2(L2)-FR3-H3(L3)-FR4. The constant domains are not involved directly in binding an antibody to an antigen, but exhibit various effector functions, such as participation of the antibody in antibody dependent cellular cytotoxicity (ADCC).

The term “variable domain residue numbering as in Kabat” or “amino acid position numbering as in Kabat,” and variations thereof, refers to the numbering system used for heavy chain variable domains or light chain variable domains of the compilation of antibodies in Kabat et al. *supra*. Using this numbering system, the actual linear amino acid sequence may contain fewer or additional amino acids corresponding to a shortening of, or insertion into, a FR or HVR of the variable domain. For example, a heavy chain variable domain may include a single amino acid insert (residue 52a according to Kabat) after residue 52 of H2 and inserted residues (e.g. residues 82a, 82b, and 82c, etc. according to Kabat)

after heavy chain FR residue 82. The Kabat numbering of residues may be determined for a given antibody by alignment at regions of homology of the sequence of the antibody with a "standard" Kabat numbered sequence.

The Kabat numbering system is generally used when referring to a residue in the variable domain (approximately residues 1-107 of the light chain and residues 1-113 of the heavy chain) (e.g., Kabat et al. *supra*). The "EU numbering system" or "EU index" is generally used when referring to a residue in an immunoglobulin heavy chain constant region (e.g., the EU index reported in Kabat et al. *supra*). The "EU index as in Kabat" refers to the residue numbering of the human IgG1 EU antibody. Unless stated otherwise herein, references to residue numbers in the variable domain of antibodies means residue numbering by the Kabat numbering system. Unless stated otherwise herein, references to residue numbers in the constant domain of antibodies means residue numbering by the EU numbering system (e.g., see United States Provisional Application No. 60/640,323, Figures for EU numbering).

As used herein, "administering" is meant a method of giving a dosage of a compound (e.g., an anti-IL-33 antibody of the invention or a nucleic acid encoding an anti-IL-33 antibody of the invention) or a composition (e.g., a pharmaceutical composition, e.g., a pharmaceutical composition including an anti-IL-33 antibody of the invention) to a subject. The compositions utilized in the methods described herein can be administered, for example, intravitreally, intramuscularly, intravenously, intradermally, percutaneously, intraarterially, intraperitoneally, intralesionally, intracranially, intraarticularly, intraprostatically, intrapleurally, intratracheally, intrathecally, intranasally, intravaginally, intrarectally, topically, intratumorally, peritoneally, subcutaneously, subconjunctivally, intravesicularly, mucosally, intrapericardially, intraumbilically, intraocularly, intraorbitally, orally, topically, transdermally, periorcularly, conjunctivally, subtenonally, intracamerally, subretinally, retrobulbarly, intracanalicularly, by inhalation, by injection, by implantation, by infusion, by continuous infusion, by localized perfusion bathing target cells directly, by catheter, by lavage, in cremes, or in lipid compositions. The compositions utilized in the methods described herein can also be administered systemically or locally. The method of administration can vary depending on various factors (e.g., the compound or composition being administered and the severity of the condition, disease, or disorder being treated).

The term "asthma" refers herein to a disorder characterized by variable and recurring symptoms, reversible airflow obstruction (e.g., by bronchodilator), and bronchial hyper-responsiveness, which may or may not be associated with underlying inflammation. Asthma may therefore be inflammatory/inflamed asthma or non-inflammatory/non-inflamed asthma. Examples of asthma include allergic asthma, exercise-induced asthma, aspirin sensitive/exacerbated asthma, atopic asthma, severe asthma, mild asthma, moderate to severe asthma, corticosteroid naïve asthma, chronic asthma, corticosteroid resistant asthma, corticosteroid refractory asthma, newly diagnosed and untreated asthma, asthma due to smoking, asthma uncontrolled on corticosteroids, and other asthmas as mentioned in Bousquet et al. *J. Allergy Clin. Immunol.* 126(5): 926-938, 2010.

A "disorder" or "disease" is any condition that would benefit from treatment with the antibody. For example, a disorder may be an IL-33-mediated disorder. This includes chronic and acute disorders or diseases including those pathological conditions which predispose the mammal to the disorder in

question. Examples of disorders to be treated herein include IL-33-mediated disorders (e.g., asthma, allergic rhinitis, atopic dermatitis, and fibrosis (e.g., pulmonary fibrosis, e.g., idiopathic pulmonary fibrosis)).

A “chemotherapeutic agent” is a chemical compound useful in the treatment of cancer. Examples of chemotherapeutic agents include alkylating agents such as thiotepa and cyclophosphamide (CYTOXAN®); alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, triethylenephosphoramide, triethylenethiophosphoramide and trimethylmelamine; acetogenins (especially bullatacin and bullatacinone); delta-9-tetrahydrocannabinol (dronabinol, MARINOL®); beta-lapachone; lapachol; colchicines; betulinic acid; a camptothecin (including the synthetic analogue topotecan (HYCAMTIN®), CPT-11 (irinotecan, CAMPTOSAR®), acetylcamptothecin, scoplectin, and 9-aminocamptothecin); bryostatin; callystatin; CC-1065 (including its adozelesin, carzelesin and bizelesin synthetic analogues); podophyllotoxin; podophyllinic acid; teniposide; cryptophycins (particularly cryptophycin 1 and cryptophycin 8); dolastatin; duocarmycin (including the synthetic analogues, KW-2189 and CB1-TM1); eleutherobin; pancratistatin; a sarcodictyin; spongistatin; nitrogen mustards such as chlorambucil, chlornaphazine, chlorophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosoureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, and ranimustine; antibiotics such as the enediyne antibiotics (e.g., calicheamicin, especially calicheamicin gamma11 and calicheamicin omegall (see, e.g., Nicolaou et al. *Angew. Chem Intl. Ed. Engl.*, 33: 183-186 (1994)); CDP323, an oral alpha-4 integrin inhibitor; dynemicin, including dynemicin A; an esperamicin; as well as neocarzinostatin chromophore and related chromoprotein enediyne antibiotic chromophores), aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, carabycin, caminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin (including ADRIAMYCIN®, morpholino-doxorubicin, cyanomorpholino-doxorubicin, 2-pyrrolino-doxorubicin, doxorubicin HCl liposome injection (DOXIL®), liposomal doxorubicin TLC D-99 (MYOCET®), pegylated liposomal doxorubicin (CAELYX®), and deoxydoxorubicin), epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins such as mitomycin C, mycophenolic acid, nogalamycin, olivomycins, peplomycin, porfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate, gemcitabine (GEMZAR®), tegafur (UFTORAL®), capecitabine (XELODA®), an epothilone, and 5-fluorouracil (5-FU); combretastatin; folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine; androgens such as calusterone, dromostanolone propionate, epitio stanol, mepitio stanol, testolactone; anti-adrenals such as aminogluthethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; eniluracil; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elformithine; elliptinium acetate; an epothilone;

etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidainine; maytansinoids such as maytansine and ansamitocins; mitoguazone; mitoxantrone; mopidanmol; nitraerine; pentostatin; phenamet; pirarubicin; losoxantrone; 2-ethylhydrazide; procarbazine; PSK® polysaccharide complex (JHS Natural Products, Eugene, Oreg.); razoxane; rhizoxin; sizofuran; spirogermanium; tenuazonic acid; triaziquone; 2,2',2'-trichlorotriethylamine; trichothecenes (especially T-2 toxin, verracurin A, roridin A and anguidine); urethan; vindesine (ELDISINE®, FILDESIN®); dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); thiotepa; taxoid, e.g., paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology, Princeton, N.J.), albumin-engineered nanoparticle formulation of paclitaxel (ABRAXANE™), and docetaxel (TAXOTERE®, Rhone-Poulenc Rorer, Antony, France); chloranbucil; 6-thioguanine; mercaptopurine; methotrexate; platinum agents such as cisplatin, oxaliplatin (e.g., ELOXATIN®), and carboplatin; vincas, which prevent tubulin polymerization from forming microtubules, including vinblastine (VELBAN®), vincristine (ONCOVIN®), vindesine (ELDISINE®, FILDESIN®), and vinorelbine (NAVELBINE®); etoposide (VP-16); ifosfamide; mitoxantrone; leucovorin; novantrone; edatrexate; daunomycin; aminopterin; ibandronate; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoids such as retinoic acid, including bexarotene (TARGRETIN®); bisphosphonates such as clodronate (for example, BONEFOS® or OSTAC®), etidronate (DIDROCAL®), NE-58095, zoledronic acid/zoledronate (ZOMETA®), alendronate (FOSAMAX®), pamidronate (AREDIA®), tiludronate (SKELID®), or risedronate (ACTONEL®); troxacitabine (a 1,3-dioxolane nucleoside cytosine analog); antisense oligonucleotides, particularly those that inhibit expression of genes in signaling pathways implicated in aberrant cell proliferation, such as, for example, PKC-alpha, Raf, H-Ras, and epidermal growth factor receptor (EGF-R) (e.g., erlotinib (Tarceva™)); and VEGF-A that reduce cell proliferation; vaccines such as THERATOPE® vaccine and gene therapy vaccines, for example, ALLOVECTIN® vaccine, LEUVECTIN® vaccine, and VAXID® vaccine; topoisomerase 1 inhibitor (e.g., LURTOTECAN®); rmRH (e.g., ABARELIX®); BAY439006 (sorafenib; Bayer); SU-11248 (sunitinib, SUTENT®, Pfizer); perifosine, COX-2 inhibitor (e.g. celecoxib or etoricoxib), proteasome inhibitor (e.g. PS341); bortezomib (VELCADE®); CCI-779; tipifarnib (R11577); orafenib, ABT510; Bcl-2 inhibitor such as oblimersen sodium (GENA-SENSE®); pixantrone; EGFR inhibitors; tyrosine kinase inhibitors; serine-threonine kinase inhibitors such as rapamycin (sirolimus, RAPAMUNE®); farnesyltransferase inhibitors such as lonafarnib (SCH 6636, SARASAR™); and pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above such as CHOP, an abbreviation for a combined therapy of cyclophosphamide, doxorubicin, vincristine, and prednisolone; and FOLFOX, an abbreviation for a treatment regimen with oxaliplatin (ELOXATIN™) combined with 5-FU and leucovorin, and pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above.

Chemotherapeutic agents as defined herein include "anti-hormonal agents" or "endocrine therapeutics" which act to regulate, reduce, block, or inhibit the effects of hormones that can promote the growth of cancer. They may be hormones themselves, including, but not limited to: anti-estrogens with mixed agonist/antagonist profile, including, tamoxifen (NOLVADEX®), 4-hydroxytamoxifen, toremifene (FARESTON®), idoxifene, droloxifene, raloxifene (EVISTA®), trioxifene, keoxifene, and selective

estrogen receptor modulators (SERMs) such as SERM3; pure anti-estrogens without agonist properties, such as fulvestrant (FASLODEX®), and EM800 (such agents may block estrogen receptor (ER) dimerization, inhibit DNA binding, increase ER turnover, and/or suppress ER levels); aromatase inhibitors, including steroidal aromatase inhibitors such as formestane and exemestane (AROMASIN®), and nonsteroidal aromatase inhibitors such as anastrozole (ARIMIDEX®), letrozole (FEMARA®) and aminoglutethimide, and other aromatase inhibitors include vorozole (RIVISOR®), megestrol acetate (MEGASE®), fadrozole, and 4(5)-imidazoles; lutenizing hormone-releasing hormone agonists, including leuprolide (LUPRON® and ELIGARD®), goserelin, buserelin, and tripterelin; sex steroids, including progestins such as megestrol acetate and medroxyprogesterone acetate, estrogens such as diethylstilbestrol and premarin, and androgens/retinoids such as fluoxymesterone, all transretinoic acid and fenretinide; onapristone; anti-progesterones; estrogen receptor down-regulators (ERDs); anti-androgens such as flutamide, nilutamide and bicalutamide; and pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above.

The term "cytotoxic agent" as used herein refers to a substance that inhibits or prevents a cellular function and/or causes cell death or destruction. Cytotoxic agents include, but are not limited to, radioactive isotopes (e.g., At²¹¹, I¹³¹, I¹²⁵, Y⁹⁰, Re¹⁸⁶, Re¹⁸⁸, Sm¹⁵³, Bi²¹², P³², Pb²¹² and radioactive isotopes of Lu); chemotherapeutic agents or drugs (e.g., methotrexate, adriamycin, vinca alkaloids (vincristine, vinblastine, etoposide), doxorubicin, melphalan, mitomycin C, chlorambucil, daunorubicin or other intercalating agents); growth inhibitory agents; enzymes and fragments thereof such as nucleolytic enzymes; antibiotics; toxins such as small molecule toxins or enzymatically active toxins of bacterial, fungal, plant or animal origin, including fragments and/or variants thereof; and the various antitumor or anticancer agents disclosed herein.

An "effective amount" of an agent, e.g., a pharmaceutical formulation, refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result.

A "growth inhibitory agent" when used herein refers to a compound or composition which inhibits growth of a cell either in vitro or in vivo. Thus, the growth inhibitory agent may be one which significantly reduces the percentage of cells in S phase. Examples of growth inhibitory agents include agents that block cell cycle progression (at a place other than S phase), such as agents that induce G1 arrest and M-phase arrest. Classical M-phase blockers include the vincas (vincristine and vinblastine), taxanes, and topoisomerase II inhibitors such as doxorubicin, epirubicin, daunorubicin, etoposide, and bleomycin. Those agents that arrest G1 also spill over into S-phase arrest, for example, DNA alkylating agents such as tamoxifen, prednisone, dacarbazine, mechlorethamine, cisplatin, methotrexate, 5-fluorouracil, and ara-C. Further information can be found in Mendelsohn et al. eds., *The Molecular Basis of Cancer*, Chapter 1, entitled "Cell cycle regulation, oncogenes, and antineoplastic drugs" by Murakami et al. (W.B. Saunders, Philadelphia, 1995), e.g., p. 13. The taxanes (paclitaxel and docetaxel) are anticancer drugs both derived from the yew tree. Docetaxel (TAXOTERE®, Rhone-Poulenc Rorer), derived from the European yew, is a semisynthetic analogue of paclitaxel (TAXOL®, Bristol-Myers Squibb). Paclitaxel and

docetaxel promote the assembly of microtubules from tubulin dimers and stabilize microtubules by preventing depolymerization, which results in the inhibition of mitosis in cells.

The term "IL-33-mediated disorder," as used herein, refers to any disorder or condition mediated by, or associated with, the IL-33 axis. In some embodiments, IL-33-mediated disorders are associated with excess IL-33 levels or activity in which atypical symptoms may manifest due to the levels or activity of IL-33 locally and/or systemically in the body. Exemplary IL-33-mediated disorders include inflammatory conditions, immune disorders, fibrotic disorders, eosinophilic disorders, infections, pain, central nervous system disorders, solid tumors, and ophthalmologic disorders. IL-33-mediated disorders are described, for example, in Liew et al. *Nature Reviews Immunology* 10: 103-110, 2010, which is incorporated herein by reference in its entirety.

Exemplary inflammatory conditions include asthma (e.g., allergic asthma, exercise-induced asthma, aspirin sensitive/exacerbated asthma, atopic asthma, severe asthma, mild asthma, moderate to severe asthma, corticosteroid naïve asthma, chronic asthma, corticosteroid resistant asthma, corticosteroid refractory asthma, newly diagnosed and untreated asthma, asthma due to smoking, asthma uncontrolled on corticosteroids, etc.), airway inflammation, airway hyperreactivity, airway hyperresponsiveness, rhinosinusitis, rhinosinusitis with polyps, nasal polyposis, arthritis (e.g., osteoarthritis, rheumatoid arthritis, collagen-induced arthritis, arthritic joints as a result of injury, etc.), eosinophilic inflammation, mast cell-mediated inflammatory diseases, sepsis, septic shock, seronegative enthesopathy and arthropathy (SEA) syndrome, osteoporosis, eosinophilic esophagitis, scleroderma, dermatitis, atopic dermatitis, allergic rhinitis, bullous pemphigoid, chronic urticaria, cartilage inflammation, polymyalgia rheumatic, polyarteritis nodosa, Wegener's granulomatosis, Behcet's disease, myolitis, polymyolitis, dermatomyolitis, dermatomyositis, vasculitis, arteritis, diabetic nephropathy, interstitial cystitis, graft versus host disease (GVHD), gastrointestinal inflammatory conditions (e.g., inflammatory bowel disease (IBD), ulcerative colitis (UC), Crohn's disease (CD), colitis (e.g., colitis caused by environmental insults (e.g., caused by or associated with a therapeutic regimen, such as chemotherapy, radiation therapy, etc.), infectious colitis, ischemic colitis, collagenous or lymphocytic colitis, necrotizing enterocolitis, colitis in conditions such as chronic granulomatous disease or celiac disease, food allergies, gastritis, infectious gastritis or enterocolitis (e.g., *Helicobacter pylori*-infected chronic active gastritis), and other forms of gastrointestinal inflammation caused by an infectious agent), and inflammatory pulmonary conditions (e.g., chronic obstructive pulmonary disease (COPD), eosinophilic pulmonary inflammation, infection-induced pulmonary conditions (including those associated with viral (e.g., influenza, parainfluenza, rotavirus, human metapneumovirus, and respiratory syncytial virus), bacterial, fungal (e.g., *Aspergillus*), parasitic, or prion infection, allergen-induced pulmonary conditions, pollutant-induced pulmonary conditions (e.g., asbestosis, silicosis, or berylliosis), gastric aspiration-induced pulmonary conditions, immune dysregulation, inflammatory conditions with genetic predisposition such as cystic fibrosis, physical trauma-induced pulmonary conditions (e.g., ventilator injury), emphysema, bronchitis, sarcoidosis, histiocytosis, lymphangiomyomatosis, acute lung injury, acute respiratory distress syndrome, chronic lung disease, bronchopulmonary dysplasia, pneumonia (e.g., community-acquired pneumonia,

nosocomial pneumonia, ventilator-associated pneumonia, viral pneumonia, bacterial pneumonia, and severe pneumonia), airway exacerbations, and acute respiratory distress syndrome (ARDS)).

Exemplary immune disorders include those mediated at least in part by mast cells, such as asthma (e.g., allergic asthma), eczema, itch, allergy, atopic allergy, anaphylaxis, anaphylactic shock, allergic bronchopulmonary aspergillosis, allergic rhinitis, allergic conjunctivitis, as well as autoimmune disorders including rheumatoid arthritis, juvenile rheumatoid arthritis, psoriatic arthritis, pancreatitis, psoriasis, plaque psoriasis, guttate psoriasis, inverse psoriasis, pustular psoriasis, erythrodermic psoriasis, paraneoplastic autoimmune diseases, autoimmune hepatitis, bullous pemphigoid, myasthenia gravis, inflammatory bowel disease, Crohn's disease, ulcerative colitis, celiac disease, thyroiditis (e.g., Graves' disease), Sjogren's syndrome, Guillain-Barre disease, Raynaud's phenomenon, Addison's disease, liver diseases (e.g., primary biliary cirrhosis, primary sclerosing cholangitis, non-alcoholic fatty liver disease, and non-alcoholic steatohepatitis), and diabetes (e.g., type I diabetes).

As used herein, the terms "fibrotic disorder" or "fibrosis" refer to conditions involving formation of excess fibrous connective tissue in an organ or tissue. Exemplary fibrotic disorders include lung fibrosis, liver fibrosis (e.g., fibrosis associated with cirrhosis (e.g., alcohol-induced cirrhosis, viral-induced cirrhosis, post-hepatitis C cirrhosis, and primary biliary cirrhosis), schistosomiasis, cholangitis (e.g., sclerosing cholangitis), and autoimmune-induced hepatitis), kidney fibrosis (e.g., tubulointerstitial fibrosis, scleroderma, diabetic nephritis, and glomerular nephritis), dermal fibrosis (e.g., scleroderma, hypertrophic and keloid scarring, nephrogenic fibrosing dermatopathy, and burns), myelofibrosis, neurofibromatosis, fibroma, intestinal fibrosis, and fibrotic adhesions resulting from surgical procedures), heart fibrosis (e.g., fibrosis associated with myocardial infarction), vascular fibrosis (e.g., fibrosis associated with postangioplasty arterial restenosis and atherosclerosis), eye fibrosis (e.g., fibrosis associated with post-cataract surgery, proliferative vitreoretinopathy, and retro-orbital fibrosis), and bone marrow fibrosis (e.g., idiopathic myelofibrosis and drug-induced myelofibrosis). The fibrosis can be organ-specific or systemic (e.g., systemic sclerosis and fibrosis associated with GVHD).

Examples of lung fibrosis include, for example, lung or pulmonary fibrosis associated with idiopathic pulmonary fibrosis, fibrosis with collagen vascular disease, Hermansky-Pudlak syndrome, adult respiratory distress syndrome, nonspecific interstitial pneumonia, respiratory bronchiolitis, sarcoidosis, histiocytosis X, bronchiolitis obliterans, and cryptogenic organizing pneumonia. In one embodiment, the lung fibrosis is idiopathic pulmonary fibrosis.

As used herein, an "eosinophilic disorder" is a disorder associated with excess eosinophil numbers in which atypical symptoms may manifest due to the levels or activity of eosinophils locally or systemically in the body. Eosinophilic disorders include but are not limited to, asthma (including aspirin sensitive asthma, atopic asthma, and severe asthma), eosinophilic inflammation, atopic dermatitis, allergic rhinitis (including seasonal allergic rhinitis), non-allergic rhinitis, chronic eosinophilic pneumonia, allergic bronchopulmonary aspergillosis, celiac disease, Churg-Strauss syndrome (periarteritis nodosa plus atopy), eosinophilic myalgia syndrome, hypereosinophilic syndrome, edematous reactions including episodic angioedema, helminth infections, where eosinophils may have a protective role, onchocercal dermatitis, eosinophil-associated gastrointestinal disorders (EGIDs), including but not limited to,

eosinophilic esophagitis, eosinophilic gastritis, eosinophilic gastroenteritis, eosinophilic enteritis and eosinophilic colitis, nasal micropolypoidosis and polypoidosis, aspirin intolerance, and obstructive sleep apnea. Eosinophil-derived secretory products have also been associated with the promotion of angiogenesis and connective tissue formation in tumors and the fibrotic responses seen in conditions such as chronic asthma, Crohn's disease, scleroderma and endomyocardial fibrosis (Munitz et al. *Allergy* 59: 268-275, 2004; Adamko et al. *Allergy* 60: 13-22, 2005; Oldhoff et al. *Allergy* 60: 693-696, 2005). Other examples include cancer (e.g., glioblastoma (such as glioblastoma multiforme) and non-Hodgkin's lymphoma (NHL)), atopic dermatitis, allergic rhinitis, inflammatory bowel disease, fibrosis (e.g., pulmonary fibrosis (e.g., idiopathic pulmonary fibrosis (IPF) and pulmonary fibrosis secondary to sclerosis) and hepatic fibrosis), and COPD.

Examples of infection include helminth infection (e.g., nematode infection, such as *Trichuris muris* infection of mice, which is a model for infection by the human parasite *Trichuris trichiura*), protozoan infection (e.g., *Leishmania major* infection), and viral infection (e.g., respiratory syncytial virus infection and influenza virus infection).

Examples of pain include inflammatory pain, hyperalgesia (e.g., mechanical hyperalgesia), allodynia, and hypernociception (e.g., cutaneous and articular hypernociception, which may or may not be antigen-induced).

Examples of central nervous system disorders include subarachnoid hemorrhage, inflammatory diseases of the central nervous system, neurodegenerative diseases (e.g., Alzheimer's disease, experimental autoimmune encephalomyelitis, multiple sclerosis, Parkinson's disease, Huntington's disease), bipolar disorder, and infection of the central nervous system (e.g., viral infection).

Examples of solid tumors include tumors of the colon, breast, prostate, lung, kidney, liver, pancreas, ovary, head and neck, oral cavity, stomach, duodenum, small intestine, large intestine, gastrointestinal tract, anus, gall bladder, labium, nasopharynx, skin, uterus, male genital organ, urinary organs, bladder, and skin. Solid tumors of non-epithelial origin include sarcomas, brain tumors, and bone tumors.

Examples of ophthalmologic disorders include age-related macular degeneration (AMD), including wet AMD, dry AMD, intermediate AMD, advanced AMD, and geographic atrophy (GA), retinopathy (e.g., diabetic retinopathy (DR), retinopathy of prematurity (ROP), and high-altitude DR), polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis (also known as Leber's congenital amaurosis), Stargardt's disease, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis, non-infectious conjunctivitis, and allergic conjunctivitis).

In some embodiments, ophthalmologic disorders include AMD (including wet AMD, dry AMD, and GA), retinopathy (e.g., DR and ROP), PCV, diabetic macular edema, dry eye disease, Behcet's disease, allergic conjunctivitis, and retina detachment.

It is to be understood that in other embodiments, ophthalmologic disorders include intermediate AMD, advanced AMD, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa,

Leber Congenital Amaurosis (also known as Leber's congenital amaurosis), Stargardt's disease, high-altitude diabetic retinopathy, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis and non-infectious conjunctivitis).

The above list is not all-inclusive, and it will be understood by the skilled artisan that a disease or disorder may fall within various categories. For example, asthma can be categorized in some instances as both an inflammatory disorder and immune disorder and considered by some clinicians to be an autoimmune disorder.

An "IL-33 axis binding antagonist" refers to a molecule that inhibits the interaction of an IL-33 axis binding partner with one or more of its binding partners. As used herein, an IL-33 axis binding antagonist includes IL-33 binding antagonists, ST2 binding antagonists, and IL1RAcP binding antagonists. Exemplary IL-33 axis binding antagonists include anti-IL-33 antibodies and antigen-binding fragments thereof (e.g., anti-IL-33 antibodies such as ANB-020 (AnaptysBio, Inc.) or any of the antibodies described in EP1725261, US8187596, WO2011031600, WO2014164959, WO2015099175 or WO2015106080, which are each incorporated herein by reference in their entirety); polypeptides that bind IL-33 and/or its receptor (ST2 and/or IL-1RAcP) and block ligand-receptor interaction (e.g., ST2-Fc proteins, such as those described in WO 2014/152195, which is herein incorporated by reference in its entirety; immunoadhesins, peptibodies, and soluble ST2, or derivatives thereof); anti-IL-33 receptor antibodies (e.g., anti-ST2 antibodies, for example, AMG-282 (Amgen) or STLM15 (Janssen) or any of the anti-ST2 antibodies described in WO 2013/173761 and WO 2013/165894, which are each incorporated herein by reference in their entirety; or ST2-Fc proteins, such as those described in WO 2013/173761; WO 2013/165894; or WO 2014/152195, which are each incorporated herein by reference in their entirety); and IL-33 receptor antagonists, such as small molecule inhibitors, aptamers that bind IL-33, and nucleic acids that hybridize under stringent conditions to IL-33 axis nucleic acid sequences (e.g., short interfering RNAs (siRNA) or clustered regularly interspaced short palindromic repeat RNAs (CRISPR-RNA or crRNA), including single guide RNAs (sgRNAs) having a crRNA and tracrRNA sequence as described in Mali et al. (*Science*. 339: 823-26, 2013), which is incorporated herein by reference in its entirety).

As used herein, "chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2)" refers to any native CRTH2 from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated. CRTH2 is also referred to as G protein coupled receptor 44 (GPR44), cluster of differentiation 294 (CD294), DL1R, and DP2. The term encompasses "full-length," unprocessed CRTH2, as well as any form of CRTH2 that results from processing in the cell. The amino acid sequence of an exemplary human CRTH2 can be found, for example, under UniProtKB accession number Q9Y5Y4.

The term "CRTH2 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of CRTH2 with one or more of its binding partners, such as prostaglandin D₂. Exemplary CRTH2 binding antagonists known in the art include AMG-853, AP768, AP-761, MLN6095, and ACT129968.

The term "interleukin-5 (IL-5)," as used herein, refers to any native IL-5 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless

otherwise indicated. The term encompasses "full-length," unprocessed IL-5, as well as any form of IL-5 that results from processing in the cell. The term also encompasses naturally occurring variants of IL-5, such as splice variants or allelic variants. The amino acid sequence of an exemplary IL-5 can be found, for example, under UniProtKB accession number P05113.

5 The term "IL-5 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of IL-5 with one or more of its binding partners, such as IL-5 receptor, alpha (*IL5RA*). Exemplary IL-5 binding antagonists that can be used in the methods of the invention include, for example, anti-IL-5 antibodies (e.g., mepolizumab and reslizumab) and anti-IL-5R antibodies.

10 As used herein, "interleukin-13 (IL-13)" refers to any native IL-13 from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated. IL-13 is a cytokine secreted by many cell types, including T helper type 2 (Th2) cells. The term encompasses "full-length," unprocessed IL-13, as well as any form of IL-13 that results from processing in the cell. The amino acid sequence of an exemplary human IL-13 can be found, for example, under
15 UniProtKB accession number P35225.

The term "IL-13 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of IL-13 with one or more of its binding partners, such as IL-4 receptor alpha (*IL4Rα*), IL-13 receptor alpha1 (*IL13RA1*) and IL-13 receptor alpha2 (*IL13RA2*). IL-13 binding antagonists include anti-IL-13 antibodies, for example,
20 lebrikizumab, 228B/C-1, 228A-4, 227-26, and 227-43 (see, for example, U.S. Pat. Nos. 7,674,459; 8,067,199; 8,088,618; 8,318,160; and 8,734,797).

As used herein, "interleukin-17 (IL-17)" refers to any native IL-17 from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated, and includes family members IL-17A, IL-17B, IL-17C, IL-17D, IL-17E, and IL-17F. The term
25 encompasses "full-length," unprocessed IL-17, as well as any form of IL-17 that results from processing in the cell. The amino acid sequence of an exemplary human IL-17A can be found, for example, under UniProtKB accession number Q16552. The amino acid sequence of an exemplary human IL-17B can be found, for example, under UniProtKB accession number Q9UHF5. The amino acid sequence of an exemplary human IL-17C can be found, for example, under UniProtKB accession number Q9P0M4. The
30 amino acid sequence of an exemplary human IL-17D can be found, for example, under UniProtKB accession number Q8TAD2. The amino acid sequence of an exemplary human IL-17E can be found, for example, under UniProtKB accession number Q9H293. The amino acid sequence of an exemplary human IL-17F can be found, for example, under UniProtKB accession number Q96PD4.

35 The term "IL-17 binding antagonist" refers to a molecule that decreases, blocks, inhibits, abrogates or interferes with signal transduction resulting from the interaction of IL-17 with one or more of its binding partners, such as interleukin-17 receptor (IL-17R) family member proteins interleukin 17 receptor A (*IL17RA*), interleukin 17 receptor B (*IL17RB*), interleukin 17 receptor C (*IL17RC*), interleukin 17 receptor D (*IL17RD*), interleukin 17 receptor E (*IL17RE*), and interleukin 17 receptor E-like (*IL17REL*).

Exemplary IL-17 binding antagonists include, for example, anti-IL-17 antibodies (e.g., ixekizumab (LY2439821) and anti-IL-17R antibodies (e.g., brodalumab (AMG-827)).

The term "Janus kinase 1 (JAK1)," as used herein, refers to any native JAK1 from any vertebrate source, including mammals such as primates (e.g. humans) and rodents (e.g., mice and rats), unless otherwise indicated. The term encompasses "full-length," unprocessed JAK1 as well as any form of JAK1 that results from processing in the cell. The term also encompasses naturally occurring variants of JAK1, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary JAK1 can be found, for example, under UniProtKB accession number P23458.

The term "JAK1 antagonist," as used herein, refers to compounds or agents which inhibit or reduce the biological activity of JAK1. Exemplary JAK1 antagonists include small molecule inhibitors (e.g., ruxolitinib, GLPG0634, and GSK2586184).

The term "ST2 binding antagonist" refers to a molecule that inhibits the interaction of an ST2 with IL-33, IL1RAcP, and/or a second ST2 molecule. The ST2 binding antagonist may be a protein, such as an "ST2-Fc protein" that includes an IL-33-binding domain (e.g., all or a portion of an ST2 or IL1RAcP protein) and a multimerizing domain (e.g., 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), which are attached to one another either directly or indirectly through a linker (e.g., a serine-glycine (SG) linker, glycine-glycine (GG) linker, or variant thereof (e.g., a SGG, a GGS, an SGS, or a GSG linker)), and includes, but is not limited to, ST2-Fc proteins and variants thereof described in WO 2013/173761, WO 2013/165894, and WO 2014/152195, which are each incorporated herein by reference in their entirety. In some embodiments, a ST2 binding antagonist may be an anti-ST2 antibody, for example, AMG-282 (Amgen) or STLM15 (Janssen) or any of the anti-ST2 antibodies described in WO 2013/173761 and WO 2013/165894.

As used herein, "tryptase-beta" refers to any native tryptase-beta from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated. As used herein, the term encompasses tryptase beta-1 (encoded by the *TPSAB1* gene, which also encodes tryptase alpha-1) and tryptase beta-2 (encoded by the *TPSB2* gene). The term encompasses "full-length," unprocessed tryptase-beta as well as any form of tryptase-beta that results from processing in the cell. The amino acid sequence of an exemplary human tryptase beta-2 can be found, for example, under UniProtKB accession number P20231.

The term "tryptase-beta antagonist," as used herein, refers to compounds or agents which inhibit or reduce the biological activity of tryptase beta.

As used herein, "Factor D" refers to any native Factor D from any vertebrate source, including mammals such as primates (e.g., humans) and rodents (e.g., mice and rats), unless otherwise indicated. Factor D is also referred to as C3 proactivator convertase, properdin factor D esterase, Factor D (complement), Complement Factor D, CFD, and adipsin. The term encompasses "full-length," unprocessed Factor D, as well as any form of Factor D that results from processing in the cell. The amino acid sequence of an exemplary human Factor D can be found, for example, under UniProtKB accession number P00746.

The term "Factor D binding antagonist," as used herein, refers to compounds or agents which inhibit or reduce the biological activity of Factor D. Exemplary Factor D binding antagonists include, for example, small molecule inhibitors and anti-Factor D antibodies, for example, any anti-Factor D antibody described in WO 2007/056227, WO 01/70818, and/or US 2002/0081293, which are each incorporated
5 herein by reference in their entirety. In some embodiments, the anti-Factor D antibody is or is derived from monoclonal antibody 166-32, produced by the hybridoma deposited with the ATCC and designated HB 12476.

The term "High-temperature requirement A serine peptidase 1" or "HtrA1," as used herein, refers to any native HtrA1 from any vertebrate source, including mammals such as primates (e.g., humans) and
10 rodents (e.g., mice and rats), unless otherwise indicated. HtrA1 is also known in the art as HtrA serine peptidase 1, L56, and Serine protease 11. The term encompasses "full-length," unprocessed HtrA1 as well as any form of HtrA1 that results from processing in the cell. The term also encompasses naturally occurring variants of HtrA1, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary human HtrA1 can be found, for example, under UniProtKB accession number Q92743.

The term "HtrA1 binding antagonist" as used herein, refers to compounds or agents which inhibit
15 or reduce the biological activity of HtrA1. Exemplary HtrA1 binding antagonists include, for example, small molecule inhibitors and anti-HtrA1 antibodies, for example, any anti-HtrA1 antibody described in WO 2013/055998, which is incorporated herein by reference in its entirety.

The term "vascular endothelial growth factor" or "VEGF" refers to vascular endothelial growth
20 factor protein A, as exemplified by Swiss Prot Accession Number P15692. The term "VEGF" encompasses the protein having the amino acid sequence exemplified by Swiss Prot Accession Number P15692 as well as homologues and isoforms thereof. The term "VEGF" also encompasses the known isoforms, e.g., splice isoforms of VEGF, e.g., VEGF₁₁₁, VEGF₁₂₁, VEGF₁₄₅, VEGF₁₆₅, VEGF₁₈₉, and VEGF₂₀₆, together with the naturally-occurring allelic and processed forms thereof, including the 110-
25 amino acid human vascular endothelial cell growth factor generated by plasmin cleavage of VEGF₁₆₅ as described in Ferrara *Mol. Biol. Cell.* 21:687 (2010), Leung et al., *Science*, 246:1306 (1989), and Houck et al., *Mol. Endocrin.*, 5:1806 (1991). The term "VEGF" also refers to VEGFs from non-human species such as mouse, rat or primate. Sometimes the VEGF from a specific species are indicated by terms such as hVEGF for human VEGF, mVEGF for murine VEGF, and the like. The term "VEGF" is also used to refer
30 to truncated forms of the polypeptide comprising amino acids 8 to 109 or 1 to 109 of the 165-amino acid human vascular endothelial cell growth factor. Reference to any such forms of VEGF may be identified in the present application, e.g., by "VEGF₁₀₉," "VEGF (8-109)," "VEGF (1-109)" or "VEGF₁₆₅." The amino acid positions for a "truncated" native VEGF are numbered as indicated in the native VEGF sequence. For example, amino acid position 17 (methionine) in truncated native VEGF is also position 17
35 (methionine) in native VEGF. The truncated native VEGF has binding affinity for the KDR and Flt-1 receptors comparable to native VEGF. The term "VEGF variant" as used herein refers to a VEGF polypeptide which includes one or more amino acid mutations in the native VEGF sequence. Optionally, the one or more amino acid mutations include amino acid substitution(s). For purposes of shorthand designation of VEGF variants described herein, it is noted that numbers refer to the amino acid residue

position along the amino acid sequence of the putative native VEGF (provided in Leung et al., *supra* and Houck et al., *supra*). Unless specified otherwise, the term “VEGF” as used herein indicates VEGF-A.

The term “VEGF antagonist,” as used herein, refers to a molecule capable of binding to VEGF, reducing VEGF expression levels, or neutralizing, blocking, inhibiting, abrogating, reducing, or interfering with VEGF biological activities, including, but not limited to, VEGF binding to one or more VEGF receptors, VEGF signaling, and VEGF-mediated angiogenesis and endothelial cell survival or proliferation. For example, a molecule capable of neutralizing, blocking, inhibiting, abrogating, reducing, or interfering with VEGF biological activities can exert its effects by binding to one or more VEGF receptor (VEGFR) (e.g., VEGFR1, VEGFR2, VEGFR3, membrane-bound VEGF receptor (mbVEGFR), or soluble VEGF receptor (sVEGFR)). Included as VEGF antagonists useful in the methods of the invention are polypeptides that specifically bind to VEGF, anti-VEGF antibodies and antigen-binding fragments thereof, receptor molecules and derivatives which bind specifically to VEGF thereby sequestering its binding to one or more receptors, fusions proteins (e.g., VEGF-Trap (Regeneron)), and VEGF₁₂₁-gelonin (Peregrine). VEGF antagonists also include antagonist variants of VEGF polypeptides, antisense nucleobase oligomers complementary to at least a fragment of a nucleic acid molecule encoding a VEGF polypeptide; small RNAs complementary to at least a fragment of a nucleic acid molecule encoding a VEGF polypeptide; ribozymes that target VEGF; peptibodies to VEGF; and VEGF aptamers. VEGF antagonists also include polypeptides that bind to VEGFR, anti-VEGFR antibodies, and antigen-binding fragments thereof, and derivatives which bind to VEGFR thereby blocking, inhibiting, abrogating, reducing, or interfering with VEGF biological activities (e.g., VEGF signaling), or fusions proteins. VEGF antagonists also include nonpeptide small molecules that bind to VEGF or VEGFR and are capable of blocking, inhibiting, abrogating, reducing, or interfering with VEGF biological activities. Thus, the term “VEGF activities” specifically includes VEGF-mediated biological activities of VEGF. In certain embodiments, the VEGF antagonist reduces or inhibits, by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or more, the expression level or biological activity of VEGF. In some embodiments, the VEGF inhibited by the VEGF-specific antagonist is VEGF (8-109), VEGF (1-109), or VEGF₁₆₅.

As used herein VEGF antagonists can include, but are not limited to, anti-VEGFR2 antibodies and related molecules (e.g., ramucirumab, tanibirumab, aflibercept), anti-VEGFR1 antibodies and related molecules (e.g., icrucumab, aflibercept (VEGF Trap-Eye; EYLEA®), and ziv-aflibercept (VEGF Trap; ZALTRAP®)), bispecific VEGF antibodies (e.g., MP-0250, vanucizumab (VEGF-ANG2), and bispecific antibodies disclosed in US 2001/0236388), bispecific antibodies including combinations of two of anti-VEGF, anti-VEGFR1, and anti-VEGFR2 arms, anti-VEGF antibodies (e.g., bevacizumab, sevacizumab, and ranibizumab), and nonpeptide small molecule VEGF antagonists (e.g., pazopanib, axitinib, vandetanib, stivarga, cabozantinib, lenvatinib, nintedanib, orantinib, telatinib, dovitinib, cediranib, motesanib, sulfatinib, apatinib, foretinib, famitinib, and tivozanib).

The terms “anti-VEGF antibody,” an “antibody that binds to VEGF,” and “antibody that specifically binds VEGF” refer to an antibody that is capable of binding VEGF with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting VEGF. In one embodiment, the extent of binding of an anti-VEGF antibody to an unrelated, non-VEGF protein is less than about 10% of

the binding of the antibody to VEGF as measured, for example, by a radioimmunoassay (RIA). In certain embodiments, an antibody that binds to VEGF has a dissociation constant (K_d) of $\leq 1 \mu\text{M}$, $\leq 100 \text{ nM}$, $\leq 10 \text{ nM}$, $\leq 1 \text{ nM}$, $\leq 0.1 \text{ nM}$, $\leq 0.01 \text{ nM}$, or $\leq 0.001 \text{ nM}$ (e.g. 10^{-8} M or less, e.g., from 10^{-8} M to 10^{-13} M , e.g., from 10^{-9} M to 10^{-13} M). In certain embodiments, an anti-VEGF antibody binds to an epitope of VEGF that is conserved among VEGF from different species.

In certain embodiments, the anti-VEGF antibody can be used as a therapeutic agent in targeting and interfering with diseases or conditions wherein the VEGF activity is involved. Also, the antibody may be subjected to other biological activity assays, e.g., in order to evaluate its effectiveness as a therapeutic. Such assays are known in the art and depend on the target antigen and intended use for the antibody. Examples include the HUVEC inhibition assay; tumor cell growth inhibition assays (as described in WO 89/06692, for example); antibody-dependent cellular cytotoxicity (ADCC) and complement-mediated cytotoxicity (CDC) assays (U.S. Pat. No. 5,500,362); and agonistic activity or hematopoiesis assays (see WO 95/27062). An anti-VEGF antibody will usually not bind to other VEGF homologues such as VEGF-B or VEGF-C, nor other growth factors such as PlGF, PDGF, or bFGF. In one embodiment, anti-VEGF antibody is a monoclonal antibody that binds to the same epitope as the monoclonal anti-VEGF antibody A4.6.1 produced by hybridoma ATCC HB 10709. In another embodiment, the anti-VEGF antibody is a recombinant humanized anti-VEGF monoclonal antibody generated according to Presta et al. (1997) *Cancer Res.* 57:4593-4599, including but not limited to the antibody known as bevacizumab (BV; AVASTIN®).

The anti-VEGF antibody "bevacizumab (BV)," also known as "rhuMAb VEGF" or "AVASTIN®," is a recombinant humanized anti-VEGF monoclonal antibody generated according to Presta et al. (1997) *Cancer Res.* 57:4593-4599. It comprises mutated human IgG1 framework regions and antigen-binding complementarity-determining regions from the murine anti-hVEGF monoclonal antibody A.4.6.1 that blocks binding of human VEGF to its receptors. Approximately 93% of the amino acid sequence of bevacizumab, including most of the framework regions, is derived from human IgG1, and about 7% of the sequence is derived from the murine antibody A4.6.1. Bevacizumab has a molecular mass of about 149,000 daltons and is glycosylated. Bevacizumab and other humanized anti-VEGF antibodies are further described in U.S. Pat. No. 6,884,879 issued Feb. 26, 2005, the entire disclosure of which is expressly incorporated herein by reference. Additional preferred antibodies include the G6 or B20 series antibodies (e.g., G6-31, B20-4.1), as described in PCT Application Publication Nos. WO 2005/012359 and WO 2005/044853, which are each incorporated herein by reference in their entirety. For additional preferred antibodies see U.S. Pat. Nos. 7,060,269, 6,582,959, 6,703,020; 6,054,297; WO98/45332; WO 96/30046; WO94/10202; EP 066868B1; U.S. Patent Application Publication Nos. 2006009360, 20050186208, 20030206899, 20030190317, 20030203409, and 20050112126; and Popkov et al., *Journal of Immunological Methods* 288:149-164 (2004). Other preferred antibodies include those that bind to a functional epitope on human VEGF comprising of residues F17, M18, D19, Y21, Y25, Q89, 191, K101, E103, and C104 or, alternatively, comprising residues F17, Y21, Q22, Y25, D63, 183, and Q89. Additional anti-VEGF antibodies include anti-VEGF antibodies described in PCT Application Publication No. WO 2009/155724.

The anti-VEGF antibody "ranibizumab" also known as "LUCENTIS®" or "rhuFab V2" is a humanized, affinity-matured anti-human VEGF Fab fragment. Ranibizumab is produced by standard recombinant technology methods in Escherichia coli expression vector and bacterial fermentation. Ranibizumab is not glycosylated and has a molecular mass of ~48,000 daltons. See WO 98/45331 and
5 US 2003/0190317.

An "isolated nucleic acid" refers to a nucleic acid molecule that has been separated from a component of its natural environment. An isolated nucleic acid includes a nucleic acid molecule contained in cells that ordinarily contain the nucleic acid molecule, but the nucleic acid molecule is present extrachromosomally or at a chromosomal location that is different from its natural chromosomal
10 location.

The term "control sequences" refers to DNA sequences necessary for the expression of an operably linked coding sequence in a particular host organism. The control sequences that are suitable for prokaryotes, for example, include a promoter, optionally an operator sequence, and a ribosome binding site. Eukaryotic cells are known to utilize promoters, polyadenylation signals, and enhancers.

The terms "host cell," "host cell line," and "host cell culture" are used interchangeably and refer to cells into which exogenous nucleic acid has been introduced, including the progeny of such cells. Host cells include "transformants" and "transformed cells," which include the primary transformed cell and progeny derived therefrom without regard to the number of passages. Progeny may not be completely identical in nucleic acid content to a parent cell, but may contain mutations. Mutant progeny that have the
15 same function or biological activity as screened or selected for in the originally transformed cell are included herein.

Nucleic acid is "operably linked" when it is placed into a functional relationship with another nucleic acid sequence. For example, DNA for a presequence or secretory leader is operably linked to DNA for a polypeptide if it is expressed as a preprotein that participates in the secretion of the
25 polypeptide; a promoter or enhancer is operably linked to a coding sequence if it affects the transcription of the sequence; or a ribosome binding site is operably linked to a coding sequence if it is positioned so as to facilitate translation. Generally, "operably linked" means that the DNA sequences being linked are contiguous, and, in the case of a secretory leader, contiguous and in reading phase. However, enhancers do not have to be contiguous. Linking is accomplished by ligation at convenient restriction
30 sites. If such sites do not exist, the synthetic oligonucleotide adaptors or linkers are used in accordance with conventional practice.

"Percent (%) amino acid sequence identity" with respect to the polypeptide sequences identified herein is defined as the percentage of amino acid residues in a candidate sequence that are identical with the amino acid residues in the polypeptide being compared, after aligning the sequences and introducing
35 gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, BLAST-2, ALIGN, or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for measuring

alignment, including any algorithms needed to achieve maximal alignment over the full-length of the sequences being compared. For purposes herein, however, % amino acid sequence identity values are generated using the sequence comparison computer program ALIGN-2. The ALIGN-2 sequence comparison computer program was authored by Genentech, Inc. and the source code has been filed with user documentation in the U.S. Copyright Office, Washington D.C., 20559, where it is registered under U.S. Copyright Registration No. TXU510087. The ALIGN-2 program is publicly available through Genentech, Inc., South San Francisco, California. The ALIGN-2 program should be compiled for use on a UNIX operating system, preferably digital UNIX V4.0D. All sequence comparison parameters are set by the ALIGN-2 program and do not vary.

In situations where ALIGN-2 is employed for amino acid sequence comparisons, the % amino acid sequence identity of a given amino acid sequence A to, with, or against a given amino acid sequence B (which can alternatively be phrased as a given amino acid sequence A that has or comprises a certain % amino acid sequence identity to, with, or against a given amino acid sequence B) is calculated as follows:

$$100 \text{ times the fraction } X/Y$$

where X is the number of amino acid residues scored as identical matches by the sequence alignment program ALIGN-2 in that program's alignment of A and B, and where Y is the total number of amino acid residues in B. It will be appreciated that where the length of amino acid sequence A is not equal to the length of amino acid sequence B, the % amino acid sequence identity of A to B will not equal the % amino acid sequence identity of B to A. Unless specifically stated otherwise, all % amino acid sequence identity values used herein are obtained as described in the immediately preceding paragraph using the ALIGN-2 computer program.

The amino acid sequences described herein are contiguous amino acid sequences unless otherwise specified.

The term "package insert" is used to refer to instructions customarily included in commercial packages of therapeutic products, that contain information about the indications, usage, dosage, administration, combination therapy, contraindications and/or warnings concerning the use of such therapeutic products.

The term "pharmaceutical composition" refers to a preparation which is in such form as to permit the biological activity of an active ingredient contained therein to be effective, and which contains no additional components which are unacceptably toxic to a subject to which the formulation would be administered.

A "pharmaceutically acceptable carrier" refers to an ingredient in a pharmaceutical formulation, other than an active ingredient, which is nontoxic to a subject. A pharmaceutically acceptable carrier includes, but is not limited to, a buffer, excipient, stabilizer, or preservative.

The term "prodrug" as used in this application refers to a precursor or derivative form of a pharmaceutically active substance that is less cytotoxic to tumor cells compared to the parent drug and is capable of being enzymatically activated or converted into the more active parent form. See, e.g.,

Wilman, "Prodrugs in Cancer Chemotherapy" *Biochemical Society Transactions*, 14, pp. 375-382, 615th Meeting Belfast (1986) and Stella et al. "Prodrugs: A Chemical Approach to Targeted Drug Delivery," *Directed Drug Delivery*, Borchardt et al. (ed.), pp. 247-267, Humana Press (1985). The prodrugs of this invention include, but are not limited to, phosphate-containing prodrugs, thiophosphate-containing prodrugs, sulfate-containing prodrugs, peptide-containing prodrugs, D-amino acid-modified prodrugs, glycosylated prodrugs, β -lactam-containing prodrugs, optionally substituted phenoxyacetamide-containing prodrugs or optionally substituted phenylacetamide-containing prodrugs, 5-fluorocytosine and other 5-fluorouridine prodrugs which can be converted into the more active cytotoxic free drug. Examples of cytotoxic drugs that can be derivatized into a prodrug form for use in this invention include, but are not limited to, those chemotherapeutic agents described above.

By "reduce or inhibit" is meant the ability to cause an overall decrease preferably of 20% or greater, more preferably of 50% or greater, and most preferably of 75%, 85%, 90%, 95%, or greater. Reduce or inhibit can refer to the symptoms of the disorder being treated, the presence or size of metastases, the size of the primary tumor.

A "subject" is a vertebrate, preferably a mammal, more preferably a human. Mammals include, but are not limited to, farm animals (such as cows, and sheep), sport animals, pets (such as cats, dogs and horses), primates (e.g., humans and non-human primates such as monkeys), and rodents (e.g., mice and rats).

The term "therapeutically effective amount" refers to an amount of an antibody or antibody fragment to treat a disease or disorder in a subject. In the case of an IL-33-mediated disorder, the therapeutically effective amount of the antibody or antibody fragment (e.g., an anti-IL-33 antibody, including bispecific anti-IL-33 antibodies that bind to IL-33 and a second biological molecule, e.g., IL-13, e.g., bispecific anti-IL-33/anti-IL-13 antibodies) may ameliorate or treat the disease, or prevent, reduce, ameliorate, or treat symptoms associated with the disease. In the case of a proliferative disease (e.g., a solid tumor), the therapeutically effective amount of the antibody or antibody fragment may reduce the number of cancer cells; reduce the primary tumor size; inhibit (i.e., slow to some extent and preferably stop) cancer cell infiltration into peripheral organs; inhibit (i.e., slow to some extent and preferably stop) tumor metastasis; inhibit, to some extent, tumor growth; and/or relieve to some extent one or more of the symptoms associated with the disorder. To the extent the antibody or antibody fragment may prevent growth and/or kill existing cancer cells, it may be cytostatic and/or cytotoxic. For cancer therapy, efficacy *in vivo* can, for example, be measured by assessing the duration of survival, time to disease progression (TTP), duration of disease free survival (DFS), duration of progression free survival (PFS), the response rates (RR), duration of response, and/or quality of life.

As used herein, "treatment" (and grammatical variations thereof such as "treat" or "treating") refers to clinical intervention in an attempt to alter the natural course of the individual being treated, and can be performed either for prophylaxis or during the course of clinical pathology. Desirable effects of treatment include, but are not limited to, preventing occurrence or recurrence of disease, alleviation of symptoms, diminishment of any direct or indirect pathological consequences of the disease, preventing metastasis, decreasing the rate of disease progression, amelioration or palliation of the disease state,

and remission or improved prognosis. In some embodiments, antibodies of the invention are used to delay development of a disease or to slow the progression of a disease. A patient may be successfully "treated" for asthma if, for example, after receiving an asthma therapy, the patient shows observable and/or measurable reduction in or absence of one or more of the following: recurrent wheezing, coughing, trouble breathing, chest tightness, symptoms that occur or worsen at night, symptoms that are triggered by cold air, exercise or exposure to allergens.

"Tumor", as used herein, refers to all neoplastic cell growth and proliferation, whether malignant or benign, and all pre-cancerous and cancerous cells and tissues.

The term "vector," as used herein, is intended to refer to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. One type of vector is a "plasmid", which refers to a circular double stranded DNA loop into which additional DNA segments may be ligated. Another type of vector is a phage vector. Another type of vector is a viral vector, wherein additional DNA segments may be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (e.g., bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (e.g., non-episomal mammalian vectors) can be integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated along with the host genome. Moreover, certain vectors are capable of directing the expression of genes to which they are operatively linked. Such vectors are referred to herein as "recombinant expression vectors" (or simply, "recombinant vectors" or "expression vectors"). In general, expression vectors of utility in recombinant DNA techniques are often in the form of plasmids. In the present specification, "plasmid" and "vector" may be used interchangeably.

II. Compositions and Methods

In one aspect, the invention is based, in part, on novel antibodies that bind to IL-33. Antibodies of the invention are useful, e.g., for the diagnosis and/or treatment of IL-33-mediated disorders.

A. Exemplary Anti-IL-33 Antibodies

The invention provides isolated antibodies that bind to IL-33. In certain embodiments, an anti-IL-33 antibody of the invention specifically binds both human and cynomolgus monkey (cyno) IL-33 with a K_D of 100 nM or lower (e.g., 100 nM or lower, 10 nM or lower, 1 nM or lower, 100 pM or lower, 10 pM or lower, 1 pM or lower, or 0.1 pM or lower). In some instances, the antibody specifically binds human IL-33 with a K_D of 1 nM or lower (e.g., 1 nM or lower, 100 pM or lower, 10 pM or lower, 1 pM or lower, or 0.1 pM or lower). For example, in some instances, the antibody specifically binds human IL-33 with a K_D between 100 fM and 1 nM. In some instances, the antibody specifically binds cyno IL-33 with a K_D of 1 nM or lower (e.g., 1 nM or lower, 100 pM or lower, 10 pM or lower, 1 pM or lower, or 0.1 pM or lower). For example, in some instances, the antibody specifically binds cyno IL-33 with a K_D between 100 fM and 1 nM. In certain instances, the antibody specifically binds both human and cyno IL-33 with a K_D of 1 nM or lower (e.g., 1 nM or lower, 100 pM or lower, 10 pM or lower, 1 pM or lower, or 0.1 pM or lower). For example, in some instances, the antibody specifically binds both human and cyno IL-33 with a K_D of

between 1 pM and 500 pM. In some instances, the antibody specifically binds human IL-33 with a K_D of between 1 pM and 10 pM. In some instances, the antibody does not specifically bind to murine IL-33.

For example, in some instances, the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 1 pM and about 900 pM, between about 1 pM and about 800 pM, between about 1 pM and about 700 pM, between about 1 pM and about 600 pM, between about 1 pM and about 500 pM, between about 1 pM and about 400 pM, between about 1 pM and about 300 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some instances, the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 250 pM (e.g., between about 1 pM and about 250 pM, between about 1 pM and about 225 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some instances, the antibody specifically binds human IL-33 with a K_D of between about 50 pM and about 180 pM (e.g., about 50 pM, about 60 pM, about 70 pM, about 80 pM, about 90 pM, about 100 pM, about 110 pM, about 120 pM, about 130 pM, about 140 pM, about 150 pM, about 160 pM, or about 180 pM). In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2, Section D and Example 8, Section E).

In some instances, the antibody specifically binds human IL-33 with a K_D of about 400 pM or lower at 25 °C. For example, in some instances, the antibody specifically binds human IL-33 with a K_D of about 390 pM or lower, about 380 pM or lower, about 375 pM or lower, about 350 pM or lower, about 325 pM or lower, about 300 pM or lower, about 275 pM or lower, about 250 pM or lower, about 250 pM or lower, about 225 pM or lower, about 200 pM or lower, about 175 pM or lower, about 150 pM or lower, about 130 pM or lower, about 125 pM or lower, about 100 pM or lower, about 75 pM or lower, about 50 pM or lower, or about 25 pM or lower at 25 °C. In some instances, the antibody specifically binds human IL-33 with a K_D of about 20 pM to about 150 pM (e.g., about 20 pM, about 30 pM, about 40 pM, about 50 pM, about 60 pM, about 70 pM, about 80 pM, about 90 pM, about 100 pM, about 110 pM, about 120 pM,

about 130 pM, about 140 pM, or about 150 pM) at 25°C. In some instances, the antibody specifically binds human IL-33 with a K_D of about 130 pM at 25°C. In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2, Section D and Example 8, Section E).

5 In some instances, the antibody specifically binds human IL-33 with a K_D of about 200 pM or lower at 37°C. For example, in some instances, the antibody specifically binds human IL-33 with a K_D of about 190 pM or lower, about 180 pM or lower, about 175 pM or lower, about 150 pM or lower, about 130 pM or lower, about 125 pM or lower, about 100 pM or lower, about 90 pM or lower, about 80 pM or lower, about 75 pM or lower, about 50 pM or lower, or about 25 pM or lower at 37°C. In some instances, the
10 antibody specifically binds human IL-33 with a K_D of about 20 pM to about 100 pM (e.g., about 20 pM, about 30 pM, about 40 pM, about 50 pM, about 60 pM, about 70 pM, about 80 pM, about 90 pM, or about 100 pM) at 37°C. In some instances, the antibody specifically binds human IL-33 with a K_D of about 90 pM at 37°C. In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2,
15 Section D and Example 8, Section E).

In some instances, the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 1 pM and about 900 pM, between about 1 pM and about 800 pM, between about 1 pM and about 700 pM, between about 1 pM and about 600 pM, between about 1 pM and about 500 pM, between about 1 pM and about 400 pM, between about 1 pM and about 300 pM,
20 between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some instances, the antibody specifically binds cyno IL-33 with a K_D of between about 100 pM and about 750 pM (e.g., between about 100 pM and about 750 pM, between about 200 pM and about 750 pM, between
30 about 225 pM and about 750 pM, between about 250 pM and about 750 pM, between about 265 pM and about 750 pM, between about 275 pM and about 750 pM, between about 300 pM and about 750 pM, between about 325 pM and about 750 pM, between about 350 pM and about 750 pM, between about 375 pM and about 750 pM, between about 400 pM and about 750 pM, between about 425 pM and about 750 pM, between about 450 pM and about 750 pM, between about 475 pM and about 750 pM, between about
35 500 pM and about 750 pM, between about 525 pM and about 750 pM, between about 550 pM and about 750 pM, between about 575 pM and about 750 pM, between about 600 pM and about 750 pM, between about 650 pM and about 750 pM, or between about 250 pM and about 650 pM). In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2, Section D and Example 8, Section E).

For example, in some instances, the antibody specifically binds cyno IL-33 with a K_D of about 650 pM or lower at 25°C. For example, in some instances, the antibody specifically binds cyno IL-33 with a K_D of about 650 pM or lower, about 625 pM or lower, about 600 pM or lower, about 575 pM or lower, about 550 pM or lower, about 525 pM or lower, about 500 pM or lower, about 475 pM or lower, about 450 pM or lower, about 425 pM or lower, about 400 pM or lower, about 375 pM or lower, about 350 pM or lower, about 325 pM or lower, about 300 pM or lower, about 275 pM or lower, about 265 pM or lower, about 250 pM or lower, about 225 pM or lower, about 200 pM or lower, about 175 pM or lower, about 150 pM or lower, about 125 pM or lower, about 100 pM or lower, about 75 pM or lower, about 50 pM or lower, or about 25 pM or lower at 25°C. In some instances, the antibody specifically binds cyno IL-33 with a K_D of about 150 pM to about 500 pM (e.g., about 150 pM, about 175 pM, about 200 pM, about 225 pM, about 250 pM, about 265 pM, about 275 pM, about 300 pM, about 325 pM, about 350 pM, about 375 pM, about 400 pM, about 425 pM, about 450 pM, about 475 pM or about 500 pM) at 25°C. In some instances, the antibody specifically binds cyno IL-33 with a K_D of about 265 pM at 25°C. In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2, Section D and Example 8, Section E).

In other instances, the antibody specifically binds cyno IL-33 with a K_D of about 1 nM or lower at 37°C. For example, in some instances, the antibody specifically binds cyno IL-33 with a K_D of about 1 nM or lower, about 950 pM or lower, about 900 pM or lower, about 850 pM or lower, about 800 pM or lower, about 750 pM or lower, about 700 pM or lower, about 650 pM or lower, about 600 pM or lower, about 550 pM or lower, about 525 pM or lower, about 500 pM or lower, about 475 pM or lower, about 450 pM or lower, about 425 pM or lower, about 400 pM or lower, about 350 pM or lower, about 300 pM or lower, about 250 pM or lower, about 200 pM or lower, about 150 pM or lower, about 100 pM or lower, or about 50 pM or lower at 37°C. In some instances, the antibody specifically binds cyno IL-33 with a K_D of about 250 pM to about 750 pM (e.g., about 250 pM, about 275 pM, about 300 pM, about 325 pM, about 350 pM, about 375 pM, about 400 pM, about 425 pM, about 450 pM, about 475 pM, about 500 pM, about 525 pM, about 550 pM, about 575 pM, about 600 pM, about 625 pM, about 650 pM, about 675 pM, about 700 pM, about 725 pM, or about 750 pM) at 37°C. In some instances, the antibody specifically binds cyno IL-33 with a K_D of about 475 pM at 37°C. In some embodiments, any of the preceding K_D values may be determined by surface plasmon resonance, for example, as described herein (see, e.g., the Examples, including Example 2, Section D and Example 8, Section E). In some embodiments, an anti-IL-33 antibody of the invention is capable of inhibiting the binding of IL-33 to an IL-33 receptor. In some embodiments, the inhibiting is measured using a cell-based blocking assay. In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 90% inhibitory concentration (IC₉₀) of between about 0.0001 µg/ml to about 1 µg/ml (e.g., about 0.001 µg/ml to about 0.5 µg/ml). In some embodiments, the IC₉₀ is between about 0.002 µg/ml to about 0.25 µg/ml. In some embodiments, the IC₉₀ is about 0.17 µg/ml. In some embodiments, the IC₉₀ is about 0.004 µg/ml. In some embodiments, IC₉₀ is about 0.003 µg/ml. In some embodiments, IC₉₀ is about 0.002 µg/ml. In some embodiments, IC₉₀ is about 0.001 µg/ml.

In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a half-maximal inhibitory concentration (IC₅₀) of between about 750 fM and about 250 pM (e.g., between about 750 fM and about 250 pM, between about 1 pM and about 250 pM, between about 1 pM and about 100 pM, between about 1 pM and about 50 pM, between about 1 pM and about 10 pM, or between about 1 pM and about 5 pM). In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC₅₀ of about 10 pM or below (e.g., about 10 pM or below, about 9 pM or below, about 8 pM or below, about 7 pM or below, about 6 pM or below, about 5 pM or below, about 4 pM or below, about 3 pM or below, about 2.5 pM or below, about 2 pM or below, about 1 pM or below, about 900 fM or below, about 800 fM or below, or about 750 fM or below). In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC₅₀ of about 2.4 pM. In some instances, the inhibiting is measured using a cell-based blocking assay using HEK-BLUE™ cells, for example, as described in Example 8, Section B.

In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of between about 1 nM and about 10 nM. (e.g., between about 1 nM and about 10 nM, between about 1 nM and about 9 nM, between about 1 nM and about 8 nM, between about 1 nM and about 7 nM, between about 1 nM and about 6 nM, between about 1 nM and about 5 nM, between about 1 nM and about 4 nM, or between about 1 nM and about 3 nM). In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of about 4.2 nM. In some instances, the inhibiting is measured using a cell-based blocking assay using HEK-BLUE™ cells, for example, as described in Example 8, Section B.

In some instances, the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human natural killer (NK) cells. For example, in some instances, the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 200 pM, between about 1 pM and about 175 pM, between about 1 pM and about 150 pM, between about 1 pM and about 125 pM, between about 1 pM and about 100 pM, between about 1 pM and about 75 pM, between about 1 pM and about 50 pM, between about 1 pM and about 30 pM, or between about 1 pM and about 25 pM). In some instances, the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of about 100 pM or below, e.g., 100 pM or below, 75 pM or below, 50 pM or below, 30 pM or below, or 25 pM or below. In some instances, the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of about 30 pM. In some instances, the inhibiting is measured using an NK primary cell assay, for example, as described in Example 8, Section C.

In some instances, the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils. For example, in some instances, the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below (e.g., 1 pM or below, 0.75 pM or below, 0.5 pM or below, 0.25 pM or below, 0.15 pM or below, 0.1 pM or below, or 0.05 pM or below). In some instances, the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in

human basophils with an IC₅₀ of about 0.15 pM. In some instances, the inhibiting is measured using a basophil primary cell assay, for example, as described in Example 8, Section D.

In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay. In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 200 pM, between about 1 pM and about 175 pM, between about 1 pM and about 150 pM, between about 1 pM and about 125 pM, between about 1 pM and about 100 pM, between about 1 pM and about 75 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 25 pM, between about 10 pM and about 60 pM, between about 10 pM and about 50 pM, or between about 20 pM and about 50 pM). In some instances, the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of about 21 pM. In some instances, the inhibiting is measured using a competitive binding ELISA, for example, as described in Example 8, Section F.

In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay. In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 20 nM (e.g., between about 1 pM and about 20 nM, between about 1 pM and about 15 nM, between about 1 pM and about 10 nM, between about 1 pM and about 5 nM, between about 1 pM and about 1 nM, between about 1 pM and about 800 pM, between about 1 pM and about 600 pM, between about 1 pM and about 500 pM, between about 1 nM and about 400 pM, between about 1 nM and about 300 pM, between about 200 pM and about 1 nM, between about 200 pM and about 800 pM, between about 200 pM and about 600 pM, between about 200 pM and about 500 pM, between about 300 pM and about 600 pM, or between about 300 pM and about 500 pM). In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of about 1 nM or below, e.g., about 1 nM or below, about 800 pM or below, about 600 pM or below, about 500 pM or below, about 430 pM or below, about 400 pM or below, or about 300 pM or below. In some instances, the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of about 430 pM. In some instances, the inhibiting is measured using a competitive binding ELISA, for example, as described in Example 8, Section F.

In some instances, any of the anti-IL-33 antibodies described herein (e.g., described above or below) may have one or more (e.g., 1, 2, 3, 4, 5, 6, 7, or 8) of the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM; (ii) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM; (iii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor (e.g., ST2 and/or IL-1RAcP) with an IC₅₀ of between about 750 fM and about 250 pM, for example, in a cell-based blocking assay using HEK-BLUE™ cells; (iv) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor (e.g., ST2 and/or IL-1RAcP) with an IC₅₀ of between about 1 nM and about 10 nM, for example, in a cell-based blocking assay using HEK-BLUE™ cells; (v) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of between about 1 pM and about 200 pM; (vi) the antibody inhibits human IL-33-

mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below; (vii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor (e.g., ST2 and/or IL-1RAcP) in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM; and/or (viii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor (e.g., ST2 and/or IL-1RAcP) in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 20 nM. In some embodiments, any of the anti-IL-33 antibodies described herein may have one of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have two of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have three of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have four of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have five of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have six of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have seven of the preceding features. In some embodiments, any of the anti-IL-33 antibodies described herein may have eight of the preceding features.

For example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC₅₀ of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells.

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells.

In yet another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM).

In a further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits

human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM).

In a still further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another embodiment, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 15 pM and about 180 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC₅₀ of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells.

In yet another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells. In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF-α from human NK cells with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM).

In a further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM).

In yet another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another embodiment, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody specifically binds cyno IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 100 pM and about 500 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC_{50} of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In a further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC_{50} of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC_{50} of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells.

In a still further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC_{50} of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF- α from human NK cells with an IC_{50} of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC_{50} of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC_{50} of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM).

In yet another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC_{50} of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC_{50} of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another embodiment, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor with an IC_{50} of between about 750 fM and about 250 pM (e.g., between about 800 fM and about 10 pM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC_{50} of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In a further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC_{50} of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for

example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF- α from human NK cells with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM).

In a still further example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC50 of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC50 of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC50 of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another embodiment, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC50 of between about 1 nM and about 10 nM (e.g., between about 1 nM and about 5 nM), for example, in a cell-based blocking assay using HEK-BLUE™ cells; and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC50 of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In yet another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF- α from human NK cells with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM); and (ii) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC50 of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF- α from human NK cells with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits human IL-33- and IL-12-mediated induction of TNF- α from human NK cells with an IC50 of between about 1 pM and about 200 pM (e.g., between about 1 pM and about 80 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC50 of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM); and (ii) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits human IL-33-mediated induction of p38 MAPK (Thr180/Tyr182) phosphorylation in human basophils with an IC₅₀ of about 1 pM or below (e.g., between about 0.05 pM to about 0.5 pM); and (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In another example, in some embodiments, any of the anti-IL-33 antibodies described herein may have the following features: (i) the antibody inhibits the binding of human IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 200 pM (e.g., between about 1 pM to about 50 pM); and/or (ii) the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor in a competitive binding ELISA assay with an IC₅₀ of between about 1 pM and about 20 nM (e.g., between about 200 pM to about 1 nM).

In some instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SFSX₁S (SEQ ID NO: 62), wherein X₁ is Met, Leu, or Val; (b) HVR-H2 comprising the amino acid sequence of TISGGKTFTDYDX₁VKG (SEQ ID NO: 63), wherein X₁ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of ANYGX₁X₂FFEY (SEQ ID NO: 64), wherein X₁ is Asn or Asp, and X₂ is Trp or Phe; (d) HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLN (SEQ ID NO: 4); (e) HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 4-6 or 62-64.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1), SFSLS (SEQ ID NO: 7), or SFSVS (SEQ ID NO: 8); (b) HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2) or TISGGKTFTDYVDAVKG (SEQ ID NO: 9); (c) HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3), ANYGNFFFEY (SEQ ID NO: 10), or ANYGDWFFEY (SEQ ID NO: 11); (d) HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLN (SEQ ID NO: 4); (e) HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6), or a combination of one or more of the above HVRs and one or more variants thereof having at least

about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 1-11.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of

- 5 EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12),
 DVNLVESGGGSVKPGGSLKLSVASGFTFS (SEQ ID NO: 16), or
 EVQLVESGGGLVKPGGSLRLSCAASGFTFS (SEQ ID NO: 20); an FR-H2 comprising the amino acid
 sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13), WVRQTPEKRLWVA (SEQ ID NO: 17), or
 WVRQAPGKGLEWVS (SEQ ID NO: 21); an FR-H3 comprising the amino acid sequence of
 10 RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14),
 RFTISRDNKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 22),
 RFTISRDDAKNTLYLQMSSLESEDAMYYCTR (SEQ ID NO: 18),
 RFTISRDDAKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 23),
 RFTISRDNKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 24), or
 15 RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and an FR-H4 comprising the amino
 acid sequence of WGQGTLLTVSS (SEQ ID NO: 15) or WGAGTTAVSS (SEQ ID NO: 19).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of

- EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25) or DIVLTQSPGFLVSLGQRATISC (SEQ ID NO: 29);
 20 an FR-L2 comprising the amino acid sequence of WFQQKPGQPRLIF (SEQ ID NO: 26) or
 WFQQKPGQPKLLIF (SEQ ID NO: 30); an FR-L3 comprising the amino acid sequence of
 GIPARFSGSGSGTDFLTLSLEPEDFAVYYC (SEQ ID NO: 27),
 GVPARFSGSGSGTDFSLNIHPMEEDDTAMYFC (SEQ ID NO: 31),
 GVPARFSGSGSGTDFLTLSLEPEDFAVYFC (SEQ ID NO: 33),
 25 GVPARFSGSGSGTDFLTLSLEPEDFAVYYC (SEQ ID NO: 34), or
 GIPARFSGSGSGTDFLTLSLEPEDFAVYFC (SEQ ID NO: 35); and an FR-L4 comprising the amino
 acid sequence of FGQGTKVEIK (SEQ ID NO: 28) or FGSGTKLEIK (SEQ ID NO: 32).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%,
 30 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 36, 38, or 40-50; (b) a light chain variable (VL) domain comprising an amino acid sequence having at
 least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence
 identity) to, or the sequence of, any one of SEQ ID NOs: 37, 39, or 51-61; or (c) a VH domain as in (a)
 and a VL domain as in (b). For example, in some instances, the antibody comprises a binding domain
 35 comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 36 and a VL domain
 comprising the amino acid sequence of SEQ ID NO: 37. In some instances, the antibody comprises a
 binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 38 and a
 VL domain comprising the amino acid sequence of SEQ ID NO: 39. In some instances, the antibody
 comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID

NO: 40 and a VL domain comprising the amino acid sequence of SEQ ID NO: 51. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 41 and a VL domain comprising the amino acid sequence of SEQ ID NO: 52. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 42 and a VL domain comprising the amino acid sequence of SEQ ID NO: 53. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 43 and a VL domain comprising the amino acid sequence of SEQ ID NO: 54. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 44 and a VL domain comprising the amino acid sequence of SEQ ID NO: 55. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 45 and a VL domain comprising the amino acid sequence of SEQ ID NO: 56. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 46 and a VL domain comprising the amino acid sequence of SEQ ID NO: 57. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 47 and a VL domain comprising the amino acid sequence of SEQ ID NO: 58. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 48 and a VL domain comprising the amino acid sequence of SEQ ID NO: 59. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 49 and a VL domain comprising the amino acid sequence of SEQ ID NO: 60. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 50 and a VL domain comprising the amino acid sequence of SEQ ID NO: 61.

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); (b) HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); (c) HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); (d) HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (e) HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6). In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 36; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 37; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12); FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13); FR-H3 comprising the amino acid sequence of RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and FR-H4 comprising the amino acid sequence of WGQGTLTVSS (SEQ ID NO: 15). In some instances, the anti-IL-33

antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25); FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLLIF (SEQ ID NO: 26); FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFLTLSLSEPEDFAVYYC (SEQ ID NO: 27); and FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28). In some instances, the anti-IL-33 antibody includes a binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 37. In some instances, the exemplary anti-IL-33 antibody is 10C12.38.H6.87Y.58I.

In other instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPX₁LKS (SEQ ID NO: 90), wherein X₁ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68); (d) HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 65, 68-71, or 90.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNP₁SLKS (SEQ ID NO: 66) or SIYYSGRTYYNPALKS (SEQ ID NO: 67); (c) HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68); (d) HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 65-71.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72), QVQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 77), or QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76); an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75) or WGNGTTVTVSS (SEQ ID NO: 78).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of EIVLTQSPGTL₁SLSPGERATLSC (SEQ ID NO: 79); an FR-L2 comprising the amino acid sequence of

WYQQKPGQAPRLLIY (SEQ ID NO: 80); an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81) or GIPDRFSGSGSGTDFTLTISRLEPKDFAVYYC (SEQ ID NO: 83); and an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82).

5 In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 84, 86, 88, 91, 92, or 95; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 85, 87, 89, 93, 94, or 96; or (c) a VH domain as in (a) and a VL domain as in (b). For example, some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 84 and a VL domain comprising the amino acid sequence of SEQ ID NO: 85. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 86 and a VL domain comprising the amino acid sequence of SEQ ID NO: 87. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 88 and a VL domain comprising the amino acid sequence of SEQ ID NO: 89. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 91 and a VL domain comprising the amino acid sequence of SEQ ID NO: 93. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 92 and a VL domain comprising the amino acid sequence of SEQ ID NO: 94. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 95 and a VL domain comprising the amino acid sequence of SEQ ID NO: 96.

25 For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPSLKS (SEQ ID NO: 66); (c) HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68); (d) HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 84; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 85; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72); FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73); FR-H3 comprising the amino acid sequence of

RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75). In some instances, the anti-IL-33 antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSPGERATLSC (SEQ ID NO: 79); FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80); FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFLTISRLEPEDFAVYYC (SEQ ID NO: 81); and FR-L4 comprising the amino acid sequence of FGGGTVKVEIK (SEQ ID NO: 82). In some instances, the anti-IL-33 antibody includes a binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 84 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 85. In some instances, the exemplary anti-IL-33 antibody is 4G12.FW4.

In some instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of NYX₁MN (SEQ ID NO: 97), wherein X₁ is Trp, Phe, or Tyr; (b) HVR-H2 comprising the amino acid sequence of EITLKFNX₁YX₂THYAESVKG (SEQ ID NO: 98), wherein X₁ is Asn, Asp, Ser, or Ala, and X₂ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of RNYGX₁X₂YINV (SEQ ID NO: 99), wherein X₁ is Asp or Asn, and X₂ is Trp or Tyr; (d) HVR-L1 comprising the amino acid sequence of RASESVDKFGX₁SFLN (SEQ ID NO: 100), wherein X₁ is Met, Val, or Leu; (e) HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 97-100, 113, or 114. In some embodiments, any of the preceding antibodies does not comprise an HVR-H1 comprising the amino acid sequence NYWMN (SEQ ID NO: 101).

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101), NYFMN (SEQ ID NO: 102), or NYMMN (SEQ ID NO: 103); (b) HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104), EITLKFNDYSTHYAESVKG (SEQ ID NO: 105), EITLKFNSYSTHYAESVKG (SEQ ID NO: 106), EITLKFNAYSTHYAESVKG (SEQ ID NO: 107), or EITLKFNNYATHYAESVKG (SEQ ID NO: 108); (c) HVR-H3 comprising the amino acid sequence of RNYGDWYINV (SEQ ID NO: 109), RNYGNWYINV (SEQ ID NO: 110), or RNYGNFYINV (SEQ ID NO: 111); (d) HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112), RASESVDKFGVSFLN (SEQ ID NO: 115), or RASESVDKFGLSFLN (SEQ ID NO: 116); (e) HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 101-116. In some embodiments, any of the preceding antibodies does not comprise an HVR-H1 comprising the amino acid sequence NYWMN (SEQ ID NO: 101).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFS (SEQ ID NO: 117) or EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 118); an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWMA (SEQ ID NO: 119) or WVRQAPGKGLEWMA (SEQ ID NO: 120); an FR-H3 comprising the amino acid sequence of RFSISRDDSKSTVYLQMNNLRAEDTGIYYCAR (SEQ ID NO: 121), RFTISRDNKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 122), or RFTISRDDSKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 123); and an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 124) or WGQGTLVTVSS (SEQ ID NO: 125). In some embodiments, any of the preceding antibodies does not comprise an HVR-H1 comprising the amino acid sequence NYWMN (SEQ ID NO: 101).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of DIVLTQSPTSLAVSLGQRATISC (SEQ ID NO: 126) or DIVMTQSPDSLAVSLGERATINC (SEQ ID NO: 127); an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 128) or WYQQKPGQPPKLLIF (SEQ ID NO: 129); an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFTSLNIHPVEEDDTAMYFC (SEQ ID NO: 130) or GVPDRFSGSGSGTDFTLTISLQAEDVAVYYC (SEQ ID NO: 131); and an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 132) or FGQGTKVEIK (SEQ ID NO: 133). In some embodiments, any of the preceding antibodies does not comprise an HVR-H1 comprising the amino acid sequence NYWMN (SEQ ID NO: 101).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 134, 136, 138, or 140-148; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 135, 137, 139, or 149-157; or (c) a VH domain as in (a) and a VL domain as in (b). For example, in some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 134 and a VL domain comprising an amino acid sequence of SEQ ID NO: 135. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 136 and a VL domain comprising an amino acid sequence of SEQ ID NO: 137. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 138 and a VL domain comprising an amino acid sequence of SEQ ID NO: 139. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 140 and a VL domain comprising an amino acid sequence of SEQ ID NO: 149. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 141 and a VL domain comprising an amino acid sequence of SEQ ID NO: 150. In some instances, the antibody comprises a binding domain comprising a VH domain

comprising an amino acid sequence of SEQ ID NO: 142 and a VL domain comprising an amino acid sequence of SEQ ID NO: 151. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 143 and a VL domain comprising an amino acid sequence of SEQ ID NO: 152. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 144 and a VL domain comprising an amino acid sequence of SEQ ID NO: 153. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 145 and a VL domain comprising an amino acid sequence of SEQ ID NO: 154. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 146 and a VL domain comprising an amino acid sequence of SEQ ID NO: 155. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 147 and a VL domain comprising an amino acid sequence of SEQ ID NO: 156. In some instances, the antibody comprises a binding domain comprising a VH domain comprising an amino acid sequence of SEQ ID NO: 148 and a VL domain comprising an amino acid sequence of SEQ ID NO: 157. In some embodiments, any of the preceding antibodies does not comprise an HVR-H1 comprising the amino acid sequence NYWMN (SEQ ID NO: 101).

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101); (b) HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104); (c) HVR-H3 comprising the amino acid sequence of RNYGDWYINV (SEQ ID NO: 109); (d) HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112); (e) HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and (f) HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 134; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 135; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFS (SEQ ID NO: 117); FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWMA (SEQ ID NO: 119); FR-H3 comprising the amino acid sequence of RFSISRDDSKSTVYLQMNNLRAEDTGIYYCAR (SEQ ID NO: 121); and FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 124). In some instances, the anti-IL-33 antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of DIVLTQSPTSLAVSLGQRATISC (SEQ ID NO: 126); FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 128); FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPVEEDDTAMYFC (SEQ ID NO: 130); and FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 132). In some instances, the anti-IL-33 antibody includes a binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 134 and

(b) a VL domain comprising an amino acid sequence of SEQ ID NO: 135. In some instances, the exemplary anti-IL-33 antibody is 10H2.

In some instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) HVR-H2 comprising the amino acid sequence of EIRLX₁X₂INYVKDYAESVKG (SEQ ID NO: 161), wherein X₁ is Asn or Ser, and X₂ is Ser or Ala, wherein X₁ is Asn, Asp, Ser, or Ala, and X₂ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 158, 160, 161, or 164-166.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) HVR-H2 comprising the amino acid sequence of EIRLNSINYVKDYAESVKG (SEQ ID NO: 159), EIRLSSINYVKDYAESVKG (SEQ ID NO: 162), or EIRLNAINYVKDYAESVKG (SEQ ID NO: 163); (c) HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 158-160, or 162-166.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFN (SEQ ID NO: 167) or EVQLVESGGGLVQPGGSLRLSCAASGFTFN (SEQ ID NO: 171); an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWVA (SEQ ID NO: 168) or WVRQAPGKGLEWVA (SEQ ID NO: 172); an FR-H3 comprising the amino acid sequence of RFTISRDDSKNSVYLQMNNLRAEDTGIYYCIR (SEQ ID NO: 169) or RFTISRDNAKNSVYLQMNSLRAEDTAVYYCIR (SEQ ID NO: 173); and an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 170) or WGQGTLTVSS (SEQ ID NO: 174).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of DIVLTQSPASLAVSLGQRATISC (SEQ ID NO: 175) or DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 179); an FR-L2 comprising the amino acid sequence of WFQQKPGQSPKLLIY (SEQ ID NO: 176) or WFQQKPGKAPKLLIY (SEQ ID NO: 180); an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPLEDDAAMYFC (SEQ ID NO: 177) or

GVPSRFSGSGSGTDFTLTISSLQPEDFATYYC (SEQ ID NO: 181); and an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 178) or FGQGTKVEIK (SEQ ID NO: 182).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 183, 185, 187, or 189; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 184, 186, 188, 190; or (c) a VH domain as in (a) and a VL domain as in (b). For example, in some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 183 and a VL domain comprising the amino acid sequence of SEQ ID NO: 184. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 185 and a VL domain comprising the amino acid sequence of SEQ ID NO: 186. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 187 and a VL domain comprising the amino acid sequence of SEQ ID NO: 188. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 189 and a VL domain comprising the amino acid sequence of SEQ ID NO: 190.

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158); (b) HVR-H2 comprising the amino acid sequence of EIRLNSINYVKDYAESVKG (SEQ ID NO: 159); (c) HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160); (d) HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164); (e) HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and (f) HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 183; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 184; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSKVASGFTFN (SEQ ID NO: 167); FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWVA (SEQ ID NO: 168); FR-H3 comprising the amino acid sequence of RFTISRDDSKNSVYLQMNNLRAEDTGIIYYCIR (SEQ ID NO: 169); and FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 170). In some instances, the anti-IL-33 antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of DIVLTQSPASLAVSLGQRATISC (SEQ ID NO: 175); FR-L2 comprising the amino acid sequence of WFQQKPGQSPKLLIY (SEQ ID NO: 176); FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPLEDDAAMYFC (SEQ ID NO: 177); and FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 178). In some instances, the anti-IL-33 antibody includes a

binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 183 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 184. In some instances, the exemplary anti-IL-33 antibody is 6C11.

In other instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) HVR-H2 comprising the amino acid sequence of DINPKX₁X₂DTFYNQNFKD (SEQ ID NO: 192), wherein X₁ is Asn or Ser, and X₂ is Gly or Ala; (c) HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) HVR-L3 comprising the amino acid sequence of QQQQSYPLT (SEQ ID NO: 199), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 191, 192, or 196-199.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) HVR-H2 comprising the amino acid sequence of DINPKNGDTFYNQNFKD (SEQ ID NO: 193), DINPKSGDTFYNQNFKD (SEQ ID NO: 194), or DINPKNADTFYQNFKD (SEQ ID NO: 195); (c) HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) HVR-L3 comprising the amino acid sequence of QQQQSYPLT (SEQ ID NO: 199), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 191 or 193-199.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of EVLLQQSGPELVKPGASVKISCNASGYTFS (SEQ ID NO: 200) or EVQLVQSGAEVKKPGASVKVCKASGYTFS (SEQ ID NO: 204); an FR-H2 comprising the amino acid sequence of WVKQSHGKSLESIG (SEQ ID NO: 201) or WVRQAPQGLESIG (SEQ ID NO: 205); an FR-H3 comprising the amino acid sequence of KATLTIDKSSSTVYMELRSLTSEDAMYYCAR (SEQ ID NO: 202) or RATLTIDKSTSTAYLELSSLRSEDVAVYYCAR (SEQ ID NO: 206); and an FR-H4 comprising the amino acid sequence of WGQGTLVTVAA (SEQ ID NO: 203) or WGQGTLVTVSS (SEQ ID NO: 207).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITTC (SEQ ID NO: 208) or DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 212); an FR-L2 comprising the amino acid sequence of WYQQKAGNNPKLLIY (SEQ ID NO: 209) or WYQQKPGKNPKLLIY (SEQ ID NO: 213); an FR-L3 comprising the amino acid sequence of GVPSRFTGSGGTFLTITLTISSLQPEDIATYYC (SEQ ID NO: 210) or

GVPSRFGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 214); and an FR-L4 comprising the amino acid sequence of FGSGTNLELK (SEQ ID NO: 211) or FGQGTKVEIK (SEQ ID NO: 215).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 216, 218, 220, or 221; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 217 or SEQ ID NO: 219; or (c) a VH domain as in (a) and a VL domain as in (b). For example, in some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 216 and a VL domain comprising the amino acid sequence of SEQ ID NO: 217. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 218 and a VL domain comprising the amino acid sequence of SEQ ID NO: 219. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 220 and a VL domain comprising the amino acid sequence of SEQ ID NO: 219. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 221 and a VL domain comprising the amino acid sequence of SEQ ID NO: 219.

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191); (b) HVR-H2 comprising the amino acid sequence of DINPKNGDTFYNQNFKD (SEQ ID NO: 193); (c) HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196); (d) HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197); (e) HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and (f) HVR-L3 comprising the amino acid sequence of QGQSYPLT (SEQ ID NO: 199). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 216; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 217; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of EVLLQQSGPELVKPGASVKISCNASGYTFS (SEQ ID NO: 200); FR-H2 comprising the amino acid sequence of WVKQSHGKSLESIG (SEQ ID NO: 201); FR-H3 comprising the amino acid sequence of KATLTIDKSSSTVYMELRSLTSEDAMYYCAR (SEQ ID NO: 202); and FR-H4 comprising the amino acid sequence of WGQGTLVTVAA (SEQ ID NO: 203). In some instances, the anti-IL-33 antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 208); FR-L2 comprising the amino acid sequence of WYQQKAGNNPKLLIY (SEQ ID NO: 209); FR-L3 comprising the amino acid sequence of GVPSRFTGSGSGTLFTLTISLQPEDATYYC (SEQ ID NO: 210); and FR-L4 comprising the amino acid sequence of FGSGTNLELK (SEQ ID NO: 211). In some instances, the anti-IL-33 antibody includes a

binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 216 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 217. In some instances, the exemplary anti-IL-33 antibody is 2B6.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SYWIN (SEQ ID NO: 222); (b) HVR-H2 comprising the amino acid sequence of RIAPGSGFISYNELFKD (SEQ ID NO: 223); (c) HVR-H3 comprising the amino acid sequence of EFYYGSFYGGFAY (SEQ ID NO: 224); (d) HVR-L1 comprising the amino acid sequence of HASQNIHVWLS (SEQ ID NO: 225); (e) HVR-L2 comprising the amino acid sequence of KASTLHT (SEQ ID NO: 226); and (f) HVR-L3 comprising the amino acid sequence of QQQQSSPLT (SEQ ID NO: 227), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 222-227.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of QVQLQQSGNDLVKPGASVKLSCKASGYTFT (SEQ ID NO: 228) or EVQLVQSGAEVKKPGASVKVSKASGYTFT (SEQ ID NO: 238); an FR-H2 comprising the amino acid sequence of WIKQRPQGQGLEWIG (SEQ ID NO: 229) or WVRQAPGQGLEWIG (SEQ ID NO: 239); an FR-H3 comprising the amino acid sequence of KATLTVDTSSTAYIQLGSLSEDSAVYFCAR (SEQ ID NO: 230) or RVTITRDTSTSTAYLESSLRSEDVAVYYCAR (SEQ ID NO: 240); and an FR-H4 comprising the amino acid sequence of WGQGTLVTVSA (SEQ ID NO: 231) or WGQGTLVTVSS (SEQ ID NO: 241).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 232) or DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 242); an FR-L2 comprising the amino acid sequence of WYQQKPGNIPKLLIY (SEQ ID NO: 233) or WYQQKPGKAPKLLIY (SEQ ID NO: 243); an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTGFTLTISLQPEDATYYC (SEQ ID NO: 234) or GVPSRFSGSGSGTDFTLTISLQPEDFATYYC (SEQ ID NO: 244); and an FR-L4 comprising the amino acid sequence of FGAGTKLEVK (SEQ ID NO: 235) or FGQGTKVEIK (SEQ ID NO: 245).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 236 or SEQ ID NO: 246; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 237 or SEQ ID NO: 247; or (c) a VH domain as in (a) and a VL domain as in (b).

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of SYWIN (SEQ ID NO: 222); (b) HVR-H2 comprising the amino acid sequence of RIAPGSGFISYNELFKD (SEQ ID NO: 223); (c) HVR-H3 comprising the amino acid sequence of

EFYYGSFYGGFAY (SEQ ID NO: 224); (d) HVR-L1 comprising the amino acid sequence of HASQNIHVWLS (SEQ ID NO: 225); (e) HVR-L2 comprising the amino acid sequence of KASTLHT (SEQ ID NO: 226); and (f) HVR-L3 comprising the amino acid sequence of QQQQSSPLT (SEQ ID NO: 227). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 236; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 237; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the following heavy chain framework regions: FR-H1 comprising the amino acid sequence of QVQLQQSGNDLVKPGASVKLSCKASGYTFT (SEQ ID NO: 228); FR-H2 comprising the amino acid sequence of WIKQRPGQGLEWIG (SEQ ID NO: 229); FR-H3 comprising the amino acid sequence of KATLTVDTSSTAYIQLGSLSSSEDSAVYFCAR (SEQ ID NO: 230); and FR-H4 comprising the amino acid sequence of WGQGTLVTVSA (SEQ ID NO: 231). In some instances, the anti-IL-33 antibody includes the following light chain framework regions: FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 232); FR-L2 comprising the amino acid sequence of WYQQKPGNIPKLLIY (SEQ ID NO: 233); FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTGFTLTISLQPEDATYYC (SEQ ID NO: 234); and FR-L4 comprising the amino acid sequence of FGAGTKLEVK (SEQ ID NO: 235). In some instances, the anti-IL-33 antibody includes a binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 236 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 237. In some instances, the exemplary anti-IL-33 antibody is 9F6.

In other instances, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of GSAX₁H (SEQ ID NO: 248), wherein X₁ is Met or Ile; (b) HVR-H2 comprising the amino acid sequence of RIRSX₁X₂NX₃YATX₄YX₅ASVKG (SEQ ID NO: 249), wherein X₁ is Arg or Lys, X₂ is Asn, Thr, or Gly, X₃ is Asn or Ser, X₄ is Ala or Glu, and X₅ is Ala or Asp; (c) comprising the amino acid sequence of X₁X₂X₃X₄PFDY (SEQ ID NO: 250), wherein X₁ is Leu or Gln, X₂ is Gln, Gly, or Phe, X₃ is Gln or Gly, and X₄ is Pro or Asp; (d) HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) HVR-L3 comprising the amino acid sequence of LQHX₁X₂YPX₃T (SEQ ID NO: 253), wherein X₁ is Asp or Ser, X₂ is Ser or Ile, and X₃ is Leu or Pro, or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 248-253.

For instance, the anti-IL-33 antibody may include at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254) or GSAIH (SEQ ID NO: 258); (b) HVR-H2 comprising the amino acid sequence of RIRSRNNYATAYAASVKG (SEQ ID NO: 255), RIRSRTNNYATEYDASVKG (SEQ ID NO: 259) or RIRSKGNSYATAYAASVKG (SEQ

ID NO: 262); (c) HVR-H3 comprising the amino acid sequence of LQQPPFDY (SEQ ID NO: 256), LGQPPFDY (SEQ ID NO: 260), or QFGDPFDY (SEQ ID NO: 263); (d) HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257) or LQHSIYPPT (SEQ ID NO: 261), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 251, 252, or 254-263.

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following heavy chain framework regions: an FR-H1 comprising the amino acid sequence of QVQLVQSGGGLVQPGGSLKLSAASGFTFS (SEQ ID NO: 264), EVQLVESGGDLVQPGGSLKLSAASGFTFS (SEQ ID NO: 265), or EVQLVESGGGLVQPGGSLKLSAASGFTFS (SEQ ID NO: 266); an FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267) or WVRQAPGKGLEWVG (SEQ ID NO: 268); an FR-H3 comprising the amino acid sequence of RFTISRDDSKRTTYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 269), RFTISRDDSKRTAYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 270), or RFSISRDDSKRTAYLQMSSLKTEDSAVYYCAR (SEQ ID NO: 271); and an FR-H4 comprising the amino acid sequence of WGQGTLTVSS (SEQ ID NO: 272).

In some instances, the anti-IL-33 antibody may include one, two, three, or four of the following light chain framework regions: an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 273), AIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 274), or AIRITQSPSSLSASVGDRVTITC (SEQ ID NO: 275); an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276); an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTEFTLTISLQPEDFATYYC (SEQ ID NO: 277), GVPSRFSGSGSGTDFLTISLQPEDFATYYC (SEQ ID NO: 278), or GVPSRFSGSGSGTEFTLTISLQPEDFATYYC (SEQ ID NO: 279); and an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280) or FGQGTKVEIK (SEQ ID NO: 281).

In some instances, the anti-IL-33 antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 282, 284, or 286; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 283, 285, or 287; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 282 and a VL domain comprising the amino acid sequence of SEQ ID NO: 283. In some instances, the antibody comprises a binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 284 and a VL domain comprising the amino acid sequence of SEQ ID NO: 285. In some instances, the antibody comprises a

binding domain comprising a VH domain comprising the amino acid sequence of SEQ ID NO: 286 and a VL domain comprising the amino acid sequence of SEQ ID NO: 287.

For instance, the anti-IL-33 antibody may include (a) HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254); (b) HVR-H2 comprising the amino acid sequence of
 5 RIRSRNNNYATAYAASVKG (SEQ ID NO: 255); (c) HVR-H3 comprising the amino acid sequence of LQQPPFDY (SEQ ID NO: 256); (d) HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251); (e) HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and (f) HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257). In some instances, the antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence
 10 having at least 90% sequence identity (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 282; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 90% sequence (e.g., at least 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 283; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the anti-IL-33 antibody includes the
 15 following heavy chain framework regions: FR-H1 comprising the amino acid sequence of QVQLVQSGGGLVQPGGSLKLSAASGFTFS (SEQ ID NO: 264); FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267); FR-H3 comprising the amino acid sequence of RFTISRDDSKRTTYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 269); and FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272). In some instances, the anti-IL-33 antibody includes the
 20 following light chain framework regions: FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 273); FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276); FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTEFTLTISLQPEDFATYYC (SEQ ID NO: 277); and FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280). In some instances, the anti-IL-33 antibody includes a
 25 binding domain comprising (a) a VH domain comprising an amino acid sequence of SEQ ID NO: 282 and (b) a VL domain comprising an amino acid sequence of SEQ ID NO: 283. In some instances, the exemplary anti-IL-33 antibody is 101.B11.

In some instances, the invention provides an antibody comprising (a) a heavy chain comprising the amino acid sequence of SEQ ID NO: 288 and/or (b) a light chain comprising the amino acid sequence
 30 of SEQ ID NO: 289. In certain embodiments, the antibody is 10C12.38.H6.87Y.58I expressed in IgG4.S228P format.

In some instances, the invention provides an antibody comprising (a) a heavy chain comprising the amino acid sequence of SEQ ID NO: 292 and/or (b) a light chain comprising the amino acid sequence of SEQ ID NO: 293. In certain embodiments, the antibody is 4G12.FW4 expressed in IgG4.S228P
 35 format.

In some instances, the invention provides an antibody comprising (a) a heavy chain comprising the amino acid sequence of SEQ ID NO: 290 and/or (b) a light chain comprising the amino acid sequence of SEQ ID NO: 291. In certain embodiments, the antibody is 10C12.38.H6.87Y.58I expressed in IgG1 format.

In some instances, the invention provides an antibody comprising (a) a heavy chain comprising the amino acid sequence of SEQ ID NO: 294 and/or (b) a light chain comprising the amino acid sequence of SEQ ID NO: 295. In certain embodiments, the antibody is 4G12.FW4 expressed in IgG1 format.

In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-IL-33 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as 10C12.38.H6.87Y.58I or 4G12.FW4.

In a further aspect of the invention, an anti-IL-33 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-IL-33 antibody is an antibody fragment, e.g., a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a full length antibody, e.g., an intact IgG1 antibody, an intact IgG4 antibody, or other antibody class or isotype as defined herein. In some instances, the antibody is an IgG4 antibody that comprises a mutation in the hinge region. In some instances, the mutation is a substitution mutation. In some instances, the substitution mutation is at amino acid residue S228 (EU numbering). In some instances, the substitution mutation is an S228P mutation.

In a further aspect, an anti-IL-33 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below:

1. Antibody Affinity

In certain embodiments, an antibody provided herein has a dissociation constant (K_D) of $\leq 1 \mu\text{M}$, $\leq 100 \text{ nM}$, $\leq 10 \text{ nM}$, $\leq 1 \text{ nM}$, $\leq 0.1 \text{ nM}$, $\leq 0.01 \text{ nM}$, $\leq 1 \text{ pM}$, or $\leq 0.1 \text{ pM}$ (e.g., 10^{-6} M or less, e.g., from 10^{-6} M to 10^{-9} M or less, e.g., from 10^{-9} M to 10^{-13} M or less).

In one embodiment, K_D is measured by a radiolabeled antigen binding assay (RIA). In one embodiment, an RIA is performed with the Fab version of an antibody of interest and its antigen. For example, solution binding affinity of Fabs for antigen is measured by equilibrating Fab with a minimal concentration of (¹²⁵I)-labeled antigen in the presence of a titration series of unlabeled antigen, then capturing bound antigen with an anti-Fab antibody-coated plate (see, e.g., Chen et al. *J. Mol. Biol.* 293:865-881, 1999). To establish conditions for the assay, MICROTITER® multi-well plates (Thermo Scientific) are coated overnight with 5 $\mu\text{g/ml}$ of a capturing anti-Fab antibody (Cappel Labs) in 50 mM sodium carbonate (pH 9.6), and subsequently blocked with 2% (w/v) bovine serum albumin in PBS for two to five hours at room temperature (approximately 23°C). In a non-adsorbent plate (Nunc #269620), 100 pM or 26 pM [¹²⁵I]-antigen are mixed with serial dilutions of a Fab of interest (e.g., consistent with assessment of the anti-VEGF antibody, Fab-12, in Presta et al. *Cancer Res.* 57:4593-4599, 1997). The Fab of interest is then incubated overnight; however, the incubation may continue for a longer period (e.g., about 65 hours) to ensure that equilibrium is reached. Thereafter, the mixtures are transferred to the capture plate for incubation at room temperature (e.g., for one hour). The solution is then removed and the plate washed eight times with 0.1% polysorbate 20 (TWEEN®-20) in PBS. When the plates have dried, 150 $\mu\text{l/well}$ of scintillant (MICROSCINT-20™; Packard) is added, and the plates are counted on a

TOPCOUNT™ gamma counter (Packard) for ten minutes. Concentrations of each Fab that give less than or equal to 20% of maximal binding are chosen for use in competitive binding assays.

According to another embodiment, K_D is measured using a BIACORE® surface plasmon resonance assay. For example, an assay using a BIACORE®-2000 or a BIACORE®-3000 (Biacore, Inc., Piscataway, NJ) is performed at 25 °C with immobilized antigen CM5 chips at ~10 response units (RU). In one embodiment, carboxymethylated dextran biosensor chips (CM5, BIACORE, Inc.) are activated with *N*-ethyl-*N'*-(3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and *N*-hydroxysuccinimide (NHS) according to the supplier's instructions. Antigen is diluted with 10 mM sodium acetate, pH 4.8, to 5 µg/ml (~0.2 µM) before injection at a flow rate of 5 µl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, two-fold serial dilutions of Fab (0.78 nM to 500 nM) are injected in phosphate buffered saline (PBS) with 0.05% polysorbate 20 (TWEEN®-20) surfactant (PBST) at 25 °C at a flow rate of approximately 25 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIACORE® Evaluation Software version 3.2) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (K_D) is calculated as the ratio k_{off}/k_{on} . See, for example, Chen et al. (*J. Mol. Biol.* 293:865-881, 1999). If the on-rate exceeds $10^6 \text{ M}^{-1}\text{s}^{-1}$ by the surface plasmon resonance assay above, then the on-rate can be determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence emission intensity (excitation = 295 nm; emission = 340 nm, 16 nm band-pass) at 25 °C of a 20 nM anti-antigen antibody (Fab form) in PBS, pH 7.2, in the presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophotometer (Aviv Instruments) or a 8000-series SLM-AMINCO™ spectrophotometer (ThermoSpectronic) with a stirred cuvette.

2. Antibody Fragments

In certain embodiments, an antibody provided herein is an antibody fragment. Antibody fragments include, but are not limited to, Fab, Fab', Fab'-SH, F(ab')₂, Fv, and scFv fragments, and other fragments described below. For a review of certain antibody fragments, see Hudson et al. *Nat. Med.* 9:129-134 (2003). For a review of scFv fragments, see, e.g., Pluckthün, in *The Pharmacology of Monoclonal Antibodies*, vol. 113, Rosenberg and Moore eds., (Springer-Verlag, New York), pp. 269-315 (1994); see also WO 93/16185; and U.S. Patent Nos. 5,571,894 and 5,587,458. For discussion of Fab and F(ab')₂ fragments comprising salvage receptor binding epitope residues and having increased in vivo half-life, see U.S. Patent No. 5,869,046.

Diabodies are antibody fragments with two antigen-binding sites that may be bivalent or bispecific. See, for example, EP 404,097; WO 1993/01161; Hudson et al. *Nat. Med.* 9:129-134, 2003; and Hollinger et al. *Proc. Natl. Acad. Sci. USA* 90: 6444-6448, 1993. Triabodies and tetrabodies are also described in Hudson et al. *Nat. Med.* 9:129-134, 2003.

Single-domain antibodies are antibody fragments comprising all or a portion of the heavy chain variable domain or all or a portion of the light chain variable domain of an antibody. In certain

embodiments, a single-domain antibody is a human single-domain antibody (see, e.g., U.S. Patent No. 6,248,516 B1).

Antibody fragments can be made by various techniques, including but not limited to proteolytic digestion of an intact antibody as well as production by recombinant host cells (e.g. *E. coli* or phage), as described herein.

3. Chimeric and Humanized Antibodies

In certain embodiments, an antibody provided herein is a chimeric antibody. Certain chimeric antibodies are described, e.g., in U.S. Patent No. 4,816,567; and Morrison et al. *Proc. Natl. Acad. Sci. USA*, 81:6851-6855, 1984). In one example, a chimeric antibody comprises a non-human variable region (e.g., a variable region derived from a mouse, rat, hamster, rabbit, or non-human primate, such as a monkey) and a human constant region. In a further example, a chimeric antibody is a "class switched" antibody in which the class or subclass has been changed from that of the parent antibody. Chimeric antibodies include antigen-binding fragments thereof.

In certain embodiments, a chimeric antibody is a humanized antibody. Typically, a non-human antibody is humanized to reduce immunogenicity to humans, while retaining the specificity and affinity of the parental non-human antibody. Generally, a humanized antibody comprises one or more variable domains in which HVRs (or portions thereof) are derived from a non-human antibody, and FRs (or portions thereof) are derived from human antibody sequences. A humanized antibody optionally will also comprise at least a portion of a human constant region. In some embodiments, some FR residues in a humanized antibody are substituted with corresponding residues from a non-human antibody (e.g., the antibody from which the HVR residues are derived), for example, to restore or improve antibody specificity or affinity.

Humanized antibodies and methods of making them are reviewed, for example, in Almagro et al. *Front. Biosci.* 13:1619-1633, 2008, and are further described, e.g., in Riechmann et al. *Nature* 332:323-329, 1988; Queen et al. *Proc. Natl. Acad. Sci. USA* 86:10029-10033, 1989; US Patent Nos. 5, 821,337, 7,527,791, 6,982,321, and 7,087,409; Kashmiri et al. *Methods* 36:25-34, 2005 (describing specificity determining region (SDR) grafting); Padlan, *Mol. Immunol.* 28:489-498, 1991 (describing "resurfacing"); Dall'Acqua et al. *Methods* 36:43-60, 2005 (describing "FR shuffling"); and Osbourn et al. *Methods* 36:61-68, 2005 and Klimka et al. *Br. J. Cancer*, 83:252-260, 2000 (describing the "guided selection" approach to FR shuffling).

Human framework regions that may be used for humanization include but are not limited to: framework regions selected using the "best-fit" method (see, e.g., Sims et al. *J. Immunol.* 151:2296, 1993); framework regions derived from the consensus sequence of human antibodies of a particular subgroup of light or heavy chain variable regions (see, e.g., Carter et al. *Proc. Natl. Acad. Sci. USA*, 89:4285, 1992; and Presta et al. *J. Immunol.*, 151:2623, 1993); human mature (somatically mutated) framework regions or human germline framework regions (see, e.g., Almagro et al. *Front. Biosci.* 13:1619-1633, 2008); and framework regions derived from screening FR libraries (see, e.g., Baca et al. *J. Biol. Chem.* 272:10678-10684, 1997 and Rosok et al. *J. Biol. Chem.* 271:22611-22618, 1996).

4. Human Antibodies

In certain embodiments, an antibody provided herein is a human antibody. Human antibodies can be produced using various techniques known in the art. Human antibodies are described generally in van Dijk et al. *Curr. Opin. Pharmacol.* 5:368-74, 2001 and Lonberg, *Curr. Opin. Immunol.* 20:450-459, 2008.

Human antibodies may be prepared by administering an immunogen to a transgenic animal that has been modified to produce intact human antibodies or intact antibodies with human variable regions in response to antigenic challenge. Such animals typically contain all or a portion of the human immunoglobulin loci, which replace the endogenous immunoglobulin loci, or which are present extrachromosomally or integrated randomly into the animal's chromosomes. In such transgenic mice, the endogenous immunoglobulin loci have generally been inactivated. For review of methods for obtaining human antibodies from transgenic animals, see Lonberg, *Nat. Biotech.* 23:1117-1125, 2005. See also, for example, U.S. Patent Nos. 6,075,181 and 6,150,584 describing XENOMOUSE™ technology; U.S. Patent No. 5,770,429 describing HUMAB® technology; U.S. Patent No. 7,041,870 describing K-M MOUSE® technology, and U.S. Patent Application Publication No. US 2007/0061900, describing VELOCIMOUSE® technology. Human variable regions from intact antibodies generated by such animals may be further modified, e.g., by combining with a different human constant region.

Human antibodies can also be made by hybridoma-based methods. Human myeloma and mouse-human heteromyeloma cell lines for the production of human monoclonal antibodies have been described. (See, e.g., Kozbor *J. Immunol.* 133:3001, 1984; Brodeur et al. *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63 (Marcel Dekker, Inc., New York, 1987); and Boerner et al. *J. Immunol.* 147: 86, 1991). Human antibodies generated via human B-cell hybridoma technology are also described in Li et al. *Proc. Natl. Acad. Sci. USA*, 103:3557-3562, 2006. Additional methods include those described, for example, in U.S. Patent No. 7,189,826 (describing production of monoclonal human IgM antibodies from hybridoma cell lines) and Ni, *Xiandai Mianyixue*, 26(4):265-268, 2006 (describing human-human hybridomas). Human hybridoma technology (Trioma technology) is also described in Vollmers et al. *Histology and Histopathology* 20(3):927-937, 2005 and Vollmers et al. *Methods and Findings in Experimental and Clinical Pharmacology* 27(3):185-91, 2005.

Human antibodies may also be generated by isolating Fv clone variable domain sequences selected from human-derived phage display libraries. Such variable domain sequences may then be combined with a desired human constant domain. Techniques for selecting human antibodies from antibody libraries are described below.

5. Library-Derived Antibodies

Antibodies of the invention may be isolated by screening combinatorial libraries for antibodies with the desired activity or activities. For example, a variety of methods are known in the art for generating phage display libraries and screening such libraries for antibodies possessing the desired binding characteristics. Such methods are reviewed, e.g., in Hoogenboom et al. in *Methods in Molecular*

Biology 178:1-37 (O'Brien et al., ed., Human Press, Totowa, NJ, 2001) and further described, e.g., in the McCafferty et al. *Nature* 348:552-554, 1990; Clackson et al. *Nature* 352: 624-628, 1991; Marks et al. *J. Mol. Biol.* 222: 581-597, 1992; Marks et al. in *Methods in Molecular Biology* 248:161-175 (Lo, ed., Human Press, Totowa, NJ, 2003); Sidhu et al. *J. Mol. Biol.* 338(2): 299-310, 2004; Lee et al. *J. Mol. Biol.* 340(5): 1073-1093, 2004; Fellouse, *Proc. Natl. Acad. Sci. USA* 101(34):12467-12472, 2004; and Lee et al. *J. Immunol. Methods* 284(1-2): 119-132, 2004.

In certain phage display methods, repertoires of VH and VL genes are separately cloned by polymerase chain reaction (PCR) and recombined randomly in phage libraries, which can then be screened for antigen-binding phage as described in Winter et al. *Ann. Rev. Immunol.*, 12: 433-455, 1994.

Phage typically display antibody fragments, either as single-chain Fv (scFv) fragments or as Fab fragments. Libraries from immunized sources provide high-affinity antibodies to the immunogen without the requirement of constructing hybridomas. Alternatively, the naive repertoire can be cloned (e.g., from human) to provide a single source of antibodies to a wide range of non-self and also self antigens without any immunization as described by Griffiths et al. *EMBO J.* 12: 725-734, 1993. Finally, naive libraries can also be made synthetically by cloning unrearranged V-gene segments from stem cells, and using PCR primers containing random sequence to encode the highly variable HVR3 regions and to accomplish rearrangement *in vitro*, as described by Hoogenboom et al. *J. Mol. Biol.*, 227: 381-388, 1992. Patent publications describing human antibody phage libraries include, for example: US Patent No. 5,750,373, and US Patent Publication Nos. 2005/0079574, 2005/0119455, 2005/0266000, 2007/0117126, 2007/0160598, 2007/0237764, 2007/0292936, and 2009/0002360.

Antibodies or antibody fragments isolated from human antibody libraries are considered human antibodies or human antibody fragments herein.

6. Multispecific Antibodies

In certain embodiments, an antibody provided herein is a multispecific antibody, for example, a bispecific antibody. Multispecific antibodies are monoclonal antibodies that have binding specificities for at least two different sites. In certain embodiments, bispecific antibodies may bind to two different epitopes of IL-33. In certain embodiments, one of the binding specificities is for IL-33 and the other is for any other antigen (e.g., a second biological molecule, e.g., IL-13, IL-4, IL-5, IL-17, Factor D, HtrA1, VEGF, or a VEGF receptor). Accordingly, the bispecific antibody may have binding specificity for IL-33 and IL-13; IL-33 and IL-4; IL-33 and IL-5; IL-33 and IL-17; IL-33 and Factor D; IL-33 and HtrA1; IL-33 and VEGF; or IL-33 and a VEGF receptor (e.g., VEGFR1, VEGFR2, VEGFR3, membrane-bound VEGF receptor (mbVEGFR), or soluble VEGF receptor (sVEGFR)). In some instances, the bispecific antibody may have binding specificity for IL-33 and Factor D. In other instances, the bispecific antibody may have binding specificity for IL-33 and HtrA1. In yet other instances, the bispecific antibody may have binding specificity for IL-33 and VEGF. In other instances, the bispecific antibody may have binding specificity for IL-33 and a VEGF receptor. In particular, the bispecific antibody may have binding specificity for IL-33 and IL-13. Bispecific antibodies can be prepared as full length antibodies or antibody fragments.

For example, in some instances, a bispecific anti-IL-33 antibody comprising a first binding domain that specifically binds IL-33 comprising at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SFSX₁S (SEQ ID NO: 62), wherein X₁ is Met, Leu, or Val; (b) HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDX₁VKG (SEQ ID NO: 63), wherein X₁ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of ANYGX₁X₂FFEY (SEQ ID NO: 64), wherein X₁ is Asn or Asp, and X₂ is Trp or Phe; (d) HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (e) HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 4-6 or 62-64, may have a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, include at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 296-301. In some embodiments, the second binding domain comprises one, two, three, four, five, or six HVRs of the anti-IL-13 antibody lebrikizumab.

For example, in some instances, a bispecific anti-IL-33 antibody comprising a first binding domain that specifically binds IL-33 comprising at least one, two, three, four, five, or six hypervariable regions (HVRs) selected from (a) HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); (b) HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); (c) HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); (d) HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); (e) HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and (f) HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6), such as 10C12.38.H6.87Y.58I, has a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, comprise at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In some embodiments, the second binding domain comprises one, two, three, four, five, or six HVRs of the anti-IL-13 antibody lebrikizumab.

In some instances, a bispecific anti-IL-33 antibody comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 36; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 37; or (c) a VH domain as in (a) and a VL domain as in (b), such as 10C12.38.H6.87Y.58I, may have a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 302; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 303; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the second binding domain that specifically binds to IL-13 may comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 328; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 329; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the second binding domain that specifically binds to IL-13 may comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the anti-IL-13 antibody lebrikizumab; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the anti-IL-13 antibody lebrikizumab; or (c) a VH domain as in (a) and a VL domain as in (b).

In other instances, a bispecific anti-IL-33 antibody comprising a first binding domain that specifically binds IL-33 including at least one, two, three, four, five, or six HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPX₁LKS (SEQ ID NO: 90), wherein X₁ is Ser or Ala; (c) HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68); (d) HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any

one of SEQ ID NOs: 65, 68-71, or 90, may have a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, include at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301), or a combination of one or more of the above HVRs and one or more variants thereof having at least about 80% sequence identity (e.g., 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity) to any one of SEQ ID NOs: 296-301. In some embodiments, the second binding domain comprises one, two, three, four, five, or six HVRs of the anti-IL-13 antibody lebrikizumab.

For example, in some instances, a bispecific anti-IL-33 antibody comprising a first binding domain that specifically binds IL-33 comprising at least one, two, three, four, five, or six hypervariable regions (HVRs) selected from (a) HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65); (b) HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPSLKS (SEQ ID NO: 66); (c) HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFYMDV (SEQ ID NO: 68); (d) HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69); (e) HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and (f) HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71), such as 4G12.FW4, may have a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, comprise at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); (b) HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); (c) HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); (d) HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); (e) HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and (f) HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In some embodiments, the second binding domain comprises one, two, three, four, five, or six HVRs of the anti-IL-13 antibody lebrikizumab.

In some instances, a bispecific anti-IL-33 antibody comprising a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 84; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 85; or (c) a VH domain as in (a) and a VL domain as in (b), such as 4G12.FW4, may have a second binding domain that binds to IL-13. The second binding domain that specifically binds to IL-13 may, for example, comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%,

88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 302; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 303; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the second binding domain that specifically binds to IL-13 may comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 328; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 329; or (c) a VH domain as in (a) and a VL domain as in (b). In some instances, the second binding domain that specifically binds to IL-13 may comprise (a) a VH domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the anti-IL-13 antibody lebrikizumab; (b) a VL domain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the anti-IL-13 antibody lebrikizumab; or (c) a VH domain as in (a) and a VL domain as in (b).

In some instances, a bispecific anti-IL-33 antibody may comprise (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 306 and the first light chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 307, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 304 or 330 and the second light chain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 305 or 331. In some embodiments, the second heavy chain and second light chain that specifically bind IL-13 are the heavy and light chain of the anti-IL-13 antibody lebrikizumab.

In some instances, a bispecific anti-IL-33 antibody may comprise (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of,

SEQ ID NO: 308 and the first light chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 309, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 304 or 330 and the second light chain comprising an amino acid sequence having at least 80% sequence identity (e.g., 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, SEQ ID NO: 305 or 331. In some embodiments, the second heavy chain and second light chain that specifically bind IL-13 are the heavy and light chain of the anti-IL-13 antibody lebrikizumab.

Any of the preceding bispecific antibodies may specifically bind both human and cynomolgus monkey (cyno) IL-33 with a K_D of about 1 nM or lower. Any of the preceding bispecific antibodies may specifically bind human IL-33 with a K_D of about 1 nM or lower. For example, in some instances, the bispecific antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 1 nM (e.g., between about 1 pM and about 900 pM, between about 1 pM and about 800 pM, between about 1 pM and about 700 pM, between about 1 pM and about 600 pM, between about 1 pM and about 500 pM, between about 1 pM and about 400 pM, between about 1 pM and about 300 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 25 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some instances, the bispecific antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 250 pM (e.g., between about 1 pM and about 250 pM, between about 1 pM and about 225 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 25 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some embodiments, the bispecific antibody specifically binds human IL-33 with a K_D of about 25 pM.

Any of the preceding bispecific antibodies may specifically bind human IL-13 with a K_D of about 1 nM or lower. For example, in some instances, the bispecific antibody specifically binds human IL-13 with a K_D of between about 1 pM and about 1 nM (e.g., between about 1 pM and about 900 pM, between about 1 pM and about 800 pM, between about 1 pM and about 700 pM, between about 1 pM and about 600 pM, between about 1 pM and about 500 pM, between about 1 pM and about 400 pM, between about 1 pM and about 300 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 25 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some instances, the bispecific antibody specifically binds human IL-13 with a K_D of between about 1 pM and about 250 pM (e.g., between about 1 pM and about 250 pM, between about 1 pM and about 225 pM, between about 1 pM and about 200 pM, between about 1 pM and about 190 pM, between about 1 pM and about 180 pM, between about 1 pM and about 170 pM, between about 1 pM and about 160 pM, between about 1 pM and about 150 pM, between about 1 pM and about 140 pM, between about 1 pM and about 130 pM, between about 1 pM and about 120 pM, between about 1 pM and about 110 pM, between about 1 pM and about 100 pM, between about 1 pM and about 90 pM, between about 1 pM and about 80 pM, between about 1 pM and about 70 pM, between about 1 pM and about 60 pM, between about 1 pM and about 50 pM, between about 1 pM and about 40 pM, between about 1 pM and about 30 pM, between about 1 pM and about 25 pM, between about 1 pM and about 20 pM, or between about 1 pM and about 10 pM). In some embodiments, the bispecific antibody specifically binds human IL-13 with a K_D of about 10 pM or below. In some embodiments, the bispecific antibody specifically binds human IL-13 with a K_D of about 1 pM to about 10 pM (e.g., about 1 pM, about 2 pM, about 3 pM, about 4 pM, about 5 pM, about 6 pM, about 7 pM, about 8 pM, about 9 pM or about 10 pM).

Techniques for making multispecific antibodies include, but are not limited to, recombinant co-expression of two immunoglobulin heavy chain-light chain pairs having different specificities (see Milstein et al. *Nature* 305: 537, 1983; WO 93/08829; and Traunecker et al. *EMBO J.* 10: 3655, 1991), and “knob-in-hole” engineering (see, e.g., U.S. Patent No. 5,731,168). Multi-specific antibodies may also be made by engineering electrostatic steering effects for making antibody Fc-heterodimeric molecules (WO 2009/089004A1); cross-linking two or more antibodies or fragments (see, e.g., US Patent No. 4,676,980, and Brennan et al. *Science*, 229: 81, 1985); using leucine zippers to produce bispecific antibodies (see, e.g., Kostelny et al. *J. Immunol.*, 148(5):1547-1553, 1992); using “diabody” technology for making bispecific antibody fragments (see, e.g., Hollinger et al. *Proc. Natl. Acad. Sci. USA* 90:6444-6448, 1993); and using single-chain Fv (scFv) dimers (see, e.g. Gruber et al. *J. Immunol.* 152:5368, 1994); and preparing trispecific antibodies as described, e.g., in Tutt et al. *J. Immunol.* 147: 60, 1991.

Engineered antibodies with three or more functional antigen binding sites, including "Octopus antibodies," are also included herein (see, e.g. US 2006/0025576A1).

The antibody or fragment herein also includes a "Dual Acting Fab" or "DAF" comprising an antigen binding site that binds to IL-33 as well as another, different antigen (see, US 2008/0069820, for example).

Knobs-into-Holes

The use of knobs-into-holes as a method of producing multispecific antibodies is described, e.g., in U.S. Pat. No. 5,731,168, WO2009/089004, US2009/0182127, US2011/0287009, Marvin and Zhu, *Acta Pharmacol. Sin.* (2005) 26(6):649-658, and Kontermann (2005) *Acta Pharmacol. Sin.*, 26:1-9. A brief nonlimiting discussion is provided below.

A "protuberance" refers to at least one amino acid side chain which projects from the interface of a first polypeptide and is therefore positionable in a compensatory cavity in the adjacent interface (i.e., the interface of a second polypeptide) so as to stabilize the heteromultimer, and thereby favor heteromultimer formation over homomultimer formation, for example. The protuberance may exist in the original interface or may be introduced synthetically (e.g., by altering nucleic acid encoding the interface). In some embodiments, a nucleic acid encoding the interface of the first polypeptide is altered to encode the protuberance. To achieve this, the nucleic acid encoding at least one "original" amino acid residue in the interface of the first polypeptide is replaced with nucleic acid encoding at least one "import" amino acid residue which has a larger side chain volume than the original amino acid residue. It will be appreciated that there can be more than one original and corresponding import residue. The side chain volumes of the various amino residues are shown, for example, in Table 1 of US 2011/0287009 or Table 1 of U.S. Patent No. 7,642,228.

In some embodiments, import residues for the formation of a protuberance are naturally occurring amino acid residues selected from arginine (R), phenylalanine (F), tyrosine (Y) and tryptophan (W). In some embodiments, an import residue is tryptophan or tyrosine. In some embodiments, the original residue for the formation of the protuberance has a small side chain volume, such as alanine, asparagine, aspartic acid, glycine, serine, threonine, or valine. See, for example, U.S. Patent No. 7,642,228.

A "cavity" refers to at least one amino acid side chain which is recessed from the interface of a second polypeptide and therefore accommodates a corresponding protuberance on the adjacent interface of a first polypeptide. The cavity may exist in the original interface or may be introduced synthetically (e.g., by altering nucleic acid encoding the interface). In some embodiments, nucleic acid encoding the interface of the second polypeptide is altered to encode the cavity. To achieve this, the nucleic acid encoding at least one "original" amino acid residue in the interface of the second polypeptide is replaced with DNA encoding at least one "import" amino acid residue which has a smaller side chain volume than the original amino acid residue. It will be appreciated that there can be more than one original and corresponding import residue. In some embodiments, import residues for the formation of a cavity are naturally occurring amino acid residues selected from alanine (A), serine (S), threonine (T), and valine (V). In some embodiments, an import residue is serine, alanine, or threonine. In some embodiments, the

original residue for the formation of the cavity has a large side chain volume, such as tyrosine, arginine, phenylalanine, or tryptophan.

The protuberance is "positionable" in the cavity which means that the spatial location of the protuberance and cavity on the interface of a first polypeptide and second polypeptide respectively and the sizes of the protuberance and cavity are such that the protuberance can be located in the cavity without significantly perturbing the normal association of the first and second polypeptides at the interface. Since protuberances such as Tyr, Phe, and Trp do not typically extend perpendicularly from the axis of the interface and have preferred conformations, the alignment of a protuberance with a corresponding cavity may, in some instances, rely on modeling the protuberance/cavity pair based upon a three-dimensional structure such as that obtained by X-ray crystallography or nuclear magnetic resonance (NMR). This can be achieved using widely-accepted techniques in the art.

In some embodiments, a knob mutation in an IgG1 constant region is T366W. In some embodiments, a hole mutation in an IgG1 constant region comprises one or more mutations selected from T366S, L368A, and Y407V. In some embodiments, a hole mutation in an IgG1 constant region comprises T366S, L368A, and Y407V.

In some embodiments, a knob mutation in an IgG4 constant region is T366W. In some embodiments, a hole mutation in an IgG4 constant region comprises one or more mutations selected from T366S, L368A, and Y407V. In some embodiments, a hole mutation in an IgG4 constant region comprises T366S, L368A, and Y407V.

7. Antibody Variants

In certain embodiments, amino acid sequence variants of the antibodies provided herein are contemplated. For example, it may be desirable to improve the binding affinity and/or other biological properties of the antibody. Amino acid sequence variants of an antibody may be prepared by introducing appropriate modifications into the nucleotide sequence encoding the antibody, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of residues within the amino acid sequences of the antibody. Any combination of deletion, insertion, and substitution can be made to arrive at the final construct, provided that the final construct possesses the desired characteristics, for example, antigen-binding.

a) Substitution, Insertion, and Deletion Variants

In certain embodiments, antibody variants having one or more amino acid substitutions are provided. Sites of interest for substitutional mutagenesis include the HVRs and FRs. Conservative substitutions are shown in Table 1 under the heading of "preferred substitutions." More substantial changes are provided in Table 1 under the heading of "exemplary substitutions," and as further described below in reference to amino acid side chain classes. Amino acid substitutions may be introduced into an antibody of interest and the products screened for a desired activity, e.g., retained/improved antigen binding, decreased immunogenicity, or improved ADCC or CDC.

TABLE 1

Original Residue	Exemplary Substitutions	Preferred Substitutions
Ala (A)	Val; Leu; Ile	Val
Arg (R)	Lys; Gln; Asn	Lys
Asn (N)	Gln; His; Asp, Lys; Arg	Gln
Asp (D)	Glu; Asn	Glu
Cys (C)	Ser; Ala	Ser
Gln (Q)	Asn; Glu	Asn
Glu (E)	Asp; Gln	Asp
Gly (G)	Ala	Ala
His (H)	Asn; Gln; Lys; Arg	Arg
Ile (I)	Leu; Val; Met; Ala; Phe; Norleucine	Leu
Leu (L)	Norleucine; Ile; Val; Met; Ala; Phe	Ile
Lys (K)	Arg; Gln; Asn	Arg
Met (M)	Leu; Phe; Ile	Leu
Phe (F)	Trp; Leu; Val; Ile; Ala; Tyr	Tyr
Pro (P)	Ala	Ala
Ser (S)	Thr	Thr
Thr (T)	Val; Ser	Ser
Trp (W)	Tyr; Phe	Tyr
Tyr (Y)	Trp; Phe; Thr; Ser	Phe
Val (V)	Ile; Leu; Met; Phe; Ala; Norleucine	Leu

Amino acids may be grouped according to common side-chain properties:

- (1) hydrophobic: Norleucine, Met, Ala, Val, Leu, Ile;
- (2) neutral hydrophilic: Cys, Ser, Thr, Asn, Gln;
- (3) acidic: Asp, Glu;
- (4) basic: His, Lys, Arg;
- (5) residues that influence chain orientation: Gly, Pro;
- (6) aromatic: Trp, Tyr, Phe.

Non-conservative substitutions will entail exchanging a member of one of these classes for another class.

One type of substitutional variant involves substituting one or more hypervariable region residues of a parent antibody (e.g., a humanized or human antibody). Generally, the resulting variant(s) selected

for further study will have modifications (e.g., improvements) in certain biological properties (e.g., increased affinity, reduced immunogenicity) relative to the parent antibody and/or will have substantially retained certain biological properties of the parent antibody. An exemplary substitutional variant is an affinity matured antibody, which may be conveniently generated, for example, using phage display-based affinity maturation techniques such as those described herein. Briefly, one or more HVR residues are mutated and the variant antibodies displayed on phage and screened for a particular biological activity (e.g., binding affinity).

Alterations (e.g., substitutions) may be made in HVRs, e.g., to improve antibody affinity. Such alterations may be made in HVR "hotspots," i.e., residues encoded by codons that undergo mutation at high frequency during the somatic maturation process (see, e.g., Chowdhury, *Methods Mol. Biol.* 207:179-196, 2008), and/or residues that contact antigen, with the resulting variant VH or VL being tested for binding affinity. Affinity maturation by constructing and reselecting from secondary libraries has been described, e.g., in Hoogenboom et al. in *Methods in Molecular Biology* 178:1-37 (O'Brien et al. ed., Human Press, Totowa, NJ, 2001). In some embodiments of affinity maturation, diversity is introduced into the variable genes chosen for maturation by any of a variety of methods (e.g., error-prone PCR, chain shuffling, or oligonucleotide-directed mutagenesis). A secondary library is then created. The library is then screened to identify any antibody variants with the desired affinity. Another method to introduce diversity involves HVR-directed approaches, in which several HVR residues (e.g., 4-6 residues at a time) are randomized. HVR residues involved in antigen binding may be specifically identified, e.g., using alanine scanning mutagenesis or modeling. HVR-H3 and HVR-L3 in particular are often targeted.

In certain embodiments, substitutions, insertions, or deletions may occur within one or more HVRs so long as such alterations do not substantially reduce the ability of the antibody to bind antigen. For example, conservative alterations (e.g., conservative substitutions as provided herein) that do not substantially reduce binding affinity may be made in HVRs. Such alterations may, for example, be outside of antigen contacting residues in the HVRs. In certain embodiments of the variant VH and VL sequences provided above, each HVR either is unaltered, or contains no more than one, two or three amino acid substitutions.

A useful method for identification of residues or regions of an antibody that may be targeted for mutagenesis is called "alanine scanning mutagenesis" as described by Cunningham et al. *Science* 244:1081-1085, 1989. In this method, a residue or group of target residues (e.g., charged residues such as Arg, Asp, His, Lys, and Glu) are identified and replaced by a neutral or negatively charged amino acid (e.g., Ala or polyalanine) to determine whether the interaction of the antibody with antigen is affected. Further substitutions may be introduced at the amino acid locations demonstrating functional sensitivity to the initial substitutions. Alternatively, or additionally, a crystal structure of an antigen-antibody complex to identify contact points between the antibody and antigen. Such contact residues and neighboring residues may be targeted or eliminated as candidates for substitution. Variants may be screened to determine whether they contain the desired properties.

Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence

insertions of single or multiple amino acid residues. Examples of terminal insertions include an antibody with an N-terminal methionyl residue. Other insertional variants of the antibody molecule include the fusion to the N- or C-terminus of the antibody to an enzyme (e.g., for ADEPT) or a polypeptide which increases the serum half-life of the antibody.

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b) Glycosylation variants

In certain embodiments, an antibody provided herein is altered to increase or decrease the extent to which the antibody is glycosylated. Addition or deletion of glycosylation sites to an antibody may be conveniently accomplished by altering the amino acid sequence such that one or more glycosylation sites is created or removed.

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Where the antibody comprises an Fc region, the carbohydrate attached thereto may be altered. Native antibodies produced by mammalian cells typically comprise a branched, biantennary oligosaccharide that is generally attached by an N-linkage to Asn297 of the CH2 domain of the Fc region. See, for example, Wright et al. *TIBTECH* 15:26-32, 1997. The oligosaccharide may include various carbohydrates, for example, mannose, N-acetyl glucosamine (GlcNAc), galactose, and sialic acid, as well as a fucose attached to a GlcNAc in the "stem" of the biantennary oligosaccharide structure. In some embodiments, modifications of the oligosaccharide in an antibody of the invention may be made in order to create antibody variants with certain improved properties.

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In one embodiment, antibody variants are provided having a carbohydrate structure that lacks fucose attached (directly or indirectly) to an Fc region. For example, the amount of fucose in such antibody may be from 1% to 80%, from 1% to 65%, from 5% to 65% or from 20% to 40%. The amount of fucose is determined by calculating the average amount of fucose within the sugar chain at Asn297, relative to the sum of all glycostructures attached to Asn 297 (e. g. complex, hybrid and high mannose structures) as measured by MALDI-TOF mass spectrometry, as described in WO 2008/077546, for example. Asn297 refers to the asparagine residue located at about position 297 in the Fc region (Eu numbering of Fc region residues); however, Asn297 may also be located about ± 3 amino acids upstream or downstream of position 297, i.e., between positions 294 and 300, due to minor sequence variations in antibodies. Such fucosylation variants may have improved ADCC function. See, e.g., US Patent Publication Nos. 2003/0157108 and 2004/0093621. Examples of publications related to "defucosylated" or "fucose-deficient" antibody variants include: US 2003/0157108; WO 2000/61739; WO 2001/29246; US 2003/0115614; US 2002/0164328; US 2004/0093621; US 2004/0132140; US 2004/0110704; US 2004/0110282; US 2004/0109865; WO 2003/085119; WO 2003/084570; WO 2005/035586; WO 2005/035778; WO 2005/053742; WO 2002/031140; Okazaki et al. *J. Mol. Biol.* 336:1239-1249, 2004; Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614, 2004. Examples of cell lines capable of producing defucosylated antibodies include Lec13 CHO cells deficient in protein fucosylation (Ripka et al. *Arch. Biochem. Biophys.* 249:533-545, 1986; US 2003/0157108; and WO 2004/056312 A1, especially at Example 11), and knockout cell lines, such as alpha-1,6-fucosyltransferase gene, *FUT8*, knockout CHO cells (see, e.g., Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614, 2004; Kanda et al. *Biotechnol. Bioeng.* 94(4):680-688, 2006; and WO 2003/085107).

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Antibodies variants are further provided with bisected oligosaccharides, e.g., in which a biantennary oligosaccharide attached to the Fc region of the antibody is bisected by GlcNAc. Such antibody variants may have reduced fucosylation and/or improved ADCC function. Examples of such antibody variants are described, e.g., in WO 2003/011878; US Patent No. 6,602,684; and US 2005/0123546. Antibody variants with at least one galactose residue in the oligosaccharide attached to the Fc region are also provided. Such antibody variants may have improved CDC function. Such antibody variants are described, e.g., in WO 1997/30087; WO 1998/58964; and WO 1999/22764.

c) *Fc region variants*

In certain embodiments, one or more amino acid modifications may be introduced into the Fc region of an antibody provided herein, thereby generating an Fc region variant. The Fc region variant may comprise a human Fc region sequence (e.g., a human IgG1, IgG2, IgG3 or IgG4 Fc region) comprising an amino acid modification (e.g. a substitution) at one or more amino acid positions.

In certain embodiments, the invention contemplates an antibody variant that possesses some but not all effector functions, which make it a desirable candidate for applications in which the half life of the antibody *in vivo* is important yet certain effector functions (such as complement and ADCC) are unnecessary or deleterious. *In vitro* and/or *in vivo* cytotoxicity assays can be conducted to confirm the reduction/depletion of CDC and/or ADCC activities. For example, Fc receptor (FcR) binding assays can be conducted to ensure that the antibody lacks FcγR binding (hence likely lacking ADCC activity), but retains FcRn binding ability. The primary cells for mediating ADCC, NK cells, express FcγRIII only, whereas monocytes express FcγRI, FcγRII and FcγRIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch et al. *Annu. Rev. Immunol.* 9:457-492, 1991. Non-limiting examples of *in vitro* assays to assess ADCC activity of a molecule of interest is described in U.S. Patent No. 5,500,362 (see, e.g. Hellstrom et al. *Proc. Natl. Acad. Sci. USA* 83:7059-7063, 1986 and Hellstrom et al. *Proc. Natl. Acad. Sci. USA* 82:1499-1502, 1985; U.S. Patent No. 5,821,337 (see Bruggemann et al. *J. Exp. Med.* 166:1351-1361, 1987). Alternatively, non-radioactive assays methods may be employed (see, for example, ACTI™ non-radioactive cytotoxicity assay for flow cytometry (CellTechnology, Inc. Mountain View, CA; and CytoTox 96® non-radioactive cytotoxicity assay (Promega, Madison, WI). Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest may be assessed *in vivo*, for example, in a animal model such as that disclosed in Clynes et al. *Proc. Natl. Acad. Sci. USA* 95:652-656, 1998. C1q binding assays may also be carried out to confirm that the antibody is unable to bind C1q and hence lacks CDC activity. See, e.g., C1q and C3c binding ELISA in WO 2006/029879 and WO 2005/100402. To assess complement activation, a CDC assay may be performed (see, e.g., Gazzano-Santoro et al. *J. Immunol. Methods* 202:163, 1996; Cragg et al. *Blood* 101:1045-1052, 2003; and Cragg et al. *Blood* 103:2738-2743, 2004). FcRn binding and *in vivo* clearance/half life determinations can also be performed using methods known in the art (see, e.g., Petkova et al. *Intl. Immunol.* 18(12):1759-1769, 2006).

Antibodies with reduced effector function include those with substitution of one or more of Fc region residues 238, 265, 269, 270, 297, 327 and 329 (U.S. Patent No. 6,737,056). Such Fc mutants include Fc mutants with substitutions at two or more of amino acid positions 265, 269, 270, 297 and 327, including the so-called "DANA" Fc mutant with substitution of residues 265 and 297 to alanine (US Patent No. 7,332,581).

Certain antibody variants with improved or diminished binding to FcRs are described. (See, e.g., U.S. Patent No. 6,737,056; WO 2004/056312; and Shields et al. *J. Biol. Chem.* 9(2): 6591-6604, 2001).

In certain embodiments, an antibody variant comprises an Fc region with one or more amino acid substitutions which improve ADCC, e.g., substitutions at positions 298, 333, and/or 334 of the Fc region (EU numbering of residues).

In some embodiments, alterations are made in the Fc region that result in altered (i.e., either improved or diminished) C1q binding and/or Complement Dependent Cytotoxicity (CDC), for example, as described in US Patent No. 6,194,551, WO 99/51642, and Idusogie et al. *J. Immunol.* 164: 4178-4184, 2000.

Antibodies with increased half lives and improved binding to the neonatal Fc receptor (FcRn), which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al. *J. Immunol.* 117:587, 1976 and Kim et al. *J. Immunol.* 24:249, 1994), are described in US2005/0014934. Those antibodies comprise an Fc region with one or more substitutions therein which improve binding of the Fc region to FcRn. Such Fc variants include those with substitutions at one or more of Fc region residues: 238, 256, 265, 272, 286, 303, 305, 307, 311, 312, 317, 340, 356, 360, 362, 376, 378, 380, 382, 413, 424 or 434, e.g., substitution of Fc region residue 434 (US Patent No. 7,371,826).

See also Duncan et al. *Nature* 322:738-40, 1988; U.S. Patent Nos. 5,648,260 and 5,624,821; and WO 94/29351 concerning other examples of Fc region variants.

d) Cysteine engineered antibody variants

In certain embodiments, it may be desirable to create cysteine engineered antibodies, for example, "thioMAbs," in which one or more residues of an antibody are substituted with cysteine residues. In particular embodiments, the substituted residues occur at accessible sites of the antibody. By substituting those residues with cysteine, reactive thiol groups are thereby positioned at accessible sites of the antibody and may be used to conjugate the antibody to other moieties, such as drug moieties or linker-drug moieties, to create an immunoconjugate, as described further herein. In certain embodiments, any one or more of the following residues may be substituted with cysteine: V205 (Kabat numbering) of the light chain; A118 (EU numbering) of the heavy chain; and S400 (EU numbering) of the heavy chain Fc region. Cysteine engineered antibodies may be generated as described, e.g., in U.S. Patent No. 7,521,541.

e) Antibody Derivatives

In certain embodiments, an antibody provided herein may be further modified to contain additional nonproteinaceous moieties that are known in the art and readily available. The moieties

suitable for derivatization of the antibody include but are not limited to water soluble polymers. Non-limiting examples of water soluble polymers include, but are not limited to, polyethylene glycol (PEG), copolymers of ethylene glycol/propylene glycol, carboxymethylcellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone, poly-1, 3-dioxolane, poly-1,3,6-trioxane, ethylene/maleic anhydride copolymer, polyaminoacids (either homopolymers or random copolymers), and dextran or poly(n-vinyl pyrrolidone)polyethylene glycol, propylene glycol homopolymers, polypropylene oxide/ethylene oxide co-polymers, polyoxyethylated polyols (e.g., glycerol), polyvinyl alcohol, and mixtures thereof. Polyethylene glycol propionaldehyde may have advantages in manufacturing due to its stability in water. The polymer may be of any molecular weight, and may be branched or unbranched. The number of polymers attached to the antibody may vary, and if more than one polymer is attached, they can be the same or different molecules. In general, the number and/or type of polymers used for derivatization can be determined based on considerations including, but not limited to, the particular properties or functions of the antibody to be improved, whether the antibody derivative will be used in a therapy under defined conditions, etc.

In another embodiment, conjugates of an antibody and nonproteinaceous moiety that may be selectively heated by exposure to radiation are provided. In one embodiment, the nonproteinaceous moiety is a carbon nanotube (Kam et al. *Proc. Natl. Acad. Sci. USA* 102: 11600-11605, 2005). The radiation may be of any wavelength, and includes, but is not limited to, wavelengths that do not harm ordinary cells, but which heat the nonproteinaceous moiety to a temperature at which cells proximal to the antibody-nonproteinaceous moiety are killed.

B. Recombinant Methods and Compositions

Antibodies may be produced using recombinant methods and compositions, for example, as described in U.S. Patent No. 4,816,567. In one embodiment, isolated nucleic acid encoding an anti-IL-33 antibody described herein is provided. Such nucleic acid may encode an amino acid sequence comprising the VL and/or an amino acid sequence comprising the VH of the antibody (e.g., the light and/or heavy chains of the antibody). In a further embodiment, one or more vectors (e.g., expression vectors) comprising such nucleic acid are provided. In a further embodiment, a host cell comprising such nucleic acid is provided. In one such embodiment, a host cell comprises (e.g., has been transformed with): (1) a vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and an amino acid sequence comprising the VH of the antibody, or (2) a first vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and a second vector comprising a nucleic acid that encodes an amino acid sequence comprising the VH of the antibody. In one embodiment, the host cell is eukaryotic, for example, a Chinese Hamster Ovary (CHO) cell, 293 cell, or lymphoid cell (e.g., Y0, NS0, Sp20 cell). In one embodiment, a method of making an anti-IL-33 antibody is provided, wherein the method comprises culturing a host cell comprising a nucleic acid encoding the antibody, as provided above, under conditions suitable for expression of the antibody, and optionally recovering the antibody from the host cell (or host cell culture medium).

For recombinant production of an anti-IL-33 antibody, nucleic acid encoding an antibody, for example, as described above, is isolated and inserted into one or more vectors for further cloning and/or expression in a host cell. Such nucleic acid may be readily isolated and sequenced using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of the antibody).

Suitable host cells for cloning or expression of antibody-encoding vectors include prokaryotic or eukaryotic cells described herein. For example, antibodies may be produced in bacteria, in particular when glycosylation and Fc effector function are not needed. For expression of antibody fragments and polypeptides in bacteria, see, for example, U.S. Patent Nos. 5,648,237, 5,789,199, and 5,840,523. (See also Charlton, *Methods in Molecular Biology*, Vol. 248 (B.K.C. Lo, ed., Humana Press, Totowa, NJ, 2003), pp. 245-254, describing expression of antibody fragments in *E. coli*.) After expression, the antibody may be isolated from the bacterial cell paste in a soluble fraction and can be further purified.

In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable cloning or expression hosts for antibody-encoding vectors, including fungi and yeast strains whose glycosylation pathways have been "humanized," resulting in the production of an antibody with a partially or fully human glycosylation pattern. See Gerngross *Nat. Biotech.* 22:1409-1414, 2004 and Li et al. *Nat. Biotech.* 24:210-215, 2006.

Suitable host cells for the expression of glycosylated antibody are also derived from multicellular organisms (invertebrates and vertebrates). Examples of invertebrate cells include plant and insect cells. Numerous baculoviral strains have been identified which may be used in conjunction with insect cells, particularly for transfection of *Spodoptera frugiperda* cells.

Plant cell cultures can also be utilized as hosts. See, for example, US Patent Nos. 5,959,177, 6,040,498, 6,420,548, 7,125,978, and 6,417,429 (describing PLANTIBODIES™ technology for producing antibodies in transgenic plants).

Vertebrate cells may also be used as hosts. For example, mammalian cell lines that are adapted to grow in suspension may be useful. Other examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7); human embryonic kidney line (293 or 293 cells as described, e.g., in Graham et al. *J. Gen Virol.* 36:59, 1977); baby hamster kidney cells (BHK); mouse sertoli cells (TM4 cells as described, e.g., in Mather *Biol. Reprod.* 23:243-251, 1980); monkey kidney cells (CV1); African green monkey kidney cells (VERO-76); human cervical carcinoma cells (HELA); canine kidney cells (MDCK; buffalo rat liver cells (BRL 3A); human lung cells (W138); human liver cells (Hep G2); mouse mammary tumor (MMT 060562); TRI cells, as described, e.g., in Mather et al., *Annals N.Y. Acad. Sci.* 383:44-68, 1982; MRC 5 cells; and FS4 cells. Other useful mammalian host cell lines include Chinese hamster ovary (CHO) cells, including DHFR⁻ CHO cells (Urlaub et al. *Proc. Natl. Acad. Sci. USA* 77:4216, 1980); and myeloma cell lines such as Y0, NS0 and Sp2/0. For a review of certain mammalian host cell lines suitable for antibody production, see, e.g., Yazaki et al. *Methods in Molecular Biology*, Vol. 248 (B.K.C. Lo, ed., Humana Press, Totowa, NJ), pp. 255-268, 2003.

C. Assays

Anti-IL-33 antibodies provided herein may be identified, screened for, or characterized for their physical/chemical properties and/or biological activities by various assays known in the art.

1. Binding assays and other assays

In one aspect, an anti-IL-33 antibody of the invention is tested for its antigen-binding activity, for example, by known methods such as ELISA, Western blot, etc.

In another aspect, competition assays may be used to identify an antibody that competes with an anti-IL-33 antibody of the invention for binding to IL-33. In certain embodiments, such a competing antibody binds to the same epitope (e.g., a linear or a conformational epitope) that is bound by an anti-IL-33 antibody of the invention. Detailed exemplary methods for mapping an epitope to which an antibody binds are provided in Morris "Epitope Mapping Protocols," in *Methods in Molecular Biology* Vol. 66 (Humana Press, Totowa, NJ), 1996.

In an exemplary competition assay, immobilized IL-33 is incubated in a solution comprising a first labeled antibody that binds to IL-33 and a second unlabeled antibody that is being tested for its ability to compete with the first antibody for binding to IL-33. The second antibody may be present in a hybridoma supernatant. As a control, immobilized IL-33 is incubated in a solution comprising the first labeled antibody but not the second unlabeled antibody. After incubation under conditions permissive for binding of the first antibody to IL-33, excess unbound antibody is removed, and the amount of label associated with immobilized IL-33 is measured. If the amount of label associated with immobilized IL-33 is substantially reduced in the test sample relative to the control sample, then that indicates that the second antibody is competing with the first antibody for binding to IL-33. See Harlow et al. *Antibodies: A Laboratory Manual* Ch.14 (Cold Spring Harbor Laboratory, Cold Spring Harbor, NY), 1988.

2. Activity assays

In one aspect, assays are provided for identifying anti-IL-33 antibodies thereof having biological activity. Biological activity may include, for example, binding to IL-33 (e.g., IL-33 in the blood stream), or a peptide fragment thereof, either *in vivo*, *in vitro*, or *ex vivo*. In other embodiments, biological activity may include blocking or neutralizing IL-33, or preventing IL-33 from binding to a ligand, for example, a receptor (e.g., the IL-33 receptor ST2 and/or IL-1RAcP). In some embodiments, biological activity may include binding to site 1 on IL-33 and blocking of binding to the IL-33 receptor (i.e., ST2 and/or IL-1RAcP). Antibodies having such biological activity *in vivo* and/or *in vitro* are also provided. In certain embodiments, an antibody of the invention is tested for such biological activity. In some embodiments, an anti-IL-33 antibody of the invention is tested for inhibition in a cell-based IL-33 blocking assay. In some embodiments, an anti-IL-33 antibody of the invention is tested for inhibition of IL-33-induced reporter activity in a cell-based blocking assay (e.g., an IL-33 HEK-BLUE™ cell-based assay as described herein (see, e.g., Example 2 and Example 8, Section B)). In some embodiments, an antibody of the invention is tested for inhibition of an IL-33 activity in primary cells, for example, in a primary NK cell assay (see, e.g.,

Example 8, Section C) or a primary basophil assay (see, e.g., Example 8, Section D). In some embodiments, an antibody of the invention is tested for inhibiting the binding of IL-33 to an IL-33 receptor in a competitive binding ELISA (see, e.g., Example 8, Section F).

D. Immunoconjugates

The invention also provides immunoconjugates comprising an anti-IL-33 antibody herein conjugated to one or more cytotoxic agents, such as chemotherapeutic agents or drugs, growth inhibitory agents, toxins (e.g., protein toxins, enzymatically active toxins of bacterial, fungal, plant, or animal origin, or fragments thereof), or radioactive isotopes.

In one embodiment, an immunoconjugate is an antibody-drug conjugate (ADC) in which an antibody is conjugated to one or more drugs, including but not limited to a maytansinoid (see U.S. Patent Nos. 5,208,020, 5,416,064 and European Patent EP 0 425 235 B1); an auristatin such as monomethylauristatin drug moieties DE and DF (MMAE and MMAF) (see U.S. Patent Nos. 5,635,483 and 5,780,588, and 7,498,298); a dolastatin; a calicheamicin or derivative thereof (see U.S. Patent Nos. 5,712,374, 5,714,586, 5,739,116, 5,767,285, 5,770,701, 5,770,710, 5,773,001, and 5,877,296; Hinman et al. *Cancer Res.* 53:3336-3342, 1993; and Lode et al. *Cancer Res.* 58:2925-2928, 1998); an anthracycline such as daunomycin or doxorubicin (see Kratz et al. *Current Med. Chem.* 13:477-523, 2006; Jeffrey et al. *Bioorganic & Med. Chem. Letters* 16:358-362, 2006; Torgov et al. *Bioconj. Chem.* 16:717-721, 2005; Nagy et al. *Proc. Natl. Acad. Sci. USA* 97:829-834, 2000; Dubowchik et al. *Bioorg. & Med. Chem. Letters* 12:1529-1532, 2002; King et al. *J. Med. Chem.* 45:4336-4343, 2002; and U.S. Patent No. 6,630,579); methotrexate; vindesine; a taxane such as docetaxel, paclitaxel, larotaxel, tesetaxel, and ortataxel; a trichothecene; and CC1065.

In another embodiment, an immunoconjugate comprises an antibody as described herein conjugated to an enzymatically active toxin or fragment thereof, including but not limited to diphtheria A chain, nonbinding active fragments of diphtheria toxin, exotoxin A chain (from *Pseudomonas aeruginosa*), ricin A chain, abrin A chain, modeccin A chain, alpha-sarcin, *Aleurites fordii* proteins, dianthin proteins, *Phytolacca americana* proteins (PAPI, PAPII, and PAP-S), momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, enomycin, and the tricothecenes.

In another embodiment, an immunoconjugate comprises an antibody as described herein conjugated to a radioactive atom to form a radioconjugate. A variety of radioactive isotopes are available for the production of radioconjugates. Examples include At²¹¹, I¹³¹, I¹²⁵, Y⁹⁰, Re¹⁸⁶, Re¹⁸⁸, Sm¹⁵³, Bi²¹², P³², Pb²¹² and radioactive isotopes of Lu. When the radioconjugate is used for detection, it may comprise a radioactive atom for scintigraphic studies, for example technetium-99m (tc99m) or I¹²³, or a spin label for nuclear magnetic resonance (NMR) imaging (also known as magnetic resonance imaging, mri), such as iodine-123 again, iodine-131, indium-111, fluorine-19, carbon-13, nitrogen-15, oxygen-17, gadolinium, manganese or iron.

Conjugates of an antibody and cytotoxic agent may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridyldithio) propionate (SPDP), succinimidyl-4-(N-

maleimidomethyl) cyclohexane-1-carboxylate (SMCC), iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCl), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). For example, a ricin immunotoxin can be prepared as described in Vitetta et al. *Science* 238:1098, 1987. Carbon-14-labeled 1-isothiocyanatobenzyl-3-methyldiethylene triaminepentaacetic acid (MX-DTPA) is an exemplary chelating agent for conjugation of radionucleotide to the antibody. See WO 94/11026. The linker may be a "cleavable linker" facilitating release of a cytotoxic drug in the cell. For example, an acid-labile linker, peptidase-sensitive linker, photolabile linker, dimethyl linker or disulfide-containing linker (see, e.g., Chari et al. *Cancer Res.* 52:127-131, 1992; U.S. Patent No. 5,208,020) may be used.

The immunoconjugates or ADCs herein expressly contemplate, but are not limited to such conjugates prepared with cross-linker reagents including, but not limited to, BMPS, EMCS, GMBS, HBVS, LC-SMCC, MBS, MPBH, SBAP, SIA, SIAB, SMCC, SMPB, SMPH, sulfo-EMCS, sulfo-GMBS, sulfo-KMUS, sulfo-MBS, sulfo-SIAB, sulfo-SMCC, and sulfo-SMPB, and SVSB (succinimidyl-(4-vinylsulfone)benzoate) which are commercially available (e.g., from Pierce Biotechnology, Inc., Rockford, IL., U.S.A.).

E. Methods and Compositions for Diagnostics and Detection

In certain embodiments, any of the anti-IL-33 antibodies provided herein is useful for detecting the presence of IL-33 in a biological sample. The term "detecting" as used herein encompasses quantitative or qualitative detection. In certain embodiments, a biological sample comprises a cell or tissue, such as smooth muscle, epithelial cells, endothelial cells, blood, blood cells (e.g., macrophages, innate type II (ILC2) cells, mast cells, basophils, eosinophils, and dendritic cells), central nervous system cells (e.g., glia cells), or eye cells (e.g., retinal cells (e.g., Müller cells or retinal pigment epithelium (RPE) cells) and vascular endothelial cells of the eye).

In one embodiment, an anti-IL-33 antibody for use in a method of diagnosis or detection is provided. In a further aspect, a method of detecting the presence of IL-33 in a biological sample is provided. In certain embodiments, the method comprises contacting the biological sample with an anti-IL-33 antibody as described herein under conditions permissive for binding of the anti-IL-33 antibody to IL-33, and detecting whether a complex is formed between the anti-IL-33 antibody and IL-33. Such method may be an *in vitro* or *in vivo* method. In one embodiment, an anti-IL-33 antibody is used to select subjects eligible for therapy with an anti-IL-33 antibody, for example, where IL-33 is a biomarker for selection of patients.

Exemplary disorders that may be diagnosed using an antibody of the invention include IL-33-mediated disorders, including, for example, inflammatory conditions (e.g., asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD)), immune disorders (e.g., asthma, rheumatoid arthritis, allergy, atopic allergy, anaphylaxis, anaphylactic shock, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease,

diabetes, and liver disease), fibrotic disorders (e.g., pulmonary fibrosis (e.g., idiopathic pulmonary fibrosis), eosinophilic disorders (e.g., eosinophil-associated gastrointestinal disorders (EGIDs) including eosinophilic esophagitis), infections (e.g., helminth infections, protozoan infections, and viral infections), pain (e.g., inflammatory pain), central nervous system disorders (e.g., Alzheimer's disease), solid tumors (e.g., breast, colon, prostate, lung, kidney, liver, pancreas, stomach, intestinal, brain, bone, and skin tumors), and ophthalmologic disorders (e.g., age-related macular degeneration (AMD) or retinopathy of the eye). In some instances, the ophthalmologic disorder that may be diagnosed using an antibody of the invention includes AMD (e.g., wet AMD, dry AMD, intermediate AMD, advanced AMD, and geographic atrophy (GA)), retinopathy (e.g., diabetic retinopathy (DR), retinopathy of prematurity (ROP), and high-altitude DR), polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis, non-infectious conjunctivitis, and allergic conjunctivitis).

In some instances, the ophthalmologic disorder includes AMD (including wet AMD, dry AMD, and GA), retinopathy (e.g., DR and ROP), PCV, diabetic macular edema, dry eye disease, Behcet's disease, allergic conjunctivitis, and retina detachment.

In other instances, the ophthalmologic disorder includes intermediate AMD, advanced AMD, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, high-altitude diabetic retinopathy, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis and non-infectious conjunctivitis).

In certain embodiments, labeled anti-IL-33 antibodies are provided. Labels include, but are not limited to, labels or moieties that are detected directly (such as fluorescent, chromophoric, electron-dense, chemiluminescent, and radioactive labels), as well as moieties, such as enzymes or ligands, that are detected indirectly, e.g., through an enzymatic reaction or molecular interaction. Exemplary labels include, but are not limited to, the radioisotopes ^{32}P , ^{14}C , ^{125}I , ^3H , and ^{131}I , fluorophores such as rare earth chelates or fluorescein and its derivatives, rhodamine and its derivatives, dansyl, umbelliferone, luciferases, e.g., firefly luciferase and bacterial luciferase (U.S. Patent No. 4,737,456), luciferin, 2,3-dihydrophthalazinediones, horseradish peroxidase (HRP), alkaline phosphatase, β -galactosidase, glucoamylase, lysozyme, saccharide oxidases, e.g., glucose oxidase, galactose oxidase, and glucose-6-phosphate dehydrogenase, heterocyclic oxidases such as uricase and xanthine oxidase, coupled with an enzyme that employs hydrogen peroxide to oxidize a dye precursor such as HRP, lactoperoxidase, or microperoxidase, biotin/avidin, spin labels, bacteriophage labels, stable free radicals, and the like.

F. Pharmaceutical Formulations

Pharmaceutical formulations of an anti-IL-33 antibody of the invention are prepared by mixing such antibody having the desired degree of purity with one or more optional pharmaceutically acceptable carriers (see, e.g., *Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed., 1980), in the form of lyophilized formulations or aqueous solutions. Pharmaceutically acceptable carriers are generally nontoxic to recipients at the dosages and concentrations employed, and include, but are not limited to:

5 buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid and methionine; preservatives (such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; benzalkonium chloride; benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low
 10 molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrans; chelating agents such as EDTA; sugars such as sucrose, mannitol, trehalose or sorbitol; salt-forming counter-ions such as sodium; metal complexes (e.g.,
 15 Zn-protein complexes); and/or non-ionic surfactants such as polyethylene glycol (PEG). Exemplary pharmaceutically acceptable carriers herein further include interstitial drug dispersion agents such as soluble neutral-active hyaluronidase glycoproteins (sHASEGP), for example, human soluble PH-20 hyaluronidase glycoproteins, such as rHuPH20 (HYLENEX®, Baxter International, Inc.). Certain exemplary sHASEGPs and methods of use, including rHuPH20, are described in US Patent Publication
 20 Nos. 2005/0260186 and 2006/0104968. In one aspect, a sHASEGP is combined with one or more additional glycosaminoglycanases such as chondroitinases.

Exemplary lyophilized antibody formulations are described in US Patent No. 6,267,958. Aqueous antibody formulations include those described in US Patent No. 6,171,586 and WO 2006/044908, the latter formulations including a histidine-acetate buffer.

20 The formulation herein may also contain more than one active ingredients as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. For example, it may be desirable to further provide an ST2 binding antagonist, a complement pathway inhibitor (e.g., a Factor D binding antagonist), an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule
 25 expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist. In some instances, the complement pathway inhibitor is a Factor D binding antagonist. In some instances, the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof, for example, as described below in Section G, "Therapeutic Methods and
 30 Compositions." In some instances, the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof, for example, as described below in Section G, "Therapeutic Methods and Compositions." In some instances, the anti-HtrA1 antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some instances, the anti-Factor D antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some instances, the VEGF antagonist is an anti-VEGF antibody or an antigen-
 35 binding fragment thereof, for example, as described below in Section G, "Therapeutic Methods and Compositions." In some instances, the anti-VEGF antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some instances, the VEGF antagonist is an anti-VEGF receptor antibody or an antigen-binding fragment thereof. In some instances, the anti-VEGF receptor antibody fragment is an

Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. Such active ingredients are suitably present in combination in amounts that are effective for the purpose intended.

Active ingredients may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacrylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules) or in macroemulsions. Such techniques are disclosed in *Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed., 1980.

Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the antibody, which matrices are in the form of shaped articles, e.g., films, or microcapsules.

For delivery to the eye (ophthalmic delivery), an antibody of the invention may be combined, for example, with ophthalmologically acceptable preservatives, co-solvents, surfactants, viscosity enhancers, penetration enhancers, buffers, sodium chloride, and/or water. Preservatives may be included, for example, to inhibit microbial contamination during use. Suitable preservatives include: edetate disodium, methyl paraben, propyl paraben, sorbic acid, phenylethyl alcohol, chlorobutanol, polyquaternium-1, or other agents known in the art. Such preservatives are typically employed at a level of from 0.001 to 1.0% w/v. In some instances, a pharmaceutical formulation of the invention does not include a preservative. In certain instances, compositions intended to be administered topically to the eye may be formulated as eye drops or eye ointments. In some instances, the total amount of antibody will be about 0.001 to 1.0% (w/w), for example, about 0.01 to about 1.0% (w/w), of such a formulation.

The formulations to be used for *in vivo* administration are generally sterile. Sterility may be readily accomplished, for example, by filtration through sterile filtration membranes.

G. Therapeutic Methods and Compositions

Any of the anti-IL-33 antibodies of the invention may be used in therapeutic methods.

The invention provides an IL-33 axis binding antagonist for use as a medicament. In one aspect, an anti-IL-33 antibody for use as a medicament is provided. In further aspects, an anti-IL-33 antibody for use in treating IL-33-mediated disorders is provided. In certain embodiments, an anti-IL-33 antibody for use in a method of treatment is provided. In certain embodiments, the invention provides an anti-IL-33 antibody for use in a method of treating an individual having an IL-33-mediated disorder comprising administering to the individual an effective amount of the anti-IL-33 antibody. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, for example, as described below. An "individual" according to any of the above embodiments is preferably a human.

The invention provides an IL-33 axis binding antagonist in the manufacture or preparation of a medicament. In a further aspect, the invention provides for the use of an anti-IL-33 antibody in the manufacture or preparation of a medicament. In one embodiment, the medicament is for treatment of an IL-33-mediated disorder. In a further embodiment, the medicament is for use in a method of treating IL-

33-mediated disorder comprising administering to an individual having IL-33-mediated disorder an effective amount of the medicament. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, e.g., as described below. An "individual" according to any of the above embodiments may be a human.

5 In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and IL-13 or an antigen-binding antibody fragment thereof in the manufacture of a medicament for an inflammatory disorder, such as, for example, asthma, airway hyperresponsiveness, airway inflammation, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, or chronic obstructive pulmonary disease (COPD), or a fibrotic disorder, such as, for example, idiopathic pulmonary
10 fibrosis (IPF). In an exemplary embodiment, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and IL-13 or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treatment of asthma. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds IL-13 as described herein.

15 In an exemplary embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs: an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); an HVR-L1 comprising the amino acid sequence of
20 RASESVAKYGLSLLN (SEQ ID NO: 4); an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and a second binding domain that specifically binds IL-13 comprising the following six HVRs: an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); an HVR-H3 comprising the amino acid
25 sequence of DGYYPYAMDN (SEQ ID NO: 298); an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an
30 amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence
35 having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising the amino

acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 303. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises the amino acid sequence of SEQ ID NO: 309, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising amino acid sequence of SEQ ID NO: 305.

In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and Factor D or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating geographic atrophy (GA). The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds Factor D that is derived from any of the anti-Factor D antibodies described below. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention provides for the use of a bispecific antibody that specifically binds both IL-33 and HtrA1 or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds HtrA1 that is derived from any of the anti-HtrA1 antibodies described herein. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In yet another aspect, the invention provides provides for the use of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating wet AMD. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds VEGF that is derived from any of the anti-VEGF antibodies described below. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In a further aspect, the invention provides a method for treating an IL-33-mediated disorder. In some instances, the method comprises administering the individual having such an IL-33-mediated

disorder an effective amount of an IL-33 axis binding antagonist. In one embodiment, the method comprises administering to an individual having such IL-33-mediated disorder an effective amount of an anti-IL-33 antibody. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, as described below. An
5 "individual" according to any of the above embodiments may be a human.

In a further aspect, the invention provides pharmaceutical formulations comprising any of the anti-IL-33 antibodies provided herein, e.g., for use in any of the above therapeutic methods. In one embodiment, a pharmaceutical formulation comprises any of the anti-IL-33 antibodies provided herein and a pharmaceutically acceptable carrier. In another embodiment, a pharmaceutical formulation
10 comprises any of the anti-IL-33 antibodies provided herein and at least one additional therapeutic agent, for example, as described below.

In any of the preceding aspects, the IL-33 mediated disorder may be an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, or an ophthalmologic disorder. For example, in some instances, an
15 inflammatory condition may be asthma, airway hyperresponsiveness, airway inflammation, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, or chronic obstructive pulmonary disease (COPD). In some instances, an immune disorder may be asthma, rheumatoid arthritis, allergy, atopic allergy, anaphylaxis, anaphylactic shock, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, or liver disease. In some instances, the fibrotic disease may be idiopathic
20 pulmonary fibrosis (IPF). In some instances, the eosinophilic disorder may be an eosinophil-associated gastrointestinal disorder (EGID). In some instances, the EGID may be eosinophilic esophagitis. In some instances, the infection may be a helminth infection, a protozoan infection, or a viral infection. In some instances, the protozoan infection may be *Leishmania major* infection. In some instances, the viral infection may be respiratory syncytial virus (RSV) infection or influenza infection. In some instances, the
25 pain may be inflammatory pain. In some instances, the central nervous system disorder may be Alzheimer's disease. In some instances, the solid tumor may be a breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, or skin tumor. In particular instances, the IL-33-mediated disorder may be asthma, allergic rhinitis, atopic dermatitis, COPD, eosinophilic esophagitis, or pulmonary fibrosis (e.g., IPF). For
30 example, in some instances, the IL-33-mediated disorder is asthma. In other instances, the IL-33-mediated disorder is pulmonary fibrosis (e.g., IPF).

In some instances of any of the preceding aspects, the IL-33-mediated disorder may be an ophthalmologic disorder, including but not limited to age-related macular degeneration (AMD), including wet AMD, dry AMD, intermediate AMD, advanced AMD, and geographic atrophy (GA)), retinopathy (e.g.,
35 diabetic retinopathy (DR), retinopathy of prematurity (ROP), and high-altitude DR), polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis, non-infectious conjunctivitis, and allergic conjunctivitis).

In some instances, the ophthalmologic disorder includes AMD (including wet AMD, dry AMD, and GA), retinopathy (e.g., DR and ROP), PCV, diabetic macular edema, dry eye disease, Behcet's disease, allergic conjunctivitis, and retina detachment.

In other instances, the ophthalmologic disorder includes intermediate AMD, advanced AMD, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, high-altitude diabetic retinopathy, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis and non-infectious conjunctivitis).

For example, the invention provides a method of treating an ophthalmologic disorder in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist. In some instances, the IL-33 axis binding antagonist is an anti-IL-33 antibody, for example, an anti-IL-33 antibody of the invention. In some instances, the IL-33 axis binding antagonist is anti-IL-33 antibody such as ANB-020 (AnaptixBio Inc.) or any of the antibodies described in WO2014164959, EP1725261, US8187569, WO2011031600, WO2015099175 or WO2015106080 (which are each incorporated herein by reference in their entirety); an anti-ST2 antibody such as AMG-282 (Amgen) or STLM15 (Janssen), or any of the antibodies described in WO2013173761 or WO2013165894 (which are each incorporated herein by reference in their entirety); or a ST2-Fc protein and variants thereof such as those described in WO 2013/173761, WO 2013/165894, or WO 2014/152195 (which are each incorporated herein by reference in their entirety). In some instances, the ophthalmologic disorder may be selected from the group consisting of age-related macular degeneration (AMD), including wet AMD, dry AMD, intermediate AMD, advanced AMD, and geographic atrophy (GA)), retinopathy (e.g., diabetic retinopathy (DR), retinopathy of prematurity (ROP), and high-altitude DR), polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis (also known as Leber's congenital amaurosis), Stargardt's disease, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis, non-infectious conjunctivitis, and allergic conjunctivitis). In some instances, the ophthalmologic disorder includes AMD (including wet AMD, dry AMD, and GA), retinopathy (e.g., DR and ROP), PCV, diabetic macular edema, dry eye disease, Behcet's disease, allergic conjunctivitis, and retina detachment. In other instances, the ophthalmologic disorder includes intermediate AMD, advanced AMD, glaucoma, uveitis (e.g., infectious and non-infectious uveitis), retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, high-altitude diabetic retinopathy, traumatic eye injury, and conjunctivitis (e.g., infectious conjunctivitis and non-infectious conjunctivitis).

IL-33 axis binding antagonists (e.g., anti-IL-33 antibodies of the invention) can be used either alone or in combination with other agents in a therapy. For instance, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with at least one additional therapeutic agent. In certain embodiments, an additional therapeutic agent is an ST2 binding antagonist, a complement pathway inhibitor (e.g., a Factor D binding antagonist), an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding

antagonist. In some embodiments, an additional therapeutic agent is a chemotherapeutic agent, an anti-hormonal agent, a cytotoxic agent, a growth inhibitory agent, or combinations thereof.

For example, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with an anti-IL-13 antibody, e.g., for the treatment of an inflammatory disorder, such as, for example, asthma, airway hyperresponsiveness, airway inflammation, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, or chronic obstructive pulmonary disease (COPD), or a fibrotic disorder, such as, for example, idiopathic pulmonary fibrosis (IPF). In an exemplary embodiment, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with an anti-IL-13 antibody for treatment of asthma. Any of the anti-IL-13 antibodies described herein may be administered in combination with an anti-IL-33 axis binding antagonist. In one embodiment, an anti-IL-33 antibody is administered in combination with an anti-IL-13 antibody. In an exemplary embodiment, the anti-IL-33 antibody comprises the following six HVRs: an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); an HVR-H2 comprising the amino acid sequence of TISGGKTFD YVDSVKG (SEQ ID NO: 2); an HVR-H3 comprising the amino acid sequence of ANYGNWFFE V (SEQ ID NO: 3); an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSL LN (SEQ ID NO: 4); an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and the anti-IL-13 antibody comprises the following six HVRs: an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); an HVR-H3 comprising the amino acid sequence of DGYYPYAMD N (SEQ ID NO: 298); an HVR-L1 comprising the amino acid sequence of RASKSVDSYGN SFMH (SEQ ID NO: 299); an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In another embodiment, the anti-IL-33 antibody comprises (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and the anti-IL-13 antibody comprises (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303. In another embodiment, the anti-IL-33 antibody comprises (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 37, and the anti-IL-13 antibody comprises (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 303. In another embodiment, the anti-IL-33 comprises a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and the anti-IL-13 antibody comprises a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and a light chain comprising an amino acid sequence having at least 99%

sequence identity to the amino acid sequence of SEQ ID NO: 305. In another embodiment, the anti-IL-33 comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 308 and a light chain comprising the amino acid sequence of SEQ ID NO: 309, and the anti-IL-13 antibody comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 304 and a light chain comprising amino acid sequence of SEQ ID NO: 305.

In another example, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with a complement pathway inhibitor. In some instances, a complement pathway inhibitor may be an inhibitor of the alternative complement pathway (e.g., Factor D, properdin, Factor B, Factor Ba, and Factor Bb) or the classical complement pathway (e.g., C3a, C5, C5a, C5b, C6, C7, C8, C9, and C5b-9). In some instances, the complement pathway inhibitor may be any complement pathway inhibitor described in WO 2007/056227, which is incorporated herein by reference in its entirety. In some instances, the complement pathway inhibitor may be a Factor D binding antagonist. In particular instances, a Factor D binding antagonist may be an anti-Factor D antibody or an antigen-binding fragment thereof, for example, any Factor D antibody described in WO 2007/056227, WO 01/70818, and/or US 2002/0081293, which are each incorporated herein by reference in their entirety. As a non-limiting example, in some instances, the anti-Factor D antibody may comprise an amino acid sequence having at least 70% sequence identity (e.g., 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the monoclonal antibody 166-32 produced from the hybridoma deposited with the American Type Culture Collection (ATCC) and designated HB12476. In some instances, the anti-Factor D antibody is a humanized derivative of monoclonal antibody 166-32. In some embodiments, the anti-Factor D antibody binds to the same epitope as monoclonal antibody 166-32. In some instances, the anti-Factor D antibody is an antibody fragment derived from monoclonal antibody 166-32. In some instances, the antibody fragment derived from monoclonal antibody 166-32 is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the antibody fragment derived from monoclonal antibody 166-32 is an Fab.

In another example, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with an HtrA1 binding antagonist. In some instances, the HtrA1 binding antagonist may be an anti-HtrA1 antibody or an antigen-binding fragment thereof. Any of the anti-HtrA1 antibodies or antigen-binding fragments thereof known in the art and/or described herein may be used. For example, in some instances, the anti-HtrA1 antibody is an anti-HtrA1 antibody described in WO 2013/055998. In some instances, the anti-HtrA1 antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the anti-HtrA1 antibody fragment is an Fab.

In another example, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be co-administered with a VEGF antagonist. In some instances, the VEGF antagonist may be an anti-VEGF antibody or an antigen-binding fragment thereof. Any of the anti-VEGF antibodies or antigen-binding fragments thereof known in the art and/or described herein may be used. For example, in some instances, the anti-VEGF antibody is bevacizumab (AVASTIN®) or ranibizumab (LUCENTIS®). In some

instances, the anti-VEGF antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the anti-VEGF antibody fragment is an Fab.

In some instances, the anti-VEGF antibody or antigen-binding fragment thereof is or is derived from any anti-VEGF antibody described in WO 2005/044853, which is incorporated herein by reference in its entirety. For example, in some instances, the anti-VEGF antibody is or is derived from a G6 series antibody (e.g., G6, G6-8, G6-23, G6-23.1, G6-23.2, or G6-31) or a B20 series antibody (e.g., B20, B20-4, or B20-4.1). For example, in some instances, the anti-VEGF antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 80% sequence identity (e.g., at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 334, 337, or 340; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 80% sequence identity (e.g., at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 335, 336, 338, 339, or 341; or (c) a VH domain as in (a) and a VL domain as in (b). For example, in some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 334 and a VL domain comprising the amino acid sequence of SEQ ID NO: 335 (such as the anti-VEGF antibody G6). In some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 334 and a VL domain comprising the amino acid sequence of SEQ ID NO: 336 (such as the anti-VEGF antibody G6.31). In some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 337 and a VL domain comprising the amino acid sequence of SEQ ID NO: 338 (such as the anti-VEGF antibody B20). In other instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 337 and a VL domain comprising the amino acid sequence of SEQ ID NO: 339 (such as the anti-VEGF antibody B20-4). In yet other instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 340 and a VL domain comprising the amino acid sequence of SEQ ID NO: 341 (such as the anti-VEGF antibody B20-4.1). In some embodiments, the anti-VEGF antibody is a humanized derivative of any of the preceding antibodies. In some embodiments, the anti-VEGF antibody is an antibody fragment derived from any of the preceding antibodies. In some embodiments, the antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the antibody fragment is an Fab.

In one aspect, the invention provides a method of treating an inflammatory disorder, such as, for example, asthma, airway hyperresponsiveness, airway inflammation, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, or chronic obstructive pulmonary disease (COPD), or a fibrotic disorder, such as, for example, idiopathic pulmonary fibrosis (IPF) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) and a therapeutically effective amount of an anti-IL-13 antibody. In an exemplary embodiment, the invention provides a method of treating asthma in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) and a

therapeutically effective amount of an anti-IL-13 antibody. Any of the anti-IL-13 antibodies described herein may be administered in combination with an anti-IL-33 axis binding antagonist. In one embodiment, an anti-IL-33 antibody is administered in combination with an anti-IL-13 antibody. In an exemplary embodiment, the anti-IL-33 antibody comprises the following six HVRs: an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and the anti-IL-13 antibody comprises the following six HVRs: an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); an HVR-H3 comprising the amino acid sequence of DGYPYAMDN (SEQ ID NO: 298); an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In another embodiment, the anti-IL-33 antibody comprises (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and the anti-IL-13 antibody comprises (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303. In another embodiment, the anti-IL-33 antibody comprises (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 37, and the anti-IL-13 antibody comprises (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 303. In another embodiment, the anti-IL-33 comprises a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and the anti-IL-13 antibody comprises a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305. In another embodiment, the anti-IL-33 comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 308 and a light chain comprising the amino acid sequence of SEQ ID NO: 309, and the anti-IL-13 antibody comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 304 and a light chain comprising amino acid sequence of SEQ ID NO: 305.

In another aspect, the the invention provides a method of treating an inflammatory disorder, such as, for example, asthma, airway hyperresponsiveness, airway inflammation, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, or chronic obstructive pulmonary disease (COPD), or a

fibrotic disorder, such as, for example, idiopathic pulmonary fibrosis (IPF) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and IL-13 or an antigen-binding antibody fragment thereof. In an exemplary embodiment, the invention provides a method of treating asthma in a subject in need thereof,

5 the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and IL-13 or an antigen-binding antibody fragment thereof. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds IL-13 as described herein. In an exemplary embodiment, the bispecific antibody that

10 specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs: an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1); an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2); an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3); an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4); an HVR-L2 comprising the amino

15 acid sequence of AASNRGS (SEQ ID NO: 5); and an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and a second binding domain that specifically binds IL-13 comprising the following six HVRs: an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296); an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297); an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298); an HVR-L1 comprising the

20 amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299); an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301). In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid

25 sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID

30 NO: 303. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising the amino acid

35 sequence of SEQ ID NO: 303. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13 comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and (b)

a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305. In another embodiment, the bispecific antibody that specifically binds both IL-33 and IL-13, comprises: (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises the amino acid sequence of SEQ ID NO: 309, and (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising amino acid sequence of SEQ ID NO: 305.

In another aspect, the invention provides a method of treating geographic atrophy in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) and a therapeutically effective amount of a Factor D binding antagonist. In some instances, the Factor D binding antagonist may be an anti-Factor D antibody or an antigen-binding fragment thereof, for example, any Factor D antibody described in WO 2007/056227, WO 01/70818, and/or US 2002/0081293. For example, in some instances, the anti-Factor D antibody may comprise an amino acid sequence having at least 70% sequence identity (e.g., 70%, 71%, 72%, 73%, 74%, 75%, 76%, 77%, 78%, 79%, 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, the monoclonal antibody 166-32 produced from the hybridoma deposited with the American Type Culture Collection (ATCC) and designated HB12476. In some instances, the anti-Factor D antibody is a humanized derivative of monoclonal antibody 166-32. In some embodiments, the anti-Factor D antibody binds to the same epitope as monoclonal antibody 166-32. In some instances, the anti-Factor D antibody is an antibody fragment derived from monoclonal antibody 166-32. In some instances, the antibody fragment derived from monoclonal antibody 166-32 is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the antibody fragment derived from monoclonal antibody 166-32 is an Fab.

In another aspect, the invention features a method of treating geographic atrophy (GA) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and Factor D or an antigen-binding antibody fragment thereof. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds Factor D that is derived from any of the anti-Factor D antibodies described above. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention provides a method of treating GA, AMD (wet or dry), DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) and a therapeutically effective amount of a HtrA1 binding antagonist. In some instances, the HtrA1 binding

antagonist may be an anti-HtrA1 antibody or an antigen-binding fragment thereof, for example, any HtrA1 antibody described in WO 2013/055998. In some instances, the anti-HtrA1 antibody is an antibody fragment. In some instances, the antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the antibody fragment derived is an Fab.

5 In another aspect, the invention features a method of treating geographic atrophy (GA), AMD (wet or dry), DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and HtrA1 or an antigen-binding antibody fragment thereof. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The
10 bispecific antibody may comprise a binding domain that specifically binds HtrA1 that is derived from any of the anti-HtrA1 antibodies described above. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In another aspect, the invention provides a method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33
15 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) and a therapeutically effective amount of a VEGF antagonist. In some instances, the VEGF antagonist may be an anti-VEGF antibody or an antigen-binding fragment thereof. Any of the anti-VEGF antibodies or antigen-binding fragments thereof known in the art and/or described herein may be used. In some instances, the anti-VEGF antibody or antigen-binding fragment thereof is or is derived from an anti-VEGF antibody described in WO
20 2005/044853, which is incorporated herein by reference in its entirety. For example, in some instances, the anti-VEGF antibody is or is derived from a G6 series antibody (G6, G6-8, G6-23, G6-23.1, G6-23.2, or G6-31) or a B20 series antibody (e.g., B20, B20-4, or B20-4.1). For example, in some instances, the anti-VEGF antibody comprises (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 80% sequence identity (e.g., at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%,
25 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 334, 337, or 340; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 80% sequence identity (e.g., at least 80%, 81%, 82%, 83%, 84%, 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% sequence identity) to, or the sequence of, any one of SEQ ID NOs: 335, 336, 338, 339, or 341; or (c) a VH domain as in (a) and
30 a VL domain as in (b). For example, in some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 334 and a VL domain comprising the amino acid sequence of SEQ ID NO: 335 (such as the anti-VEGF antibody G6). In some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 334 and a VL domain comprising the amino acid sequence of SEQ ID NO: 336 (such as the anti-VEGF antibody
35 G6.31). In some instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 337 and a VL domain comprising the amino acid sequence of SEQ ID NO: 338 (such as the anti-VEGF antibody B20). In other instances, the anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 337 and a VL domain comprising the amino acid sequence of SEQ ID NO: 339 (such as the anti-VEGF antibody B20-4). In yet other instances, the

anti-VEGF antibody comprises a VH domain comprising the amino acid sequence of SEQ ID NO: 340 and a VL domain comprising the amino acid sequence of SEQ ID NO: 341 (such as the anti-VEGF antibody B20-4.1). In some embodiments, the anti-VEGF antibody is a humanized derivative of any of the preceding antibodies. In some embodiments, the anti-VEGF antibody is an antibody fragment derived from any of the preceding antibodies. In some embodiments, the antibody fragment is an Fab, Fab'-SH, Fv, scFv, or an (Fab')₂ fragment. In some embodiments, the antibody fragment is an Fab.

In another aspect, the invention features a method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof. The bispecific antibody may comprise a binding domain that specifically binds IL-33 that is derived from any of the anti-IL-33 antibodies described herein. The bispecific antibody may comprise a binding domain that specifically binds VEGF that is derived from any of the anti-VEGF antibodies described above. In some embodiments, the antigen-binding antibody fragment is a (Fab')₂ fragment.

In yet another aspect, the invention provides a method of treating uveitis (e.g., infectious or non-infectious uveitis) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention). In some embodiments, the IL-33 axis binding antagonist may be administered as a monotherapy.

In a still further aspect, the invention provides a method of treating conjunctivitis (e.g., infectious conjunctivitis, non-infectious conjunctivitis, or allergic conjunctivitis) in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention). In some embodiments, the IL-33 axis binding antagonist may be administered as a monotherapy.

In some embodiments, an additional therapeutic agent is an asthma therapy, as described below. Moderate asthma is currently treated with a daily inhaled anti-inflammatory-corticosteroid or mast cell inhibitor such as cromolyn sodium or nedocromil plus an inhaled beta2-agonist as needed (3-4 times per day) to relieve breakthrough symptoms or allergen- or exercise-induced asthma. Exemplary inhaled corticosteroids include QVAR®, PULMICORT®, SYMBICORT®, AEROBID®, FLOVENT®, FLONASE®, ADVAIR®, and AZMACORT®. Additional asthma therapies include long acting bronchial dilators (LABD). In certain embodiments, the LABD is a long-acting beta-2 agonist (LABA), leukotriene receptor antagonist (LTRA), long-acting muscarinic antagonist (LAMA), theophylline, or oral corticosteroids (OCS). Exemplary LABDs include SYMBICORT®, ADVAIR®, BROVANA®, FORADIL®, PERFOROMIST™ and SEREVENT®.

Such combination therapies noted above encompass combined administration (where two or more therapeutic agents are included in the same or separate formulations), and separate administration, in which case, administration of the antibody of the invention can occur prior to, simultaneously, and/or following, administration of the additional therapeutic agent or agents. In one embodiment, administration of the anti-IL-33 antibody and administration of an additional therapeutic agent occur within about one

month, or within about one, two or three weeks, or within about one, two, three, four, five, or six days, of each other. Antibodies of the invention can also be used in combination with radiation therapy.

An IL-33 axis binding antagonist, for example, an anti-IL-33 antibody of the invention (and any additional therapeutic agent) can be administered by any suitable means, including parenteral, intrapulmonary, and intranasal, and, if desired for local treatment, intralesional administration. Parenteral infusions include intramuscular, intravenous, intraarterial, intraperitoneal, or subcutaneous administration. In some instances, a IL-33 axis binding antagonist, for example, an anti-IL-33 antibody of the invention may be administered intravitreally, intramuscularly, intravenously, intradermally, percutaneously, intraarterially, intraperitoneally, intralesionally, intracranially, intraarticularly, intraprostatically, intrapleurally, intratracheally, intrathecally, intranasally, intravaginally, intrarectally, topically, intratumorally, peritoneally, subcutaneously, subconjunctivally, intravesicularly, mucosally, intrapericardially, intraumbilically, intraocularly, intraorbitally, orally, topically, transdermally, periorcularly, conjunctivally, subtenonally, intracamerally, subretinally, retrobulbarly, intracanalicularly, by inhalation, by injection, by implantation, by infusion, by continuous infusion, by localized perfusion bathing target cells directly, by catheter, by lavage, in cremes, or in lipid compositions. The compositions utilized in the methods described herein can also be administered systemically or locally. Dosing can be by any suitable route, for example, by injections, such as intravenous or subcutaneous injections, depending in part on whether the administration is brief or chronic. Various dosing schedules including but not limited to single or multiple administrations over various time-points, bolus administration, and pulse infusion are contemplated herein.

In some instances, an IL-33 axis binding antagonist (e.g., an anti-IL-33 antibody of the invention) may be administered directly to the eye by ocular tissue injection, for example, using intravitreal, intraocular, periorcular, conjunctival, subconjunctival, subtenon, intracameral, subretinal, retrobulbar, or intracanalicular injections; by direct application to the eye, for example, using a catheter or other placement device (e.g., a retinal pellet, intraocular insert, suppository or an implant comprising a porous, non-porous, or gelatinous material); by topical ocular drops or ointments; or by a slow-release device in the cul-de-sac or implanted adjacent to the sclera (transscleral) or in the sclera (intrasccleral) or within the eye. Intracameral injection may be through the cornea into the anterior chamber to allow the agent to reach the trabecular meshwork. Intracanalicular injection may be into the venous collector channels draining Schlemm's canal or into Schlemm's canal.

Antibodies of the invention would be formulated, dosed, and administered in a fashion consistent with good medical practice. Factors for consideration in this context include the particular disorder being treated, the particular mammal being treated, the clinical condition of the individual patient, the cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners. The antibody need not be, but is optionally formulated with one or more agents currently used to prevent or treat the disorder in question. The effective amount of such other agents depends on the amount of antibody present in the formulation, the type of disorder or treatment, and other factors discussed above. These are generally used in the same dosages and with administration routes as described herein, or about from 1 to 99% of the dosages

described herein, or in any dosage and by any route that is empirically/clinically determined to be appropriate.

For the prevention or treatment of disease, the appropriate dosage of an antibody of the invention (when used alone or in combination with one or more other additional therapeutic agents) will depend on the type of disease to be treated, the type of antibody, the severity and course of the disease, whether the antibody is administered for preventive or therapeutic purposes, previous therapy, the patient's clinical history and response to the antibody, and the discretion of the attending physician. The antibody is suitably administered to the patient at one time or over a series of treatments. Depending on the type and severity of the disease, about 1 µg/kg to 15 mg/kg (e.g., 0.1 mg/kg to 10 mg/kg) of antibody can be an initial candidate dosage for administration to the patient, whether, for example, by one or more separate administrations, or by continuous infusion. One typical daily dosage might range from about 1 µg/kg to 100 mg/kg or more, depending on the factors mentioned above. For repeated administrations over several days or longer, depending on the condition, the treatment would generally be sustained until a desired suppression of disease symptoms occurs. One exemplary dosage of the antibody would be in the range from about 0.05 mg/kg to about 10 mg/kg. Thus, one or more doses of about 0.5 mg/kg, 2.0 mg/kg, 4.0 mg/kg or 10 mg/kg (or any combination thereof) may be administered to the patient. Such doses may be administered intermittently, e.g. every week, every two weeks, every three weeks, or every four weeks (e.g., such that the patient receives from about two to about twenty, or e.g., about six doses of the antibody). For example, a dose may be administered once per month, (e.g., by subcutaneous injection). An initial higher loading dose, followed by one or more lower doses may be administered. However, other dosage regimens may be useful. The progress of this therapy is easily monitored by conventional techniques and assays.

It is understood that any of the above formulations or therapeutic methods may be carried out using an immunoconjugate of the invention in place of or in addition to an anti-IL-33 antibody.

H. Articles of Manufacture

In another aspect of the invention, an article of manufacture containing materials useful for the treatment, prevention and/or diagnosis of the disorders described above is provided. The article of manufacture comprises a container and a label or package insert on or associated with the container. Suitable containers include, for example, bottles, vials, syringes, IV solution bags, etc. The containers may be formed from a variety of materials such as glass or plastic. The container holds a composition which is by itself or combined with another composition effective for treating, preventing and/or diagnosing the condition and may have a sterile access port (for example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection needle). At least one active agent in the composition is an antibody of the invention. The label or package insert indicates that the composition is used for treating the condition of choice. Moreover, the article of manufacture may comprise (a) a first container with a composition contained therein, wherein the composition comprises an antibody of the invention; and (b) a second container with a composition contained therein, wherein the composition comprises a further cytotoxic or otherwise therapeutic agent. The article of manufacture in

this embodiment of the invention may further comprise a package insert indicating that the compositions can be used to treat a particular condition. Alternatively, or additionally, the article of manufacture may further comprise a second (or third) container comprising a pharmaceutically-acceptable buffer, such as bacteriostatic water for injection (BWI), phosphate-buffered saline, Ringer's solution and dextrose solution. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, and syringes.

It is understood that any of the above articles of manufacture may include an immunoconjugate of the invention in place of or in addition to an anti-IL-33 antibody.

III. EXAMPLES

The following are examples of methods and compositions of the invention. It is understood that various other embodiments may be practiced, given the general description provided above.

Example 1. Generation of anti-IL-33 antibodies

Several strategies were pursued to develop therapeutic anti-IL-33 antibodies, as described below. Desired characteristics for a candidate anti-IL-33 antibody included specific binding to human IL-33, cross-reactivity with cynomolgus monkey (cyno) IL-33, inhibition of IL-33 activity (as measured, for example, in a cell-based IL-33 reporter assay), and/or blocking of binding to the IL-33 receptor (ST2 and IL-1RAcP).

A. Development and characterization of mouse monoclonal anti-human IL-33 hybridoma antibodies

BALB/c mice (Charles River, Hollister, CA) or *IL33* knockout (ko) mice (Genentech, Inc.) were immunized intraperitoneally twice weekly with 2 µg each of human (hu) IL-33 and cynomolgus (cyno) monkey IL-33 protein (Genentech, Inc.) mixed with monophosphoryl-lipid A and trehalose dicorynomycolate (MPL®+TDM) adjuvant (Sigma-Aldrich, St. Louis, MO) or a combination of the Toll-like receptor (TLR) agonists MPL® (Sigma-Aldrich, St. Louis, MO), polyinosinic-polycytidylic acid (PolyI:C; InvivoGen, San Diego, CA), R848 (InvivoGen), and CpG oligodeoxynucleotides (InvivoGen). Spleens and bone marrow were harvested three days after the last immunization. Splenocytes from these mice were fused with P3X63-Ag8U.1 mouse myeloma cells (American Type Culture Collection, Rockville, MD) via electrofusion (Harvard Apparatus, Holliston, MA). Fused cells were incubated at 37°C, 7% CO₂, overnight in CLONACELL™-HY Medium C (StemCell Technologies, Vancouver, BC, Canada), before resuspension in semi-solid CLONACELL™-HY Medium D (StemCell Technologies) with anti-species IgG-FITC (Jackson ImmunoResearch, West Grove, PA) and plating into OMNIWELL™ trays (Thermo Fisher Scientific, Rochester, NY). Seven days after plating, fluorescent colonies were selected and transferred into 96-well plates containing CLONACELL™-HY Medium E (StemCell Technologies) using a CLONEPIX™ FL (Genetix, New Milton, Hampshire, UK). Supernatants were screened by enzyme-linked immunosorbant assay (ELISA) against human IL-33 protein seven days after picking, as described below. Hybridoma cell lines that showed human IL-33 binding were expanded and retested by ELISA;

supernatant from cell lines demonstrating binding to both human and cynomolgus IL-33 by ELISA were harvested and purified by protein A (MABSELECT™ SURE™, GE Healthcare, Pittsburgh, PA). Purified IgG was evaluated for ability to block binding of IL-33 to ST2 using a HEK-BLUE™ cell reporter kit (InvivoGen), as described below. Using a high-throughput system of IgG purification from a large panel of hybridomas allowed for early and efficient selection of potential blocking clones. RNA was extracted from strong blocking hybridoma cell lines using the RNEASY® kit (Qiagen, Hilden, Germany), and cDNA was generated and amplified for sequence determination, as described below. Variable region genes of heavy and light chains were inserted into pRK plasmid vectors (Genentech, Inc.) for expression. Plasmid DNA from unique clones demonstrating the highest IL-33 blocking activity and affinity were expressed recombinantly in 293 cells. Supernatants were then purified by Protein A affinity chromatography.

B. Generation of anti-IL-33 monoclonal antibodies from single B cell cloning

Transgenic mice were immunized with human and cynomolgus IL-33 as described above. Following the initial immunization and seven boosts, serum from the immunized transgenic mice was tested for binding to IL-33. Mice with significantly high titers to human and cynomolgus IL-33 were identified and then tested for serum inhibition of IL-33 binding to ST-2 in the HEK-BLUE™ assay. Splenic, lymph nodal, and bone marrow tissues were isolated from the mice that demonstrated IL-33 blocking activity. The tissues were mechanically reduced to single cell suspensions, premixed with IL-33 antigen (human and cynomolgus) and implanted intrasplenically into muSCID mice. 7-8 days later, the spleens were removed and resuspended as single cells. Splenic cells were stained with fluorophore-conjugated markers to identify CD138-positive plasmablast and IgM-positive populations. Plasmablast populations that were IgM-negative and able to bind both human and cynomolgus IL-33 were sorted singly into 96-well plates by FACS™ flow cytometry. The immunoglobulin variable regions of the sorted cells were molecularly cloned and reformatted into human IgG1 mammalian expression vectors. Each reformatted monoclonal antibody was expressed transiently in mammalian cells and purified. A general method is described in Lin et al. (*Nature Protocols* 9:1563-1577, 2014).

C. Generation of anti-IL-33 monoclonal antibodies from immunized phage derived libraries

Single chain Fv libraries displayed on phage were constructed from RNA isolated from transgenic mice that were immunized with human and cynomolgus IL-33. The ScFv phage display libraries were panned for several rounds against human and cynomolgus IL-33. Individual phage clones were propagated and assayed by ELISA for binding to human and cynomolgus IL-33. Positive binding clones were reformatted for expression in IgG format and transiently expressed. IgG was purified from the transiently-expressing cultures and tested for binding to IL-33 and for inhibition of IL-33 binding to HEK-BLUE™ cells.

Example 2. Screening and sequencing of anti-IL-33 antibodies*A. ELISA screening for anti-human/cyno IL-33 antibodies*

Hybridoma clones generated as described above were screened for production of monoclonal antibodies that bind to human and cyno IL-33 in an ELISA format. To screen the 1921 hybridoma cell lines generated, ELISA was performed generally as described in Baker et al. (*Trends Biotechnol.* 20:149-156, 2002). Briefly, 96-well MAXISORP® flat bottom plates (Nalge Nunc International, Rochester, NY) were coated with 50 µl of soluble IL-33 (Genentech) at a concentration of 2 µg/ml in coating buffer (0.05 M carbonate buffer, pH 9.6), sealed, and stored overnight at 4°C. After removing the coating solution, 200 µl of assay/blocking solution containing 0.5% bovine serum albumin (BSA) and 0.05% TWEEN®-20 in phosphate buffered saline (PBS) pH 7.4 (ELISA diluent) was added to each well and incubated at room temperature for one hour with agitation. Wells were then washed three times with 300 µl of 0.05% TWEEN®-20 in PBS (wash buffer).

After the washing step, 100 µl of culture supernatant from individual hybridoma clones was added to individual wells. Plates were incubated at room temperature for one hour with agitation, and the wells were washed three times with wash buffer as before.

After washing, 50 µl of a 1:1000 dilution of sheep anti-mouse IgG coupled to horseradish peroxidase (no cross-reactivity to human IgG (MP Biomedicals, Solon, OH)) in ELISA diluent was added to each well. Plates were incubated at room temperature for one hour with agitation, washed three times with wash buffer as before, and patted dry. Wells were developed by adding 50 µl of tetramethylbenzidine (TMB) microwell peroxidase substrate (BioFX Laboratories, Owing Mills, MD, catalog #TMBW-0100-01) to each well and incubating at room temperature for 5-10 minutes or until color change was observed. Enzymatic color development was stopped by adding 50 µl of TMB Stop Solution (BioFX Laboratories catalog #BSTP-0100-01) to each well. Plates were analyzed with a SUNRISE™ plate reader (Tecan US, Inc., Research Triangle Park, NC) at 650 nm.

Pre-immune sera collected before the first immunization was used as a negative control. Immune sera collected after seven immunizations was used as a positive control.

Clones 2B6, 6C11, 9F6, 10C12, and 10H2 were positive for human IL-33 and cynomolgus IL-13 binding.

B. Cell-based IL-33 blocking assay

The IL-33 neutralizing activities of anti-IL-33 antibodies obtained using the methods described above were determined by a cell-based blocking assay, in which IL-33 stimulates HEK-BLUE™ IL-33/IL-1β cells (InvivoGen) and activates the NF-κB and AP-1 pathways, triggering the production of secreted alkaline phosphatase (SEAP) (Figure 1A). HEK-BLUE™ IL-33/IL-1β cells are human HEK293 cells which have been stably transfected with a human ST2 construct (pUNO1-hIL01RL1a; SEQ ID NO: 311), and contain a SEAP reporter gene under the control of the IFN-β minimal promoter fused to five NF-κB and five AP-1 binding sites (InvivoGen). The pUNO1-hIL01RL1a plasmid encodes ST2L protein having an amino acid sequence of SEQ ID NO: 312. HEK293 cells express endogenous IL-1RAcP. The amino

acid sequences of IL-33 used in cell-based blocking assays were as follows: mature human IL-33 (S112-T270), SEQ ID NO:313; human IL-33 N-His, SEQ ID NO: 314; human IL-33 N-His C-Avi, SEQ ID NO: 315; mature cyno IL-33 (S112-T270), SEQ ID NO: 316; cyno IL-33 N-His, SEQ ID NO: 317; and cyno IL-33 N-His C-Avi, SEQ ID NO: 318.

Briefly, IL-33 ligand and pre-diluted anti-IL-33 antibodies were mixed and incubated for 1 hour at room temperature. The antibody and ligand mixture were transferred to HEK-BLUE™ IL-33/ IL-1 β cells. After incubation at 37°C for 20 hours in a CO₂ incubator, the SEAP activities in cell culture supernatants were measured by recording the OD values at 630 nm after incubating with the substrate of alkaline phosphatase (QUANTI-BLUE™, InvivoGen). The full-length amino acid sequence of sST2-LZ (sST2 (M1-F328) C-terminal leucine zipper (LZ)-Flag-His), which was used in the cell-based blocking assay as a positive control (see, e.g., Figure 2), can be found in SEQ ID NO: 319. The mature form of sST2-LZ in which the signal peptide has been removed is shown in SEQ ID NO: 310.

When expressed in IgG format, the purified anti-IL-33 antibodies showed complete inhibition of IL-33 at concentrations less than 1 nM (Figure 2). In contrast, no inhibition was observed with a negative control monoclonal antibody specific for IL-13 (not shown).

C. Hybridoma molecular cloning and sequencing

The antibody expressed by each hybridoma cell line was cloned directly from cells without RNA purification. Variable heavy and light immunoglobulin regions were cloned using a modified 5' RACE (rapid amplification of cDNA ends) protocol (Qzawa et al. *BioTechniques* 40(4):469-478, 2006). First strand cDNA was generated directly from the hybridoma cells using SUPERScript® III (Invitrogen, Carlsbad, CA) reverse transcriptase with oligonucleotide primers specific for murine heavy (5'-TTTYYTGTCCACCKTGGTGCTGC-3', SEQ ID NO: 320) and light constant (5'-GTAGAAGTTGTTCAAGAAG-3'; SEQ ID NO: 321) regions at 55°C for 1 hour. Degenerate primers were designed to allow priming across the various murine heavy chain isotypes. The 3' end of the reverse transcriptase product was poly-G tailed using terminal deoxynucleotidyl transferase (Promega, San Luis Obispo, CA) and dGTP (Roche Diagnostics, Indianapolis, IN) for 1 h at 37°C. Amplification of the variable heavy and light chain cDNA was performed separately by touchdown PCR (ADVANTAGE®-GC 2, Clontech, Mountain View, CA) using nested heavy chain constant region primer (5'-GTGTAGAGKYCAGACTSCAGG-3'; SEQ ID NO: 322) and light constant region primer (5'-GAGGCACCTCCAGATGTTAAC-3'; SEQ ID NO: 323), and a poly-C containing N-terminal primer (5'-GATTCAAATCTCAATTATATAATCCGAATATGTTTACCGGCTCGCTCATGGACCCCCCCCCCCCCDN-3'; SEQ ID NO: 324). A second nested touchdown PCR set was performed using N-terminal primer (5'-CAATTATATAATCCGAATATG-3'; SEQ ID NO: 325), heavy chain constant region primer (5'-GAARTARCCCTTGACCAGGC-3'; SEQ ID NO: 326) and light chain constant region primer (5'-GAAGATGGATACAGTTGGTGC-3'; SEQ ID NO: 327).

PCR products were ligated into a pCR2.1®-TOPO® cloning vector (TOPO® TA cloning Kit, Invitrogen, Carlsbad, CA) and transformed into ONESHOT® TOP10 Competent cells. Transformed *Escherichia coli* (*E. coli*) colonies were isolated and cultured for DNA plasmid isolation. The plasmids

were sequenced to determine DNA sequences of the VH and VL for each cell line. Following the sequence determination, variable heavy and light chains regions were amplified by PCR using primers containing endonuclease restriction sites (EcoRI and XhoI) to allow subcloning into murine IgG_{2a} and kappa constant region encoding mammalian IgG and IgK expression vectors respectively.

5 Prior to subcloning of the hybridoma cells, the parental clones were molecularly cloned to determine the sequence of the variable heavy and light domains. The cloning was performed prior to subcloning to capture the sequence in event that the hybridoma clones were lost due to instability during the subcloning process. Based on the molecular cloning sequence data, 17C4, 17H2, and 19C11 were determined to be sibling clones based on alignment of CDR and framework sequences. This agreed with
10 the assay data generated for the three clones.

D. Humanization of murine hybridoma-derived clones

Murine hybridomas expressing antibodies that bind to IL-33 with high affinity and that block cytokine binding to its receptor ST2 were selected for humanization. Variable sequences for the
15 antibodies obtained from cloning the hybridomas were aligned to the closest matching human variable consensus sequences. The hypervariable regions (HVRs) from the murine hybridoma antibodies were grafted into the corresponding human variable consensus sequences using Kunkel mutagenesis (see, e.g., Kunkel et al. *Methods Enzymol.* 154: 367-382, 1987). Additional variants for each clone were generated by mutating residues in both the light chain and heavy chain at key Vernier positions back to
20 murine as well as sites of framework/HVR interactions and variable heavy and variable light interactions. For instance, the cloned HVR sequences for hybridoma clone 10C12 were grafted into a consensus kappa III light chain and a consensus VHIII heavy chain to generate humanized variants. The cloned HVR sequences for hybridoma clone 10H2 were grafted into a consensus kappa IV light chain and a consensus VH III heavy chain to generate humanized variants. The cloned HVR sequences
25 for 6C11, 2B6, and 9F6 were humanized in a similar format to 10C12 and 10H2. Humanized variants were expressed transiently in 293 cells and then tested for binding and function.

The binding kinetics of the humanized variants of the hybridoma-derived clones 10C12, 10H2, 6C11, 2B6, and 9F6 to IL-33 were measured using surface plasmon resonance (SPR) on a Biacore 3000 or T200 instrument (GE Healthcare). Anti-human Fc (GE Healthcare) was immobilized on a CM5 sensor
30 chip via amine-based coupling according to the manufacturer's protocol. The humanized variant anti-IL-33 antibody was captured at a level of 500-600 resonance units (RU). Antibody binding was measured to human IL-33 (Genentech, huIL33.his). Two-fold concentration series of human IL-33 with a range of 0.78 to 50 nM was used for the experiments. Sensograms for binding of IL-33 were recorded using an injection time of 2 minutes with a flow rate of 30 µl/min, at a temperature of 25°C, and with a running
35 buffer of 10mM HEPES, pH 7.4, 150 mM NaCl, 3 mM EDTA, and 0.005% TWEEN®-20. After injection, disassociation of the ligand from the antibody was monitored for 600 seconds in running buffer. The surface was regenerated between binding cycles with a 40 µl injection of 3M magnesium chloride. After subtraction of a blank which contained running buffer only, sensograms observed for IL-33 binding to humanized anti-IL-33 antibodies were analyzed using a 1:1 Langmuir binding model with software

supplied by the manufacturer to calculate the kinetics and binding constants, including the dissociation constant (K_D). Anti-IL-33 10C12 humanized variants retained high affinity binding to human IL-33 after humanization as measured by Biacore (see Figure 3 and Table 2). Table 2 also shows kinetic data for selected antibody clones derived from B cell cloning and phage display.

5 To test the function of the humanized anti-IL-33 antibodies, as well as antibodies obtained from single B cell cloning (e.g., 4G12 and derivatives and 3E3) and phage display, their activity in cell-based receptor-blocking assays was measured, as described above. Antibodies were tested for blocking of both human and cynomolgus IL-33 binding to ST2. The results of receptor-blocking assays for a selected group of antibodies are shown in Table 3.

10

Table 2: Kinetic Data for selected anti-IL-33 antibody clones

Clone	Type	Source	K_D (hu)	K_D (cyno)
10C12	Murine	<i>IL33 KO</i>	≤ 7 pM	70 pM
10C12.38.H6.87Y.58I	Humanized		15 pM	37 pM
10C12.38.H7.87Y.58I	Humanized		177 pM	
10H2	Murine	Balb/C	60 pM	90 pM
10H2.36.F10	Humanized		220 pM	
10H2.36.F10.30V.54D	Humanized		220 pM	
4G12	B cell cloning		96 pM	60 pM
4G12.62A	Humanized		84 pM	73 pM
4G12.FW4	Humanized		38 pM	70 pM
4G12.F10.F6	B cell cloning		110 pM	60 pM
4G12.F11.F8	B cell cloning		100 pM	40 pM
3E3	B cell cloning		260 pM	40 pM
6C11	Murine	Balb/C	60 pM	790 pM
6C11.34.B2	Humanized		225 pM	
6C11.34.B2.52bS	Humanized		310 pM	
6C11.HC.G.2.52CA	Humanized		152 pM	
2B6	Murine	Balb/C	30 pM	330 pM
2B6.35.D1	Humanized		312 nM	
2B6.54S	Humanized		336 nM	
2B6.55A (NA)	Humanized		363 pM	
9F6	Murine	Balb/C	70 pM	910 pM
9F6.34.E10	Humanized		795 pM	
101.B11	Transgenic mouse/ phage display		527 pM	783 pM
101.E11	Transgenic mouse/ phage display		420 pM	467 pM

Clone	Type	Source	K _D (hu)	K _D (cyno)
101.D9	Transgenic mouse/ phage display		361 pM	576 pM

Table 3: Receptor-blocking data for selected anti-IL-33 antibody clones

Clone	Cell assay (hu) IC ₉₀ (μg/mL)	Cell assay (hu) IC ₉₀ (nM)	Cell assay (cy) IC ₉₀ (μg/mL)	Cell assay (cy) IC ₉₀ (nM)
10C12	0.002	0.013	0.193	1.27
10C12.38.H6.87Y.58I	0.004	0.026	0.185	1.22
10C12.38.H7.87Y.58I	0.003	0.02	0.09	0.594
10H2	0.003	0.02	0.041	0.27
10H2.36.F10	0.17	1.12	0.025	0.165
10H2.36.F10.30V.54D	0.344	2.27	>1.5	>9.9
4G12	0.128	0.845	0.032	0.211
4G12.62A	0.187	1.23	0.014	0.092
4G12.FW4	0.17	1.12	0.034	0.224
4G12.F10.F6	0.16			
4G12.F11.F8	0.31			
3E3	0.21			
6C11	0.021	0.14	>1.5	>9.9
6C11.34.B2	0.017	0.112	>1.5	>9.9
6C11.34.B2.52bS	0.0087	0.057	>1.5	>9.9
6C11.HC.G.2.52CA	0.0305	0.201	>1.5	>9.9
2B6	0.02	0.13	0.526	3.47
2B6.35.D1	0.0093	0.061	0.184	1.21
2B6.54S	ND	ND	ND	ND
2B6.55A (NA)	ND	ND	ND	ND
9F6	0.011	0.73	>1.5	>9.9
9F6.34.E10	0.0128	0.84	> 1.5	>9.9
101.B11	0.3			
101.E11	0.1			
101.D9	0.3			

Example 3. Role of IL-33 in inflammation in ophthalmologic disorders including age-related macular degeneration (AMD)

Inflammation is typically considered a defense response triggered by infection or injury. Inflammation can also be induced by tissue stress and malfunction in the absence of infection or overt tissue damage. Examples of such sterile inflammatory responses are found at immune-privileged areas in the central nervous system, including the retina. In AMD, lifelong exposure of the retina and the underlining retinal pigment epithelium (RPE) cells to various stimuli (e.g., light, oxidative stress, and proteolytic enzymes) can lead to aberrant neovascularization, RPE cell death, and photoreceptor loss. Neural retina loss is often associated with a sterile inflammatory response, which is in part characterized by accumulation of mononuclear phagocytes in the photoreceptor and photoreceptor outer-segment layers. The factors that initiate recruitment of mononuclear phagocytes remain largely unknown.

A. IL-33 expression in Müller cells of the human macula is increased in AMD

The macula, an area near the center of the human retina, is critical for high-acuity vision. Reduced viability of RPE and photoreceptor cells in the macula due to lifelong exposure to oxidative stress or exposure to toxic by-products of the visual cycle can have important consequences for visual function. To determine whether IL-33 expression is different in the macula compared with the peripheral retina, dissected post-mortem human retinas (Figure 4A) were analyzed by RNA sequencing (RNA-seq). IL-33 transcripts were significantly increased in the macula compared to the peripheral retina of normal donors, while expression levels of other interleukin 1 (IL-1) family cytokines, IL-1 α , IL-1 β , and IL-18, were either similar or increased in the peripheral retina compared to the macula (Figure 4B).

To further determine the cellular source of IL-33 in the normal human retina, 7 eyes from human donors with no history of ocular disease were processed for immunohistochemistry. IL-33 was predominantly present in the nuclei of vimentin-positive Müller cells of the central retina, with significantly lower numbers of IL-33-positive (IL-33⁺) Müller cells in the peripheral retina (Figures 5A-5E) in line with the RNA-sequencing results. IL-33 was also expressed in the nucleus of a sub-population of RPE cells, with slightly higher expression in the central retina compared to peripheral retina (Figures 5B, 5C, and 5D). The number of IL-33⁺ astrocytes (glial fibrillary acidic protein-positive (GFAP⁺)) in the retinal ganglion cell layer and IL-33⁺ endothelial cells (plasmalemma vesicle associated protein-positive (PLVAP⁺)) of the choroid were not different in the central retina compared with the peripheral retina.

In donors with a history of AMD, areas of RPE and photoreceptor cell loss, reminiscent of advanced dry AMD or geographic atrophy, were observed in the macula (Figures 6A and 6B). Using multi-marker fluorescence immunohistochemistry, an increased number of IL-33⁺ Müller cells and myeloid cells was observed in areas of RPE and photoreceptor atrophy (Figures 6A-6E). The number of IL-33⁺ Müller cells in the AMD non-lesion area was significantly lower than those in the central retina of controls (Figures 6C). Without wishing to be bound by theory, this could be due to the fact that the non-lesion areas are typically located in the peripheral retina, where IL-33⁺ Müller cells are less abundant than in the central retina of non-AMD eyes (Figure 5D). Increased IL-33⁺ cells were also observed in the choroid of AMD lesion areas relative to controls or non-lesion areas (Figure 6D). None of the Iba1⁺ myeloid cells were positive for IL-33 (Figure 6E). In the vitreous of a subpopulation of AMD patients, IL-33 levels were

significantly increased compared to normal controls (patients with macular hole or macular pucker) (Figure 6F).

B. IL-33 is processed and released from Müller cells in vitro and in vivo following phototoxic stress

In the rat retina, IL-33 was primarily expressed in vimentin-positive Müller cells of the central and peripheral retina (Figure 7A), as previously described for the mouse retina (Figure 7B). In contrast to the IL-33 expression pattern in human eyes, IL-33 expression was very low in RPE or choroidal endothelial cells in normal rat and mouse eyes, and few IL-33⁺ cells were observed in the RPE or choroid (Figures 7A and 7B). In the normal mouse eye, IL-33 mRNA and protein expression was orders of magnitude higher compared to other IL-1 family members (IL-1 α , IL-1 β , and IL-18) (Figure 7C). rMC-1 cells, a Müller cell line obtained from rats exposed to bright light (Sarthy et al. *Invest. Ophthalmol. Vis. Sci.* 39:212-216, 1998), were used to study the regulation of IL-33 release *in vitro*. The rMC-1 Müller cells in culture displayed an activated phenotype as shown by expression of GFAP (Figure 7D) (see also Sarthy et al. *supra*). Subcellular fractionation of rMC-1 Müller cells identified 30 kDa pro-IL-33 (IL-33p30) and ~24 kDa and ~19 kDa (IL-33p19) C-terminal peptides in the nuclear fraction, while IL-33p19 was the primary species expressed in the cytoplasm (Figure 7E). Exposure of rMC-1 cells to high-glucose (25 mM) medium, which activates the Müller cells (Figure 7F; see also Sarthy et al., *supra*), significantly increased IL-33 secretion compared to cells cultured in low-glucose (5.5 mM) medium (Figure 7G). Western blot analysis of the culture supernatant demonstrated IL-33p19 as the only IL-33 species (Figure 7G). High-glucose stimulation (up to 72 h) did not induce cell permeability or annexin V staining on rMC-1 cells (Figure 7H), indicating that increased IL-33p19 secretion in high-glucose medium was not associated with increased cell death. These data demonstrated that IL-33 is expressed in both human and rodent Müller cells with predominant localization to the nucleus, and that IL-33p19 can be released from activated live rat Müller cells in culture.

Next, an analysis of whether IL-33 is secreted from Müller cells following Müller cell activation *in vivo* was performed. Constant exposure of rodents to bright (1200 lux) light for several days resulted in progressive loss of rods and cones in parallel with increased activation of Müller cells, microglia, and macrophages (LaVail et al. *Proc. Natl. Acad. Sci. USA* 89: 11249-11253, 1992). Following constant light exposure (CLE), an increased number of terminal dUTP nick end labelling (TUNEL)-positive cells was observed in the outer nuclear layer (ONL) (Figure 7I), with subsequent loss of rods and cones (Figure 7J). Rare TUNEL-positive cells were observed in the inner nuclear layer (INL) where the Müller cells reside.

To determine whether IL-33 is released by cells *in vivo*, vitreous was collected at various time points following CLE. IL-33 levels in normal rat vitreous were approximately 1 ng/ml. IL-33 concentration increased two-fold in light-activated eyes, reaching a plateau at day 3 (Figure 7K), indicative of release of IL-33 following light-induced retina stress. Western blot analysis confirmed that the processed C-terminal 19 kDa protein (IL-33p19), identical in size to the IL-33 fragment released from rMC-1 cells in culture (Figure 7G), was the predominant IL-33 species present in vitreous before and after CLE (Figure 7K). Full-length IL-33p30 was the primary species in the retina with an increased presence of the processed IL-33p19 species starting at day 3 following light exposure (Figure 7K) with a time course similar to IL-

33p19 expression in vitreous. To determine whether the increased presence of IL-33p19 in the light-injured retina and rMC-1 cells cultured in high glucose medium was due to the presence of an alternative IL-33 transcript variant, RT-PCR was performed using PCR primers spanning the 5' untranslated region (5'-UTR) (exon 1) to the stop codon (exon 9) of IL-33. Only the full-length IL-33 transcript was detected in both cases (Figure 7L). Without wishing to be bound by theory, this suggests that IL-33p19 was generated by proteolysis rather than by alternative splicing. The protease responsible for IL-33 processing has yet to be identified and is the focus of ongoing studies.

Following CLE, a loss of native IL-33 from rat Müller cells was observed. Genetically-engineered IL33^{tm2/tm2} mice (Bessa et al. *J. Autoimmunity* 55: 33-41, 2014), in which the N-terminal 112 amino acids of IL-33, containing the nuclear localization signal and the chromatin binding domain, is fused to a dsRed reporter, were analyzed to determine the regulation of IL-33 protein expression in Müller cells *in vivo*. In retina from IL33^{tm2/tm2} mice, IL-33 N-term-dsRed localized primarily to the nucleus of Müller cells located in the INL of the retina (Figure 7M), similar to the localization of native, full-length IL-33 (Figure 7B). Flow cytometry analysis of the IL33^{tm2/tm2} retina confirmed the selective expression of IL-33-N-term-dsRed in Müller cells (Figure 7M). A significant loss of IL-33-dsRed from live Müller cells was observed following CLE without loss of Müller cells (Figure 7M), which reflects the release of the IL-33 C-terminus from Müller cells in the absence of cell death. This finding is consistent with the observed loss of native IL-33 from rat Müller cells following light exposure. Therefore, these data demonstrate that C-terminal processed forms of IL-33 are released from Müller cells following cell activation in response to phototoxicity.

C. ST2 is expressed on activated Müller cells and contributes to photoreceptor loss

IL-33 triggers MyD88-mediated signalling following binding to its hetero-dimeric receptor, ST2/IL1RAcP (see, e.g., Schmitz et al. *Immunity* 23: 479-490, 2005). Retina transcripts encoding trans-membrane ST2 (ST2L) and a splice variant of ST2 that lacks the trans-membrane domain (sST2) increased 4- to 10-fold following CLE, peaking at day 3 (Figure 8A). Flow cytometry analysis in parallel samples identified activated (GFAP⁺) Müller cells as the primary source of trans-membrane ST2 in the light-exposed retina (Figure 8B), while ST2 was not detectable on Müller cells before light exposure. ST2 was not detected on CD11b⁺CD45^{lo} microglia (Figure 8B), RGCs, or photoreceptors.

An analysis was performed to determine whether IL-33 binding to ST2 impacts photoreceptor survival following CLE. Spectral Domain Optical Coherence Tomography (SD-OCT) demonstrated sparing of retina in ST2^{-/-} compared to ST2^{+/+} mice following 7 days (Figure 8C) and 14 days (Figure 8D) of CLE. Flow cytometry of total retina further confirmed that rods, cones, and ganglion cells were protected in ST2^{-/-} vs ST2^{+/+} mice during CLE for 14 days (Figure 8E). Morphometric analysis on sections through the eye showed significant protection of photoreceptors in ST2^{-/-} mice after retinal phototoxic injury in both the superior and inferior halves of the retina (Figure 8F). Electroretinograms (ERG) were recorded at day 7 following CLE and demonstrated that sparing of retina cells in ST2^{-/-} compared to ST2^{+/+} mice translated to improved a- and b-wave responses, reflecting improvement of retina function (Figure 8G). In contrast to retinas of ST2^{-/-} mice, retinas of IL-1R1^{-/-} and IL-18R1^{-/-} mice that lack the

receptors for IL-1 α , IL-1 β , and IL-18, respectively, were not protected compared with wild-type littermates following CLE (Figure 8D).

To further determine whether pharmacological blockade of the ST2/IL-33 interaction protects photoreceptors, mice were treated with a recombinant adeno-associated virus (AAV) expressing soluble ST2 (AAV-sST2) followed by CLE. Blocking activity of sST2 was verified in IL-33-stimulated bone marrow-derived mast cells (BMMC) (Figure 9A). ELISA and Western blot analysis confirmed the expression of sST2 in AAV infected HEK293 cells (Figure 9B). Subretinal injection of AAV-sST2 led to high level expression of sST2 in the retina and RPE (Figure 9C). Light-exposed mice treated with AAV-sST2, but not control vector, showed protection of rods, cones, and ganglion cells (Figure 10). These results demonstrate that IL-33 binding to its signalling receptor ST2/IL1RAcP results in a pathogenic response that leads to photoreceptor loss in the light-exposed retina.

D. IL-33 increases recruitment of myeloid cells to the photoreceptor layer

To determine which pathways downstream of ST2/IL1RAcP signaling cause photoreceptor loss, micro-array analysis of retinas of ST2^{+/+} and ST2^{-/-} mice exposed to constant light for 3 days was performed. Following CLE, the retinas of ST2^{+/+} mice displayed an overall increase in signatures of inflammation compared to ST2^{-/-} mice, including CCL2, IL-1 β , IL-6, IRF1, IRF7, and STAT3 (Figures 11A and 11B). Real-time PCR confirmed increased expression of CCL2, IL-1 β , and IL-6, with significantly lower expression in ST2^{-/-} mice compared to ST2^{+/+} mice (Figure 11C). Consistent with the mRNA expression data, CCL2 protein expression in the retina was reduced in ST2^{-/-} compared with ST2^{+/+} mice following CLE (Figure 11C).

An analysis was performed to determine whether IL-33 induces CCL2 expression in Müller cells. Consistent with the *in vivo* results described above, rMC-1 cells expressing the Müller cell activation marker GFAP expressed trans-membrane, surface-exposed ST2 (Figure 11D). When stimulated with recombinant IL-33, rMC-1 cells showed a dose-dependent increase in CCL2 expression, which was blocked by addition of IL-33 TRAP, confirming that IL-33 signals through ST2 on Müller cells (Figure 11D). In addition to IL-33, rMC-1 cells expressed and secreted CCL2 over time when cultured in high-glucose medium (Figure 11E). Neutralizing IL-33 secreted by Müller cells by addition of IL-33 TRAP to the culture medium significantly reduced CCL2 expression compared to rMC-1 cells cultured in the presence of vehicle (Figure 11E). These results demonstrate that Müller cells in culture release bioactive IL-33 that in turn can induce CCL2 through autocrine activation.

Both CD11b⁺CD45^{lo} (Figure 12A and Figure 13D) and CD11b⁺CD45^{hi} (Figure 13D) cells in the retina express CCR2, the receptor for CCL2 (Figure 12A). To determine whether IL-33 had any effect on myeloid cell distribution in the retina, Iba1⁺ myeloid cells in each retinal layer were quantified before and after CLE in ST2^{+/+} and ST2^{-/-} mice. Before light exposure, Iba1⁺ cells populated the inner plexiform layer (IPL) and outer plexiform layer (OPL), with very few cells in the ONL, outer segment (OS), and retinal ganglion cell layer (GCL) (Figure 12B). After CLE for 14 days, Iba1⁺ cells accumulated in the ONL, OS, and GCL, with a concomitant reduction of Iba1⁺ cells in the OPL and IPL in ST2^{+/+} mice. ST2^{-/-} mice showed a 40-50% reduction of Iba1⁺ cells in the ONL and OS, and a 50% increase in Iba1⁺ cells in the OPL compared to ST2^{+/+} mice (Figure 12C). Therefore, following CLE, ST2/IL1RAcP signaling promoted

CCL2 expression, increased presence of Iba1⁺ myeloid cells in the outer retina layers, and loss of photoreceptor rods and cones. These results expand on a previously proposed role for Müller cell-secreted CCL2 in promoting myeloid cell presence in the ONL and induction of photoreceptor death following light-injury or retina detachment.

To determine whether IL-33/ST2-induced photoreceptor loss upon light exposure is mediated by infiltrating myeloid cells, we depleted peripheral monocytes in ST2^{+/+} and ST2^{-/-} mice with clodronate and quantified the number of photoreceptors and ganglion cells after 7 days of CLE. Clodronate treatment depleted Ly6C^{hi}CD115⁺ and Ly6C^{lo/-} CD115⁺ peripheral monocytes by greater than 80% and 70%, respectively (Figure 12D). Monocyte depletion resulted in protection of rods, cones, and RGC following CLE in ST2^{+/+} mice (Figure 12E). However, ST2 deficiency did not provide further protection for photoreceptors when monocytes were depleted, indicating that infiltrating myeloid cells mediate IL-33/ST2-induced photoreceptor loss.

To further determine whether IL-33 released from Müller cells has a pathogenic role, a genetically modified mouse in which the N-terminal nuclear localization signal and chromatin binding domain of IL-33 are replaced with dsRed (IL33^{tm1/tm1} mice) was analyzed (Bessa et al. *J. Autoimmunity* 55: 33-41, 2014) (Figure 12F). Similar to IL33^{tm2/tm2} mice, the IL33^{tm1/tm1} mice showed dsRed staining selectively in Müller cells of the neural retina. However, in contrast to IL33^{tm2/tm2} mice, where dsRed is anchored to the nucleus via the IL-33 N-terminus, replacing the IL-33 N-terminus with dsRed in IL33^{tm1/tm1} mice prevented IL-33 anchoring to the nucleus, resulting in release of dsRed-IL-33-C-term into the cytoplasm of Müller cell processes spanning the inner nuclear layer (Figure 12F). Compatible with IL-33 transcription remaining under control of the endogenous promoter (Bessa et al., *supra*), IL-33 mRNA in the retina was unaltered in IL33^{tm1/+} and IL33^{tm1/tm1} mice compared to IL33^{+/+} littermate mice, while IL-33 protein in serum and retina was elevated (Figure 12F) due to spontaneous release of IL-33 lacking the N-terminus. In further agreement with a pathogenic role of the IL-33 axis, retina from the IL33^{tm1/+} and IL33^{tm1/tm1} mice showed increased CCL2 and IL-6 expression and loss of photoreceptor cones and ganglion cells when the mice expressed the ST2 receptor chain (ST2^{+/+} background) (Figure 12G). CCL2 and IL-6 expression and retinal cell loss were restored to control values in IL33^{tm1/+} and IL33^{tm1/tm1} mice lacking ST2 (Figure 12G). These results indicate that IL-33, when deprived of its capacity to localize to the nucleus, is released from the cell and induces ST2-dependent cytokine and chemokine release, along with death of retinal cells.

E. Circulating monocytes homing to the retina are required for IL-33/ST2-induced photoreceptor cell loss following retinal pigment epithelium disruption

The retinal pigment epithelium (RPE) performs an important role in photoreceptor homeostasis through ingestion and recycling of photoreceptor outer segments, inactivating toxic visual cycle products, and fulfilling the metabolic demand of the retina. The RPE also maintains the outer blood-retina barrier integrity (see, e.g., Strauss, "The Retinal Pigment Epithelium." In *Webvision: The Organization of the Retina and Visual System* (Kolb et al., eds.) 1995). Loss of RPE cells has been proposed to be causal to photoreceptor loss in both wet and dry forms of AMD (see, e.g., Bhutto et al. *Molecular Aspects of*

Medicine 33:295-317, 2012). Sodium iodate (NaIO_3) is an oxidizing compound that irreversibly affects RPE cell survival upon systemic administration (Carido et al. *Invest. Ophthalmol. Vis. Sci.* 55:5431-5444, 2014), allowing investigation of the role of retinal pathways important in photoreceptor loss secondary to RPE cell death.

Systemic administration of NaIO_3 resulted in elimination of the majority of RPE cells in the central retina by day 3. This was accompanied by loss of photoreceptor outer nuclear cells, activation of Müller cells (Figure 13A), and by the increased presence of 19-kDa processed form of IL-33 (IL-33p19) in the neural retina, peaking at day 3 following treatment (Figure 13B). Treatment with NaIO_3 also resulted in a >1500-fold increase in CCL2 (Figure 13C). The increase in CCL2 protein levels due to NaIO_3 administration was attenuated by approximately 35% in mice lacking ST2 (Figure 13C). Given that IL-33 stimulation of Müller cells induced CCL2, a chemo-attractant for myeloid cells, an analysis was performed to determine whether blockade of IL-33 affected the number of myeloid cells in the retina. Treatment of $\text{ST2}^{+/+}$ mice with NaIO_3 resulted in a >20-fold increase in the number of $\text{CD45}^{\text{hi}}\text{CD11b}^+\text{CCR2}^+$ myeloid cells present in the retina, peaking at day 3. $\text{ST2}^{-/-}$ mice showed a ~70% and ~50% attenuated increase in $\text{CD45}^{\text{hi}}\text{CD11b}^+\text{CCR2}^+$ myeloid cell numbers at day 3 and day 7, respectively, following NaIO_3 treatment compared to $\text{ST2}^{+/+}$ mice (Figure 13D). In contrast, the numbers of $\text{CD45}^{\text{low}}\text{CD11b}^+\text{CCR2}^+$ microglia dropped over 5-fold in both $\text{ST2}^{+/+}$ and $\text{ST2}^{-/-}$ mice at day 3 following NaIO_3 treatment and did not recover at day 7. Immunohistochemistry analysis of Iba1^+ cells showed approximately 50-60% reduction of infiltrating Iba1^+ myeloid cells in OS and ONL in $\text{ST2}^{-/-}$ mice compared to $\text{ST2}^{+/+}$ mice at day 3 after NaIO_3 treatment (Figure 13E). The neural retina of $\text{ST2}^{-/-}$ mice was protected following NaIO_3 treatment, as shown by significantly thicker retina in $\text{ST2}^{-/-}$ mice compared to $\text{ST2}^{+/+}$ mice at day 7 following NaIO_3 treatment (Figure 13F). Significant sparing of rods, cones, and retinal ganglion cells was further demonstrated by FACS analysis. In contrast to $\text{ST2}^{-/-}$ mice, the retina of $\text{IL-1R1}^{-/-}$ or $\text{IL-18}^{-/-}$ mice was not protected compared to WT mice at day 7 following NaIO_3 treatment (Figure 13G).

To determine whether infiltrating myeloid cells were required for IL-33-induced photoreceptor loss, peripheral myeloid cells in $\text{ST2}^{+/+}$ and $\text{ST2}^{-/-}$ mice were depleted with clodronate prior to NaIO_3 treatment, and the number of photoreceptors and ganglion cells at day 3 was quantified. Successful depletion of $\text{Ly6C}^{\text{hi}}\text{CD11b}^+\text{CCR2}^+$ and $\text{Ly6C}^{\text{lo}}\text{CD115}^+\text{CCR2}^+$ peripheral monocytes and $\text{CD45}^{\text{hi}}\text{CD11b}^+\text{CCR2}^+$ retina macrophages was confirmed by flow cytometry (Figures 13H and 13I). Clodronate-mediated myeloid cell depletion resulted in protection of the neural retina following NaIO_3 -induced RPE cell loss (Figure 13I). Similar to the results from monocyte depletion experiments in CLE, loss of ST2 did not result in further protection when myeloid cells were depleted, indicating that infiltrating macrophages were required for IL-33/ST2-induced photoreceptor loss when the RPE is disrupted.

In sum, using genetic and pharmacological approaches, these results demonstrated that IL-33 contributes to myeloid cell recruitment to the photoreceptor layer and retina cell loss. In both a light-induced injury model (CLE) and an RPE disruption model, IL-33 axis signaling promoted accumulation of myeloid cells in the ONL and OS layers of the retina. In a model of RPE cell loss, IL-33 axis signaling promoted the accumulation of myeloid cells in the retina. In both rodent models of retina injury and in

human AMD, accumulation of myeloid cells in the injured retina was anatomically associated with photoreceptor cell loss.

F. Materials and Methods

5 *Mice*

ST2 knock-out (ST2^{-/-}) BALB/c mice (eight generations) were obtained from MRC Laboratory of Molecular Biology, Cambridge, UK (see Townsend et al. *J. Exp. Med.* 191:1069-1076, 2000). ST2^{-/-} mice were backcrossed to the C57BL/6 background for ten generations to generate ST2^{-/-} C57BL/6 mice. IL33^{tm1/+} and IL33^{tm2/tm2} BALB/c mice were obtained from F. Hoffmann-La Roche Ltd., Basel, Switzerland (see Bessa et al. *J. Autoimmunity* 55: 33-41, 2014). Due to significant morbidity and mortality of IL33^{tm1/+} mice, IL33^{tm1/+} mice were crossed with ST2^{-/-} BALB/c mice and maintained on the ST2^{-/-} background. IL33^{tm1/tm1} ST2^{+/-} mice were generated by breeding female IL33^{tm1/+} ST2^{-/-} mice with male IL33^{tm1/+} ST2^{+/-} mice. IL-1R1^{-/-} (Il1r1^{tm1mx}), IL-18R1^{-/-} (Il18r1^{tm1Aki}) and IL-18^{-/-} (Il18^{tm1Aki}) C57BL/6 mice were purchased from The Jackson Laboratory. IL-1R1^{-/-} and IL-18R1^{-/-} mice were backcrossed to the BALB/c background by speed congenics to generate IL-1R1^{-/-} and IL-18R1^{-/-} BALB/c mice (nine generations), respectively. Sprague-Dawley rats were purchased from The Charles River Laboratories. All animals were housed in a pathogen-free animal facility with a 12/12 h light/dark cycle at Genentech, Inc, and littermates were used in experiments. Animal experiments were conducted in accordance with protocols approved by the Genentech Institutional Animal Care and Use Committee and with the Association for Research in Vision and Ophthalmology (ARVO) Statement for the Use of Animals in Ophthalmic and Vision Research.

Recombinant Proteins

Recombinant mouse IL-33 (a.a. 109-266) was purchased from R&D Systems. Recombinant rat IL-33 (a.a. 109-264) was generated by subcloning a rat cDNA fragment encoding amino acids 109-264 of IL-33 into a pET28 vector (Novagen). The protein was expressed in *E. coli* and purified by Ni-NTA chromatography followed by gel filtration. Recombinant sST2 was generated by subcloning of mouse soluble ST2 (a.a. 1-337) into a pRK5 expression vector with a 8x-histidine (His) tag at the C-terminus. The fusion protein expressed in CHO cells was purified by Ni-NTA chromatography followed by SUPERDEX® 200 gel filtration. The neutralizing activity of sST2 was verified by blockade of cytokine production from IL-33-stimulated bone marrow-derived mast cell (BMMC). BMMCs were generated and stimulated with IL-33 as described (Moulin et al. *Cytokine* 40:216-225, 2007). Briefly, 10⁵ cells were stimulated with 1 ng/ml IL-33 in the presence of 20 µg/ml sST2 or a control His-tagged protein in 200 µl RPMI-1640 culture medium in 96-well plates for 24 h. Culture supernatant was collected for measurement of IL-6 and IL-13 by ELISA (R&D Systems). Recombinant IL-33 TRAP in which the extracellular domain (ECD) of ST2 was heterodimerized with the ECD of IL1RAcP was generated using knobs-in-hole technology (see, e.g., U.S. Patent No. 5,731,168 and Merchant et al. *Nature Biotechnology* 16:677-681, 1998). A pRK5 expression vector encoding the ECD of mouse ST2 (a.a. 26-328) with a C-terminal mIgG2a Fc fragment containing "knob" mutations was co-transfected into CHO cells with a pRK5 expression vector encoding the ECD of mouse IL1RAcP (a.a. 21-350) with a C-terminal mIgG2a Fc

fragment containing "hole" mutations. The fusion protein was purified by MabSURE SELECT column (GE Healthcare) and SUPERDEX® 200 gel filtration.

Constant Light Exposure (CLE)

5 Male BALB/c mice aged 8-12 weeks or Sprague-Dawley rats aged 6-8 weeks were kept in normal housing with light intensity of <100 lux (used as baseline, d0). For light exposure, animals were housed singly in slightly modified normal cages covered with only a flat wire rack with no filter lid. To avoid disruption of light entering the cages, food pellets were placed on the bottom of cages and water was provided through a water bottle attached to the side of the cages. Retinal degeneration was induced by placing the cages on the shelves of a Metro rack outfitted with 48" fluorescent cool white lights above each shelf. The rack was also enclosed in hanging white panels to reflect light evenly back to shelves. Shelf height was adjusted in relation to light source so that light intensity on each shelf was ~1200 lux as measured by a luminometer. Cages were rotated within each shelf and between shelves during CLE to ensure equal light exposure. Animals were exposed to light for various days as indicated before evaluation.

RPE Damage-Induced Retinal Degeneration

Male C57Bl/6 mice aged 6-8 weeks were intravenously injected with 20 mg/kg body weight of sodium iodate (NaIO₃) (Sigma). The dosage of NaIO₃ was chosen based on previous dose titration experiments assessing RPE damage by fundus imaging and retina thickness change by OCT. Retinas were evaluated 3 or 7 days after NaIO₃ injection as indicated. Mice injected with equal volume of saline served as controls.

Spectral Domain Optical Coherence Tomography (SD-OCT)

25 After CLE, retinal thickness was measured by SD-OCT using the SPECTRALIS® HRA+OCT system (Heidelberg Engineering). To adjust for rodent optics, the system was modified according to the manufacturer's recommendations with a 55° wide field lens placed in front of the camera. Mice were anesthetized by intraperitoneal injection of ketamine (70-80 mg/kg body weight) and xylazine (15 mg/kg body weight). Pupils were dilated with drops of Tropicamide Ophthalmic Solution USP 1% (Bausch & Lomb). Drops of artificial tear were applied bilaterally to prevent corneal dehydration during the procedure. Horizontal volume scans through the region dorsal-temporal from the optic nerve (superior quadrant) were used to evaluate the retina thickness. Total retina thickness was defined as the width from the inner limiting membrane (ILM) to the RPE/choroid layer on the cross-sectional images, and measured using custom automated image segmentation routines in MATLAB® (MathWorks).

Electroretinography (ERG)

ERG recordings were performed with the ESPION²™ electrophysiology system (Diagnosys). Mice were dark-adapted overnight before ERG recording, and all procedures were performed under dim red light. Mice were anesthetized and their pupils dilated as described above. Body temperature was

maintained using a homeothermic plate and held at 37°C. A reference electrode was inserted subcutaneously through the forehead and a ground electrode was inserted subcutaneously in the lumbar region. A gold-ring electrode (mouse electrode 1.5 mm \varnothing 3.2 mm) (LKC Technologies) was placed on the corneal surface of each eye. A drop of GONIOVISC™ Hypromellose Ophthalmic Demulcent Solution 2.5% (HUB Pharmaceuticals) was applied on the cornea to establish an electrical contact between the cornea and the electrode, and to maintain corneal moisture during the procedure. The mice were placed in a platform covered with a COLORDOME™ light stimulator. Eyes were stimulated with white light of three flash intensities (0.05, 1, and 25 cd·s/m²) in five flashes per intensity. Maximum rod recovery between consecutive flashes was allowed by introducing an inter-stimulus interval ranging from 15 s at the lowest stimulus intensity to 1 min at the highest stimulus intensity. Signals were bandpass-filtered at 0.15-1000 Hz and sampled at 2 kHz. Between animals, electrodes were cleaned using ethanol wipes followed by rinsing in sterile PBS. After ERG, ophthalmic ointment was topically applied on the cornea to prevent desiccation. All of the recorded data points were analyzed using custom MATLAB® software (Mathworks) with a-wave amplitude measured from the baseline to the trough of the a-wave while b-wave amplitude from the trough of the a-wave to the peak of the b-wave. Responses to 3-5 flashes of light stimulation were averaged.

Clodronate Depletion of Monocytes/Macrophages

To deplete monocytes/macrophages, a dose of 1 mg in 200 μ l volume of liposome-encapsulated clodronate (Encapsula Nano Sciences) was administered intravenously daily starting 2 days or 1 day prior to CLE or NaIO₃ treatment, respectively. Control mice received the same volume of control liposomes. To monitor systemic monocyte depletion, blood was collected by cardiac puncture under anesthesia with isoflurane. Erythrocytes were removed from whole blood samples with ACK (Ammonium-Chloride-Potassium) Lysing Buffer (Life Technologies). The cells were then resuspended in flow cytometry buffer, Fc blocked, stained with allophycocyanin (APC)-conjugated anti-CD115 (clone AFS98, eBioscience), fluorescein isothiocyanate (FITC)-conjugated anti-Ly6C (clone AL-21, BD Biosciences) and phycoerythrin (PE)-conjugated anti-CCR2 (R&D systems), and analyzed by flow cytometry.

Subretinal injection of AAV vectors

The AAV2/5 vector encoding mouse sST2 (a.a. 1-337)-8xHis (SEQ ID NO: 332) under the control of the ubiquitous CAG promoter was custom-made by Vector Biosystems. The amino acid sequence of mouse sST2 (a.a. 1-337)-8XHis is provided in SEQ ID NO: 333. Viral activity was verified by infection of HEK293 cells with multiplicity of infection (MOI) of 10⁵ genome copies (GC)/cell. Culture supernatant was harvested 6 days post-infection and analyzed for sST2 secretion by ELISA (R&D Systems) and Western blotting using the goat anti-mouse ST2 Ab (AF1004, R&D Systems). Infection with an AAV empty vector was used as a negative control. For subretinal injection of AAV, mice were anesthetized with ketamine/xylazine and pupils dilated as described above. Under a dissecting microscope, a small incision was made with a 30-gauge needle in the sclera near the junction with the cornea. 1 μ l of AAV suspension containing 10¹² GC/ml was injected into the subretinal space of the right eye through the

incision using a blunt 33-gauge Hamilton needle and an auto-injection device. After injection, a triple antibiotic (neomycin, polymyxin B, and Bacitracin) ophthalmic ointment was applied topically to prevent infection and drying of the eye prior to recovery from anesthesia.

5 *Vitreous and Retina Tissue Collection*

To collect vitreous from rat eyes, rats were euthanized by CO₂ asphyxiation and enucleated. After removal of the cornea, the anterior chamber fluid was absorbed with a SUGI® wedge-shaped absorbent swab (Kettenbach Medical). The lens with the vitreous body attached was carefully pulled out from the posterior chamber using an angled microsurgical forceps. The lens-vitreous tissue was placed
 10 into a filtered centrifugation tube (Costar) containing 20 µl of protease inhibitor cocktail (Roche) dissolved in PBS and centrifuged at 14,000 x G for 5 min at 4 °C. The vitreous was collected as the eluent from the lower chamber. The retina was separated from the sclera and pigment epithelium and rinsed in PBS. The retina was either dissociated for flow cytometry analysis or homogenized for ELISA and Western blotting. Retina was homogenized in the cell lysis buffer (Cell Signaling) using a tissue homogenizer
 15 (IKA). The retina and RPE/choroid homogenate was centrifuged at 14, 000 x G for 10 min at 4 °C and the supernatant was collected. The vitreous and retina tissue lysates were stored at -80 °C until analysis.

Flow cytometry

Retina was isolated as described above and digested with Earle's balanced salt solution (EBSS)
 20 containing 20 IU/ml papain and 200 IU/ml DNase (Worthington Biochemicals) for 30 min at 37 °C. Tissue was dissociated by gentle pipetting. Papain digestion was terminated by resuspending the retinal cells in EBSS containing the ovomucoid protease inhibitor (Worthington Biochemicals). Total retinal cells were quantified by mixing an aliquot of single cell suspension 1:1 with a standard concentration of 6 µm FLUORESBRITE® YG microspheres (Polysciences) followed by counting on an LSRFORTESSA™ flow
 25 cytometer (BD Biosciences). Live cells were gated on propidium iodide-negative (PI⁻) cells. Primary retinal cells were resuspended in flow cytometry buffer (PBS containing 0.5% bovine serum albumin and 2 mM EDTA, pH 8) and incubated with anti-CD16/CD32 (BD Biosciences) for 30 min to block non-specific staining. Mouse retinal cells were stained with PE-CY7®-conjugated anti-CD11b (clone M1/70, BD Biosciences), APC-conjugated anti-CD90.2 (clone 53-2.1, BD Biosciences), ALEXA FLUOR® 700-
 30 conjugated anti-CD45 (clone 30-F11, BioLegend), FITC-conjugated anti-ST2 (clone DJ8, MD Bioproducts), PE-conjugated anti-CCR2 (R&D systems), and FITC-conjugated anti-Ly6C and PE-conjugated anti-CD115 (clone AFS98, eBioscience). Rat retinal cells were stained with PE-CY7®-conjugated anti-CD11b/c (clone OX-42, BD Biosciences), APC-conjugated anti-CD90 (clone OX-7, BD Biosciences), and/or ALEXA FLUOR® 700-conjugated anti-CD45 (clone OX-1, BioLegend).

35 To detect intracellular markers for both mouse and rat, the following fluorophore-conjugated antibodies were generated using the antibody conjugation kits (Abcam) according to manufacturer's instructions: PE-conjugated anti-cone arrestin (CAR) (EMD Millipore), PE- CY7®-conjugated anti-rhodopsin (Rho) (clone 1D4, EMD Millipore), PerCP-CY5.5®-conjugated anti-glial fibrillary acidic protein (GFAP) (clone GA5, Thermo Scientific). ALEXA FLUOR® 647-conjugated anti-vimentin (clone D21H3)

was purchased from Cell Signaling Technology. Cells were stained with violet fixable viability dye (Life Technologies), fixed and permeabilized by using INTRAPREP™ permeabilization reagent (Beckman Coulter) according to the manufacturer's instructions. Cells were then stained with the antibody cocktail for 30 min and washed and analyzed on the LSRFORTESSA™ flow cytometer. Staining of ST2, vimentin, and GFAP in rMC-1 cells was performed in the same way as described for the primary retinal cells. All data was acquired with BD FACSDIVA™ software and analyzed with FLOWJO® software (FlowJo). Total numbers of rods (Rho^+CAR^-), cones (Rho^-CAR^+), ganglion cells ($\text{CD90}^+\text{CD45}^-$), microglia ($\text{CD11b}^+\text{CD45}^{\text{lo}}$), and macrophages ($\text{CD11b}^+\text{CD45}^{\text{hi}}$) were calculated by multiplying the percentage of each cell type with total live retinal cells.

rMC-1 stimulation

rMC-1 cells (Kerafast) were maintained in low glucose (5.5 mM) in Dulbecco's modified Eagle's medium (LG-DMEM) with 10% heat-inactivated fetal bovine serum (FBS), 100 U/ml penicillin, and 100 µg/ml streptomycin. For high-glucose stimulation, 5×10^5 cells were cultured in 2 ml of LG-DMEM with 2% FBS in a 6-well plate at 37°C overnight. The medium was replaced by either LG-DMEM or high-glucose (25 mM)-containing DMEM (HG-DMEM) with 2% FBS and cultured for up to 72 h. Cell viability was determined by staining the cells with annexin V and propidium iodide (PI) using the FITC Annexin V Apoptosis Detection Kit (BD Biosciences) according to the manufacturer's instructions. Culture supernatant was harvested and IL-33 expression was analyzed by ELISA and Western blotting. For IL-33 stimulation of rMC-1 cells, 2×10^5 cells were cultured in 1 ml of LG-DMEM with 10% FBS in a 12-well plate and stimulated with rat IL-33 (1, 10, or 100 ng/ml) for 24 h. ST2-dependent activity of IL-33 on rMC-1 cells was determined by stimulating the cells with IL-33 in the presence of 10 µg/ml IL-33 TRAP or a control Fc protein. CCL2 levels in the culture supernatant were measured by ELISA. To determine autocrine activity of IL-33 in rMC-1 cells, cells were stimulated with high-glucose medium as described above in the presence of 10 µg/ml IL-33 TRAP or a control Fc protein for various time as indicated. RNA and culture supernatant were collected for CCL2 expression by qPCR and ELISA respectively.

ELISA

IL-33 concentrations in the vitreous, retina lysate, serum, and rMC-1 culture supernatant were measured using the mouse/rat IL-33 QUANTIKINE® ELISA kit (R&D Systems). CCL2, IL-1α, IL-1β, ST2, IL-6, and IL-13 were quantified with QUANTIKINE® ELISA kits (R&D Systems). IL-18 was measured with mouse IL-18 ELISA kit (MBL International). Cytokine concentrations in the retina lysate were normalized to total protein content measured by BCA assay (Pierce Biotechnology). To assess IL-33 levels in the vitreous of AMD patients, patients diagnosed with AMD (1 male and 5 females, age 68-91, median age 79) and patients undergoing surgery for macular pucker (3 males and 9 females, age 56-79, median age 72) and macular hole (5 males and 16 females, age 46-75, median age 65) were acquired from Midwest Eye Institute, with approval from Western Institutional Review Board (WIRB) and written patient informed consent. Eye dissection and vitreous collection were performed as previously described (Loyet et al. *Invest. Ophthalmol. Vis. Sci.* 53:6628-6637, 2012). Transconjunctival pars plana vitrectomy was

performed under local anesthesia using a 25-gauge cannula (Alcon). IL-33 levels in the vitreous were measured using the human IL-33 QUANTIKINE® ELISA kit (R&D Systems).

Quantitative RT-PCR

5 Total RNA was isolated from retina and rMC-1 cells using the RNEASY® Plus Mini kit (Qiagen). First-strand cDNA was synthesized using the High-Capacity cDNA Reverse Transcription kit (Applied Biosystems). Quantitative PCR (qPCR) of IL-33, CCL2, ST2L, sST2, IL-6, IL-1 α , IL-1 β , IL-18, and GFAP was performed using the TAQMAN® Gene Expression Assay with verified primer and probe sets (Applied Biosystems) and the levels were normalized by expression of 18s rRNA (mouse) or β -actin (rat). To
10 examine potential alternative splice variants of IL-33 in rMC-1 cells and rat retina, RT-PCR was performed using PCR primers spanning the 5' untranslated region (5'-UTR) (exon 1) to the stop codon (exon 9) of the full-length IL-33 mRNA using the following primers: 5'-TTAAGACCAGCTATCTCCCATCA-3' (SEQ ID NO: 342) and 5'-ACGTTACATCTTAGAGAGCTTAAACA-3' (SEQ ID NO: 343). PCR was performed using the EXPAND™ High Fidelity PCR System (Roche) according to the manufacturer's instructions.
15 The resulting PCR products were analyzed by electrophoresis on 1% agarose gel.

Western blotting

Vitreous, retina lysates, or rMC-1 culture supernatants were separated by electrophoresis on NOVEX® SDS 4-20% Tris-Glycine polyacrylamide gels (Life Technologies) and transferred to
20 nitrocellulose membranes using the IBLOT® system (Invitrogen). After blocking, the membranes were probed with goat anti-mouse C-terminal IL-33 (AF3626, R&D Systems) that cross-reacts to rat IL-33, or rabbit anti-GAPDH (Cell Signaling), followed by probing with appropriate HRP-conjugated secondary antibodies (Jackson ImmunoResearch). Blots were processed by using ECL Plus Western blot detection reagents (GE Healthcare). Nuclear and cytoplasmic fractions of rMC-1 cells were prepared using the NE-
25 PER® Nuclear and Cytoplasmic Extraction reagent (Thermo Scientific) according to the manufacturer's instructions. Protein concentration was quantitated by the BCA protein assay. Equal amounts of protein were analyzed for IL-33 expression by Western blotting as described above. Subcellular fractionation of nucleus and cytoplasm was verified by probing the blot with mouse anti-HDAC2 and anti-HSP90 (EMD Millipore), respectively.

30

Microarray analysis

Total RNA was converted to double-stranded cDNA and then to CY® dye-labeled cRNA using an Agilent Fluorescent Linear Amplification kit. CY® dye-labeled cRNA was fragmented and hybridized to Agilent's whole mouse genome array as described in Agilent's In Situ Hybridization Kit Plus. All samples
35 were labeled with CY5® dye and hybridized against CY3® dye-labeled universal mouse reference. Following hybridization, the arrays were washed, dried, and scanned on Agilent's DNA microarray scanner. Array imaging data was analyzed using Agilent's Feature Extraction software 8.5. Raw feature extracted data were processed as previously described (Vander Lugt et al. *Nature Immunology* 15:161-167, 2014). Microarray data were filtered to include only a single probe per gene, selecting the probe

with the highest variance when multiple probes were present for a given gene (Bourgon et al. *Proc. Natl. Acad. Sci. USA* 107:9546-9551, 2010). Differential expression analysis was performed using the limma software package (Smyth, *Statistical Applications in Genetics and Molecular Biology* 3:Article 3, 2004). To identify genes differentially regulated in the ST2^{-/-} mice, probes up-regulated by CLE in ST2^{+/-} mice were identified, selecting probes that showed >1.5-fold change at a Benjamini-Hochberg adjusted P value of <0.01 (see, e.g., Hochberg et al. *Statistics in Medicine* 9:811-818, 1990). These probes were further filtered to those that showed >1.25-fold difference at a Benjamini-Hochberg adjusted P value of <0.05 between ST2^{+/-} and ST2^{-/-} mice.

Gene Ontology Analysis

Genes identified as differentially expressed were subjected to Gene Ontology analysis using the GOstats R package (Falcon et al. *Bioinformatics* 23:257-258, 2007). The set of genes differentially regulated by ST2^{+/-} and ST2^{-/-} mice was used as a test set, and the set of genes differentially regulated by CLE as the universe of genes to consider. The search was restricted to the biological process ontology, using a conditional test of significance. Gene Ontology terms that showed significant enrichment at a nominal (unadjusted) P value of 0.01 were selected.

RNA-seq

For RNA-seq analysis of human retina, post-mortem healthy donor eyes with no history of ocular diseases were acquired from the Lions Eye Institute with written donor informed consent. Donor eyes were enucleated 4 h or less post-mortem and preserved in RNALATER® immediately after collection. The macula is fully contained within the boundaries of superior and inferior temporal vascular arcades and is easily visualized. After the macula was dissected out from the peripheral fundus using dissecting scissors, the macular retina was separated from the RPE and choroid underneath the retina. Total RNA was isolated from the retina using RNEASY® Mini kit (Qiagen). RNA concentration was determined using a NANODROP™ 8000 Spectrophotometer. Samples preserved in RNALATER® usually yield high quality as assessed with an Agilent 2100 Bioanalyzer (Agilent Technologies). RNA-seq libraries were prepared using the TRUSEQ® RNA Sample Preparation kit (Illumina) according to the manufacturer's instructions and then sequenced by an Illumina HiSEQ® 2000 system (Illumina). Sequencing data analysis was performed as previously described (Durinck et al. *Nature Genetics* 47:13-21, 2015). Sequencing reads were mapped to the reference human genome (GRCh37), using the GSNAP short read aligner (Wu et al. *Bioinformatics* 26:873-881, 2010). Expression was measured in reads per kilobase per million total reads (RPKM) by normalizing the number of reads aligning to coding sequence in a given gene to the total length of the coding sequence and the total number of reads.

Histology and Immunohistochemistry

For morphometric analysis of the outer nuclear layer (ONL) thickness, eyes were fixed in Davidson's fixative (Electron Microscopy Sciences) for 24 h. Paraffin-embedded 5 µm sections covering the entire retina including the optic nerve were cut along the vertical meridian of the globe and stained

with hematoxylin and eosin (H&E). After mounting of the sections, slides were scanned using an Olympus NANOZOOMER® 2.0 HT digital slide scanner (Hamamatsu) running NDP Scan software with an Olympus Uplan SApo 0.75 NA 20x objective lens. Images were analyzed using custom automated image segmentation routines in MATLAB® (MathWorks).

Only sections cut through optic nerves were analyzed. The ONL thickness was measured at a distance of 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, and 1.0 mm starting from either side of the optic nerve head. For imaging of IL33^{tm2/tm2} and IL33^{tm1/tm1} flat-mount retina, eyes were fixed in 4% paraformaldehyde for 2 h and rinsed in PBS. Retina tissues were dissected intact from the globe and stained with 1 µg/ml DAPI (Invitrogen) in PBST buffer (1x PBS, 0.5% TWEEN®-20) for 2 h followed by five times of wash in PBST buffer and rinse in PBS. The retina was flat-mounted and imaged with a Nikon A1R confocal microscope using a 40x objective lens. Images in Figure 7M and Figure 12F were optimized by making minor adjustments to brightness and contrast using PHOTOSHOP® (Adobe). For IL-33 and vimentin co-staining of rat eyes, eyes were fixed in Davidson's fixative for 24 h, immersed in 70% ethanol, and processed for paraffin-embedding and sectioning. IHC staining of sections was performed on a Dako Autostainer platform (Dako). After rehydration, sections were treated in Dako Target Retrieval Solution (Dako). Sections were incubated with 5 µg/ml of a mouse monoclonal antibody (mAb) mAb to IL-33 (clone Nessy 1, Enzo Life Sciences) and 0.18 µg/ml rabbit mAb to vimentin (Cell Signaling Technologies) or negative control antibodies in blocking buffer for 1 h. After washing, the sections were incubated with PowerVision Poly-HRP anti-mouse IgG and Poly-AP anti-rabbit IgG (Leica Biosystems) for 30 min followed by detection with diaminobenzidine (DAB) and Fast Red/Naphthol Phosphate reagent (ScyTek). After counterstaining with hematoxylin, the sections were imaged with bright field microscopy. IL-33, GFAP, and Iba1 staining of mouse eyes were performed in the same way with a rabbit polyclonal antibody to GFAP (DAKO) at 1:500 and a rabbit polyclonal antibody to Iba1 (Wako Chemicals) (0.5 µg/ml). Microglia quantification was performed by manually counting the Iba1⁺ cells in each retinal layer along the full length of retinal sections cut in the vertical meridian including the optic disc. TUNEL staining of rat eye sections was performed with the APOTAG® Peroxidase In Situ Apoptosis Detection Kit (Chemicon) according to manufacturer's instructions.

For IHC analysis of human eyes, eyes from 7 normal donors (5 males and 2 females) with age range of 67-89 years and 7 AMD patients (2 males and 5 females) with age range of 82-92 years were obtained from the Lions Eye Institute with consent of the donors or donor families. Eyes were fixed and sectioned as described above. Fluorescent IHC co-staining of IL-33, vimentin, GFAP, Iba1, and PLVAP were performed using the antibodies to IL-33, vimentin, GFAP, and Iba1 as described above and an in-house mouse monoclonal antibody to PLVAP followed by staining with appropriate fluorescent dye-labeled secondary antibodies or fluorescent dye-TSA (tyramide signal amplification) and counterstaining with DAPI. Slides were scanned with the slide scanner as described above. Brightness was slightly adjusted for images in Figures 5A-5C, 5E, and 6A-6B using NDP view 2 software (Hamamatsu) to better visualize the signal, but all images within a panel were similarly modified. IL-33⁺ and Iba1⁺ cell quantification were performed by manually counting IL-33⁺ and Iba1⁺ cells along an approximately 500

µm-long region in the central and peripheral area of normal eyes or lesion and non-lesion area of AMD eyes.

Statistical Analysis

All data unless otherwise indicated were analyzed and graphed using Prism 6 software (GraphPad). Statistical analysis was performed using an unpaired two-tailed Student's *t*-test or ANOVA as indicated for comparison between groups. A P value of < 0.05 was considered significant.

Example 4. Blockade of both the IL-33 pathway and the IL-13 pathway leads to a greater inhibition of Type 2 inflammation in the lung compared to blockade of either pathway alone

A. Nippostrongylus brasiliensis model of Type 2 (Th2) inflammation

The cytokines IL-33 and IL-13 promote inflammation in Type 2 immune responses, with the majority of data supporting a role for IL-33 in regulating expression of IL-13. It is appreciated that the loss of either the IL-33 pathway or the IL-13 pathway attenuates Type 2 inflammatory responses, revealing non-redundant roles for the individual cytokines in vivo. However, it has been unclear whether the absence of the IL-33 signal impacts Type 2 immunity solely due to a reduction in IL-13, or due to inhibition of additional inflammatory pathways.

To address this question, ST2^{+/+} and ST2^{-/-} mice were challenged with agents that cause Type 2 inflammation in vivo, in the presence or absence of a neutralizing antibody to murine IL-13. The helminth *N. brasiliensis* causes an acute Type 2 inflammatory response in the lung and intestine, characterized by eosinophil mobilization into the tissues and Th2 cytokine production (IL-4, IL-5, IL-13) (see, e.g., *Frontiers in Immunology* 4(74):1, 2013). Both innate and adaptive immune pathways are required for anti-helminthic immunity. ST2^{+/+} mice were treated with anti-IL-13 or control anti-ragweed antibodies to evaluate the role of IL-13 in Type 2 lung inflammation (Figure 14A). Likewise, ST2^{-/-} mice were treated with control or anti-IL-13 antibodies to assess the contribution of IL-33, and the combined contribution of IL-13 and IL-33 in vivo. Consistent with previous reports (see, e.g., *Nature* 464:1367), *N. brasiliensis* infection caused robust eosinophilic inflammation in both the BALF and lung tissue of ST2^{+/+} mice, which was significantly diminished in the absence of ST2 (i.e., as shown in ST2^{-/-} mice). Similarly, treatment with a neutralizing antibody to IL-13 resulted in a significant reduction in BALF and tissue eosinophils. Surprisingly, the combined blockade of both IL-33 signaling and IL-13 led to a greater inhibition of eosinophil mobilization into the lung, with levels comparable to the naïve controls (Figure 14B). Furthermore, IL-13 was not detected in the BALF of the ST2^{-/-} mice, consistent with the role for IL-33 in IL-13 induction. In addition, combined blockade of both pathways led to a greater reduction IL-4 and IL-5 in BALF over blockade of either pathway alone (Figure 14C).

Material and Methods

Female ST2^{+/+} and ST2^{-/-} Balb/C mice aged 7-9 weeks were infected with 500 *Nippostrongylus brasiliensis* (*N. brasiliensis*) L3 larvae suspended in 200 µl of saline via subcutaneous injection on the

flank on day 0. After infection, animals were placed on polymixin b- and neomycin-medicated water for five days. Antibodies (200 µg/mouse in 200 µl of PBS) were administered via intraperitoneal (i.p.) injection on days -1, 1, 3, 6, and 8 post-infection (see Figure 14A). Animals were sacrificed on day 10 post-infection for analysis of lung inflammation. Bronchial lavage fluid (BALF) and perfused lung tissues were collected for flow cytometry and protein analysis. Naïve ST2^{+/+} and ST2^{-/-} mice were used as controls.

For lung tissue processing, perfused lungs were digested in 2 mg/ml Collagenase D (Roche) for 1 h at 37°C and dissociated using GENTLEMACS™ C tubes (Miltenyi) according to the manufacturer's instructions. Single-cell suspensions were incubated for 15 min with Fc Receptor Block (2.4G2; BD Pharmingen) before being stained with antibody for 30 min on ice. Eosinophils, neutrophils, and macrophages were analyzed with the following antibodies: biotinylated anti-CD45 (30-F11; eBioscience), allophycocyanin/Cy7–anti-CD11b (M1/70; BD Pharmingen), phycoerythrin/Cy7–anti-CD11c (HL3; BD Pharmingen), phycoerythrin–anti-Siglec-F (E50-2440; BD Pharmingen), allophycocyanin–anti-F4/80 (BM8; eBioscience), fluorescein isothiocyanate–anti-Gr-1 (RB6-8C5; BD Pharmingen), and followed by streptavidin PACIFIC ORANGE™ (S32365; Molecular Probes). BALF cytokines were measured by ELISA.

B. TNP-OVA study

The *N. Brasiliensis* infection model described above in Section A of this Example is an acute response to a pathogen, and is considered to not reflect the antigen-induced responses seen in chronic allergic inflammation. The question of redundancy between the IL-33 pathway and the IL-13 pathway in allergic inflammation was addressed using the well-characterized TNP-OVA sensitization/challenge model of airway inflammation. In this model, an adaptive immune response against the TNP-OVA antigen is mounted, characterized by eosinophil mobilization into the tissues, and T cell IL-5 and IL-13 cytokine production.

ST2^{+/+} and ST2^{-/-} mice were sensitized with TNP-OVA/Alum and challenged with TNP-OVA in the presence or absence of an anti-IL-13 blocking antibody. Consistent with studies using neutralizing reagents to IL-33 or ST2, the robust eosinophilic inflammation seen in ST2^{+/+} mice following TNP-OVA sensitization/challenge was significantly diminished in the ST2^{-/-} strain (see, e.g., *Exp. Lung Research* 40(2):66, 2014). As previously demonstrated, inhibition of IL-13 also attenuated accumulation of lung tissue eosinophils (Taube et al., *J. Immunol.* 169(11):6482, 2002). In agreement with the *N. brasiliensis* infection study described above in Section A of this Example, the combined blockade of both IL-33 signaling and IL-13 reduced eosinophil influx into the lung to levels seen in naïve mice (Figure 15A). Analysis of T cell responses to TNP-OVA antigen again revealed the absence of both pathways had a greater effect on IL-13 and IL-5 production over inhibition of each pathway alone (Figure 15B).

The in vivo studies described in this section and in Section A of this Example demonstrate that blocking both IL-33 and IL-13 had a greater effect on Type 2 lung inflammation compared to blocking either of the pathways individually, and highlight the non-overlapping functions of IL-33 and IL-13. The *N. brasiliensis* helminth infection leads to activation of innate and adaptive immune components, while the

TNP-OVA study is a classic model of the adaptive immune response to antigen. Although the models reflect different aspects of Type 2 inflammation, both stress the roles of IL-13 and IL-33 in mediating eosinophilic inflammation, with inhibition of both pathways completely abrogating this response. These data emphasize the additional functions of IL-33 that contribute to inflammation, and the additional benefit that blocking both IL-33 and IL-13 will bring to Type 2 immune disorders including IL-33-mediated disorders such as asthma.

Materials and Methods

Female ST2^{+/+} and ST2^{-/-} Balb/C mice aged 7-8 weeks were sensitized via intraperitoneal (i.p.) injection of 50 µg TNP-OVA and 2 mg alum in 100 µl PBS, on day 0 (Biosearch Technologies). Seven mice were used per group. Starting on day 35 post-sensitization, mice were challenged for 7 consecutive days with aerosol 1% TNP-OVA in PBS via a nebulizer. Anti-gp120 IgG1 or anti-mouse IL-13 IgG1 (100 µg/mouse in 200 µl of PBS) were administered i.p. on days 35-41 post-sensitization. Animals were sacrificed on day 42 for analysis of lung inflammation. BALF and perfused lung tissues were collected for flow cytometry and protein analysis. Mediastinal lymph nodes were collected for T cell recall assays. Naïve ST2^{+/+} and ST2^{-/-} mice were used as controls. BALF cytokines levels were measured by ELISA. Perfused lungs were digested in 2 mg/ml Collagenase D (Roche) for 1 hour at 37°C and dissociated using GENTLEMACS™ C tubes (Miltenyi) according to the manufacturer's instructions. Single-cell suspensions were incubated for 15 min with Fc Receptor Block (2.4G2; BD Pharmingen) before being stained with antibody for 30 min on ice. Eosinophils, neutrophils, and macrophages were analyzed with the following antibodies: biotinylated anti-CD45 (30-F11; eBioscience), allophycocyanin/Cy7–anti-CD11b (M1/70; BD Pharmingen), phycoerythrin/Cy7–anti-CD11c (HL3; BD Pharmingen), phycoerythrin–anti-Siglec-F (E50-2440; BD Pharmingen), allophycocyanin–anti-F4/80 (BM8; eBioscience), fluorescein isothiocyanate–anti-Gr-1 (RB6-8C5; BD Pharmingen), and followed by streptavidin PACIFIC ORANGE™ (S32365; Molecular Probes).

For the in vitro T cell recall assay, single-cell suspensions from mediastinal lymph nodes (3x10⁵ cells per well) were cultured for 6 days in the presence or absence of 100 µg/ml TNP-OVA (Biosearch Technologies) in RPMI 1640 media containing 10% FBS and supplemented with L-glutamine and penicillin/streptomycin. After 6 days, cell proliferation was measured by CELLTITER-GLO® Luminescent Cell Viability Assay (Promega) and supernatants were collected for cytokine level analysis via ELISA.

Example 5. Regulation of mast cell degranulation and cytokine secretion by IL-33

A. IL-33 augments antigen-induced mast cell degranulation in vitro and in vivo

Stimulation of mast cells with antigen-IgE complexes results in the rapid release of vasoactive and proinflammatory mediators from preformed granules. These mediators, which include histamines, proteases, and proteoglycans, serve as a first-line defense against invading pathogens. To determine whether IL-33 augments this response, mast cells were sensitized with IgE for 24 h, and stimulated with anti-IgE in the presence or absence of IL-33 for 1 h. While IL-33 did not induce degranulation by itself, it significantly augmented degranulation of β-hexosaminidase, tryptase, and histamine (Figure 16A).

To confirm IL-33-dependent augmentation of mast cell activation and degranulation in vivo, a model of passive systemic anaphylaxis was utilized. Following sensitization with anti-dinitrophenyl (anti-DNP) IgE for 28 h, ST2^{+/+} and ST2^{-/-} mice were challenged with DNP-HSA with or without IL-33. The anaphylactic response was measured as a decrease in body temperature over the course of 1 h (Figure 16B). Similar to the in vitro studies described above, in the absence of antigen, IL-33 did not promote the anaphylactic response (Figure 16C). Likewise, ST2^{+/+} and ST2^{-/-} displayed similar changes in body temperature following FcεRI (Fc epsilon RI) activation (Figure 16D). However, in agreement with the in vitro studies, the addition of IL-33 augmented the mast cell response, as demonstrated by the greater drop in body temperature compared to the control group (Figure 16E).

B. IL-33 amplifies antigen-induced mast cell cytokine secretion

In addition to degranulation, mast cells contribute to host defense through secretion of cytokines and chemokines. To evaluate the role of IL-33 in mast cell cytokine release, mast cells were sensitized with IgE for 24 hours, and stimulated with anti-IgE in the presence or absence of IL-33 for 72 h. Antigen stimulation resulted in IL-8 secretion, which was augmented by the addition of IL-33 (Figure 16F). FcεRI crosslinking alone did not result in secretion of IL-5 or IL-13 (Figure 16F). As reported earlier, IL-33 stimulated the release of IL-5 and IL-13, which was significantly increased with the addition of FcεRI stimulation. In addition, IL-33-mediated release of TNF-α and IL-10 from mast cells was observed (Figure 16G). Microarray analysis revealed that IL-33 induced a number of chemokines, cytokines, and growth factors (Figure 16H) (see, e.g., Nagarkar et al. *J. Allergy Clin. Immunol.* 136(1): 202-205, 2015). These results highlight the role of IL-33 in promoting mast cell responses and defense mechanisms.

C. Materials and Methods

In vitro mast cell assays

Mast cells were isolated as previously described (see, e.g., Nagarkar et al. *J. Allergy Clin. Immunol.* 136(1): 202-205, 2015). Peripheral blood-derived CD34⁺ cells derived from 10 donors were purchased from Stemcell Technologies (Vancouver, BC, Canada) and were differentiated into primary cultured in vitro CD34⁺ cell-derived human mast cells for a period of 12 weeks in the presence of IL-6 and SCF as described previously. At 0 weeks, the cells were suspended in serum-free Iscove's methylcellulose medium (METHOCULT™ SFBIT H4236, Stemcell Technologies) containing 200 ng/ml SCF, 50 ng/ml IL-6, 5 ng/ml IL-3, 11 μM 2-mercaptoethanol (2-ME, Invitrogen (Carlsbad, CA)), 100 U/ml penicillin, and 100 μg/ml streptomycin (Invitrogen), and then incubated at 37°C in 5% CO₂. At 2 weeks of culture, fresh methylcellulose medium containing 200 ng/ml SCF, 50 ng/ml IL-6, 11 μM 2-ME, 100 U/ml penicillin, and 100 μg/ml streptomycin was layered over the methylcellulose cultures. At 4 weeks of culture, a 1 ml aliquot of Iscove's Modified Dulbecco's Medium (IMDM), supplemented with 200 ng/ml SCF, 50 ng/ml IL-6, insulin-transferrin-selenium (Invitrogen), 55 μM 2-ME, 100 U/ml penicillin, and 100 μg/ml streptomycin was layered over the methylcellulose cultures. At 6 weeks of culture, all cells were retrieved after dissolving the methylcellulose medium with PBS. The cells were then suspended and cultured in IMDM supplemented with 100 ng/ml SCF, 50 ng/ml IL-6, 0.1% BSA, insulin-transferrin-

selenium, 55 μ M 2-ME, 100 U/ml penicillin, and 100 μ g/ml streptomycin, and the culture medium was replaced a week later. After an additional week of culture, the culture medium was switched to IMDM supplemented with 100 ng/ml SCF, 50 ng/ml IL-6, 5% FBS (Invitrogen), 55 μ M 2-ME, 100 U/ml penicillin, and 100 μ g/ml streptomycin. The culture medium was changed weekly thereafter, and the cells were incubated for an additional 5-7 weeks. By the end of 12 weeks, the majority of non-mast cells were expected to undergo attrition. The final purity of the mast cells was determined by measuring Fc ϵ RI expression using flow cytometry after 12 weeks of culture following 48 hours treatment with 1 μ g/ml myeloma IgE (EMD Millipore, Billerica, MA). The final purity of mast cells was 90 %. Mast cells from 10 independent donors were generated in this manner.

For microarray analysis of IL-33-stimulated mast cells, mast cells from two donors (1×10^6 cells/ml) were stimulated with 10 ng/ml IL-33 in duplicate for a period of 24 h. RNA was then collected for microarray analysis. For determining IL-33 responses, mast cells were stimulated with IL-33 as indicated (Figure 16A) for 48 h. Cell-free supernatants were collected for analysis of IL-5, IL-13, IL-4, IL-10, and TNF- α levels using Meso Scale Discovery Th1/Th2 10-plex panel (MSD, Rockville, MD) according to the manufacturer's instructions. For IL-33 and IgE crosslinking co-stimulation experiments, IgE-sensitized mast cells (0.5×10^6 cells/ml) were stimulated with IL-33 as indicated in the presence or absence of 10 μ g/ml anti-IgE (411520; EMD Millipore) and cell-free supernatants were collected after 72 h. Released cytokine levels were analyzed with ELISA kits for IL-8 (DY208; R&D systems), IL-5 (88-7056; eBioscience) and IL-13 (88-7439; eBioscience).

Degranulation

Human mast cell degranulation was measured as the percentage of β -hexaminodase, tryptase, and histamine released over the total cellular content. The calcium ionophore A23187 (C7522; Sigma Aldrich) was used a positive control at 10 μ M. Mast cells were sensitized with 2 μ g/ml purified human IgE (AG30P; EMD Millipore) for 24 hours. Sensitized mast cells were washed and resuspended at 6.25×10^6 cells/ml in Tyrode's buffer (10 mM HEPES, 130 mM NaCl, 6.2 mM D-glucose, 3.0 mM KCl, 1.4 mM CaCl₂, 1.0 mM MgCl₂, and 0.1% BSA). Mast cells (6.25×10^4 /well) were plated in triplicate in 96-well v-bottom plates and stimulated with 10 μ g/ml anti-IgE (411520; EMD Millipore) in the presence or absence of 100 ng/ml human IL-33 for 1 hour, in a final volume of 20 μ l. Cell supernatants were collected and cell pellets were lysed with 20 μ l of 0.5% TRITON™ X-100 in Tyrode's buffer. β -hexosaminidase release was assayed by using a fluorometric assay. Supernatants and cell lysates (10 μ l) were incubated for 1 hour with 50 μ l 4mM p-nitrophenyl-N-acetyl- β -D-glucosaminide (N9376, Sigma Aldrich) in 0.1 M citrate buffer, pH 4.5, and 150 μ l 0.2 M glycine was added to stop the reaction. Absorbance was measured at 405 nm in an ELISA reader. Tryptase levels and activity in supernatants and cell lysates were calculated using the Mast Cell Degranulation Assay Kit (IMM001; EMD Millipore) according to the manufacturer's instructions. Histamine levels in supernatants and cell lysates were assayed using a Histamine ELISA kit and following the manufacturer's instructions (409010; Neogen).

Passive Systemic Anaphylaxis

Female ST2^{+/+} and ST2^{-/-} Balb/C mice aged 7-8 weeks were sensitized with 200 µg of DNP-mouse IgE (Biosearch Technologies) in 200 µl of saline via intravenous injection (i.v.) on day 0. Five mice were used per group. After 28 hours, mice were challenged i.v. with 100 µg DNP-HAS (Biosearch Technologies), 2 µg murine IL-33 (R&D Systems), or the combination in 200 µl of saline. Body temperature was measured by scanning an implanted chip with a scanner at 5 minute intervals for 1 h post-challenge.

Gene expression analysis

RNA extraction and PCR were performed as previously described (see, e.g., Nagarkar et al. *J. Allergy Clin. Immunol.* 136(1): 202-205, 2015). Total RNA was extracted from mast cells using the Qiagen RNEASY® Kit (Germantown, MD). cDNA was generated from total RNA using ISCRIP™ Reverse Transcription Supermix from Bio-Rad (Hercules, CA). Amplification of cDNA was performed using TAQMAN® Gene Expression Assays (Applied Biosystems, Foster City, CA). Fold changes in gene expression, unless otherwise indicated, were compared to respective medium control. For microarray analysis, RNA from mast cell samples was submitted for Agilent single-round amplification.

Microarray Analysis and Statistics

Microarray and statistics were performed as described (see, e.g., Nagarkar et al. *J. Allergy Clin. Immunol.* 136(1): 202-205, 2015). The quantity and quality of total RNA samples were determined, respectively, using an ND-1000 spectrophotometer (Thermo Scientific, Wilmington, DE, USA) and Bioanalyzer 2100 (Agilent Technologies, Santa Clara, CA, USA). A CY® dye-labeled cRNA preparation and array hybridization were prepared according to the manufacturer's instructions (Agilent Technologies).

Briefly, total RNA sample was converted to double-stranded cDNA and then to CY® dye-labeled cRNA using an Agilent Quick Amp Labeling kit. The labeled cRNA was purified using an RNEASY® Mini kit (Qiagen). cRNA yield and CY® dye incorporation were determined using the ND-1000 spectrophotometer (Thermo Scientific). 750 ng of the labeled cRNA was fragmented and hybridized to Agilent Whole Human Genome 4 44K v2 arrays. All samples were labeled with CY®5 dye and hybridized against a CY®3 dye-labeled universal human reference (Stratagene, La Jolla, CA, USA). Samples were hybridized for 17 h at 65°C. Following hybridization, the arrays were washed, dried, and scanned using an Agilent scanner. The Agilent Feature Extraction software version 11.5 was used to analyze the acquired array images. All statistical calculations were performed using the R Project software package, version 2.15.1. Array quality control was assessed using arrayQualityMetrics package for R. Microarrays were normalized and probe intensities transformed using the vsn package of Bioconductor. Independent filtering of microarray data was conducted using the genefilter package to increase statistical power to detect true positives while maintaining type I error control.

As array features that are invariant or do not correspond to an Entrez gene transcripts are typically uninformative for differential gene expression analysis, filtering on the basis of annotation and expression variability was conducted. Briefly, filtering was conducted as follows: 1) only array features representing Entrez or CCGf genes were retained; 2) multiple array features corresponding to a single Entrez gene were reduced to a single array feature on the basis of highest inter-quartile range (IQR); and 3) linear model test statistics of gene expression microarray data was performed with the limma package of Bioconductor. In brief, this method utilizes an empirical Bayes approach equivalent to shrinkage of the estimated sample variances towards a pooled estimate, resulting in far more stable inference when the number of arrays is limited. Differential expression test statistics were estimated as a linear contrast of a model including treatment as a factor. Adjusted *P*-values to account for multiple hypothesis testing was addressed utilizing the method of Benjamini and Hochberg.

Example 6. Pro-inflammatory role for the IL-33 axis in the K/BxN serum transfer arthritis model

A. Loss of IL33 or ST2 ameliorates arthritic disease.

K/BxN serum contains autoantibodies to glucose-6-phosphate isomerase (GPI), which form immune complexes. Administration of these immune complexes to naïve immunocompetent mice induces pathology similar to rheumatoid arthritis, such as joint swelling, bone erosion, immune cell infiltration, and increase in cytokines and chemokines. This reaction is dependent on the innate immune system, including the alternative complement pathway, mast cells, and neutrophils. The non-redundant role of mast cells, in particular during disease initiation, was previously demonstrated (see, e.g., Lee et al. *Science* 297:1689-1692, 2002). Given the role for IL-33 in mast cell activation (as demonstrated in Example 6), disease activity was examined in IL33^{-/-} (Figure 17A) and ST2^{-/-} (Figures 17B-17D) mice. Consistent with previous reports, deficiency in ST2 resulted in reduced arthritis. A similar observation was seen in the IL33^{-/-} mice. These data expand on cellular studies demonstrating that IL-33 can affect multiple aspects of mast cell function, including pro-inflammatory cytokine secretion, survival, and degranulation.

B. Materials and Methods

Female ST2^{+/+} and ST2^{-/-} C57Bl/6 mice were generated by backcrossing the ST2^{+/+} and ST2^{-/-} Balb/C strain 10 generations. Mice aged 7-8 weeks were administered 20 µl of arthrogenic K/BxN serum on day 0 intravenously (i.v.). Ten mice were used per group. Serum was first tested to determine the optimal amount needed to induce arthritis in ST2^{+/+} mice. Paws were checked daily for evidence of arthritis. The extent of disease was scored by visual observation using the following metric:

0 = No evidence of erythema and swelling

1 = Erythema and mild swelling confined to the mid-foot (tarsal) or ankle

2 = Erythema and mild swelling extending from the ankle to the mid-foot

3 = Erythema and moderate swelling extending from the ankle to the metatarsal joints

4 = Erythema and severe swelling encompass the ankle, foot and digits

Data were plotted as the mean score, which is the sum of the 4 paw scores. Disease severity was determined using the following metric:

Mild (mean score 0-3)

Moderate (mean score 4-8)

Severe disease (mean score 9-above).

The mean score reflects the number of joints involved.

Female $IL33^{+/+}$ and $IL33^{-/-}$ C57Bl/6 mice aged 7-8 weeks were administered 70 μ l of arthrogenic K/BxN serum on day 0 intravenously (i.v.). Five mice were used per group. Serum was again tested to determine the optimal amount needed to induce arthritis in the $IL33^{+/+}$ strain. Scoring of disease activity was performed as indicated above.

Example 7. IL-33 induced macrophage recruitment into the lung is independent of IL-4, IL-5, and IL-13

The in vivo studies described herein exemplify the non-redundant role for IL-33 in promoting Type 2 inflammation, including, for example, eosinophil recruitment to tissues. However, IL-33 also induces other components of host defense that are not exclusively linked to Type 2 immunity. Macrophages, in particular, contribute to multiple aspects of anti-microbial responses and tissue homeostasis, including phagocytosis, cytokine and growth factor secretion, and wound repair. Central to their function is recruitment to the site of infection, which is mediated in part by cytokines such as IL-33.

To address whether IL-33-induced mobilization of macrophages into the lung is independent of Type 2 cytokines, and therefore indicative of a broader aspect of IL-33 function in immunity, mice were treated with IL-33 in the presence or absence of neutralizing antibodies to IL-4, IL-5, and IL-13 (Figures 18A-18C). Given the role for these cytokines in lung inflammation, BALF cellularity was analyzed. Consistent with the roles for these cytokines in eosinophil mobilization, IL-33-induced eosinophil infiltration into BALF was completely abrogated upon blockade of IL-4, IL-5, and IL-13 (Figure 18C). However, macrophage infiltration into the lung was not perturbed by this treatment (Figure 18B), emphasizing the unique properties of IL-33 beyond induction of IL-4, IL-5, and IL-13. Given the roles for macrophages in host defense, these data suggest alternative functions for IL-33 in vivo beyond the traditional Type 2 immune responses.

Materials and Methods

Female C57BL/6 mice aged 7-8 weeks were purchased from the Jackson Laboratory. Five mice were used per group. Recombinant mouse IL-33 (a.a. 109-266) was purchased from R&D Systems. A control group of animals received only saline treatments. From days 0-7, mice were injected intraperitoneally (i.p.) daily with either 100 μ g of control antibodies or with neutralizing antibodies to IL-4, IL-5, and IL-13 (anti-IL-4 and anti-IL-5 were from R&D Systems, anti-IL13 was generated in-house) (Figure 18A). On days 1 through day 7, mice were i.p. injected daily with 0.5 μ g of recombinant murine IL-33. Mice were euthanized on day 8 and Bronchial Lavage Fluid (BALF) was collected. Cell counts were assessed by flow cytometry analysis. BALF cells were incubated for 15 min with Fc Receptor Block

(2.4G2; BD Pharmingen) before being stained with antibody for 30 min on ice. Eosinophils, neutrophils, and macrophages were analyzed with the following antibodies: biotinylated anti-CD45 (30-F11; eBioscience), allophycocyanin/Cy7–anti-CD11b (M1/70; BD Pharmingen), phycoerythrin/Cy7–anti-CD11c (HL3; BD Pharmingen), phycoerythrin–anti-Siglec-F (E50-2440; BD Pharmingen), allophycocyanin–anti-F4/80 (BM8; eBioscience), fluorescein isothiocyanate–anti-Gr-1 (RB6-8C5; BD Pharmingen), and followed by streptavidin PACIFIC ORANGE™ (S32365; Molecular Probes).

Example 8. Characterization of anti-IL-33 monospecific and anti-IL-33/anti-IL-13 bispecific antibodies

We previously established a technology to generate human IgG1 bispecific antibodies with two different light chains in *E. coli* (Yu et al., 2011, *Sci Transl Med* 3, 84ra44). The method utilizes knobs-into-holes technology (see, e.g., U.S. Patent No. 5,731,168, Ridgway et al., 1996, *Protein Eng.* 9, 617–621; Atwell et al., 1997, *J Mol Biol* 270, 26–35, which are incorporated herein by reference in its entirety) to promote hetero-dimerization of immunoglobulin heavy chains. To enable the use of two different light chains without light chain mispairing, we cultured each arm as half antibodies in separate *E. coli* cells. We applied this approach to generate the anti-IL-13/IL-33 bispecific antibody by subcloning the anti-IL-33 and anti-IL-13 parental antibodies into vectors allowing the expression of the anti-IL-33 arm as a human IgG4 hole and of the anti-IL-13 arm as a human IgG4 knob.

A bispecific anti-IL-33/anti-IL-13 antibody referred to as 10C12.38.H6.87Y.58I/IL-13 IgG4 was generated using knob-in-hole (KIH) technology. The anti-IL-33 arm of 10C12.38.H6.87Y.58I/IL-13 IgG4 has a VH amino acid sequence of SEQ ID NO: 36 and a VL amino acid sequence of SEQ ID NO: 37, corresponding to antibody 10C12.38.H6.87Y.58I. The anti-IL-33 arm of 10C12.38.H6.87Y.58I/IL-13 IgG4 has a VH amino acid sequence of SEQ ID NO: 302 and a VL amino acid sequence of SEQ ID NO: 303. The anti-IL-33 arm of 10C12.38.H6.87Y.58I/IL-13 IgG4 has a heavy chain amino acid sequence of SEQ ID NO: 306 and a light chain amino acid sequence of SEQ ID NO: 307, and the anti-IL-13 arm of 10C12.38.H6.87Y.58I/IL-13 IgG4 has a heavy chain amino acid sequence of SEQ ID NO: 304 and a light chain amino acid sequence of SEQ ID NO: 305.

We based the anti-IL-13 CDRs of the bispecific antibody on lebrikizumab, which has been previously generated and characterized. See, e.g., PCT Publication No. WO 2005/062967. For the bispecific antibody, the anti-IL-13 antibody had two deviations in the FR region as compared to lebrikizumab: Q1E on heavy chain and M4L on the light chain.

For antibody expression, *E. coli* strain 64B4 was used. An overnight culture was grown at 30°C in LB (100 µg/ml carbenicillin), diluted 1:100 into 5 ml CRAP media (100 µg/ml carbenicillin) (Simmons et al., 2002, *J. Immunol. Methods*, 263: 133-147) and grown for 24 hours at 30°C.

For scale-up to 10L fermenters, initial starter cultures (500 ml) were grown into stationary phase and used to inoculate 10L fermentations (Simmons et al., 2002, *J. Immunol. Methods*, 263: 133-147). 10L fed-batch cultures were grown and whole broths were harvested via microfluidics. The lysed cells were then treated overnight at 4°C with a final concentration of 0.4% PEI (v/v). Each mixture was subsequently centrifuged at 15,000 x g for 20 minutes followed by filtration through a 0.22µm filter. The

IL-33 antibody was then captured at 4 °C on a 400 mL MabSURE SELECT column (GE Healthcare Life Sciences). The column was washed to baseline with 25 mM TRIS pH 7.5, 150mM NaCl, 2mM NaN₃ (TBS) followed by washes with TBS containing 0.1% Triton X-114 overnight, 0.4M KPO₄, 5 mM EDTA, 0.2% Polysorbate 20, 1 mM sodium azide, pH 7.0 and finally washing to baseline with TBS. The IL-33 arm was then eluted with 0.1 M Acetic acid pH 2.7 and the eluted pool titrated to pH 5.0 using 1M Arginine/Succinate pH 9.0.

The identity of the IL-33 and the IL-13 half antibodies were confirmed by liquid chromatography electrospray ionization with time-of-flight (LC-ESI/TOF) analysis. Purity was analyzed by 4-20% gradient Tris-Glycine SDS PAGE gel and aggregate levels were determined by SEC.

Following the assembly reaction with the two half antibodies, the bispecific antibody was purified by hydrophobic interaction, cation exchange and gel filtration chromatography. Specifically, for the assembly, the half antibodies were combined at a 1:1 molar ratio at pH 8.5 in arginine succinate with a 200 molar excess of GSH for 4 days at room temperature and followed by the addition of 5mM DHAA for 16 hours at 4 °C. This material was fractionated on a hydrophobic chromatography column (Thermo ProPac HIC-10) using an ammonium sulfate gradient containing 25% isopropanol at pH 6.5. The pool containing the IL-13/IL-33 bispecific antibody was then dialyzed into 20 mM Histidine, pH 5.5 (H buffer) and loaded onto a cation exchange column (SPFF, GE Healthcare Life Sciences), washed with H buffer containing 0.1% Triton X114, 0.1% Triton X100 overnight, washed to baseline with H buffer and then eluted with 300 mM Arginine succinate pH 5.5. The bispecific antibody fractions were pooled and loaded onto a size exclusion chromatography column (S200, GE Healthcare Life Sciences). The fractions containing the purified anti-IL-13/IL-33 bispecific were pooled, dialyzed and vialled.

The potency of a monospecific anti-IL-33 antibody (10C12.38.H6.87Y.58I IgG4) and the bispecific anti-IL-33/anti-IL-13 bispecific antibody 10C12.38.H6.87Y.58I/IL-13 IgG4 (also referred to herein as "10C12-IL-13 KIH IgG4") as inhibitors of human IL-33 cellular activity was examined using both a cell-based blocking assay using a reporter cell line and in primary human cells. The monospecific anti-IL-33 IgG4 and the bispecific anti-IL-33/anti-IL-13 IgG4 formats were tested against the cellular potency of a decoy receptor, ST2-LZ.

Stimulation of HEK-BLUE™ IL-33 cells with IL-33 results in robust NF-κB and AP-1 activation, which was measured by NF-κB/AP-1-driven SEAP reporter activity. Activity was not perturbed by the addition of the control IgG4 antibody. Both the monospecific anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and the bispecific antibody 10C12-IL-13 KIH IgG4 displayed potent dose-dependent inhibition of IL33 activity, with IC₉₀ values of 102.1 and 204.7 pM, respectively (Figure 19A). As expected, the IC₉₀ value for the bispecific antibody activity was approximately half of the value obtained for the monospecific counterpart. Both clones displayed greater inhibition over the decoy receptor, ST2-LZ (see Example 2).

In addition to the cell-based blocking assay using HEK-BLUE™ cells, the monospecific anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and the bispecific antibody 10C12-IL-13 KIH IgG4 were tested for inhibition of IL-33 activity in primary cells. Addition of IL-33 to human basophils results in rapid phosphorylation of the signaling molecule p38, which can be measured by flow cytometry using intracellular staining methods (Figure 19B). By adding the CD123 marker, basophil activity can be

examined within the bulk peripheral blood monocyte (PBMC) population, obviating the need for cell isolation (Figure 19B). Using this flow cytometry-based methodology, the monoclonal and bispecific antibody clones were examined for blockade of IL-33 induction of phosphorylated p38 (phospho-p38) in basophils (Figure 19C). Consistent with the reporter cell data described above, addition of either the monospecific anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 or the bispecific antibody 10C12-IL-13 KIH IgG4 caused a dose-dependent inhibition in IL-33-induced phospho-p38 levels in basophils (Figure 19D). The control IgG4 antibody did not affect the IL-33 signal (Figure 19D).

The binding kinetics of the bispecific antibody 10C12-IL-13 KIH IgG4 to human IL-33, cyno IL-33, and human IL-13 was assessed using BIAcore® 3000 SPR (Figure 20). The average K_D of this antibody across three experiments using different antibody preparations is shown in Table 4.

Table 4: K_D of bispecific antibody 10C12-IL-13 KIH IgG4 to IL-33 and IL-13

K_D (nM) Human IL-33	K_D (nM) Cyno IL-33	K_D (nM) Human IL-13
0.025	0.076	<0.010

Materials and Methods

HEK-BLUE™ IL-33/ IL-1 β reporter cells were purchased from Invivogen (Catalog # hkb-il33). 300 pg/ml IL-33 ligand (IL-33 N-His, SEQ ID NO: 314) and pre-diluted anti-IL-33 antibodies: control IgG4, anti-IL33 10C12.38.H6.87Y.58I IgG4, 10C12-IL13 KIH IgG4, or ST2 LZ (SEQ ID NO: 319), were mixed and incubated for 1 hour at room temperature. The antibody and ligand mixture were transferred to HEK-BLUE™ IL-33/ IL-1 β cells, seeded at 50,000 cells per well. After incubation at 37 °C for 20 hours in a CO₂ incubator, the SEAP activities in cell culture supernatants were measured by recording the optical density (OD) values at 630 nm after incubating with the substrate of alkaline phosphatase (QUANTI-BLUE™, InvivoGen).

Human PBMCs were stimulated for 30 minutes with 10ng/ml of recombinant human IL33. Prior to stimulation, cells were treated with increasing concentrations of control IgG4, anti-IL33 10C12.38.H6.87Y.58I IgG4, or 10C12-IL-13 KIH IgG4 for 1 hour. Cells were fixed for FACS analysis. Basophils were identified using the fluorescein isothiocyanate–anti-CD123 (11-1239-42; eBioscience). IL-33 activity was analyzed by intracellular staining with phycoerythrin-anti-phospho-p38 MAPK (Thr180/Tyr182) (6908S; Cell Signaling) according to the manufacturer's protocol. Data is shown as the mean fluorescence intensity (MFI) of the phospho-p38 signal within the gated CD123⁺ basophil population.

The binding kinetics of the bispecific antibody 10C12-IL13 KIH IgG4 to human IL-33, cyno IL-33, and human IL-13 was assessed using SPR on a BIAcore® 3000 (GE Healthcare). Anti-human Fab (GE Healthcare) was immobilized on a CM5 sensor chip via amine-based coupling according to the manufacturer's protocol. The bispecific antibody was captured and binding was measured to human IL-33 (Genentech), cyno IL-33 (Genentech), and human IL-13 (Peprotech). Two-fold concentration series of cytokine with a range of 1.56 to 25 nM was used for the experiments. Sensograms for binding of cytokine

were recorded using an injection time of 2 min with a flow rate of 30 μ l/min, at a temperature of 25°C, and with a running buffer of 10 mM HEPES, pH 7.4, 150 mM NaCl, 3 mM EDTA, and 0.005% TWEEN®-20. After injection, disassociation of the ligand from the antibody was monitored for 600 sec in running buffer. The surface was regenerated between binding cycles with a 40 μ l injection of 10 mM Glycine-HCl pH 2.1.

5 After subtraction of a blank which contained running buffer only, sensograms observed for cytokine binding to the bispecific antibody were analyzed using a 1:1 Langmuir binding model with software supplied by the manufacturer to calculate the kinetics and binding constants, including the dissociation constant (K_D).

10 **Example 9. Comparison of inhibitory activity and binding kinetics of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 with other anti-IL-33 antibodies**

A. Introduction

The blocking activity and binding kinetics of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4
15 were directly compared with the blocking activities and binding kinetics of twenty anti-IL-33 antibodies (referred to herein as RG1-RG20) described in International Patent Application Publication No. WO 2014/164959. The anti-IL-33 antibodies from WO 2014/164959 that were compared to 10C12.38.H6.87Y.58I IgG4 are shown in Table 5, which indicates the antibody name from WO 2014/164959, the abbreviated name used herein, the constant region (IgG1 or IgG4), and the amino acid
20 and nucleotide sequences SEQ ID NOs for the VH and VL of each antibody.

Table 5: Anti-IL-33 antibodies from WO 2014/164959

Antibody Name from WO 2014/164959	Abbreviated Name	Constant Region	Amino Acid Sequence SEQ ID NO		Nucleotide Sequence SEQ ID NO	
			VH	VL	VH	VL
H1M9559N	RG1	IgG1	344	345	346	347
H1M9566N	RG2	IgG1	348	349	350	351
H1M9568N	RG3	IgG1	352	353	354	355
H4H9629P	RG4	IgG4	356	357	358	359
H4H9633P	RG5	IgG4	360	361	362	363
H4H9640P	RG6	IgG4	364	365	366	367
H4H9659P	RG7	IgG4	368	369	370	371
H4H9660P	RG8	IgG4	372	373	374	375
H4H9662P	RG9	IgG4	376	377	378	379
H4H9663P	RG10	IgG4	380	381	382	383
H4H9664P	RG11	IgG4	384	385	386	387
H4H9665P	RG12	IgG4	388	389	390	391
H4H9666P	RG13	IgG4	392	393	394	395

Antibody Name from WO 2014/164959	Abbreviated Name	Constant Region	Amino Acid Sequence SEQ ID NO		Nucleotide Sequence SEQ ID NO	
			VH	VL	VH	VL
H4H9667P	RG14	IgG4	396	397	398	399
H4H9670P	RG15	IgG4	400	401	402	403
H4H9671P	RG16	IgG4	404	405	406	407
H4H9672P	RG17	IgG4	408	409	410	411
H4H9675P	RG18	IgG4	412	413	414	415
H4H9676P	RG19	IgG4	416	417	418	419
H1M9565N	RG20	IgG1	420	421	422	423

B. Cell-based IL-33 blocking assay using a reporter cell line

The potency of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and each anti-IL-33 antibody listed in Table 5 (RG1-RG20) as an inhibitor of human IL-33 cellular activity was examined using a cell-based IL-33 blocking assay using a HEK-BLUE™ reporter cell line (Figure 21A). A natural inhibitor of IL-33 activity, sST2 (sST2-LZ), served as a positive control. Stimulation of HEK-BLUE™ IL-33/IL-1 β cells with human IL-33 resulted in robust NF- κ B and AP-1 activation, which was measured by NF- κ B/AP-1-driven SEAP reporter activity (Figure 21B). IL-33 activity was not perturbed by the addition of the control IgG4 antibody (Figure 21A). Most anti-IL-33 antibodies tested displayed dose-dependent inhibition of human IL-33 activity (Figure 21A), with IC₅₀ values listed in Figure 21C. Only two antibodies displayed greater inhibition over the decoy receptor, sST2-LZ (IC₅₀ = 27 pM). 10C12.38.H6.87Y.58I IgG4 displayed the highest blocking activity (IC₅₀ = 2.4 pM), followed by the RG18 antibody (IC₅₀ = 11 pM). The five RG antibodies with the highest blocking activity (RG3, RG4, RG7, RG8, and RG18) are displayed in Figure 21D, along with sST2-LZ and 10C12.38.H6.87Y.58I IgG4.

Similarly, the potency of each antibody as an inhibitor of cynomolgus monkey IL-33 cellular activity was examined using a cell-based blocking assay using a HEK-BLUE™ reporter cell line (Figure 22A). Stimulation of HEK-BLUE™ IL-33/IL-1 β cells with cyno IL-33 resulted in robust NF- κ B and AP-1 activation, which was measured by NF- κ B/AP-1-driven SEAP reporter activity (Figure 22B). In general, the anti-IL-33 antibodies tested displayed weaker dose-dependent inhibition of cynomolgus monkey IL-33 activity compared to the blocking activities against human IL-33, with IC₅₀ values listed in Figure 21C. The decoy receptor sST2-LZ displayed the highest blocking activity (IC₅₀ = 30 pM) and was followed by 10C12.38.H6.87Y.58I IgG4 (IC₅₀ = 4.2 nM) and then the RG20 antibody (IC₅₀ = 6.1 nM). The five RG antibodies with the highest blocking activity (RG3, RG9, RG10, RG12, and RG20) are displayed in Figure 22C, along with sST2-LZ and 10C12.38.H6.87Y.58I IgG4. Of note, the RG18 antibody that displayed high blocking activity against human IL-33, displayed 14-fold weaker blocking activity for cynomolgus monkey IL-33 relative to 10C12.38.H6.87Y.58I IgG4. Figure 22D shows the dose-response curves of the RG antibodies that were non-blocking in this assay.

Materials and Methods

IL-33 pathway activity in HEK-BLUE™ IL-33/IL-1 β reporter cells (InvivoGen, hkb-il33) was measured using a colorimetric assay performed according to the manufacturer's instructions. HEK-BLUE™ IL-33/IL-1 β reporter cells were plated at 50,000 cells per well in 96-well plates in DMEM 4.5 g/l glucose, supplemented with 2 mM L-Glutamine, 10% FBS, 50 U/ml penicillin, 50 μ g/mL streptomycin, 100 μ g/mL NORMOCIN™ (InvivoGen, ant-nr-1). The cells were incubated with a 5-fold serial dilution ranging from 139 nM to 0.003 pM of human IL-33 (hIL-33; R&D Systems, #3625-IL-010/CF) or in-house generated cynomolgus monkey N-terminal 6-His-tagged and C-terminal Avi-tagged IL-33 (S112-T270) (see Example 2). For blocking experiments, the cells were incubated with 10 pM of human IL-33 or 5 pM cyno IL-33 in combination with 3-fold serial dilutions of antibodies or sST2-LZ (sST2 (M1-F328) C-terminal leucine zipper (LZ)-Flag-His) ranging from 90 nM to 0.51 pM. The antibodies or sST2-LZ were pre-incubated with IL-33 for 30 minutes at 37°C prior to addition to the cells. Each reaction had at a final volume of 200 μ L per well and each condition was tested in triplicate. The cells were incubated at 37°C in a humidified incubator with 5% CO₂ and supernatants were collected after 20 h. SEAP reporter activity was detected using QUANTI-BLUE™ assay (InvivoGen, rep-qb1). 20 μ L of supernatants were added to 80 μ L of dissolved and filtered QUANTI-BLUE™ reagent in flat 96-well plates and incubated for 1 h at 37°C. SEAP levels were determined using a spectrophotometer at 620 nm.

C. Natural Killer (NK) primary cell assay for IL-33 activity

In addition to the reporter cell assay described above, the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and each anti-IL-33 antibody listed in Table 5 (RG1-RG20) were also tested for inhibition of IL-33 activity in primary human natural killer (NK) cells (Figures 23A-23D). IL-33 and IL-12 cannot activate NK cells by themselves, but together they can synergize to induce IFN- γ from NK cells (see, e.g., Smithgall et al. *Int. Immunol.* 20(8): 1019-1030, 2008). The inhibitory activity of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and the anti-IL-33 antibodies RG1-RG20 were compared to a natural inhibitor, sST2 (sST2-LZ). Stimulation of freshly-purified NK cells (Figure 23A) with increasing concentrations of human IL-33 in the presence of IL-12 resulted in robust IFN- γ secretion after 24 h, as measured by ELISA (Figure 23B). Most anti-IL-33 antibodies tested displayed dose-dependent inhibition of human IL-33 activity (Figure 23C), with IC₅₀ values listed in Figure 23D. Similar to the reporter cell line results described above in Section B, only two antibodies displayed greater inhibition over the decoy receptor, sST2-LZ (IC₅₀ = 150 pM). 10C12.38.H6.87Y.58I IgG4 displayed the highest blocking activity (IC₅₀ = 30 pM), followed by the RG18 antibody (IC₅₀ = 97 pM). The five RG antibodies with the highest blocking activity (RG7, RG8, RG9, RG18, and RG19) are displayed in Figure 23E, along with sST2-LZ and 10C12.38.H6.87Y.58I IgG4. Figures 23F-23I compare the IC₅₀ curves between groups of five RG antibodies, 10C12.38.H6.87Y.58I IgG4, and sST2-LZ.

Materials and Methods

PBMCs were isolated from fresh whole blood by density gradient centrifugation. Whole blood was diluted two-fold in PBS, layered over FICOLL®-Paque (GE Healthcare, #17-1440-03) in

LEUCOSEP™ tubes (Greiner Bio One, #227290), and centrifuged at 2,000 RPM for 20 min at room temperature. The interphase layer containing the PBMCs was aspirated and transferred to a new tube, and washed twice with PBS. NK cells were isolated using the NK Cell Isolation Kit (Miltenyi Biotec, 130-092-657) according to the manufacturer's instructions. The purity of the cells was analyzed by flow cytometry with CD56-APC (BD Pharmingen, 555518) and CD3-FITC (BD Pharmingen, 561807) staining. Isolated NK cells (>90% purity) were plated in flat-bottom 96-well plates at a final concentration of 5×10^5 cells/ml in RPMI 1640 supplemented with 10% FBS, 2 mM L-glutamine, 100 U/ml penicillin, and 100 µg/mL streptomycin. The cells were incubated with 1 ng/ml of human IL-12 (hIL-12; R&D Systems, #219-IL-025/CF) and a 5-fold serial dilution of human IL-33 (hIL-33; R&D Systems, #3625-IL-010/CF) alone from 139 nM to 0.003 pM, or with 260 pM of hIL-33 in combination with 3-fold serial dilutions of antibodies or sST2-LZ from 100 nM to 0.56 pM. The antibodies or sST2-LZ were pre-incubated with IL-33 for 30 min at 37 °C prior addition to the cells. Each reaction was at a final volume of 200 µl per well and each condition was tested in triplicate. The cells were incubated overnight at 37 °C in a humidified incubator with 5% CO₂. Supernatants were collected after 24 h. The levels of human IFN-γ in the culture supernatant were measured by ELISA (R&D Systems, #DY285) according to the manufacturer's instructions. For each plate, % IL-33 activity was calculated as follows:

$$\% \text{ IL-33 activity} = 100 \times (\text{OD}_{450_{\text{sample}}} - \text{OD}_{450_{\text{no IL-33}}}) / (\text{OD}_{450_{\text{no antibody}}} - \text{OD}_{450_{\text{no IL-33}}}).$$

D. IL-33-Induced p38 MAPK (Thr180/Tyr182) Phosphorylation in Human Basophils

The anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and each anti-IL-33 antibody listed in Table 5 (RG1-RG20) were also tested for inhibition of IL-33 activity in primary human basophils. Addition of IL-33 to human basophils resulted in rapid phosphorylation of the signaling molecule p38 MAPK (Thr180/Tyr182), which can be measured by flow cytometry using intracellular staining methods. By adding the CD123 marker, basophil activity can be examined within the bulk PBMC population, obviating the need for cell isolation.

Using this flow cytometry-based methodology, the anti-IL-33 antibodies were examined for blockade of IL-33-mediated induction of phospho-p38 in basophils (Figure 24A). Addition of IL-33 to PBMCs resulted in a dose-dependent increase in p38 MAPK (Thr180/Tyr182) phosphorylation (phospho-p38) in the basophil population (Figure 24B). Consistent with the reporter cell line and NK cell data described above, addition of anti-IL-33 antibodies caused a dose-dependent inhibition in IL-33-induced phospho-p38 in basophils (Figure 24C), with IC₅₀ values listed in Figure 24D. The antibodies with highest blocking activity as determined using the IC₅₀ curves were RG11 (IC₅₀ = 0.14 pM), 10C12.38.H6.87Y.58I IgG4 (IC₅₀ = 0.15 pM), followed by the RG18 antibody (IC₅₀ = 0.38 pM). The five RG antibodies with the highest blocking activity (RG3, RG4, RG8, RG11, and RG18) are displayed in Figure 24E, along with sST2-LZ and 10C12.38.H6.87Y.58I IgG4. Figures 24F-24I compare the IC₅₀ curves between groups of five RG antibodies, 10C12.38.H6.87Y.58I IgG4, and sST2-LZ.

Since the IC₅₀ curves were made from only six points, the results described above were analyzed at specific antibody concentrations (Figures 24J-24K). The mean fluorescence intensity (MFI) obtained at either 0.4 nM (Figure 24J) or 2 nM (Figure 24K) anti-IL-33 antibody or sST2-LZ concentration was plotted.

The plots in Figures 24J and 24K display the antibodies sorted from highest to lowest blocking activity. At both concentrations, 10C12.38.H6.87Y.58I IgG4 displayed the highest blocking activity, and hence the lowest MFI value. Consistent with the reporter cell line and NK primary cell data, the RG18 antibody was among the top three antibodies in terms of blocking activity against human IL-33.

5 *Materials and Methods*

PBMCs were isolated from fresh whole blood by density gradient centrifugation. Whole blood was diluted two-fold in PBS, layered over FICOLL®-Paque (GE Healthcare, #17-1440-03) in LEUCOSEP™ tubes (Greiner Bio One, #227290), and centrifuged at 2000 RPM for 20 min at room temperature. The interphase layer containing the PBMCs was aspirated and transferred to a new tube, and washed twice with PBS. The isolated PBMCs were plated in v-bottom 96-well plates at 1 million cells/well in 50 µl of PBS. 5-fold serial dilutions (ranging from 10 nM to 3.2 pM) of anti-IL-33 antibodies, sST2-LZ, or an isotype control antibody were pre-incubated with 500 pM (final concentration) of human IL-33 (R&D Systems, #6325-IL/CF) for 30 min at 37°C. 50 µl of the mix were added to the PBMCs for a final volume of 100 µl per well. The cells were incubated for 20 min at 37°C in a humidified incubator with 5% CO₂. The reactions were stopped by addition of 100 µl of pre-warmed BD PHOSFLOW™ fix buffer (BD Biosciences, 557870) and incubated for 10 min at 37°C. The cells were pelleted by centrifugation at 1500 RPM for 5 min and the supernatants were decanted. The cell pellets were washed with 200 µl flow cytometry buffer (1X PBS, 0.5% BSA, 0.05% sodium azide). The cells were permeabilized by slowly adding 100 µl cold BD PHOSFLOW™ Perm Buffer II (BD Biosciences, 558052) and incubated on ice for 30 min. The cell pellets were washed twice in flow cytometry buffer. IL-33 dependent phosphorylation of p38 in basophils was analyzed by staining each sample with anti-Phospho-p38 MAPK (Thr180/Tyr182)-PE (used at 1:50, Cell Signaling Technology, 6908S) and anti-CD123-FITC (used at 1:10, eBiosciences, 11-1239-42). The samples were incubated at room temperature for 1 h in the dark. The cells were pelleted and washed twice with flow cytometry buffer. The cells were analyzed on a BD FACSCALIBUR™ to determine the mean fluorescence intensity (MFI) levels of phospho-p38 MAPK (Thr180/Tyr182) in CD123⁺ basophils.

E. Anti-IL-33 antibody binding to IL-33 as determined by surface plasmon resonance

The binding kinetics of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and each anti-IL-33 antibody listed in Table 5 (RG1-RG20) to IL-33 were measured using surface plasmon resonance (SPR) on a BIACORE® T200 instrument (GE Healthcare). Anti-human Fc or anti-murine Fc (GE Healthcare, #BR-1008-39 or BR-1008-38, respectively) was immobilized on a CM5 sensor chip via amine-based coupling according to the manufacturer's protocol. Surfaces were used to capture monoclonal human IgG4 and monoclonal murine IgGs for kinetic studies. Antibody binding was measured to human IL-33 (R&D systems, #3625-IL-010/CF) and cyno IL-33 N-His (SEQ ID NO: 317) (Genentech, Inc.). A three-fold concentration series of cytokine with a range of 3.7 to 100 nM was used for the experiments. Sensograms for binding of IL-33 were recorded using an injection time of 4 min with a flow rate of 30 µl/minute with a running buffer of 0.01 M N-(2-Acetamido)iminodiacetic acid (ADA) pH 7.4, 0.15 M NaCl, 3 mM EDTA, and 0.05% TWEEN®-20. After injection, disassociation of the ligand from the antibody was

monitored for 10 min in running buffer. The surface was regenerated in between cycles with an injection of 3 M magnesium chloride or Glycine-HCl pH 1.7. All binding experiments were performed at a temperature of 25°C and 37°C. After subtraction of a blank which contained running buffer only, sensograms observed for IL-33 binding to anti-IL-33 antibodies were analyzed using a 1:1 Langmuir binding model with software supplied by the manufacturer to calculate the kinetics and binding constants, including the dissociation constant (K_D). Dissociative half-lives ($t_{1/2}$) were calculated from the kinetic rate constants. K_D (M) = k_{off}/k_{on} and $t_{1/2}$ (min) = $\ln(2)/(60*k_{off})$. Table 6 shows the results of the binding kinetics for binding to human IL-33 at 25°C. Table 7 shows the results of the binding kinetics for binding to human IL-33 at 37°C. Table 8 shows the results of the binding kinetics for binding to cyno IL-33 at 25°C. Table 9 shows the results of the binding kinetics for binding to cyno IL-33 at 37°C. In Tables 6-9, *IC indicates the result is inconclusive due to weak capture of antibody was observed, leading to poor binding data.

In each condition, the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 had the highest affinity to human or cyno IL-33, as measured by K_D , compared to the anti-IL-33 antibodies RG1-RG20 (Tables 6-9). 10C12.38.H6.87Y.58I IgG4 had approximately 2-4 fold improved affinity compared to the RG antibody with the highest affinity for human IL-33, which was RG18 (Tables 6 and 7). 10C12.38.H6.87Y.58I IgG4 also had had approximately 2-4 fold improved affinity compared to the RG antibody with the highest affinity for cyno IL-33, which was RG2 at 25°C and RG10 at 37°C.

Table 6: Binding kinetics of anti-IL-33 antibodies for binding to human IL33 at 25°C.

Antibody	k_{on} (1/Ms)	k_{off} (1/s)	K_D (M)	$t_{1/2}$ (min)
RG1	226000	0.000184	8.11E-10	63
RG2	96900	0.000773	7.98E-10	149
RG3	IC*	IC*	IC*	IC*
RG4	1130000	0.000632	5.59E-10	18
RG5	491000	0.000462	9.41E-10	25
RG6	797000	0.000438	5.49E-10	26
RG7	456000	0.000499	1.09E-09	23
RG8	581000	0.00039	6.7E-10	30
RG9	871000	0.000459	5.27E-10	25
RG10	1680000	0.000937	5.58E-10	12
RG11	339000	0.000445	1.31E-09	26
RG12	931000	0.00116	1.25E-09	10
RG13	665000	0.00115	1.74E-09	10
RG14	626000	0.000328	5.25E-10	35
RG15	680000	0.000517	7.61E-10	22
RG16	1310000	0.000963	7.36E-10	12
RG17	960000	0.000806	8.39E-10	14
RG18	1630000	0.000637	3.91E-10	18
RG19	1790000	0.001	5.6E-10	12
RG20	84400	0.000238	2.82E-09	49
10C12.38.H6.87Y.58I IgG4	4600000	0.000613	1.33E-10	19

Table 7: Binding kinetics of anti-IL-33 antibodies for binding to human IL-33 at 37°C.

Antibody	k_{on} (1/Ms)	k_{off} (1/s)	K_D (M)	$t_{1/2}$ (min)
RG1	374000	0.000888	2.37E-09	13
RG2	129000	0.000522	4.04E-09	22
RG3	IC*	IC*	IC*	IC*
RG4	2820000	0.000738	2.61E-10	16
RG5	1160000	0.000845	7.26E-10	14
RG6	1740000	0.000626	3.59E-10	18
RG7	1080000	0.000498	4.62E-10	23
RG8	1370000	0.000413	3.02E-10	28
RG9	2340000	0.000566	2.42E-10	20
RG10	3110000	0.00161	5.17E-10	7
RG11	789000	0.000531	6.74E-10	22
RG12	2350000	0.00235	1E-09	5
RG13	1690000	0.00158	9.34E-10	7
RG14	1210000	0.000497	4.11E-10	23
RG15	1280000	0.000663	5.19E-10	17
RG16	3680000	0.00203	5.52E-10	6
RG17	2390000	0.00127	5.31E-10	9
RG18	4060000	0.000779	1.92E-10	15
RG19	3470000	0.00158	4.57E-10	7
RG20	218000	0.000162	7.42E-10	71
10C12.38.H6.87Y.58I IgG4	6160000	0.000547	8.89E-11	21

Table 8: Binding kinetics of anti-IL-33 antibodies for binding to cyno IL33 at 25°C.

Antibody	k_{on} (1/Ms)	k_{off} (1/s)	K_D (M)	$t_{1/2}$ (min)
RG1	122000	0.000458	3.76E-09	25
RG2	117000	0.0000766	6.56E-10	151
RG3	IC*	IC*	IC*	IC*
RG4	379000	0.0204	5.4E-08	1
RG5	227000	0.00337	1.49E-08	3
RG6	244000	0.000528	2.17E-09	22
RG7	183000	0.000479	2.61E-09	24
RG8	238000	0.00064	2.69E-09	18
RG9	245000	0.000313	1.28E-09	37
RG10	511000	0.000545	1.07E-09	21
RG11	99000	0.000556	5.62E-09	21
RG12	437000	0.000426	9.76E-10	27
RG13	164000	0.00625	3.8E-08	2
RG14	208000	0.00059	2.83E-09	20
RG15	212000	0.000557	2.63E-09	21
RG16	533000	0.000915	1.72E-09	13
RG17	331000	0.0019	5.74E-09	6
RG18	362000	0.000988	2.73E-09	12
RG19	787000	0.00248	3.15E-09	5
RG20	203000	0.000606	2.98E-09	19
10C12.38.H6.87Y.58I IgG4	1050000	0.000278	2.65E-10	42

Table 9: Binding kinetics of anti-IL-33 antibodies for binding to cyno IL33 at 37°C

Antibody	k_{on} (1/Ms)	k_{off} (1/s)	K_D (M)	t_{1/2} (min)
RG1	232000	0.00193	8.33E-09	6
RG2	185000	0.000469	2.54E-09	25
RG3	IC*	IC*	IC*	IC*
RG4	916	0.000502	5.47E-07	23
RG5	265000	0.0113	4.27E-08	1
RG6	9340000	0.0392	4.2E-09	0
RG7	277000	0.00114	4.13E-09	10
RG8	385000	0.00305	7.93E-09	4
RG9	484000	0.00112	2.31E-09	10
RG10	1960000	0.00202	1.03E-09	6
RG11	205000	0.00213	1.04E-08	5
RG12	727000	0.00142	1.96E-09	8
RG13	293000	0.0139	4.74E-08	1
RG14	398000	0.00214	5.38E-09	5
RG15	380000	0.00221	5.82E-09	5
RG16	890000	0.00326	3.66E-09	4
RG17	584000	0.00757	1.3E-08	2
RG18	751000	0.00505	6.72E-09	2
RG19	1600000	0.0111	6.93E-09	1
RG20	IC*	IC*	IC*	IC*
10C12.38.H6.87Y.58I IgG4	1690000	0.000804	4.76E-10	14

F. Competitive binding ELISA to measure blocking activity of anti-IL-33 antibodies

Materials

5 Recombinant human ST2-Fc chimera protein and human IL-33 protein were obtained from R&D Systems (Minneapolis, MN). Recombinant cynomolgous monkey IL-33 protein was made at Genentech. Both human and cyno IL-33 proteins were biotin-labeled using EZ-LINK® NHS-PEG4-Biotin (Thermo Scientific; Rockford, IL) according to the manufacturer's protocol.

10 *Experimental Method*

The ability of the anti-IL-33 antibody 10C12.38.H6.87Y.58I IgG4 and each anti-IL-33 antibody listed in Table 5 (RG1-RG20) to block either human IL-33 or cyno IL-33 binding to human ST2 receptor was tested in a competitive binding ELISA. Briefly, 1 µg/ml of recombinant human ST2-Fc chimera protein prepared in coating buffer (50 mM sodium carbonate, pH 9.6) was coated on a 384-well
15 MAXISORP® plate (Nalgene Nunc International; Rochester, NY) and incubated overnight at 4°C. On the next day, non-specific binding was blocked with PBS containing 0.5% (w/v) solution of bovine serum albumin (BSA). Fixed concentrations of biotinylated human or cyno IL-33 prepared in assay buffer (25 mM PBS, pH 7.2, 0.1% BSA, 0.05% TWEEN®-20) were mixed with an equal volume of serially-diluted anti-IL-33 antibodies or assay buffer alone and incubated for 1 h at room temperature. The final assay
20 concentrations of biotinylated human IL-33 or cyno IL-33 were 20 pM and 45 pM, respectively, and the final assay concentration of each antibody ranged from 0-300 nM. The pre-mixed solutions were added to the ST2-Fc coated plate and incubated for 1 h at room temperature. The binding of biotinylated IL-33

to coated ST2-Fc was detected by the sequential addition of Streptavidin Poly-HRP80 (Fitzgerald; Buckinghamshire, UK) and 3,3',5,5'-tetramethyl benzidine (TMB) Microwell Peroxidase Substrate System (KPL; Gaithersburg, MD). The absorbance (450 nm) was recorded using a MULTISKAN ASCENT® plate reader (Thermo Scientific; Rockford, IL). The binding activity (%) of biotin-IL-33 to ST2 in the presence of anti-IL-33 was plotted as a function of antibody concentration. The data generated were fitted to a four-parameter equation to determine IC_{50} values for each antibody (Figures 25A and 25B) using Prism software (Graphpad Software; La Jolla, CA). The maximum blocking (%) of each antibody was calculated as the ratio of the reduction in signal measured in the presence of antibody relative to the difference between the signal with IL-33 alone and background measurements. The IC_{50} and maximum blocking activity for each antibody are summarized in Table 10. Results show the average data of three independent experiments.

As shown in Table 10, 10C12.38.H6.87Y.58I IgG4 was the most efficient blocker of any of the antibodies tested, with lower IC_{50} values and higher maximum blocking compared to all of the antibodies from WO 2014/164959.

Table 10: Blocking of biotin-huIL-33 or biotin-cyIL-33 binding to huST2 by anti-IL-33 antibodies

Antibody	Blocking 20 pM biotin-huIL-33 to hST2-Fc, IC_{50} (M)	Maximum Blocking	Blocking 40 pM biotin-cyIL-33 to hST2-Fc, IC_{50} (M)	Maximum Blocking
10C12.38.H6.87Y.58I IgG4	2.1E-11	92%	4.3E-10	87%
H1M9559N	4.1E-09	75%	NA	NB
H1M9566N	9.9E-11	27%	NA	NB
H1M9565N	5.4E-08	81%	1.9E-08	85%
H1M9568N	1.9E-10	85%	7.7E-08	45%
H4H9629P	9.2E-11	82%	NA	NB
H4H9633P	1.1E-09	68%	NA	NB
H4H9640P	1.9E-10	80%	4.5E-08	25%
H4H9659P	2.3E-10	88%	4.7E-08	42%
H4H9660P	9.2E-11	78%	1.2E-07	18%
H4H9662P	2.5E-10	85%	6.6E-08	47%
H4H9663P	4.4E-10	82%	2.6E-08	61%
H4H9664P	1.9E-10	87%	NA	10%
H4H9665P	7.0E-10	63%	1.9E-08	53%
H4H9666P	2.1E-10	81%	NA	NB
H4H9667P	4.1E-10	77%	NA	7%
H4H9670P	4.2E-10	80%	1.5E-07	27%
H4H9671P	9.6E-11	77%	7.0E-08	40%
H4H9672P	2.2E-10	77%	NA	NB

Antibody	Blocking 20 pM biotin-huIL-33 to hST2-Fc, IC ₅₀ (M)	Maximum Blocking	Blocking 40 pM biotin-cylL-33 to hST2-Fc, IC ₅₀ (M)	Maximum Blocking
H4H9675P	6.3E-11	84%	NA	NB
H4H9676P	9.7E-10	73%	NA	NB

NA= Not applicable

NB= Non-blocker

Other Embodiments

- 5 Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, the descriptions and examples should not be construed as limiting the scope of the invention. The disclosures of all patent and scientific literature cited herein are expressly incorporated in their entirety by reference.

WHAT IS CLAIMED IS:

1. An isolated antibody that specifically binds both human and cynomolgus monkey (cyno) interleukin-33 (IL-33) with a K_D of about 500 pM or lower.
2. The antibody of claim 1, wherein the antibody specifically binds human IL-33 with a K_D between about 100 fM and about 500 pM.
3. The antibody of claim 1 or 2, wherein the antibody specifically binds human IL-33 with a K_D between about 1 pM and about 200 pM.
4. The antibody of any one of claims 1-3, wherein the antibody specifically binds human IL-33 with a K_D between about 15 pM and about 180 pM.
5. The antibody of any one of claims 1-4, wherein the antibody specifically binds human IL-33 with a K_D between about 15 pM and about 140 pM.
6. The antibody of any one of claims 1-5, wherein the antibody specifically binds cyno IL-33 with a K_D between about 100 fM and about 500 pM.
7. The antibody of any one of claims 1-6, wherein the antibody specifically binds cyno IL-33 with a K_D between about 1 pM and about 500 pM.
8. The antibody of any one of claims 1-7, wherein the antibody specifically binds cyno IL-33 with a K_D between about 100 pM and about 500 pM.
9. The antibody of any one of claims 1-8, wherein the antibody specifically binds cyno IL-33 with a K_D between about 125 pM and about 500 pM.
10. The antibody of any one of claims 1, 2, 6, and 7, wherein the antibody specifically binds both human and cyno IL-33 with a K_D of between about 1 pM and about 500 pM.
11. The antibody of claim 10, wherein the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 200 pM.
12. The antibody of any one of claims 1-11, wherein the antibody is capable of inhibiting the binding of IL-33 to an IL-33 receptor.
13. The antibody of claim 12, wherein the inhibiting is measured using a cell-based blocking assay.

14. The antibody of any one of claims 1-13, wherein the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 90% inhibitory concentration (IC₉₀) of between about 0.001 µg/ml and about 0.5 µg/ml.

15. The antibody of claim 14, wherein the IC₉₀ is between about 0.002 µg/ml and about 0.25 µg/ml.

16. The antibody of claim 15, wherein the IC₉₀ is about 0.17 µg/ml.

17. The antibody of claim 15, wherein the IC₉₀ is about 0.004 µg/ml.

18. The antibody of any one of claims 1-13, wherein the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 50% inhibitory concentration (IC₅₀) of between about 800 fM and about 10 pM.

19. The antibody of claim 18, wherein the IC₅₀ is between about 1 pM and about 5 pM.

20. The antibody of claim 19, wherein the IC₅₀ is about 2.5 pM.

21. The antibody of any one of claims 1-20, wherein the antibody inhibits the binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of between about 1 nM and about 5 nM.

22. The antibody of claim 21, wherein the IC₅₀ is about 4 nM.

23. The antibody of any one of claims 1-22, wherein the antibody comprises a binding domain comprising:

- (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1);
- (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2);
and
- (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3).

24. The antibody of claim 23, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13);
- (c) an FR-H3 comprising the amino acid sequence of
RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLTVSS (SEQ ID NO: 15).

25. The antibody of claim 23, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of DVNLVESGGGSKPKGGSLKLSCVASGFTFS (SEQ ID NO: 16);
- (b) an FR-H2 comprising the amino acid sequence of WVRQTPEKRLEWVA (SEQ ID NO: 17);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDDAKNTLYLQMSSLESEDAMYCTR (SEQ ID NO: 18); and
- (d) an FR-H4 comprising the amino acid sequence of WGAGTTVAVSS (SEQ ID NO: 19).

26. The antibody of claim 23, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12) or EVQLVESGGGLVKPGGSLRLSCAASGFTFS (SEQ ID NO: 20);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13) or WVRQAPGKGLEWVS (SEQ ID NO: 21);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDNKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 22), RFTISRDDAKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 23), RFTISRDNKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 24), or RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLLTVSS (SEQ ID NO: 15).

27. The antibody of any one of claims 23-26, wherein the binding domain further comprises:

- (a) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLN (SEQ ID NO: 4);
- (b) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and
- (c) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6).

28. The antibody of claim 27, wherein the binding domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLIF (SEQ ID NO: 26);
- (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTISSELPEDFAVYYC (SEQ ID NO: 27); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28).

29. The antibody of claim 27, wherein the binding domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPGFLVSLGQRATISC (SEQ ID NO: 29);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 30);
- (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPMEEDDTAMYFC (SEQ ID NO: 31); and
- (d) an FR-L4 comprising the amino acid sequence of FGSGTKLEIK (SEQ ID NO: 32).

30. The antibody of claim 27, wherein the binding domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLLIF (SEQ ID NO: 26);
- (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTISSLEPEDFAVYYC (SEQ ID NO: 27), GVPARFSGSGSGTDFTLTISSLEPEDFAVYFC (SEQ ID NO: 33), GVPARFSGSGSGTDFTLTISSLEPEDFAVYYC (SEQ ID NO: 34), or GIPARFSGSGSGTDFTLTISSLEPEDFAVYFC (SEQ ID NO: 35); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28).

31. The antibody of any one of claims 1-22, wherein the antibody comprises a binding domain comprising:

- (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65);
- (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPALKS (SEQ ID NO: 66) or SIYYSGRTYYNPALKS (SEQ ID NO: 67); and
- (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68).

32. The antibody of claim 31, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72);
- (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73);
- (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75).

33. The antibody of claim 31, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76);
- (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73);
- (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and
- (d) an FR-H4 comprising the amino acid sequence of WGNQTTVTVSS (SEQ ID NO: 78).

34. The antibody of claim 31, wherein the binding domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72), QLQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 76) or QVQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 77);

- (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73);
- (c) an FR-H3 comprising the amino acid sequence of
RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75) or
WGNGTTVTVSS (SEQ ID NO: 78).

35. The antibody of any one of claims 31-34, wherein the binding domain further comprises:

- (a) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69);
- (b) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and
- (c) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71).

36. The antibody of claim 35, wherein the binding domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSPGERATLSC (SEQ ID NO: 79);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80);
- (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82).

37. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SFSX₁S (SEQ ID NO: 62), wherein X₁ is Met, Leu, or Val;
- (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDX₁VKG (SEQ ID NO: 63), wherein X₁ is Ser or Ala;
- (c) an HVR-H3 comprising the amino acid sequence of ANYGX₁X₂FFEY (SEQ ID NO: 64), wherein X₁ is Asn or Asp, and X₂ is Trp or Phe;
- (d) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4);
- (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6).

38. The antibody of claim 37, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1);
- (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2);
- (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4);
- (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6).

39. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 36; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 37; or (c) a VH domain as in (a) and a VL domain as in (b).

40. The antibody of claim 39, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLTVSS (SEQ ID NO: 15).

41. The antibody of claim 40, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 36.

42. The antibody of any one of claims 39-41, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLLIF (SEQ ID NO: 26);
- (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTISSELPEDFAVYYC (SEQ ID NO: 27); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTVKVEIK (SEQ ID NO: 28).

43. The antibody of claim 42, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 37.

44. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37.

45. The antibody of claim 39, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of DVNLVESGGGSVKPGGSLKLSCVASGFTFS (SEQ ID NO: 16);
- (b) an FR-H2 comprising the amino acid sequence of WVRQTPEKRLEWVA (SEQ ID NO: 17);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDDAKNTLYLQMSSLESEDAMYYCTR (SEQ ID NO: 18); and

(d) an FR-H4 comprising the amino acid sequence of WGAGTTVAVSS (SEQ ID NO: 19).

46. The antibody of claim 45, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 38.

47. The antibody of any one of claims 39, 45, and 46, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPGFLVSLGQRATISC (SEQ ID NO: 29);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 30);
- (c) an FR-L3 comprising the amino acid sequence of
GVPARFSGSGGTDFSLNIHPMEEDDTAMYFC (SEQ ID NO: 31); and
- (d) an FR-L4 comprising the amino acid sequence of FGSGTKLEIK (SEQ ID NO: 32).

48. The antibody of claim 47, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 39.

49. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 38 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 39.

50. The antibody of claim 39, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 12) or EVQLVESGGGLVKPGGSLRLSCAASGFTFS (SEQ ID NO: 20);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 13) or WVRQAPGKGLEWVS (SEQ ID NO: 21);
- (c) an FR-H3 comprising the amino acid sequence of
RFTISRDN SKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 22),
RFTISRDDAKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 23),
RFTISRDN AKNSLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 24), or
RFTISRDDSKNTLYLQMNSLRAEDTAVYYCTR (SEQ ID NO: 14); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 15).

51. The antibody of claim 50, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 40.

52. The antibody of any one of claims 39, 50, and 51, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPATLSLSPGERATLSC (SEQ ID NO: 25);

- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPRLIF (SEQ ID NO: 26);
- (c) an FR-L3 comprising the amino acid sequence of GIPARFSGSGSGTDFTLTSSLEPEDFAVYYC (SEQ ID NO: 27), GVPARFSGSGSGTDFTLTSSLEPEDFAVYFC (SEQ ID NO: 33), GVPARFSGSGSGTDFTLTSSLEPEDFAVYYC (SEQ ID NO: 34), or GIPARFSGSGSGTDFTLTSSLEPEDFAVYFC (SEQ ID NO: 35); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 28).

53. The antibody of claim 52, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 41.

54. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 40 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 41.

55. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65);
- (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPX₁LKS (SEQ ID NO: 90), wherein X₁ is Ser or Ala;
- (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68);
- (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69);
- (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and
- (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71).

56. The antibody of claim 55, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65);
- (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNP₁SLKS (SEQ ID NO: 66);
- (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68);
- (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69);
- (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and
- (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71).

57. The antibody of claim 55, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65);
- (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPALKS (SEQ ID NO: 67);

- (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFSFYMDV (SEQ ID NO: 68);
- (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69);
- (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and
- (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71).

58. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 84; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 85; or (c) a VH domain as in (a) and a VL domain as in (b).

59. The antibody of claim 58, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of ELQLQESGPGLVKPSETLSLTCTVSGGSIR (SEQ ID NO: 72);
- (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73);
- (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTTVTVSS (SEQ ID NO: 75).

60. The antibody of claim 59, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 84.

61. The antibody of any one of claims 58-60, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSPGERATLSC (SEQ ID NO: 79);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80);
- (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82).

62. The antibody of claim 61, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 85.

63. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 84 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 85.

64. The antibody of claim 59, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 86.

65. The antibody of any one of claims 58, 59, and 64, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSSLSPGERATLSC (SEQ ID NO: 79);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80);
- (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82).

66. The antibody of claim 65, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 87.

67. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 86 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 87.

68. The antibody of claim 58, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of QLQLQESGPGLVKPSSETLSLTCTVSGGSIR (SEQ ID NO: 76);
- (b) an FR-H2 comprising the amino acid sequence of WIRQPPGKGLEWIG (SEQ ID NO: 73);
- (c) an FR-H3 comprising the amino acid sequence of RVTISVDTSKNQFSLMLTSVTAADTAVYYCAR (SEQ ID NO: 74); and
- (d) an FR-H4 comprising the amino acid sequence of WGNGTTVTVSS (SEQ ID NO: 78).

69. The antibody of claim 68, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 88.

70. The antibody of any one of claims 58, 68, and 69, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of EIVLTQSPGTLSSLSPGERATLSC (SEQ ID NO: 79);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQAPRLLIY (SEQ ID NO: 80);
- (c) an FR-L3 comprising the amino acid sequence of GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYC (SEQ ID NO: 81); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 82).

71. The antibody of claim 70, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 89.

72. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 88 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 89.

73. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of NYX₁MN (SEQ ID NO: 97), wherein X₁ is Trp, Phe, or Tyr;
- (b) an HVR-H2 comprising the amino acid sequence of EITLKFNX₁YX₂THYAESVKG (SEQ ID NO: 98), wherein X₁ is Asn, Asp, Ser, or Ala, and X₂ is Ser or Ala;
- (c) an HVR-H3 comprising the amino acid sequence of RNYGX₁X₂YINV (SEQ ID NO: 99), wherein X₁ is Asp or Asn, and X₂ is Trp or Phe;
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGX₁SFLN (SEQ ID NO: 100), wherein X₁ is Met, Val, or Leu;
- (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114).

74. The antibody of claim 73, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101);
- (b) an HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGDWYINV (SEQ ID NO: 109);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112);
- (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114).

75. The antibody of claim 73, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101);
- (b) an HVR-H2 comprising the amino acid sequence of EITLKFNNYSTHYAESVKG (SEQ ID NO: 104);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWYINV (SEQ ID NO: 110);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGMSFLN (SEQ ID NO: 112);
- (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114).

76. The antibody of claim 73, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of NYWMN (SEQ ID NO: 101);
- (b) an HVR-H2 comprising the amino acid sequence of EITLKFNDYSTHYAESVKG (SEQ ID NO: 105);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWYINV (SEQ ID NO: 110);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDKFGVSFLN (SEQ ID NO: 115);
- (e) an HVR-L2 comprising the amino acid sequence of VASSQGS (SEQ ID NO: 113); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKDIPYT (SEQ ID NO: 114).

77. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 134; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 135; or (c) a VH domain as in (a) and a VL domain as in (b).

78. The antibody of claim 77, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFS (SEQ ID NO: 117);
- (b) an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWMA (SEQ ID NO: 119);
- (c) an FR-H3 comprising the amino acid sequence of RFSISRDDSKSTVYLQMNNLRAEDTGIYYCAR (SEQ ID NO: 121); and
- (d) an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 124).

79. The antibody of claim 78, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 134.

80. The antibody of any one of claims 77-79, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPTSLAVSLGQRATISC (SEQ ID NO: 126);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQPPKLLIF (SEQ ID NO: 128);
- (c) an FR-L3 comprising the amino acid sequence of GVPARFSGSGSGTDFSLNIHPVEEDDTAMYFC (SEQ ID NO: 130); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 132).

81. The antibody of claim 80, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 135.

82. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence

identity to the amino acid sequence of SEQ ID NO: 134 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 135.

83. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 136; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 137; or (c) a VH domain as in (a) and a VL domain as in (b).

84. The antibody of claim 83, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 118);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWMA (SEQ ID NO: 120);
- (c) an FR-H3 comprising the amino acid sequence of
RFTISRDNKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 122) or
RFTISRDDSKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 123); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 125).

85. The antibody of claim 84, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 136.

86. The antibody of any one of claims 83-85, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIVMTQSPDSLAVSLGERATINC (SEQ ID NO: 127);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQPPKLLIF (SEQ ID NO: 129);
- (c) an FR-L3 comprising the amino acid sequence of
GVPDRFSGSGSGTDFTLTISLQAEDVAVYYC (SEQ ID NO: 131); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTEKVEIK (SEQ ID NO: 133).

87. The antibody of claim 86, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 137.

88. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 136 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 137.

89. The antibody of claim 83, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFS (SEQ ID NO: 118);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWMA (SEQ ID NO: 120);
- (c) an FR-H3 comprising the amino acid sequence of
RFTISRDNKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 122) or
RFTISRDDSKNTVYLQMNSLRAEDTAVYYCAR (SEQ ID NO: 123); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLTVSS (SEQ ID NO: 125).

90. The antibody of claim 89, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 138.

- 91. The antibody of any one of claims 83, 89, and 90, wherein the VL domain further comprises:
 - (a) an FR-L1 comprising the amino acid sequence of DIVMTQSPDSLAVSLGERATINC (SEQ ID NO: 127);
 - (b) an FR-L2 comprising the amino acid sequence of WYQQKPGQPPKLLIF (SEQ ID NO: 129);
 - (c) an FR-L3 comprising the amino acid sequence of
GVPDRFSGSGSGTDFTLTISLQAEDVAVYYC (SEQ ID NO: 131); and
 - (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 133).

92. The antibody of claim 91, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 139.

93. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 138 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 139.

94. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158);
- (b) an HVR-H2 comprising the amino acid sequence of EIRLX₁X₂INYVKDYAESVKG (SEQ ID NO: 161), wherein X₁ is Asn or Ser, and X₂ is Ser or Ala;
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164);
- (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and
- (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166).

95. The antibody of claim 94, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158);

- (b) an HVR-H2 comprising the amino acid sequence of EIRLNSINYVKDYAESVKG (SEQ ID NO: 159);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164);
- (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and
- (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166).

96. The antibody of claim 94, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158);
- (b) an HVR-H2 comprising the amino acid sequence of EIRLSSINYVKDYAESVKG (SEQ ID NO: 162);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164);
- (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and
- (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166).

97. The antibody of claim 94, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of KFWMN (SEQ ID NO: 158);
- (b) an HVR-H2 comprising the amino acid sequence of EIRLNAINYVKDYAESVKG (SEQ ID NO: 163);
- (c) an HVR-H3 comprising the amino acid sequence of RNYGNWFFEI (SEQ ID NO: 160);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVDRYGISFMN (SEQ ID NO: 164);
- (e) an HVR-L2 comprising the amino acid sequence of AASNQGS (SEQ ID NO: 165); and
- (f) an HVR-L3 comprising the amino acid sequence of QHSKEVPYT (SEQ ID NO: 166).

98. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 183; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 184; or (c) a VH domain as in (a) and a VL domain as in (b).

99. The antibody of claim 98, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVKLEESGGGLVQPGGSMKLSCVASGFTFN (SEQ ID NO: 167);
- (b) an FR-H2 comprising the amino acid sequence of WVRQSPEKGLEWVA (SEQ ID NO: 168);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKNSVYLQMNNLRAEDTGIYYCIR (SEQ ID NO: 169); and
- (d) an FR-H4 comprising the amino acid sequence of WGAGTTVTVSS (SEQ ID NO: 170).

100. The antibody of claim 99 wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 183.

101. The antibody of any one of claims 98-100, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIVLTQSPASLAVSLGQRATISC (SEQ ID NO: 175);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGQSPKLLIY (SEQ ID NO: 176);
- (c) an FR-L3 comprising the amino acid sequence of
GVPARFSGSGSGTDFSLNIHPLEEDDAAMYFC (SEQ ID NO: 177); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKLEIK (SEQ ID NO: 178).

102. The antibody of claim 101, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 184.

103. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 183 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 184.

104. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 185; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 186; or (c) a VH domain as in (a) and a VL domain as in (b).

105. The antibody of claim 104, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLRLSCAASGFTFN (SEQ ID NO: 171);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVA (SEQ ID NO: 172);
- (c) an FR-H3 comprising the amino acid sequence of
RFTISRDNKNSVYLQMNSLRAEDTAVYYCIR (SEQ ID NO: 173); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 174).

106. The antibody of claim 105, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 185.

107. The antibody of any one of claims 104-106, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVITC (SEQ ID NO: 179);
- (b) an FR-L2 comprising the amino acid sequence of WFQQKPGKAPKLLIY (SEQ ID NO: 180);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISSLQPEDFATYYC (SEQ ID NO: 181); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 182).

108. The antibody of claim 107, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 186.

109. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 185 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 186.

110. The antibody of claim 105, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 187.

111. The antibody of claim 107, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 188.

112. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 187 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 188.

113. The antibody of claim 105, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 189.

114. The antibody of claim 107, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 190.

115. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 189 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 190.

116. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191);
- (b) an HVR-H2 comprising the amino acid sequence of DINPKX₁X₂DTFYNQNFKD (SEQ ID NO: 192), wherein X₁ is Asn or Ser, and X₂ is Gly or Ala;
- (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196);
- (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197);
- (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and
- (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199).

117. The antibody of claim 116, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191);
- (b) an HVR-H2 comprising the amino acid sequence of DINPKNGDTFYNQNFKD (SEQ ID NO: 193);
- (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196);
- (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197);
- (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and
- (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199).

118. The antibody of claim 116, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of DYNMN (SEQ ID NO: 191);
- (b) an HVR-H2 comprising the amino acid sequence of DINPKSGDTFYNQNFKD (SEQ ID NO: 194) or DINPKNADTFYQNFKD (SEQ ID NO: 195);
- (c) an HVR-H3 comprising the amino acid sequence of HYYYGSSYGGFVY (SEQ ID NO: 196);
- (d) an HVR-L1 comprising the amino acid sequence of HASQNINWLS (SEQ ID NO: 197);
- (e) an HVR-L2 comprising the amino acid sequence of AASKLHT (SEQ ID NO: 198); and
- (f) an HVR-L3 comprising the amino acid sequence of QQGQSYPLT (SEQ ID NO: 199).

119. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 216; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 217; or (c) a VH domain as in (a) and a VL domain as in (b).

120. The antibody of claim 119, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVLLQQSGPELVKPGASVKISCNASGYTFS (SEQ ID NO: 200);
- (b) an FR-H2 comprising the amino acid sequence of WVKQSHGKSLESIG (SEQ ID NO: 201);
- (c) an FR-H3 comprising the amino acid sequence of KATLTIDKSSSTVYMELRSLTSEDAMYYCAR (SEQ ID NO: 202); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVAA (SEQ ID NO: 203).

121. The antibody of claim 120, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 216.

122. The antibody of any one of claims 119-121, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 208);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKAGNNPKLLIY (SEQ ID NO: 209);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFTGSGSGTLFTLTISLQPEDATYYC (SEQ ID NO: 210); and
- (d) an FR-L4 comprising the amino acid sequence of FGSGTNLELK (SEQ ID NO: 211).

123. The antibody of claim 122, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 217.

124. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 216 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 217.

125. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 218; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 219; or (c) a VH domain as in (a) and a VL domain as in (b).

126. The antibody of claim 125, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVQSGAEVKKPGASVKVSCKASGYTFS (SEQ ID NO: 204);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGQGLESIG (SEQ ID NO: 205);
- (c) an FR-H3 comprising the amino acid sequence of RATLTIDKSTSTAYLELSSLRSEDATVYYCAR (SEQ ID NO: 206); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 207).

127. The antibody of claim 126, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 218.

128. The antibody of any one of claims 125-127, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVITITC (SEQ ID NO: 212);

- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKNP KLLIY (SEQ ID NO: 213);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFLTISSLQPEDFATYYC (SEQ ID NO: 214); and
- (d) an FR-L4 comprising the amino acid sequence of FGQG TKVEIK (SEQ ID NO: 215).

129. The antibody of claim 128, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 219.

130. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 218 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 219.

131. The antibody of claim 126, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 220.

132. The antibody of claim 128, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 219.

133. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 220 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 219.

134. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SYWIN (SEQ ID NO: 222);
- (b) an HVR-H2 comprising the amino acid sequence of RIAPGSGFISYNELFKD (SEQ ID NO: 223);
- (c) an HVR-H3 comprising the amino acid sequence of EFYYGSFYGGFAY (SEQ ID NO: 224);
- (d) an HVR-L1 comprising the amino acid sequence of HASQNIHVWLS (SEQ ID NO: 225);
- (e) an HVR-L2 comprising the amino acid sequence of KASTLHT (SEQ ID NO: 226); and
- (f) an HVR-L3 comprising the amino acid sequence of QQGQSSPLT (SEQ ID NO: 227).

135. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 236; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 237; or (c) a VH domain as in (a) and a VL domain as in (b).

136. The antibody of claim 135, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of QVQLQQSGNDLVKPGASVKLSCKASGYTFT (SEQ ID NO: 228);
- (b) an FR-H2 comprising the amino acid sequence of WIKQRPGQGLEWIG (SEQ ID NO: 229);
- (c) an FR-H3 comprising the amino acid sequence of KATLTVDTSSSTAYIQLGSLSEDSAVYFCAR (SEQ ID NO: 230); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSA (SEQ ID NO: 231).

137. The antibody of claim 136, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 236.

138. The antibody of any one of claims 135-137, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIQMNQSPSSLSASLGDTITITC (SEQ ID NO: 232);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGNIPKLLIY (SEQ ID NO: 233);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTGFTLTISLQPEDATYYC (SEQ ID NO: 234); and
- (d) an FR-L4 comprising the amino acid sequence of FGAGTKLEVK (SEQ ID NO: 235).

139. The antibody of claim 138, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 237.

140. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 236 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 237.

141. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 246; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 247; or (c) a VH domain as in (a) and a VL domain as in (b).

142. The antibody of claim 141, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVQSGAEVKKPGASVKVSCKASGYTFT (SEQ ID NO: 238);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGQGLEWIG (SEQ ID NO: 239);
- (c) an FR-H3 comprising the amino acid sequence of RVTITRDTSTSTAYLESSLRSEDTAVYYCAR (SEQ ID NO: 240); and

(d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 241).

143. The antibody of claim 142, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 246.

144. The antibody of any one of claims 141-143, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 242);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKLLIY (SEQ ID NO: 243);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISSLQPEDFATYYC (SEQ ID NO: 244); and
- (d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 245).

145. The antibody of claim 144, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 247.

146. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 246 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 247.

147. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of GSAX₁H (SEQ ID NO: 248), wherein X₁ is Met or Ile;
- (b) an HVR-H2 comprising the amino acid sequence of RIRSX₁X₂NX₃YATX₄YX₅ASVKG (SEQ ID NO: 249), wherein X₁ is Arg or Lys, X₂ is Asn, Thr, or Gly, X₃ is Asn or Ser, X₄ is Ala or Glu, and X₅ is Ala or Asp;
- (c) an HVR-H3 comprising the amino acid sequence of X₁X₂X₃X₄PFDY (SEQ ID NO: 250), wherein X₁ is Leu or Gln, X₂ is Gln, Gly, or Phe, X₃ is Gln or Gly, and X₄ is Pro or Asp;
- (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251);
- (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and
- (f) an HVR-L3 comprising the amino acid sequence of LQHX₁X₂YPX₃T (SEQ ID NO: 253), wherein X₁ is Asp or Ser, X₂ is Ser or Ile, and X₃ is Leu or Pro.

148. The antibody of claim 147, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254);
- (b) an HVR-H2 comprising the amino acid sequence of RIRSRNNNYATAYAASVKG (SEQ ID NO: 255);
- (c) an HVR-H3 comprising the amino acid sequence of LQQPPFDY (SEQ ID NO: 256);

- (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251);
- (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and
- (f) an HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257).

149. The antibody of claim 147, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of GSAIH (SEQ ID NO: 258);
- (b) an HVR-H2 comprising the amino acid sequence of RIRSRTNNYATEYDASVKG (SEQ ID NO: 259);
- (c) an HVR-H3 comprising the amino acid sequence of LGQPPFDY (SEQ ID NO: 260);
- (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251);
- (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and
- (f) an HVR-L3 comprising the amino acid sequence of LQHSIYPPT (SEQ ID NO: 261).

150. The antibody of claim 147, wherein the binding domain comprises the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of GSAMH (SEQ ID NO: 254);
- (b) an HVR-H2 comprising the amino acid sequence of RIRSKGNSYATAYAASVKG (SEQ ID NO: 262);
- (c) an HVR-H3 comprising the amino acid sequence of QFGDPFDY (SEQ ID NO: 263);
- (d) an HVR-L1 comprising the amino acid sequence of RASQGIRNDLD (SEQ ID NO: 251);
- (e) an HVR-L2 comprising the amino acid sequence of AASSLQS (SEQ ID NO: 252); and
- (f) an HVR-L3 comprising the amino acid sequence of LQHDSYPLT (SEQ ID NO: 257).

151. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 282; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 283; or (c) a VH domain as in (a) and a VL domain as in (b).

152. The antibody of claim 151, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of QVQLVQSGGGLVQPGGSLKLSAASGFTFS (SEQ ID NO: 264);
- (b) an FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267);
- (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKRTTYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 269); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272).

153. The antibody of claim 152, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 282.

154. The antibody of any one of claims 151-153, wherein the VL domain further comprises:
- (a) an FR-L1 comprising the amino acid sequence of DIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 273);
 - (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276);
 - (c) an FR-L3 comprising the amino acid sequence of GVPSRFNGSGSGTEFTLTISSLQPEDFATYYC (SEQ ID NO: 277); and
 - (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280).
155. The antibody of claim 154, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 283.
156. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 282 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 283.
157. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 284; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 285; or (c) a VH domain as in (a) and a VL domain as in (b).
158. The antibody of claim 157, wherein the VH domain further comprises:
- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGDLVQPGGSLKLSCAASGFTFS (SEQ ID NO: 265);
 - (b) an FR-H2 comprising the amino acid sequence of WVRQASGKGLEWVG (SEQ ID NO: 267);
 - (c) an FR-H3 comprising the amino acid sequence of RFTISRDDSKRTAYLQMNSLKTEDTAVYYCTR (SEQ ID NO: 270); and
 - (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272).
159. The antibody of claim 158, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 284.
160. The antibody of any one of claims 157-159, wherein the VL domain further comprises:
- (a) an FR-L1 comprising the amino acid sequence of AIQMTQSPSSLSASVGDRVTITC (SEQ ID NO: 274);
 - (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276);
 - (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTDFTLTISSLQPEDFATYYC (SEQ ID NO: 278); and

(d) an FR-L4 comprising the amino acid sequence of FGQGTKVEIK (SEQ ID NO: 281).

161. The antibody of claim 160, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 285.

162. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 284 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 285.

163. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a heavy chain variable (VH) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 286; (b) a light chain variable (VL) domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 287; or (c) a VH domain as in (a) and a VL domain as in (b).

164. The antibody of claim 163, wherein the VH domain further comprises:

- (a) an FR-H1 comprising the amino acid sequence of EVQLVESGGGLVQPGGSLKLSCAASGFTFS (SEQ ID NO: 266);
- (b) an FR-H2 comprising the amino acid sequence of WVRQAPGKGLEWVG (SEQ ID NO: 268);
- (c) an FR-H3 comprising the amino acid sequence of RFSISRDDSKRTAYLQMSSSLKTEDSAVYYCAR (SEQ ID NO: 271); and
- (d) an FR-H4 comprising the amino acid sequence of WGQGTLVTVSS (SEQ ID NO: 272).

165. The antibody of claim 164, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 286.

166. The antibody of any one of claims 163-165, wherein the VL domain further comprises:

- (a) an FR-L1 comprising the amino acid sequence of AIRITQSPSSLSASVGDRVTITC (SEQ ID NO: 275);
- (b) an FR-L2 comprising the amino acid sequence of WYQQKPGKAPKRLIY (SEQ ID NO: 276);
- (c) an FR-L3 comprising the amino acid sequence of GVPSRFSGSGSGTEFTLTISSLQPEDFATYYC (SEQ ID NO: 279); and
- (d) an FR-L4 comprising the amino acid sequence of FGGGTKVEIK (SEQ ID NO: 280).

167. The antibody of claim 166, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 287.

168. An isolated antibody that specifically binds IL-33, wherein the antibody comprises a binding domain comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 286 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 287.

169. An isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 288 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 289.

170. An isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 290 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 291.

171. An isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 292 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 293.

172. An isolated antibody that specifically binds IL-33, wherein the antibody comprises (a) a heavy chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 294 and (b) a light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 295.

173. The antibody of any one of claims 37-172, wherein the antibody specifically binds human or cyno IL-33.

174. The antibody of claim 173, wherein the antibody specifically binds both human and cyno IL-33.

175. The antibody of claim 174, wherein the antibody specifically binds both human and cyno IL-33 with a K_D of about 1 nM or lower.

176. The antibody of claim 175, wherein the antibody specifically binds human IL-33 with a K_D between about 100 fM and about 1 nM.

177. The antibody of claim 176, wherein the antibody specifically binds human IL-33 with a K_D between about 1 pM and about 200 pM.

178. The antibody of claim 177, wherein the antibody specifically binds human IL-33 with a K_D between about 15 pM and about 180 pM.

179. The antibody of claim 178, wherein the antibody specifically binds human IL-33 with a K_D between about 15 pM and about 140 pM.

180. The antibody of claim 175, wherein the antibody specifically binds cyno IL-33 with a K_D between about 100 fM and about 1 nM.

181. The antibody of claim 180, wherein the antibody specifically binds cyno IL-33 with a K_D between about 1 pM and about 500 pM.

182. The antibody of claim 181, wherein the antibody specifically binds cyno IL-33 with a K_D between about 100 pM and about 500 pM.

183. The antibody of claim 182, wherein the antibody specifically binds cyno IL-33 with a K_D between about 125 pM and about 500 pM.

184. The antibody of claim 176 or 181, wherein the antibody specifically binds both human and cyno IL-33 with a K_D of between about 1 pM and about 500 pM.

185. The antibody of claim 184, wherein the antibody specifically binds human IL-33 with a K_D of between about 1 pM and about 200 pM.

186. The antibody of any one of claims 1-7 or 37-185, wherein the antibody is capable of inhibiting the binding of IL-33 to an IL-33 receptor.

187. The antibody of claim 186, wherein the inhibiting is measured using a cell-based blocking assay.

188. The antibody of claim 187, wherein the antibody inhibits the binding of human IL-33 to an IL-33 receptor with a 90% inhibitory concentration (IC₉₀) of between about 0.001 µg/ml and about 0.5 µg/ml.

189. The antibody of claim 188, wherein the IC₉₀ is between about 0.002 µg/ml and about 0.25 µg/ml.

190. The antibody of claim 189, wherein the IC₉₀ is about 0.17 µg/ml.

191. The antibody of claim 189, wherein the IC₉₀ is about 0.004 µg/ml.

192. The antibody of any one of claims 1-7 or 37-191, wherein the antibody inhibits binding of human IL-33 to an IL-33 receptor with an IC₅₀ of between about 800 fM and about 10 pM.
193. The antibody of claim 192, wherein the IC₅₀ is between about 1 pM and about 5 pM.
194. The antibody of claim 193, wherein the IC₅₀ is about 2.5 pM.
195. The antibody of any one of claims 1-7 or 37-194, wherein the antibody inhibits binding of cyno IL-33 to an IL-33 receptor with an IC₅₀ of between about 1 nM and about 5 nM.
196. The antibody of claim 195, wherein the IC₅₀ is about 4 nM.
197. The antibody of any one of claims 1-196, wherein the antibody comprises an aglycosylation site mutation.
198. The antibody of any one of claims 1-198, wherein the antibody is monoclonal, human, humanized, or chimeric.
199. The antibody of any one of claims 1-198, wherein the antibody is an antibody fragment that binds IL-33.
200. The antibody of claim 199, wherein the antibody fragment is selected from the group consisting of Fab, Fab'-SH, Fv, scFv, and (Fab')₂ fragments.
201. The antibody of any one of claims 1-198, wherein the antibody is a full-length antibody.
202. The antibody of claim 201, wherein the antibody is an IgG antibody.
203. The antibody of claim 202, wherein the IgG antibody is an IgG1 antibody.
204. The antibody of claim 202, wherein the IgG antibody is an IgG4 antibody.
205. The antibody of claim 204, wherein the IgG4 antibody comprises a mutation in the hinge region.
206. The antibody of claim 205, wherein the mutation is a substitution mutation.
207. The antibody of claim 206, wherein the substitution mutation is at amino acid residue S228 (EU numbering).

208. The antibody of claim 207, wherein the substitution mutation is an S228P mutation.
209. The antibody of any one of claims 1-208, wherein the antibody is a monospecific antibody.
210. The antibody of any one of claims 1-208, wherein the antibody is a multispecific antibody.
211. The antibody of claim 210, wherein the antibody is a bispecific antibody.
212. The antibody of claim 211, wherein the bispecific antibody comprises a second binding domain that binds to a second biological molecule, wherein the second biological molecule is selected from the group consisting of interleukin-13 (IL-13), interleukin-4 (IL-4), interleukin-5 (IL-5), interleukin-17 (IL-17), Factor D, HtrA1, VEGF, and a VEGF receptor.
213. The antibody of claim 212, wherein the second biological molecule is Factor D.
214. The antibody of claim 212, wherein the second biological molecule is HtrA1.
215. The antibody of claim 212, wherein the second biological molecule is VEGF.
216. The antibody of claim 212, wherein the second biological molecule is IL-13.
217. The antibody of claim 216, wherein the second binding domain comprises the following six HVRs:
- (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296);
 - (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297);
 - (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298);
 - (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299);
 - (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and
 - (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301).
218. The antibody of claim 217, wherein the second binding domain comprises (a) a VH domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 302; (b) a VL domain comprising an amino acid sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 303; or (c) a VH domain as in (a) and a VL domain as in (b).
219. The antibody of claim 218, wherein the VH domain comprises the amino acid sequence of SEQ ID NO: 302.

220. The antibody of claim 218, wherein the VL domain comprises the amino acid sequence of SEQ ID NO: 303.

221. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SFSMS (SEQ ID NO: 1);
- (b) an HVR-H2 comprising the amino acid sequence of TISGGKTFTDYVDSVKG (SEQ ID NO: 2);
- (c) an HVR-H3 comprising the amino acid sequence of ANYGNWFFEY (SEQ ID NO: 3);
- (d) an HVR-L1 comprising the amino acid sequence of RASESVAKYGLSLLN (SEQ ID NO: 4);
- (e) an HVR-L2 comprising the amino acid sequence of AASNRGS (SEQ ID NO: 5); and
- (f) an HVR-L3 comprising the amino acid sequence of QQSKEVPFT (SEQ ID NO: 6); and

a second binding domain that specifically binds IL-13 comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296);
- (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297);
- (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298);
- (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299);
- (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and
- (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301).

222. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of SSIFYWG (SEQ ID NO: 65);
- (b) an HVR-H2 comprising the amino acid sequence of SIYYSGRTYYNPSLKS (SEQ ID NO: 66);
- (c) an HVR-H3 comprising the amino acid sequence of AGGLYNWNDESFYMDV (SEQ ID NO: 68);
- (d) an HVR-L1 comprising the amino acid sequence of RASQSFSSSYLA (SEQ ID NO: 69);
- (e) an HVR-L2 comprising the amino acid sequence of GASSRAT (SEQ ID NO: 70); and
- (f) an HVR-L3 comprising the amino acid sequence of QQYDRSPLT (SEQ ID NO: 71); and

a second binding domain that specifically binds IL-13 comprising the following six HVRs:

- (a) an HVR-H1 comprising the amino acid sequence of AYSVN (SEQ ID NO: 296);
- (b) an HVR-H2 comprising the amino acid sequence of MIWGDGKIVYNSALKS (SEQ ID NO: 297);
- (c) an HVR-H3 comprising the amino acid sequence of DGYYPYAMDN (SEQ ID NO: 298);
- (d) an HVR-L1 comprising the amino acid sequence of RASKSVDSYGNSFMH (SEQ ID NO: 299);
- (e) an HVR-L2 comprising the amino acid sequence of LASNLES (SEQ ID NO: 300); and
- (f) an HVR-L3 comprising the amino acid sequence of QQNNEDPRT (SEQ ID NO: 301).

223. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 36 and (b) a

VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 37, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303.

224. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises a first binding domain that specifically binds IL-33 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 84 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 85, and a second binding domain that specifically binds IL-13 comprising (a) a VH domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 302 and (b) a VL domain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 303.

225. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises:

- (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 306 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 307, and
- (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305.

226. An isolated antibody that specifically binds both IL-33 and IL-13, wherein the antibody comprises:

- (a) a first heavy chain and a first light chain that specifically bind IL-33, wherein the first heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 308 and the first light chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 309, and
- (b) a second heavy chain and a second light chain that specifically bind IL-13, wherein the second heavy chain comprises an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 304 and the second light chain comprising an amino acid sequence having at least 99% sequence identity to the amino acid sequence of SEQ ID NO: 305.

227. The antibody of any one of claims 210-226, wherein the antibody is an antigen-binding antibody fragment.

228. The antibody of claim 227, wherein the antigen-binding antibody fragment is selected from the group consisting of Fab, Fab'-SH, Fv, scFv, and (Fab')₂ fragments.

229. The antibody of claim 228, wherein the antigen-binding antibody fragment is an Fab or an (Fab')₂ fragment.

230. An isolated nucleic acid encoding the antibody of any one of claims 1-229.

231. A vector comprising the isolated nucleic acid of claim 230.

232. A host cell comprising the vector of claim 231.

233. The host cell of claim 232, wherein the host cell is a mammalian cell.

234. The host cell of claim 233, wherein the mammalian cell is a Chinese hamster ovary (CHO) cell.

235. The host cell of claim 232, wherein the host cell is a prokaryotic cell.

236. The host cell of claim 235, wherein the prokaryotic cell is *E. coli*.

237. A method of producing the antibody of any one of claims 1-229, the method comprising culturing the host cell of claim 232 in a culture medium.

238. The method of claim 237, wherein the method further comprises recovering the antibody from the host cell or the culture medium.

239. A composition comprising the antibody of any one of claims 1-229.

240. The composition of claim 239, further comprising a pharmaceutically acceptable carrier, excipient, or diluent.

241. The composition of claim 240, wherein the composition is a pharmaceutical composition.

242. The composition of any one of claims 239-241, wherein the pharmaceutical composition further comprises an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist.

243. The composition of claim 242, wherein the pharmaceutical composition comprises a Factor D binding antagonist.

244. The composition of claim 243, wherein the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.

245. The composition of claim 242, wherein the pharmaceutical composition comprises an HtrA1 binding antagonist.

246. The composition of claim 245, wherein the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.

247. The composition of claim 242, wherein the pharmaceutical composition comprises a VEGF antagonist.

248. The composition of claim 247, wherein the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

249. The antibody of any one of claims 1-229 for use as a medicament.

250. The antibody of any one of claims 1-229 for use in treating an IL-33-mediated disorder.

251. The antibody of claim 250, wherein the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder.

252. The antibody of claim 251, wherein the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD).

253. The antibody of claim 251, wherein the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergy, anaphylaxis, anaphylactic shock, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease.

254. The antibody of claim 251, wherein the fibrotic disease is idiopathic pulmonary fibrosis (IPF).

255. The antibody of claim 251, wherein the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID).

256. The antibody of claim 255, wherein the EGID is eosinophilic esophagitis.
257. The antibody of claim 251, wherein the infection is a helminth infection, a protozoan infection, or a viral infection.
258. The antibody of claim 257, wherein the protozoan infection is a *Leishmania major* infection.
259. The antibody of claim 257, wherein the viral infection is a respiratory syncytial virus (RSV) infection or an influenza infection.
260. The antibody of claim 251, wherein the pain is inflammatory pain.
261. The antibody of claim 251, wherein the central nervous system disorder is Alzheimer's disease.
262. The antibody of claim 251, wherein the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor.
263. The antibody of claim 251, wherein the ophthalmologic disorder is selected from the group consisting of age-related macular degeneration (AMD), retinopathy of the eye, polypoidal choroidal vasculopathy (PCV), diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis.
264. The antibody of claim 263, wherein the AMD is wet AMD, dry AMD, or geographic atrophy (GA).
265. The antibody of claim 263, wherein the AMD is intermediate AMD or advanced AMD.
266. The antibody of claim 263, wherein the retinopathy of the eye is diabetic retinopathy (DR) or retinopathy of prematurity (ROP).
267. The antibody of claim 263, wherein the retinopathy of the eye is high-altitude DR.
268. The antibody of claim 263, wherein the conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis.
269. The antibody of claim 263, wherein the conjunctivitis is allergic conjunctivitis.

270. Use of an antibody of any one of claims 1-229 in the manufacture of a medicament for treating an IL-33-mediated disorder.

271. The use of claim 270, wherein the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder.

272. The use of claim 271, wherein the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD).

273. The use of claim 271, wherein the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergy, anaphylaxis, anaphylactic shock, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease.

274. The use of claim 271, wherein the fibrotic disease is idiopathic pulmonary fibrosis (IPF).

275. The use of claim 271, wherein the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID).

276. The use of claim 275, wherein the EGID is eosinophilic esophagitis.

277. The use of claim 271, wherein the infection is a helminth infection, a protozoan infection, or a viral infection.

278. The use of claim 277, wherein the protozoan infection is a *Leishmania major* infection.

279. The use of claim 277, wherein the viral infection is a RSV infection or an influenza infection.

280. The use of claim 271, wherein the pain is inflammatory pain.

281. The use of claim 271, wherein the central nervous system disorder is Alzheimer's disease.

282. The use of claim 271, wherein the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor.

283. The use of claim 271, wherein the ophthalmologic disorder is selected from the group consisting of AMD, retinopathy of the eye, PCV, diabetic macular edema, dry eye disease, Behcet's disease, retina

detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis.

284. The use of claim 283, wherein the AMD is wet AMD, dry AMD, or GA.

285. The use of claim 283, wherein the AMD is intermediate AMD or advanced AMD.

286. The use of claim 283, wherein the retinopathy of the eye is DR or ROP.

287. The use of claim 283, wherein the retinopathy of the eye is high-altitude DR.

288. The use of claim 283, wherein the conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis.

289. The use of claim 283, wherein the conjunctivitis is allergic conjunctivitis.

290. The use of any one of claims 270-289, wherein the medicament is formulated for use in combination with an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist.

291. The use of claim 290, wherein the medicament is formulated for use in combination with a Factor D binding antagonist.

292. The use of claim 291, wherein the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.

293. The use of claim 290, wherein the medicament is formulated for use in combination with an HtrA1 binding antagonist.

294. The use of claim 293, wherein the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.

295. The use of claim 290, wherein the medicament is formulated for use in combination with a VEGF antagonist.

296. The use of claim 295, wherein the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

297. Use of a bispecific antibody that specifically binds both IL-33 and Factor D or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating GA.

298. The use of claim 297, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.

299. Use of an antibody of any one of claims 1-229 in the manufacture of a medicament for treating GA, wherein the medicament is formulated for use in combination with a Factor D binding antagonist.

300. The use of claim 299, wherein the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.

301. Use of a bispecific antibody that specifically binds both IL-33 and HtrA1 or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating GA, AMD, DR, PCV, or ROP.

302. The use of claim 301, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.

303. Use of an antibody of any one of claims 1-229 in the manufacture of a medicament for treating GA, AMD, DR, PCV, or ROP, wherein the medicament is formulated for use in combination with an HtrA1 binding antagonist.

304. The use of claim 303, wherein the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.

305. Use of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof in the manufacture of a medicament for treating wet AMD.

306. The use of claim 305, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.

307. Use of an antibody of any one of claims 1-229 in the manufacture of a medicament for treating wet AMD, wherein the medicament is formulated for use in combination with a VEGF antagonist.

308. The use of claim 307, wherein the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.

309. A method of treating an IL-33-mediated disorder in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of the antibody of any one of claims 1-229.

310. The method of claim 309, wherein the IL-33-mediated disorder is selected from the group consisting of an inflammatory condition, an immune disorder, a fibrotic disorder, an eosinophilic disorder, an infection, pain, a central nervous system disorder, a solid tumor, and an ophthalmologic disorder.

311. The method of claim 310, wherein the inflammatory condition is selected from the group consisting of asthma, sepsis, septic shock, atopic dermatitis, allergic rhinitis, rheumatoid arthritis, and chronic obstructive pulmonary disease (COPD).

312. The method of claim 310, wherein the immune disorder is selected from the group consisting of asthma, rheumatoid arthritis, allergy, anaphylaxis, anaphylactic shock, allergic rhinitis, psoriasis, inflammatory bowel disease (IBD), Crohn's disease, diabetes, and liver disease.

313. The method of claim 310, wherein the fibrotic disease is idiopathic pulmonary fibrosis (IPF).

314. The method of claim 310, wherein the eosinophilic disorder is an eosinophil-associated gastrointestinal disorder (EGID).

315. The method of claim 314, wherein the EGID is eosinophilic esophagitis.

316. The method of claim 310, wherein the infection is a helminth infection, a protozoan infection, or a viral infection.

317. The method of claim 316, wherein the protozoan infection is a Leishmania major infection.

318. The method of claim 316, wherein the viral infection is a respiratory syncytial virus (RSV) infection or an influenza infection.

319. The method of claim 310, wherein the pain is inflammatory pain.

320. The method of claim 310, wherein the solid tumor is selected from the group consisting of breast tumor, colon tumor, prostate tumor, lung tumor, kidney tumor, liver tumor, pancreas tumor, stomach tumor, intestinal tumor, brain tumor, bone tumor, and skin tumor.

321. The method of claim 310, wherein the ophthalmologic disorder is selected from the group consisting of AMD, retinopathy of the eye, PCV, diabetic macular edema, dry eye disease, Behcet's disease, retina detachment, glaucoma, uveitis, retinitis pigmentosa, Leber Congenital Amaurosis, Stargardt's disease, traumatic eye injury, and conjunctivitis.

322. The method of claim 321, wherein the AMD is wet AMD, dry AMD, or GA.

323. The method of claim 321, wherein the AMD is intermediate AMD or advanced AMD.
324. The method of claim 321, wherein the retinopathy of the eye is DR or ROP.
325. The method of claim 321, wherein the retinopathy of the eye is high-altitude DR.
326. The method of claim 321, wherein the conjunctivitis is infectious conjunctivitis or non-infectious conjunctivitis.
327. The method of claim 321, wherein the conjunctivitis is allergic conjunctivitis.
328. The method of any one of claims 309-327, further comprising administering to the subject an ST2 binding antagonist, a Factor D binding antagonist, an HtrA1 binding antagonist, a VEGF antagonist, a tryptase-beta binding antagonist, a chemoattractant receptor-homologous molecule expressed on Th2 cells (CRTH2) binding antagonist, an interleukin-13 (IL-13) binding antagonist, an interleukin-17 (IL-17) binding antagonist, a JAK1 antagonist, and/or an interleukin-5 (IL-5) binding antagonist.
329. The method of claim 328, wherein the method further comprises administering to the subject a Factor D binding antagonist.
330. The method of claim 329, wherein the Factor D binding antagonist is anti-Factor D antibody or an antigen-binding fragment thereof.
331. The method of claim 328, wherein the method further comprises administering to the subject an HtrA1 binding antagonist.
332. The method of claim 331, wherein the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.
333. The method of claim 328, wherein the method further comprises administering to the subject a VEGF antagonist.
334. The use of claim 333, wherein the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.
335. A method of treating GA in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and Factor D, or an antigen-binding antibody fragment thereof.

336. The method of claim 335, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.
337. A method of treating GA in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of the antibody of any one of claims 1-229 and a therapeutically effective amount of a Factor D binding antagonist.
338. The method of claim 337, wherein the Factor D binding antagonist is an anti-Factor D antibody or an antigen-binding fragment thereof.
339. A method of treating GA, AMD, DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and HtrA1, or an antigen-binding antibody fragment thereof.
340. The method of claim 339, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.
341. A method of treating GA, AMD, DR, PCV, or ROP in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of the antibody of any one of claims 1-229 and a therapeutically effective amount of an HtrA1 binding antagonist.
342. The method of claim 341, wherein the HtrA1 binding antagonist is an anti-HtrA1 antibody or an antigen-binding fragment thereof.
343. A method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of a bispecific antibody that specifically binds both IL-33 and VEGF or an antigen-binding antibody fragment thereof.
344. The method of claim 343, wherein the antigen-binding antibody fragment is a (Fab')₂ fragment.
345. A method of treating wet AMD in a subject in need thereof, the method comprising administering to the subject a therapeutically effective amount of the antibody of any one of claims 1-229 and a therapeutically effective amount of a VEGF antagonist.
346. The method of claim 345, wherein the VEGF antagonist is an anti-VEGF antibody or an antigen-binding fragment thereof.
347. The method of any one of claims 309-346, wherein the antibody is administered subcutaneously, intravenously, intramuscularly, topically, orally, transdermally, intraperitoneally, intraorbitally, by implantation, by inhalation, intrathecally, intraventricularly, intranasally, intravitreally, intraocularly,

periocularly, conjunctivally, subconjunctivally, subtenonly, intracamerally, subretinally, retrobulbarly, or intracranially.

348. The method of any one of claims 309-347, wherein the subject is a human.

Figure 1A

IL-33 cell-based blocking assay

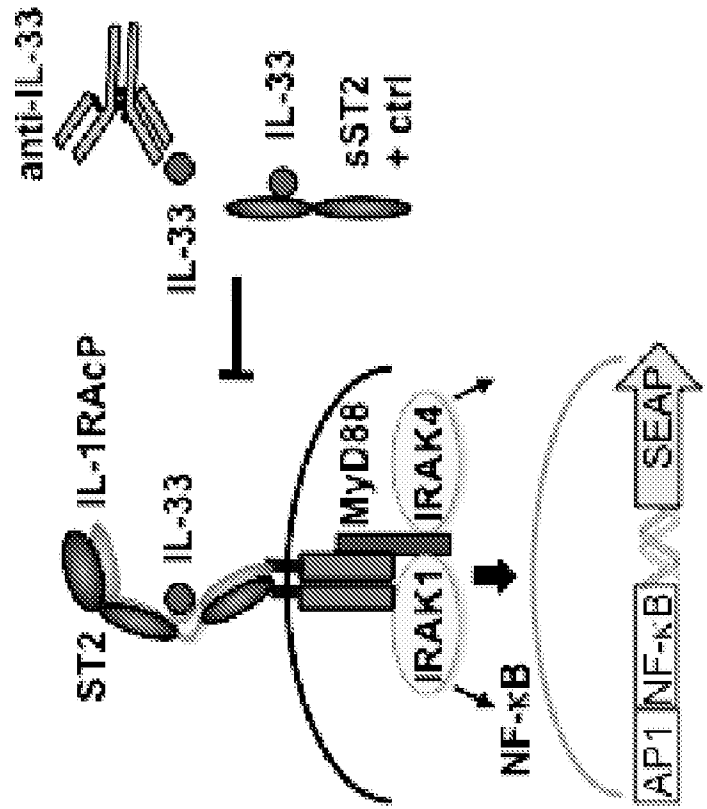
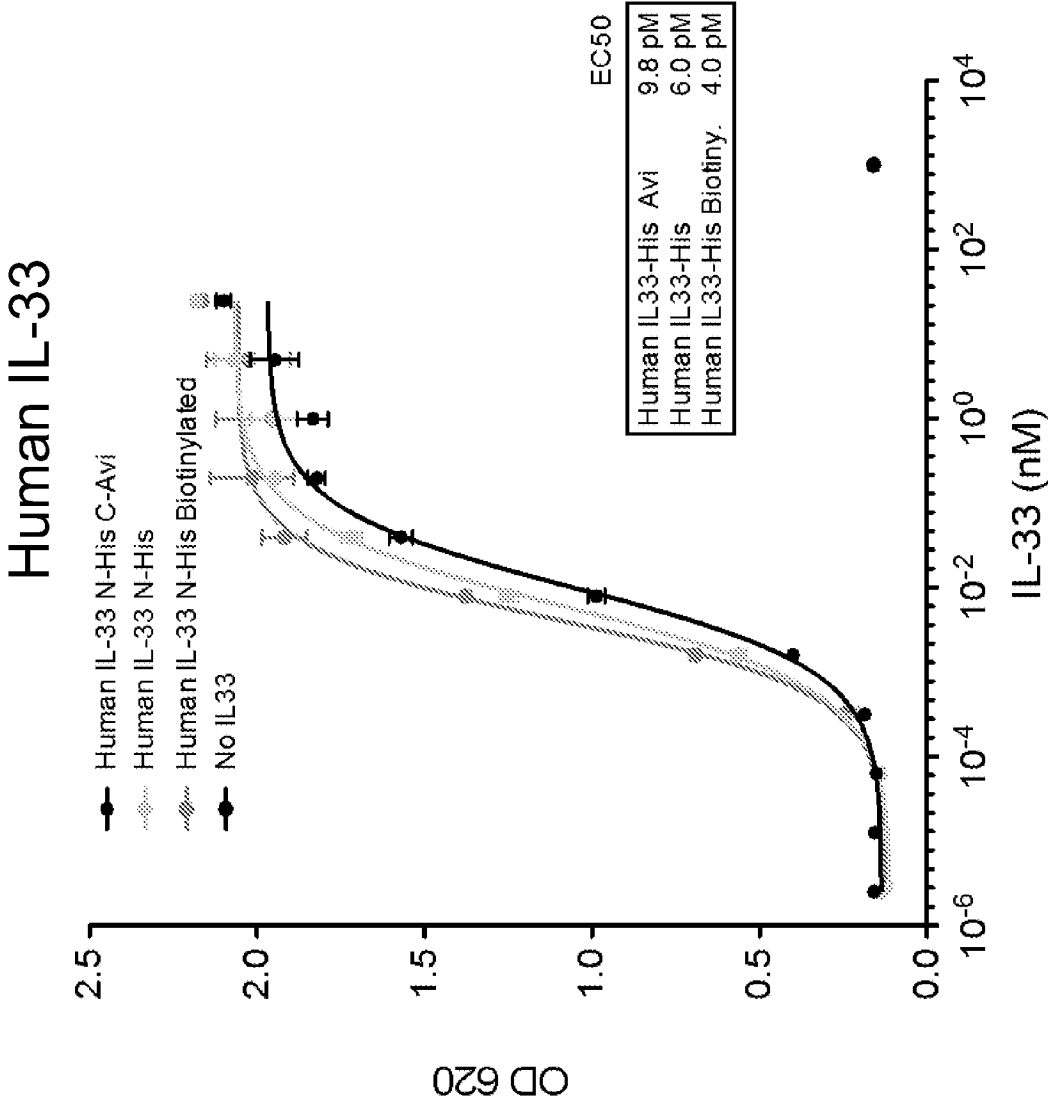


Figure 1B



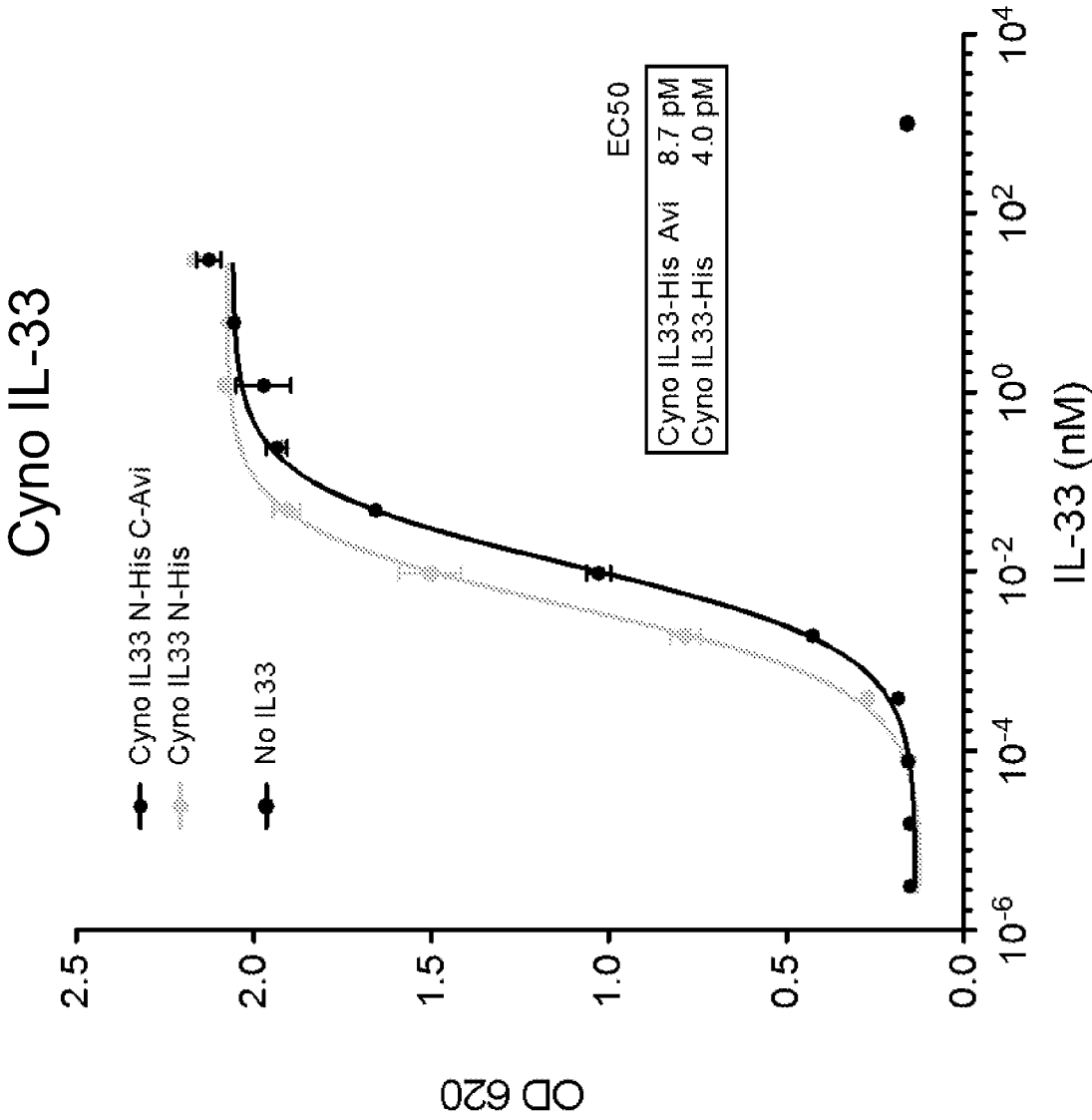
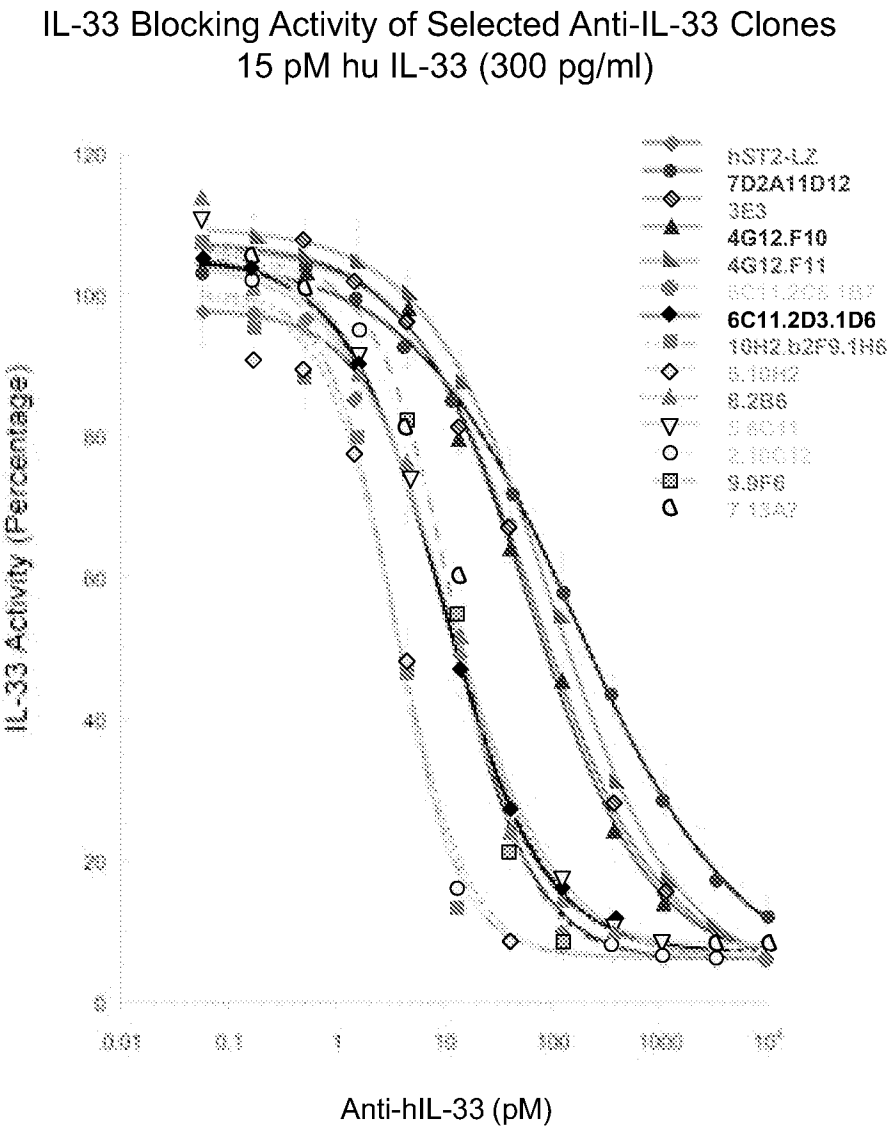


Figure 1C

Figure 2



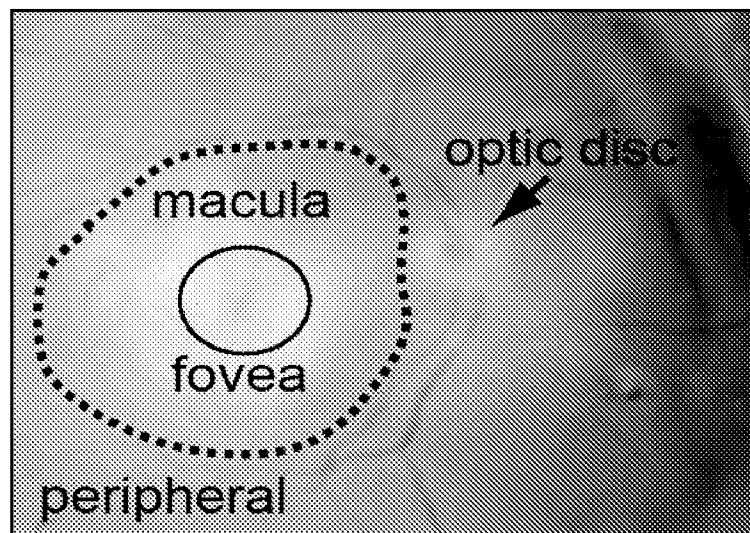
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Figure 3

anti-IL-33	Hu IL-33 IC ₅₀ (pM)	Hu IL-33 IC ₅₀ (pM)	Hu IL-33 IC ₅₀ (pM)	Hu IL-33 IC ₅₀ (log/mL)	Cyno IL-33 IC ₅₀ (pM)	Cyno IL-33 IC ₅₀ (pM)	Cyno IL-33 IC ₅₀ (log/mL)
h5T2-LZ	12.2	46.7			1.8	3.6	
10C12 Mouse Version	3.9	16.2		0.0027	141.0	1269.0	0.1934
10C12 36 H7 HC 62A	2.7	7.7		0.0012	43.5	435.5	0.0653
10C12 36 H7 HC 100Y	>10000	>10000		>1.5	>10000	>10000	>1.5
10C12 36 H7 HC 34L	2.5	8.0		0.0012	39.5	592.9	0.0469
10C12 36 H7 HC 100F	121.3	1625.0		0.2438	>10000	>10000	>1.5
10C12 36 H7 HC 34V	4.5	20.0		0.0031	89.1	1313.0	0.1970
10C12 36 H7 HC 58I	12.9	182.2		0.0273	134.9	1451.0	0.2177
10C12 36 H7 HC 58I	3.6	33.3		0.0060	50.6	531.6	0.0787
10C12 36 H7 HC 87Y	2.6	17.4		0.0026	119.1	1674.0	0.2531
10C12 36 H7 HC 87Y 58I	2.0	20.5		0.0031	181.9	1217.0	0.1826
10C12 36 H7 HC 58I	3.2	18.5		0.0028	156.6	2289.0	0.3449
10C12 36 H7 87Y	2.7	10.9		0.0016	55.0	583.8	0.0676
10C12 36 H7 87Y 58I	3.4	15.2		0.0023	59.1	1087.0	0.1631
10C12 36 H7 58I	2.1	6.5		0.0010	28.6	374.6	0.0562
10H2 Mouse Version	5.2	31.0		0.0047	17.4	271.0	0.0407
10H2 36 F10 LC34L	3.1	11.0		0.0017	4.2	17.0	0.0025
10H2 36 F10 LC30V	6.5	34.7		0.0062	39.6	1185.0	0.1776
10H2 36 F10 HC54D	6.9	32.5		0.0049	72.2	1531.0	0.2297
10H2 36 F10 HC54S	3.5	13.4		0.0020	24.8	435.7	0.0354
10H2 36 F10 HC59A	2.9	11.5		0.0017	22.9	260.1	0.0300
10H2 36 F10 HC100Y	>10000	>10000		>1.5	>10000	>10000	>1.5
10H2 36 F10 HC33F	4.3	26.8		0.0040	17.6	431.0	0.0647
10H2 36 F10 HC33Y	5.6	77.8		0.0117	62.8	527.1	0.0791
10H2 36 F10 HC54A	9.0	15.1		0.0023	21.5	471.6	0.0767
10H2 36 F10 HC100F	46.7	447.5		0.0671	1168.0	>10000	>1.5
6C11 Mouse Version	21.3	120.4		0.0181	>10000	>10000	>1.5
6C11 36 B2 52CA	18.3	203.5		0.0305	1099.0	>10000	>1.5
6C11 36 B2 52aS	4.9	58.1		0.0067	2153.0	>10000	>1.5
6C11 36 B2 100Y	>10000	>10000		>1.5	>10000	>10000	>1.5
6C11 36 B2 100F	1350.0	>10000		>1.5	6664.0	>10000	>1.5
4G12 parental	60.7	854.2		0.1261	19.3	215.6	0.0323
4G12 100aY	4433.0	>10000		>1.5	1181.0	>10000	>1.5
4G12 100aF	2636.0	>10000		>1.5	2427.0	>10000	>1.5
4G12 62A	94.1	1244.0		0.1866	19.6	93.7	0.0341

Figures 4A-4B

A.



B.

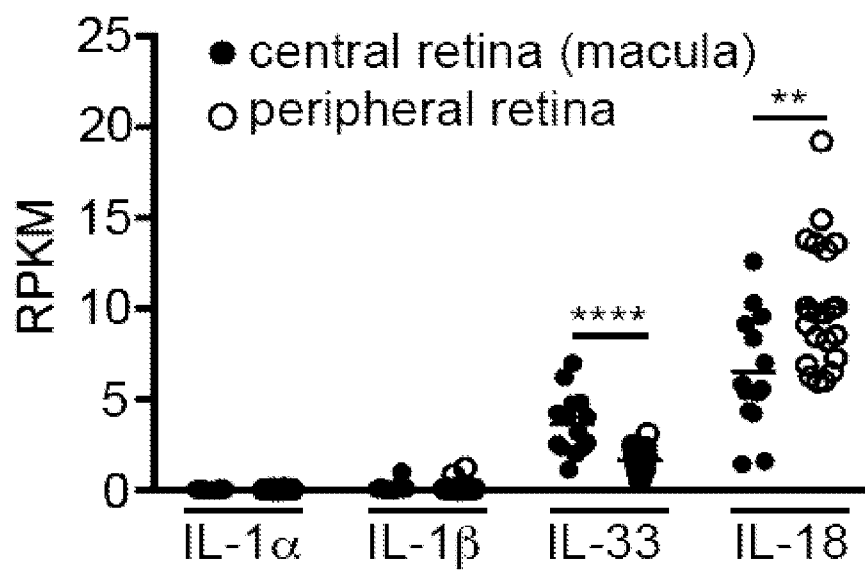
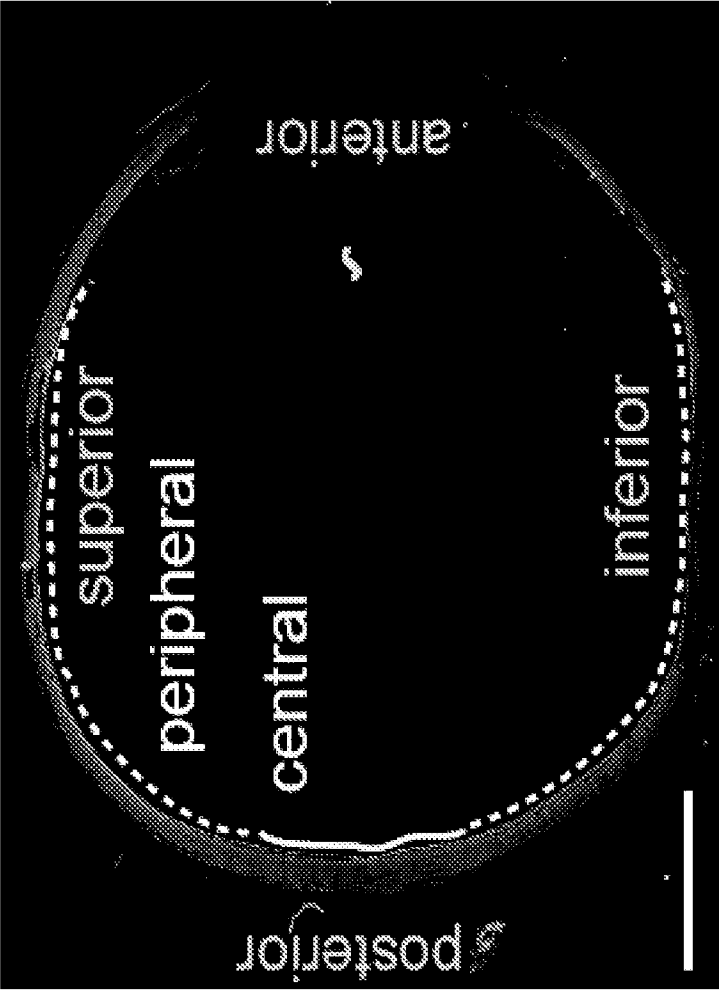


Figure 5A



Figures 5B-5C

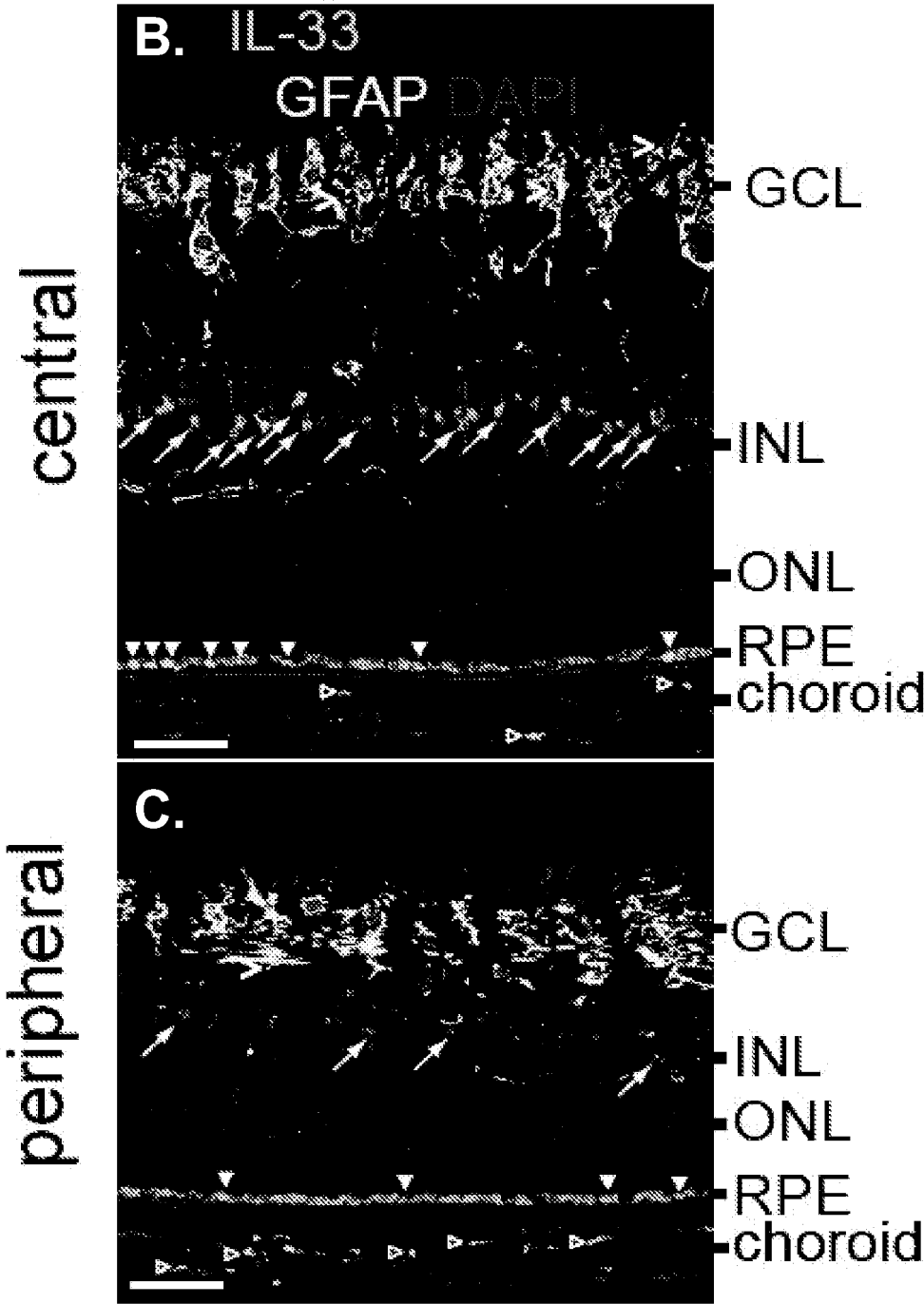
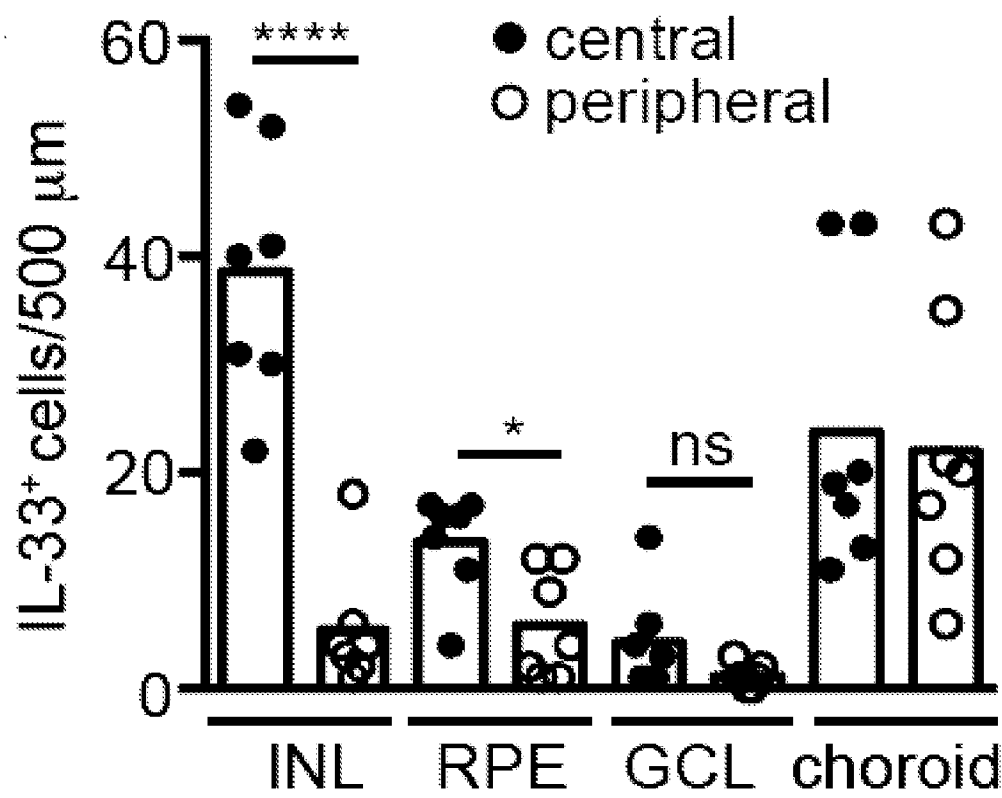


Figure 5D



Figures 5E

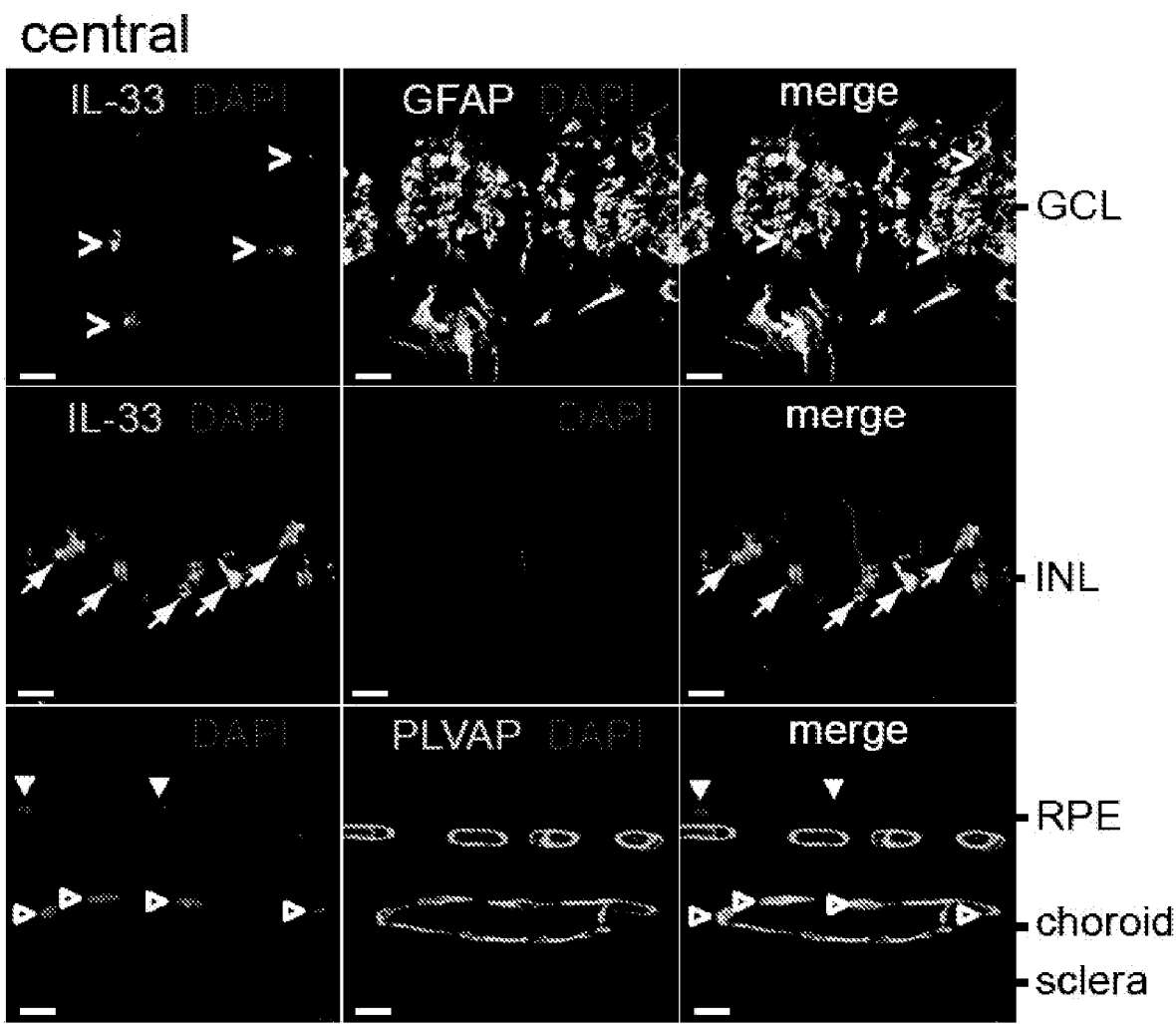


Figure 6A

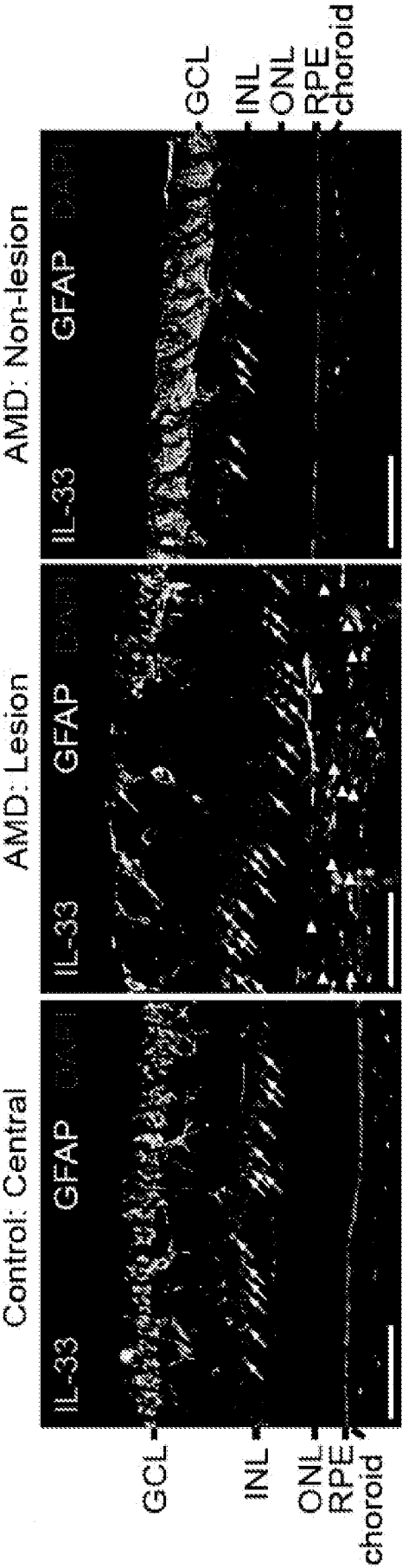
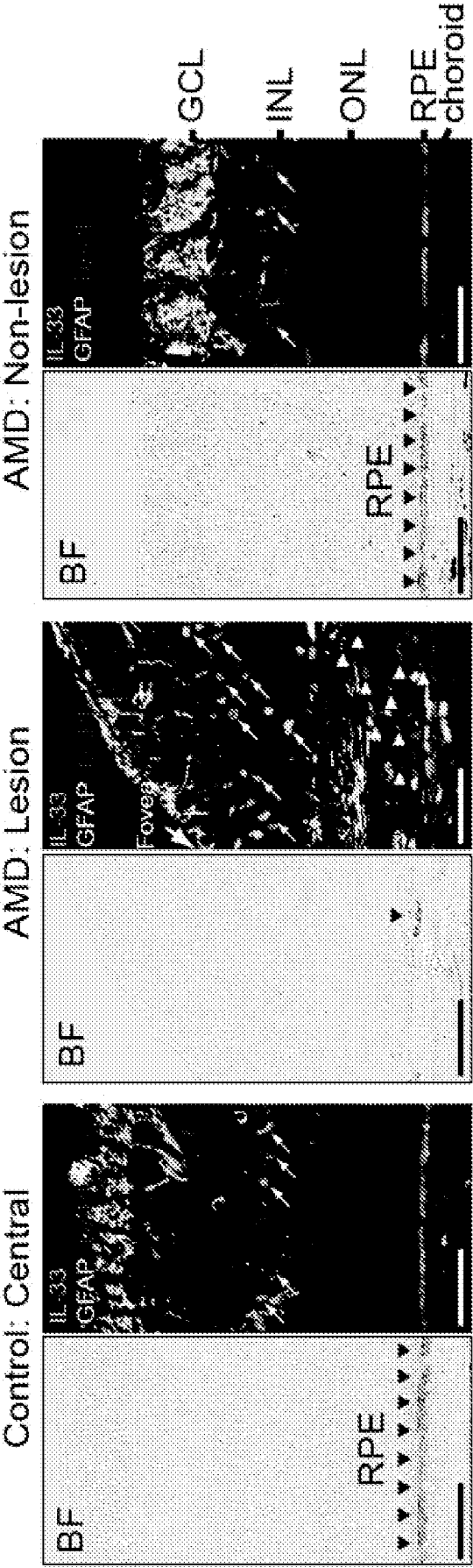
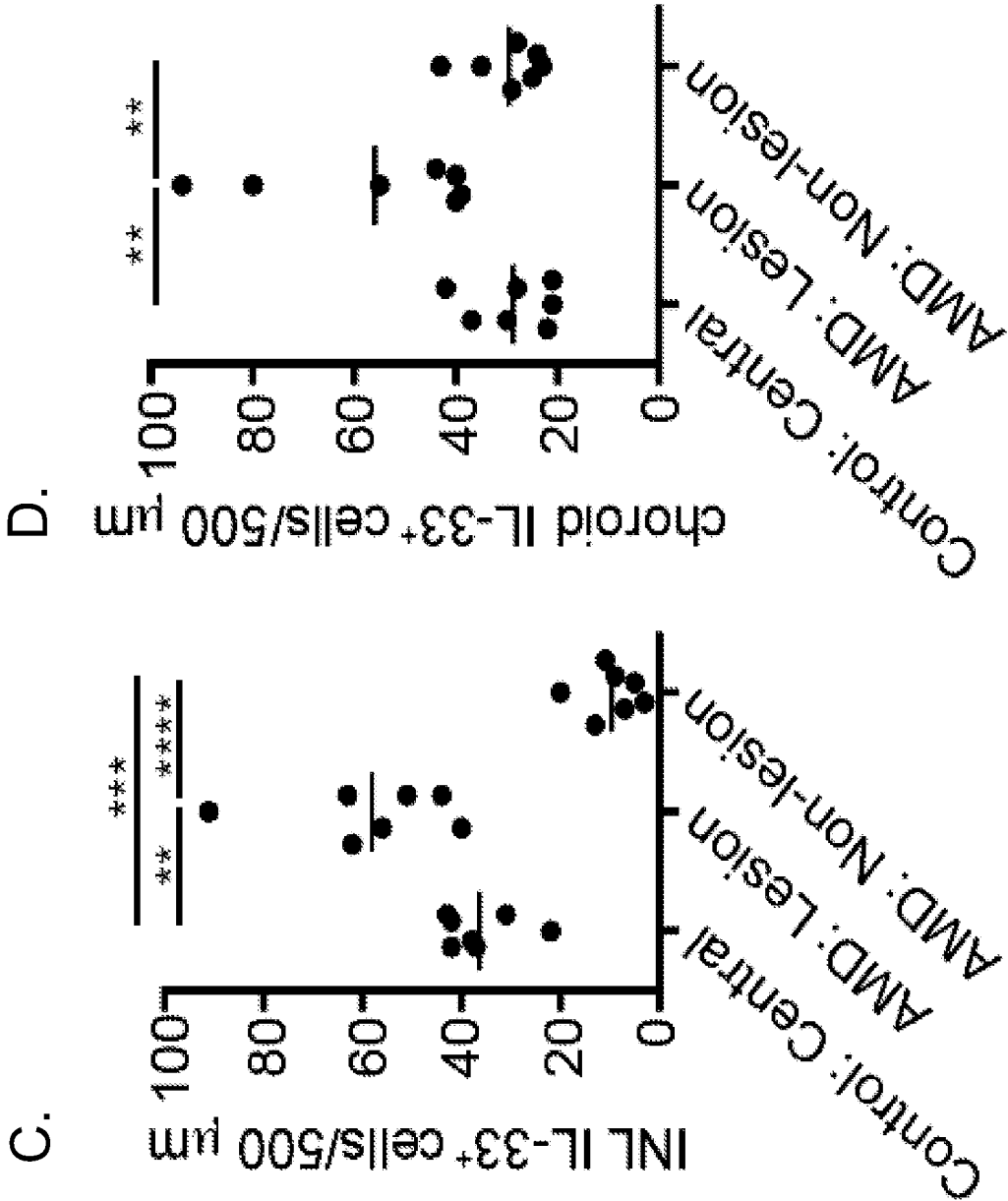


Figure 6B





Figures 6C-6D

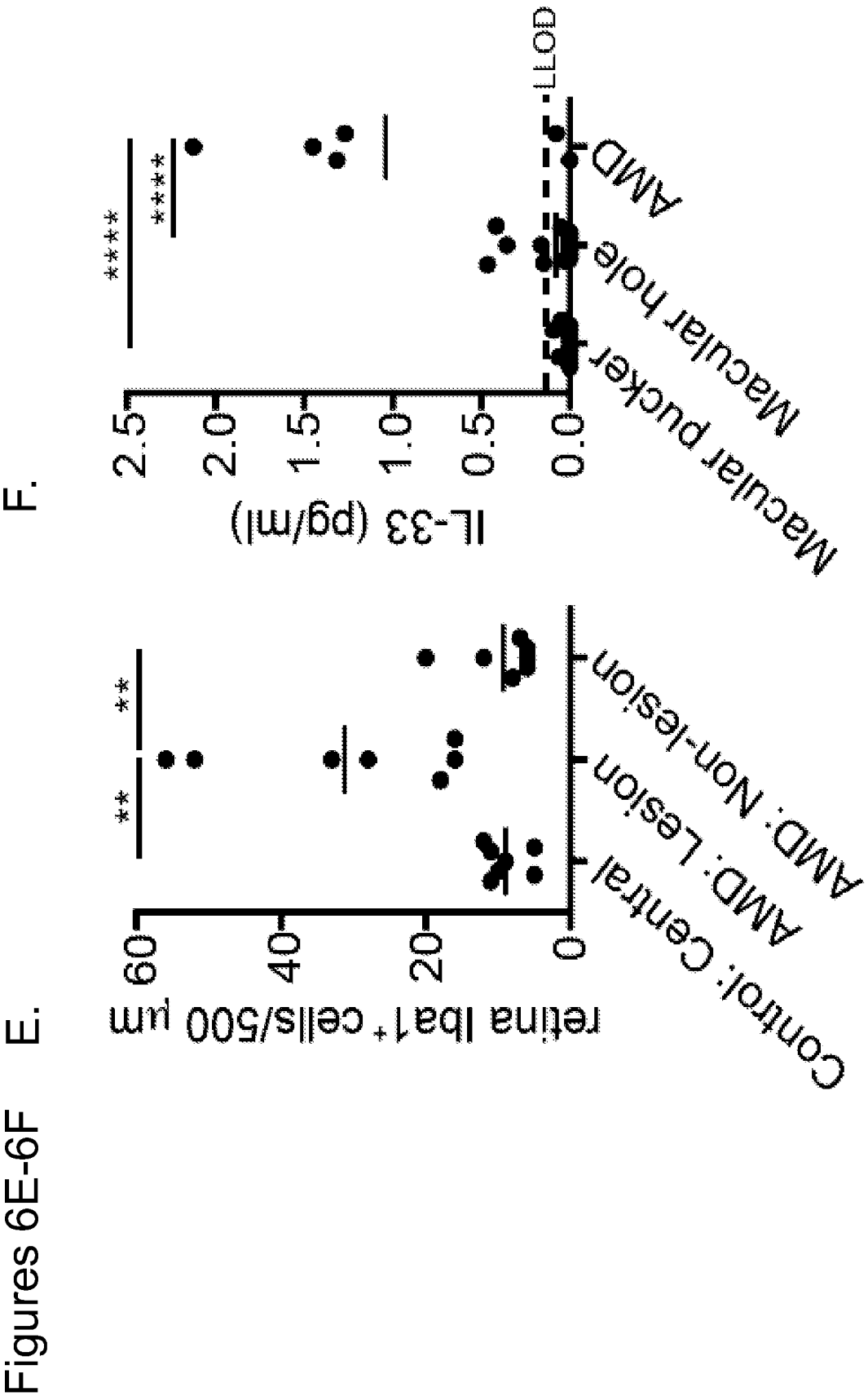


Figure 7A

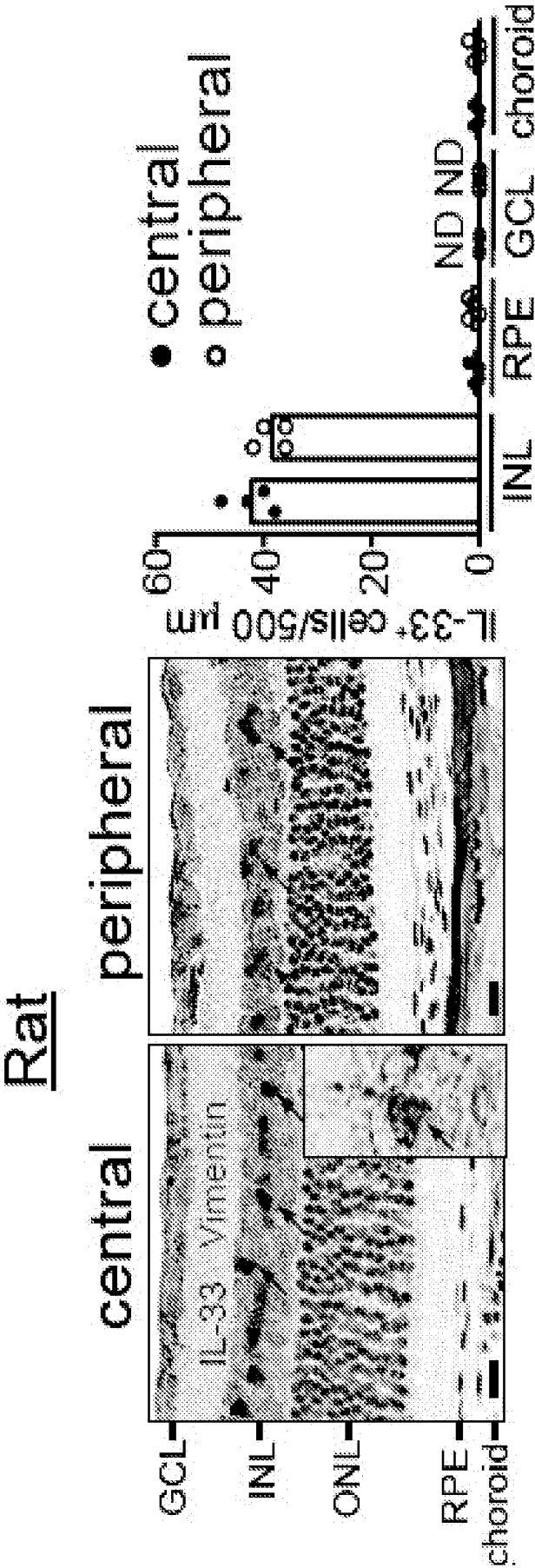


Figure 7B

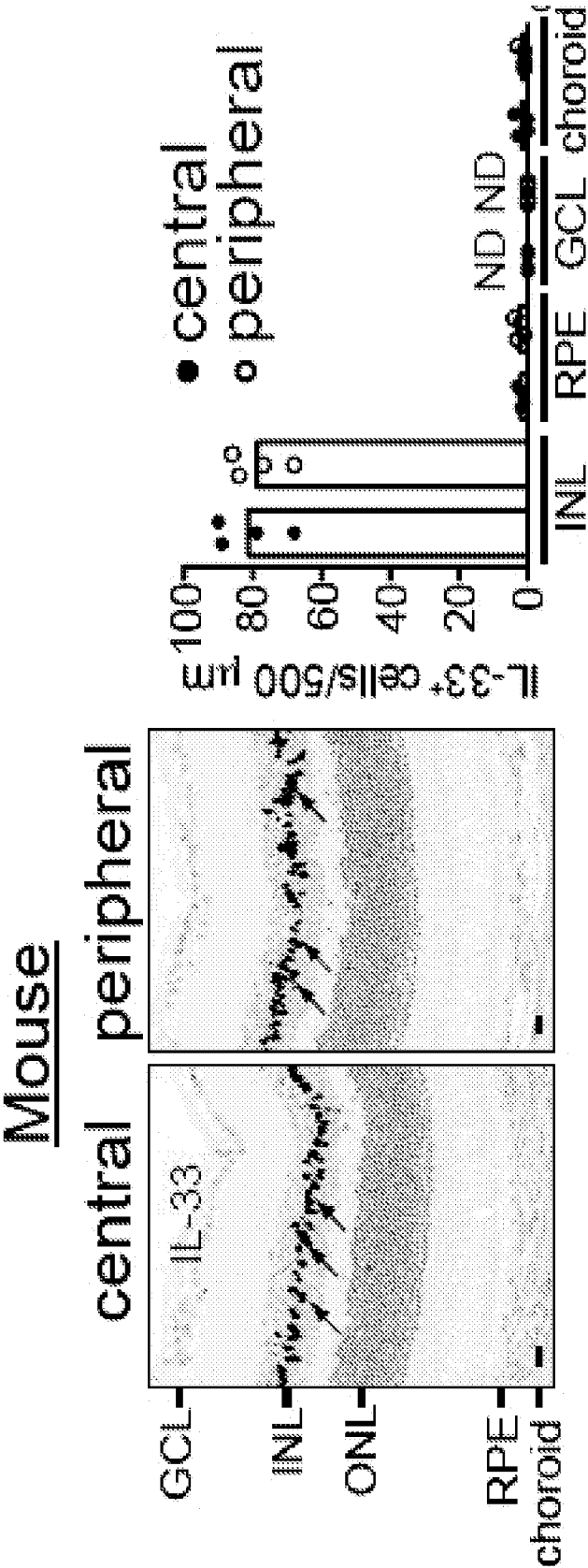


Figure 7C

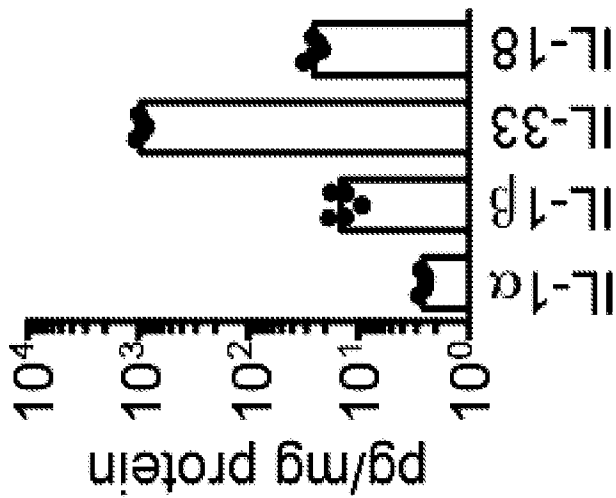
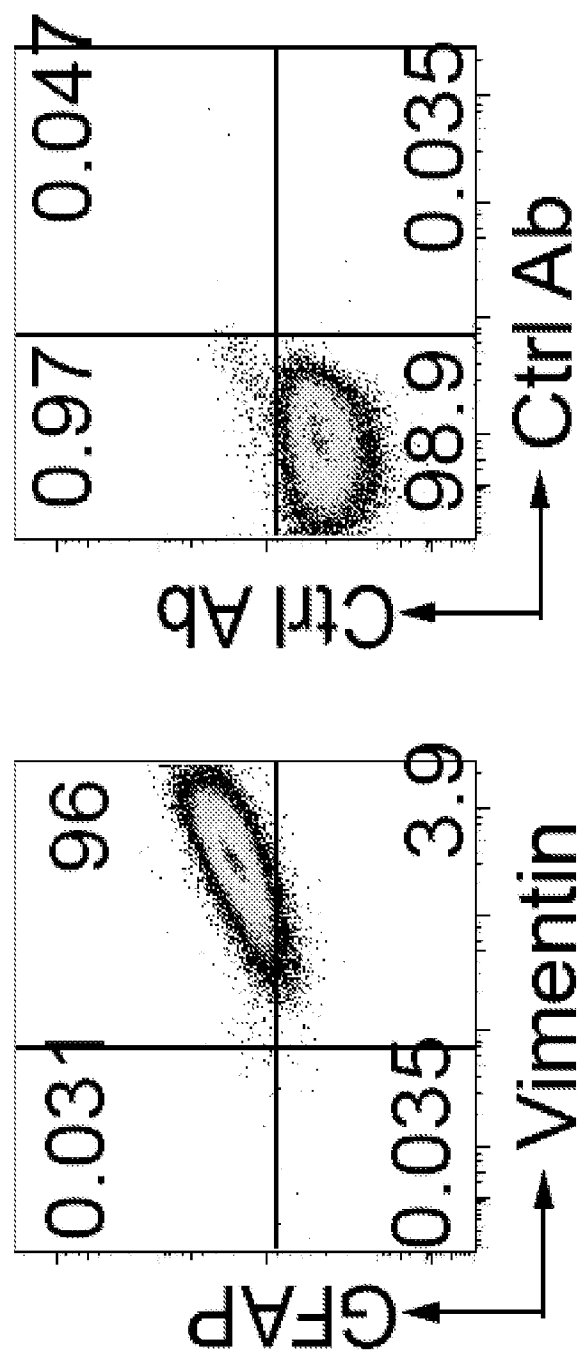


Figure 7D



Figures 7E-7F

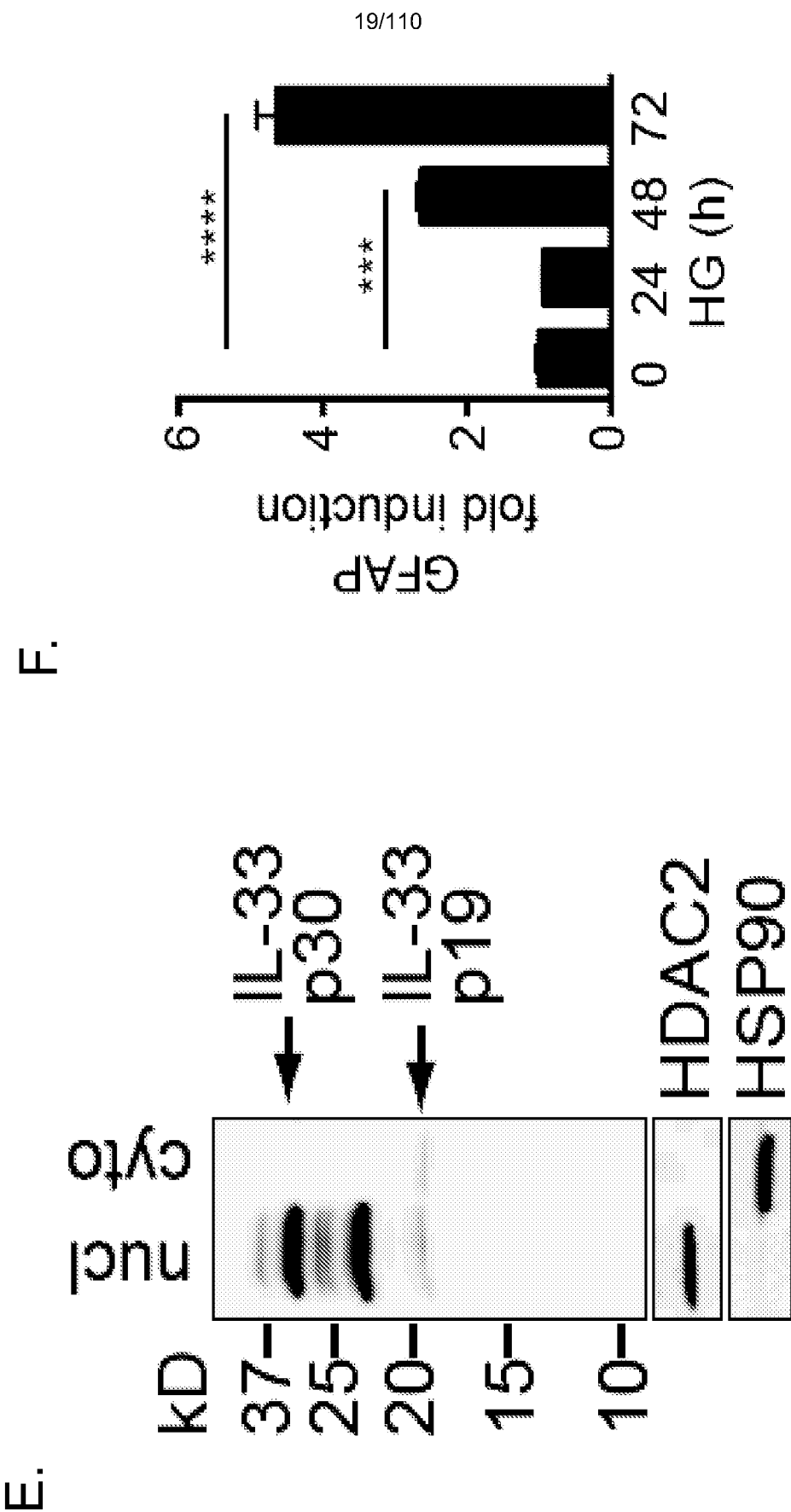
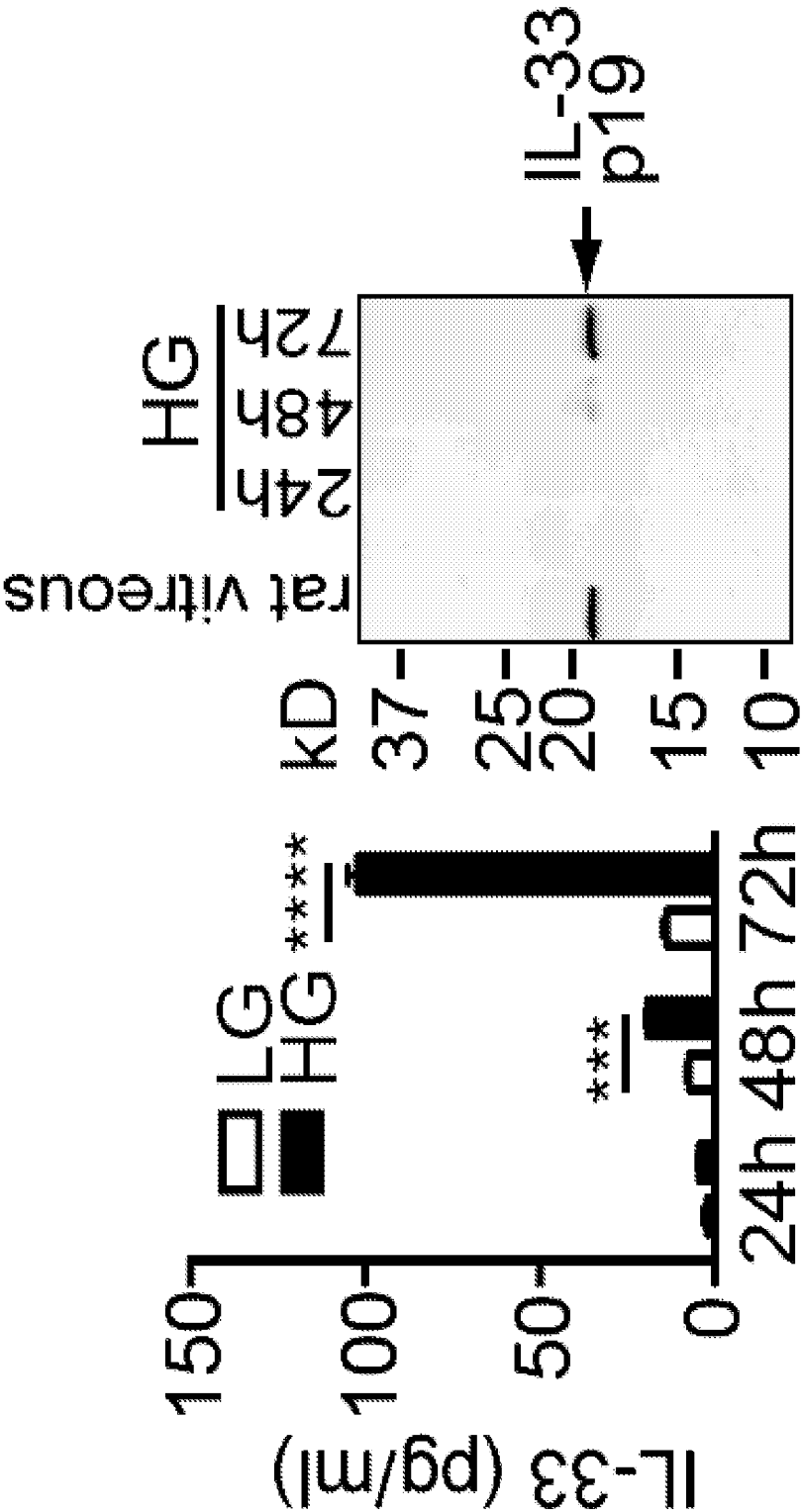


Figure 7G



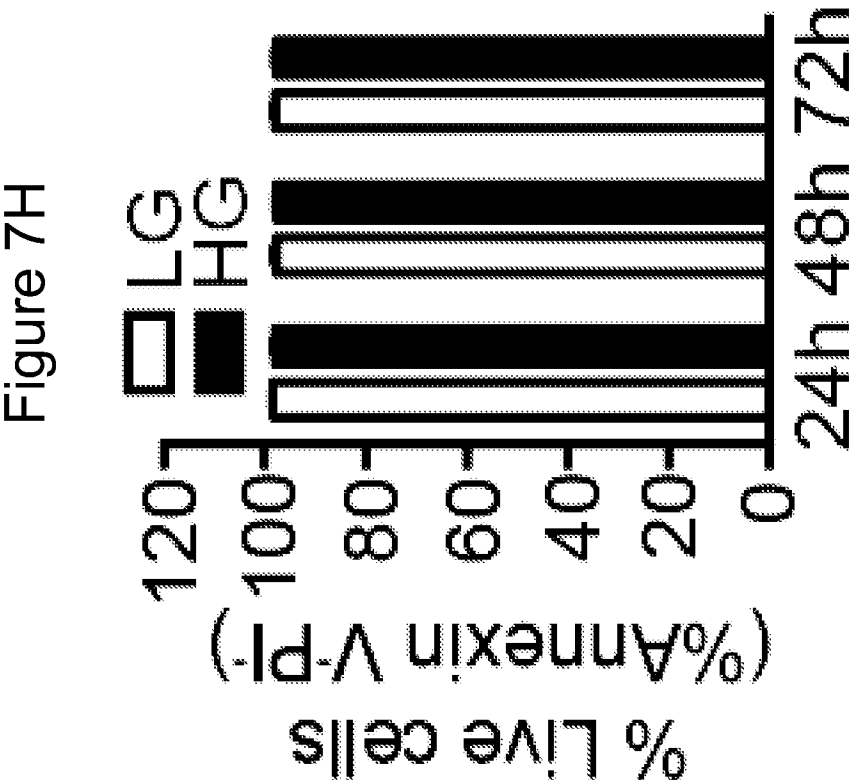
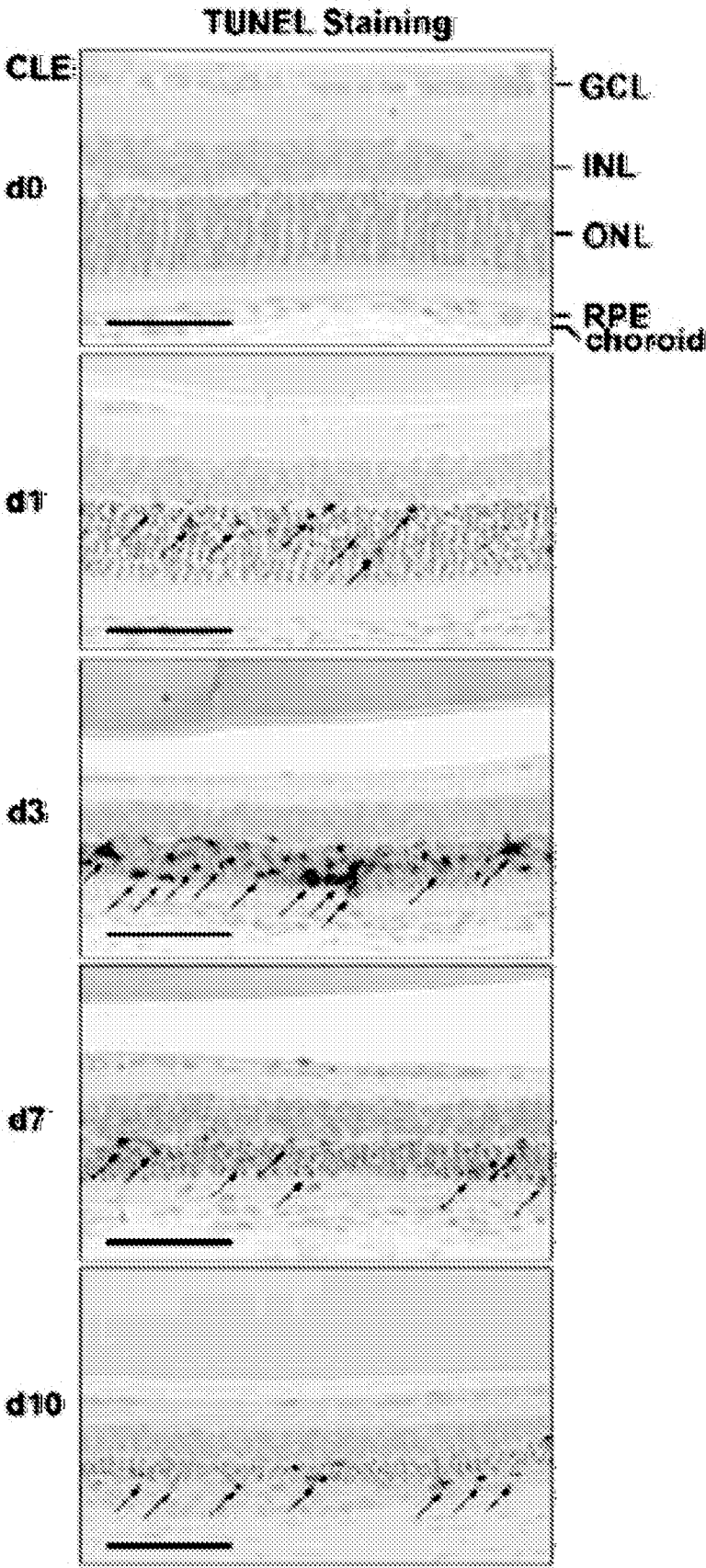


Figure 7I



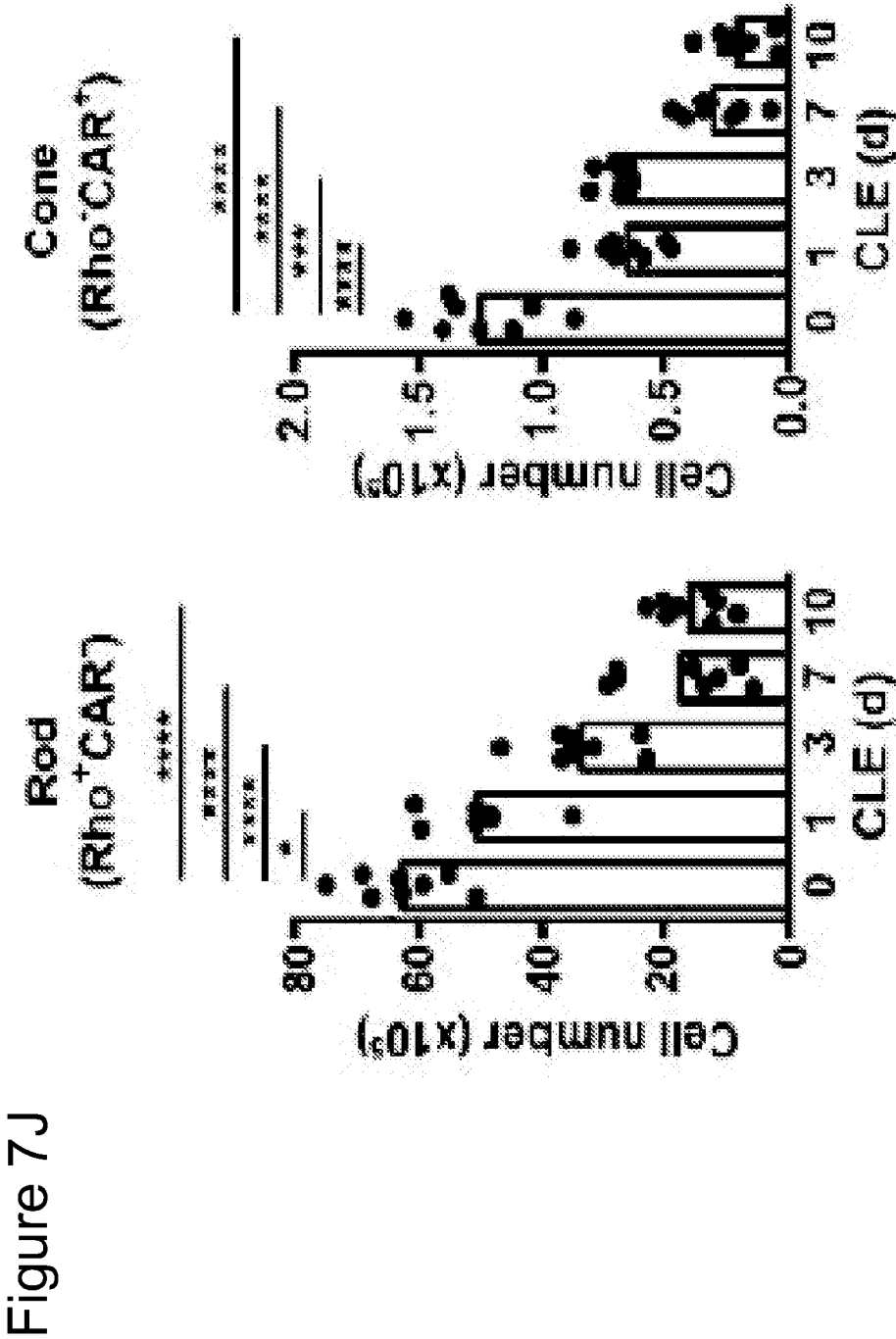


Figure 7K

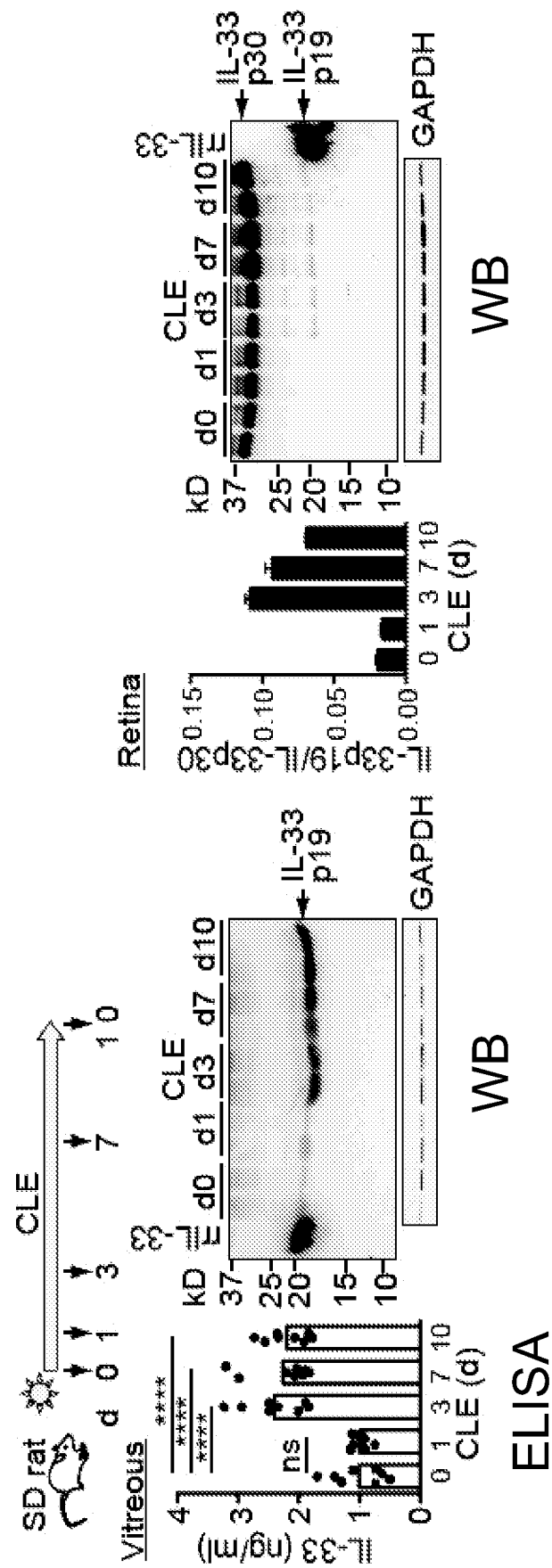


Figure 7L

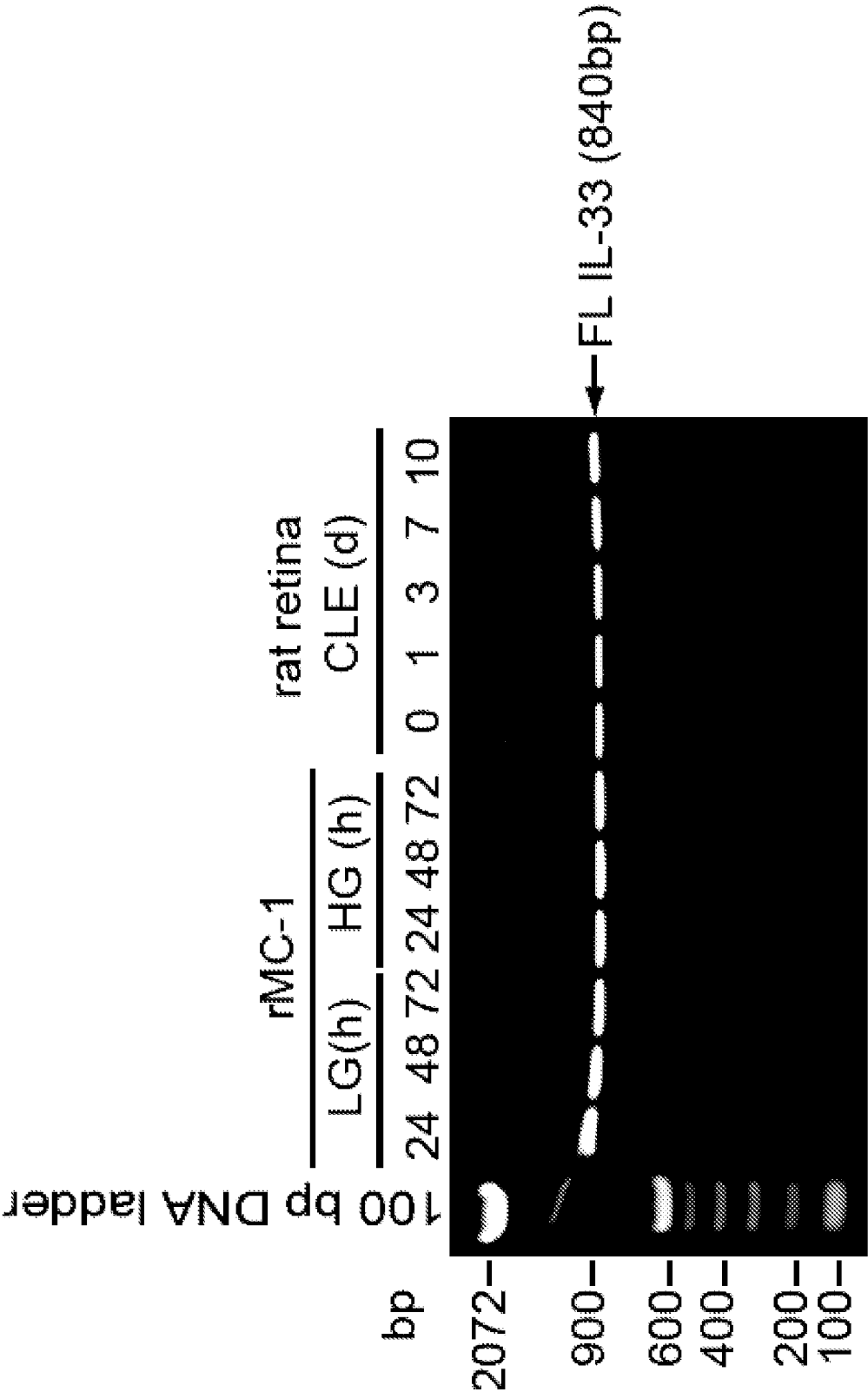


Figure 7M

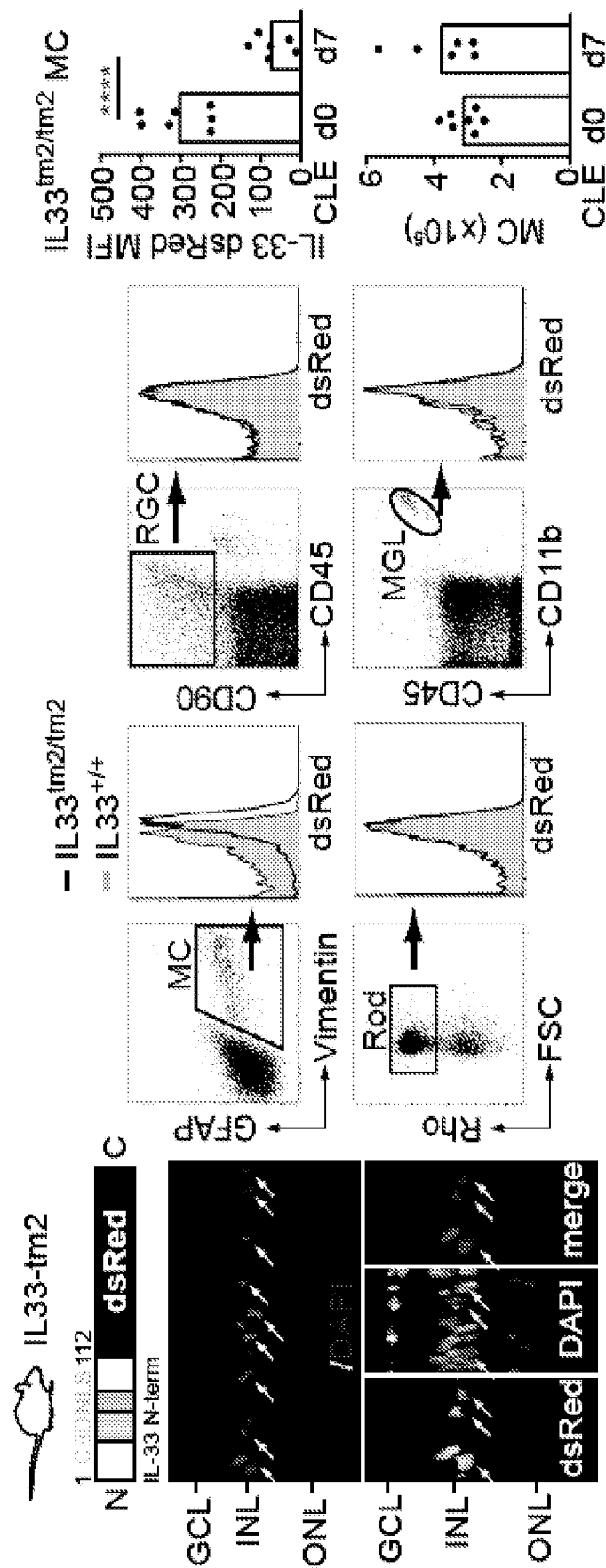


Figure 8A

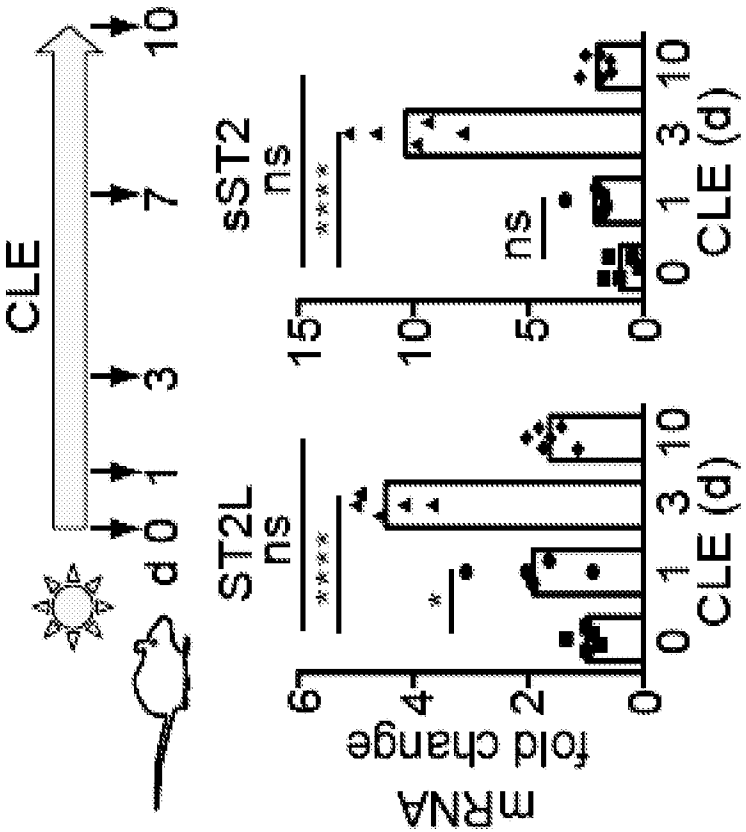
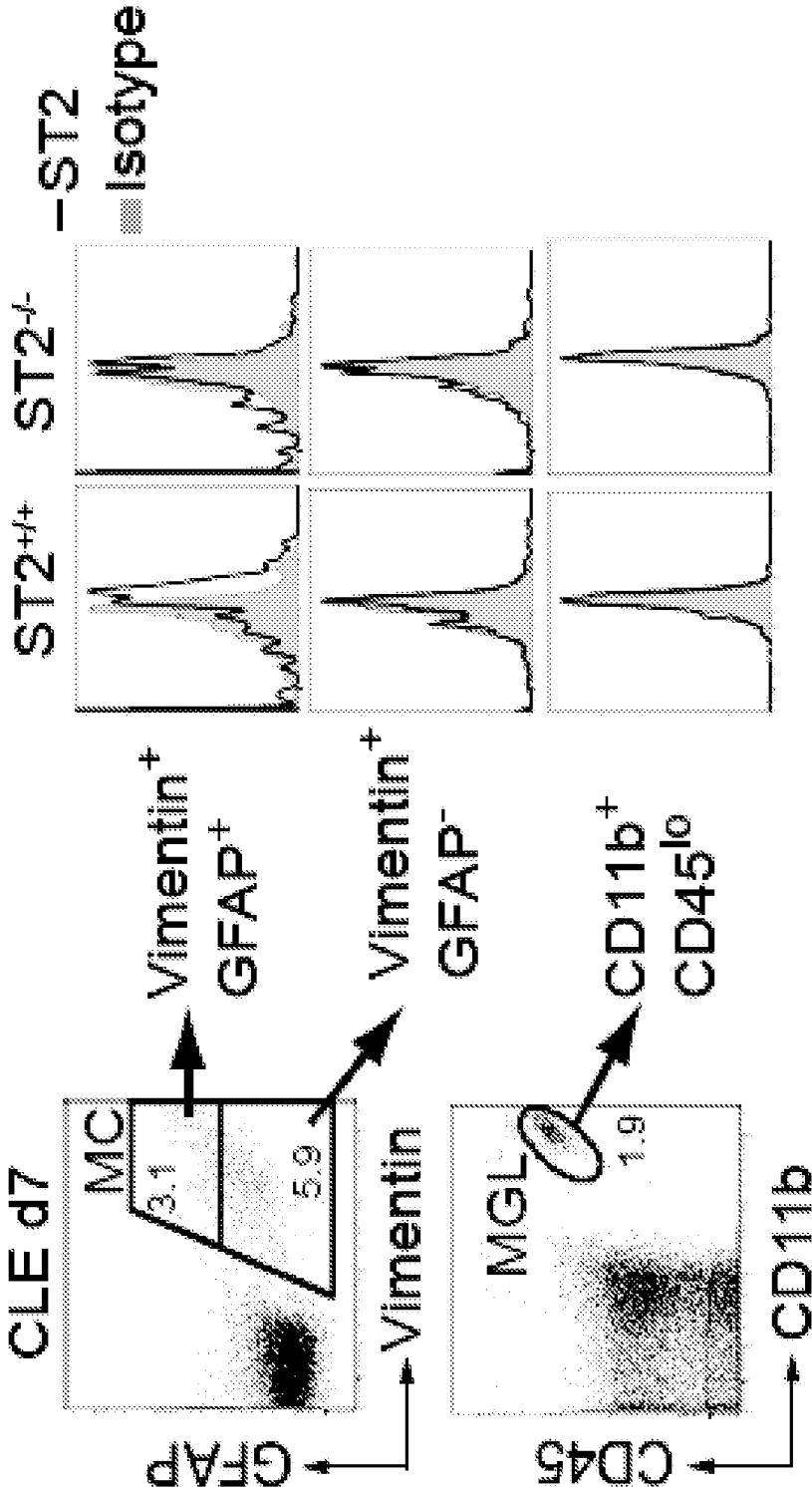


Figure 8B



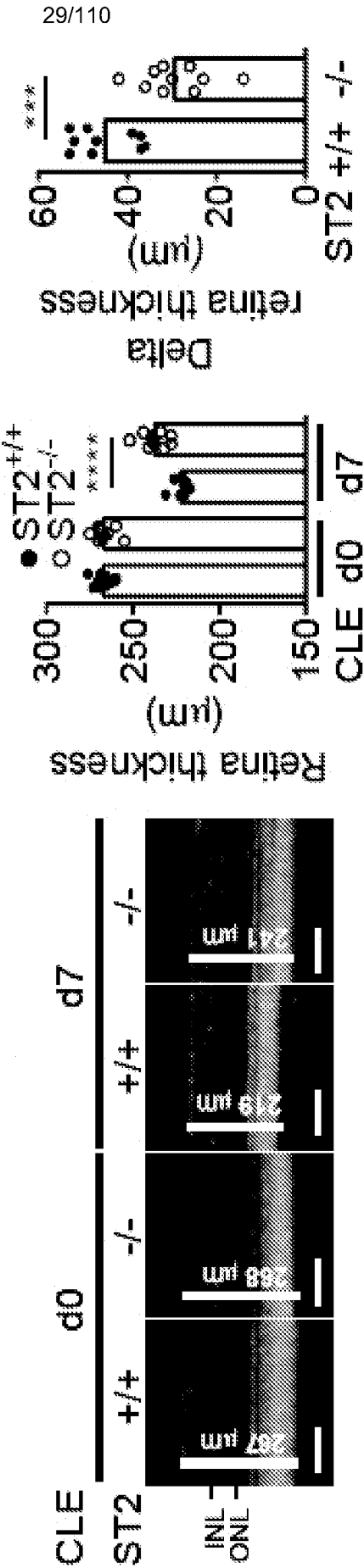


Figure 8C

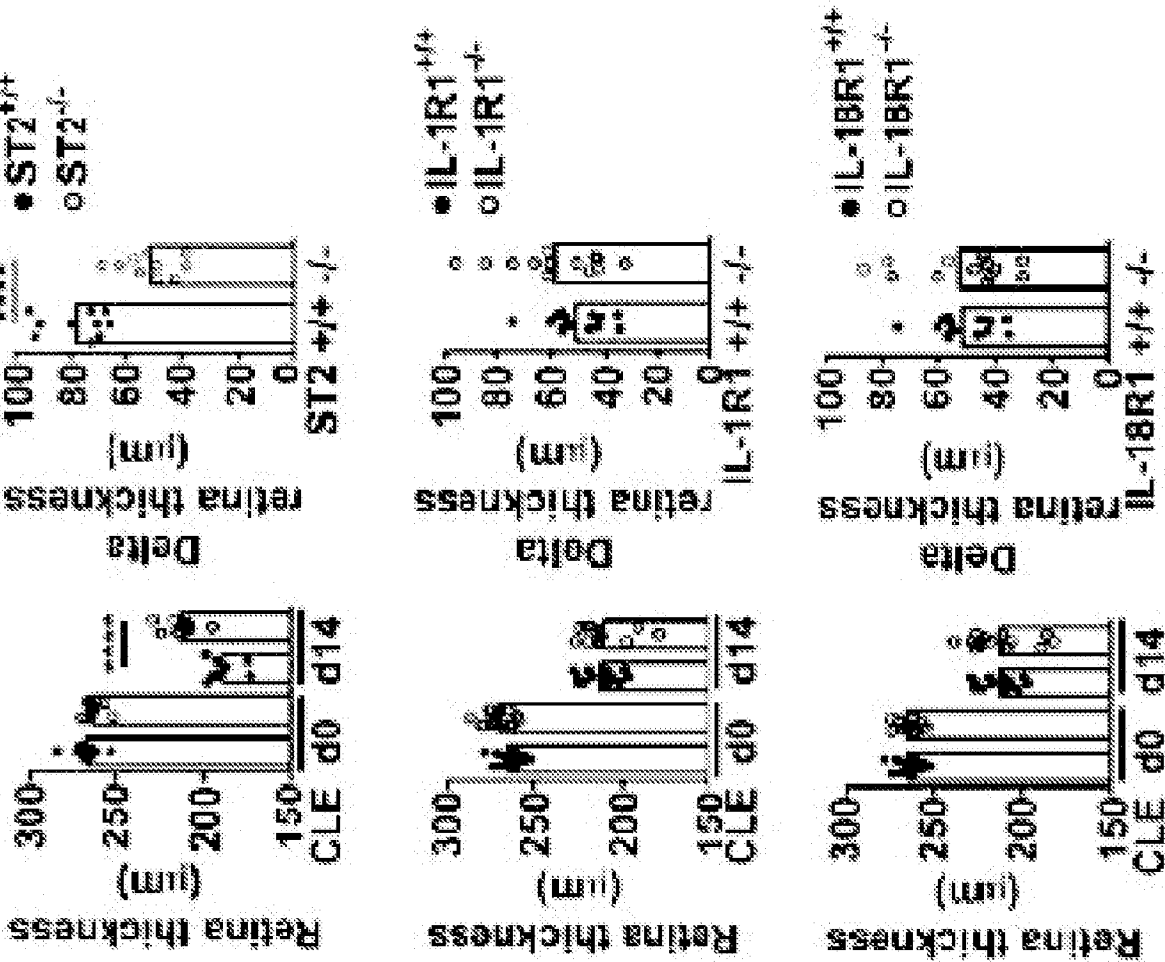


Figure 8D

Figure 8E

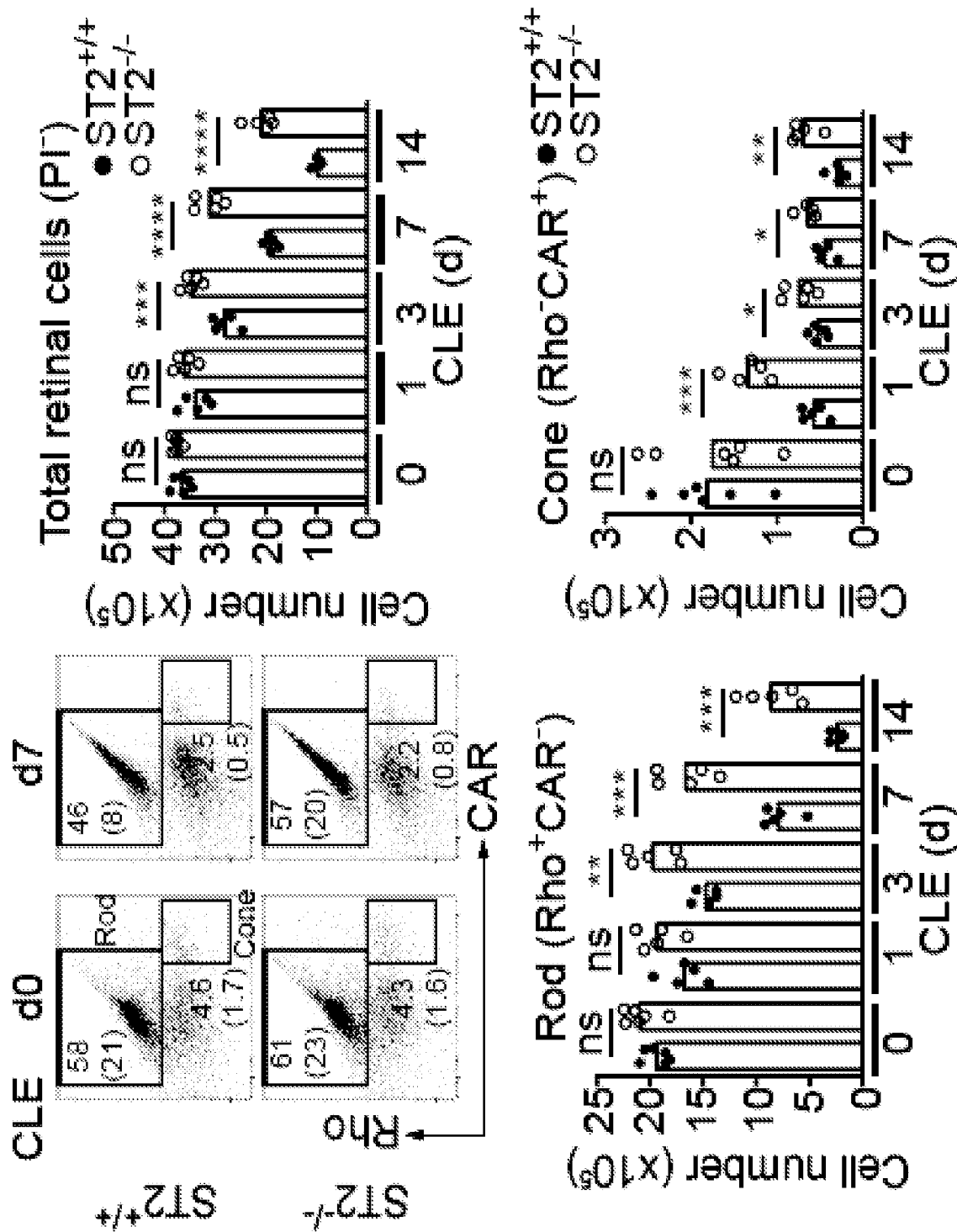


Figure 8F

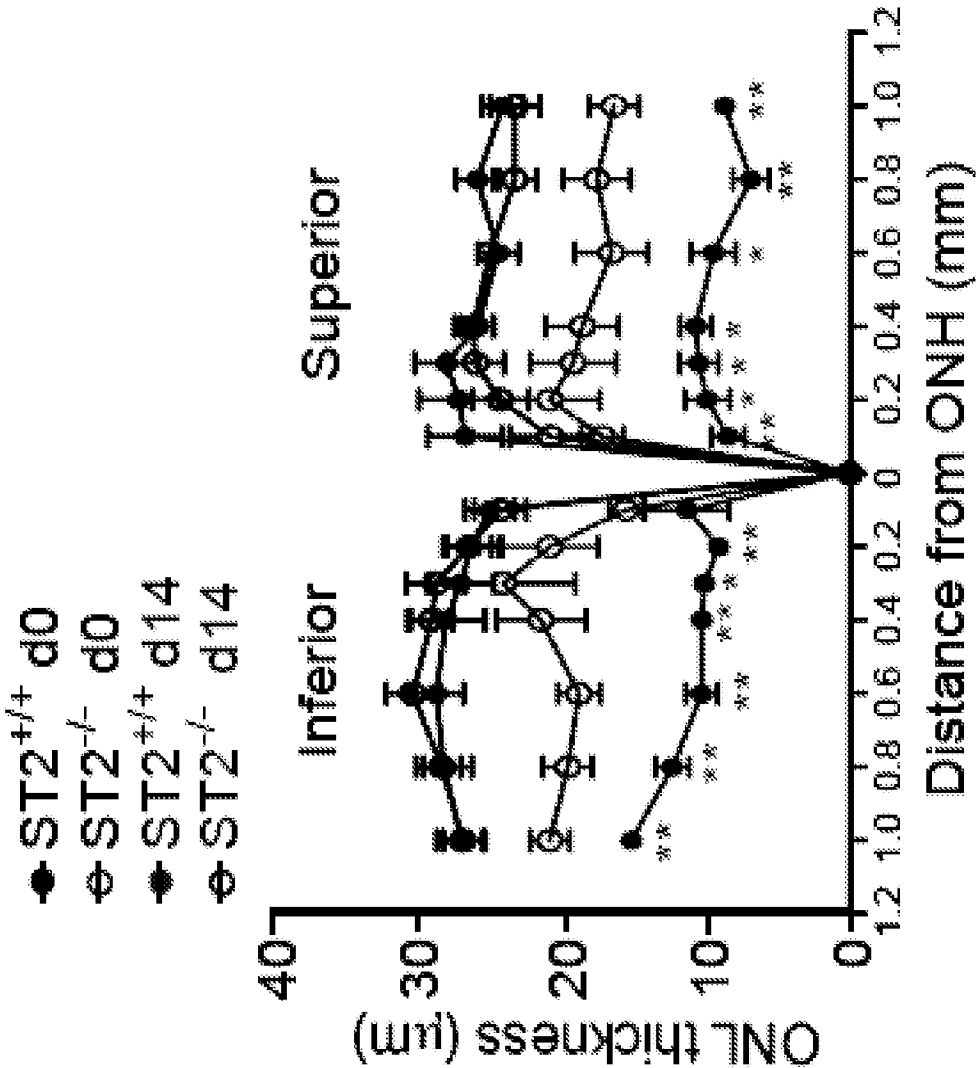


Figure 8G

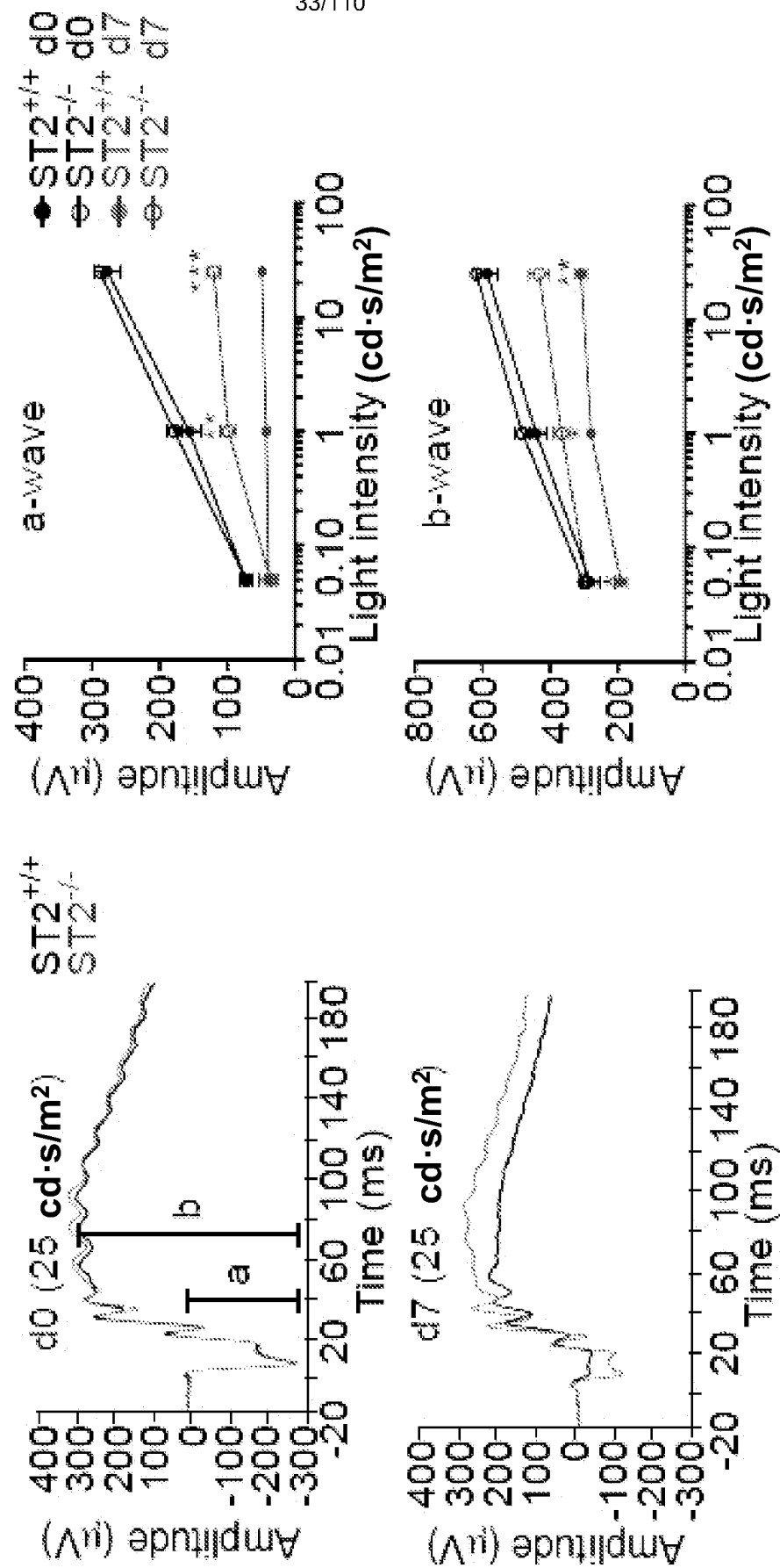


Figure 9A

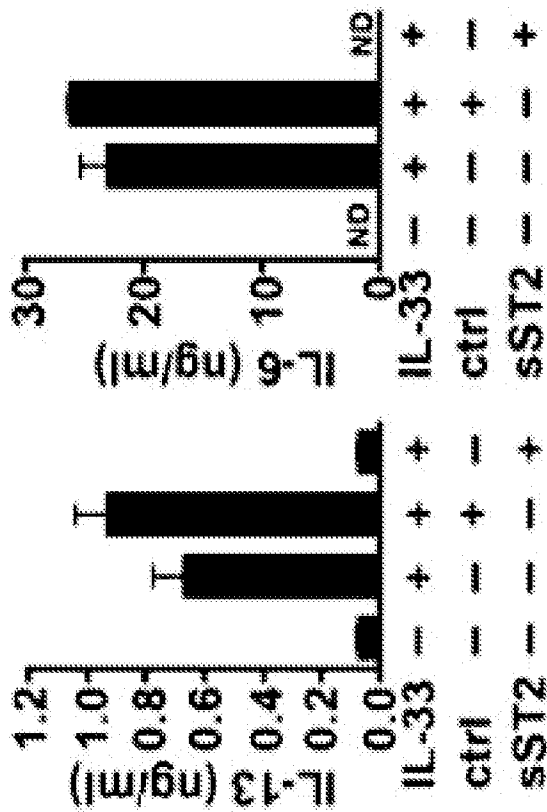


Figure 9B

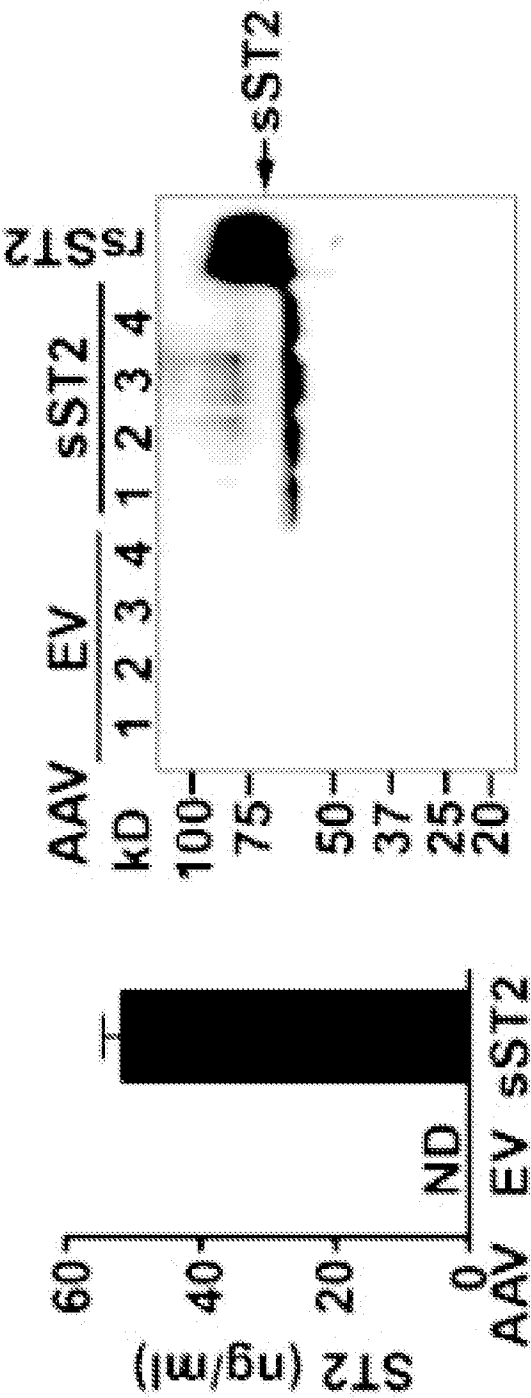


Figure 9C

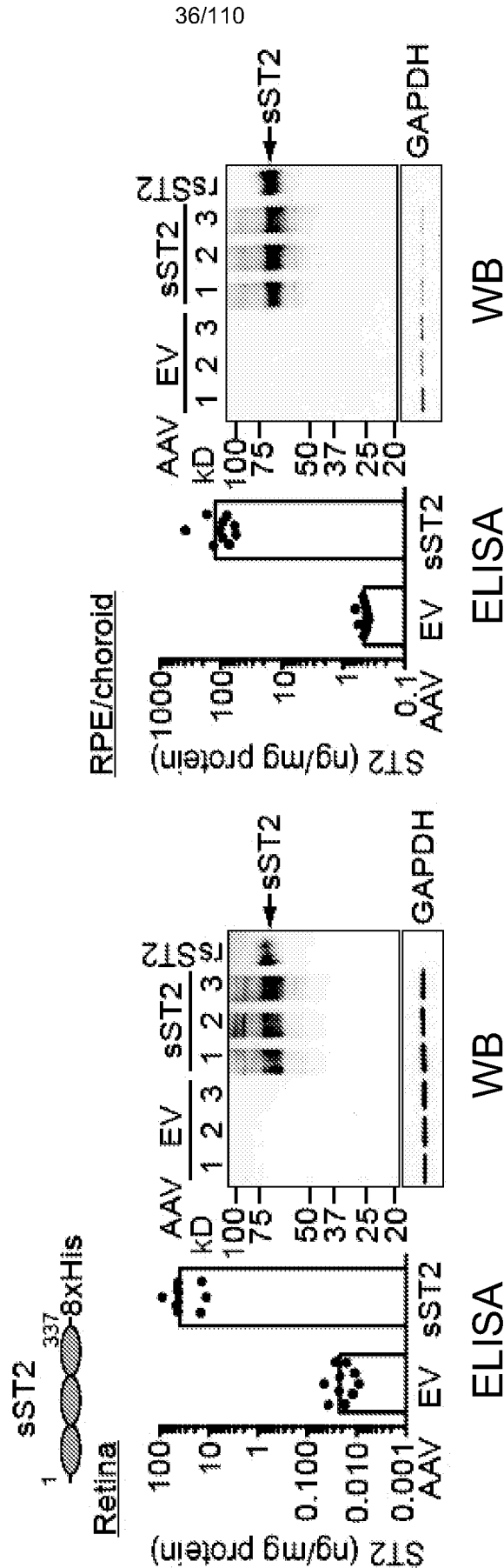


Figure 10



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Figure 11A

Gene Symbol	Log ₂ Fold Change	P value
Parp10	-0.4070	0.031338
Mx2	-0.5531	0.023956
Tap1	-0.3652	0.008909
Igtp	-0.4489	0.011741
Irgm2	-0.4251	0.028030
Timp1	-0.4043	0.004441
Rtp4	-0.6969	0.016280
Irf7	-0.3266	0.031338
Cp	-0.4225	0.007205
Stat3	-0.3860	0.006960
Mt2	-0.4169	0.047613
Osmr	-0.3798	0.006583
Irf1	-0.3453	0.004749
Cebpd	-0.3662	0.004441
Bcl3	-0.4159	0.002762
Egr2	-0.4352	0.004441
Hsd17b2	-0.4163	0.004441
Ccl4	-0.4988	0.007205
Il1b	-0.4339	0.010421
Ifi202b	-0.6794	0.044264
Gbp7	-0.5574	0.004441
Ccl2	-0.3398	0.013638

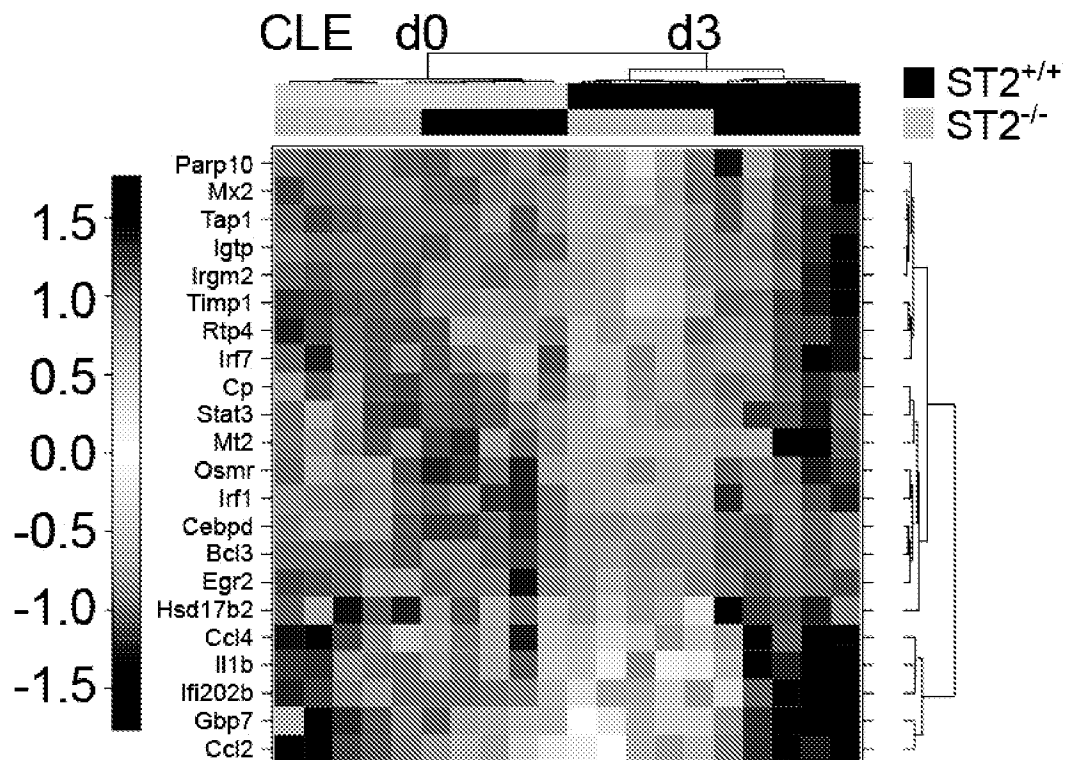


Figure 11B

Pathway analysis of genes down-regulated in ST2^{-/-} retina after CLE

GO ID	Biological Function	p-value	Genes Down-regulated
GO:0006886	Intracellular protein transport	0.001504	<i>Bcl3, Egr2, Il1b, Stat3, Tap1, Rtp4, Parp10</i>
GO:0071345	Cellular response to cytokine stimulus	0.001569	<i>Igfb, Il1b, Irf1, Osmr, Ccl2, Stat3, Il202b, Irf7, Gbp7</i>
GO:0034124	MyD88-dependent TLR signaling pathway	0.002303	<i>Irf1, Irf7</i>
GO:0060416	Response to growth hormone	0.002303	<i>Irf1, Stat3</i>
GO:0045944	Transcription from RNA Pol II promoter	0.004203	<i>Bcl3, Cebpd, Egr2, Il1b, Irf1, Stat3, Irf7</i>
GO:0006913	Nucleocytoplasmic transport	0.005390	<i>Bcl3, Egr2, Il1b, Stat3, Parp10</i>
GO:0032870	Cellular response to hormone stimulus	0.005669	<i>Egr2, Il1b, Irf1, Stat3</i>
GO:0042089	Cytokine biosynthetic process	0.005669	<i>Bcl3, Il1b, Irf1, Irf7</i>
GO:0079727	Cellular macromolecule localization	0.006119	<i>Bcl3, Egr2, Il1b, Stat3, Tap1, Rtp4, Parp10</i>
GO:0042221	Response to chemical	0.006125	<i>Cp, Egr2, Hsd17b2, Igfb, Il1b, Irf1, Mx2, Osmr, Ccl2, Ccl4, Stat3, Il202b, Irf7, Irgm2, Rtp4, Gbp7</i>
GO:0031330	Negative regulation of cellular catabolism	0.006697	<i>Stat3, Timp1</i>
GO:0045084	Th2 cell differentiation	0.006697	<i>Bcl3, Irf1</i>
GO:0046686	Response to copper ion	0.006697	<i>Cp, Mx2</i>
GO:1901652	Response to peptide	0.007156	<i>Egr2, Il1b, Irf1, Stat3</i>
GO:0042832	Defense response to protozoan	0.007270	<i>Bcl3, Irgm2, Gbp7</i>
GO:0019557	Regulation of Macromolecule biosynthesis	0.007896	<i>Bcl3, Cebpd, Egr2, Il1b, Irf1, Ccl2, Stat3, Irf7</i>
GO:0034341	Response to interferon-gamma	0.008682	<i>Irf1, Ccl2, Irgm2, Gbp7</i>

Figure 11C

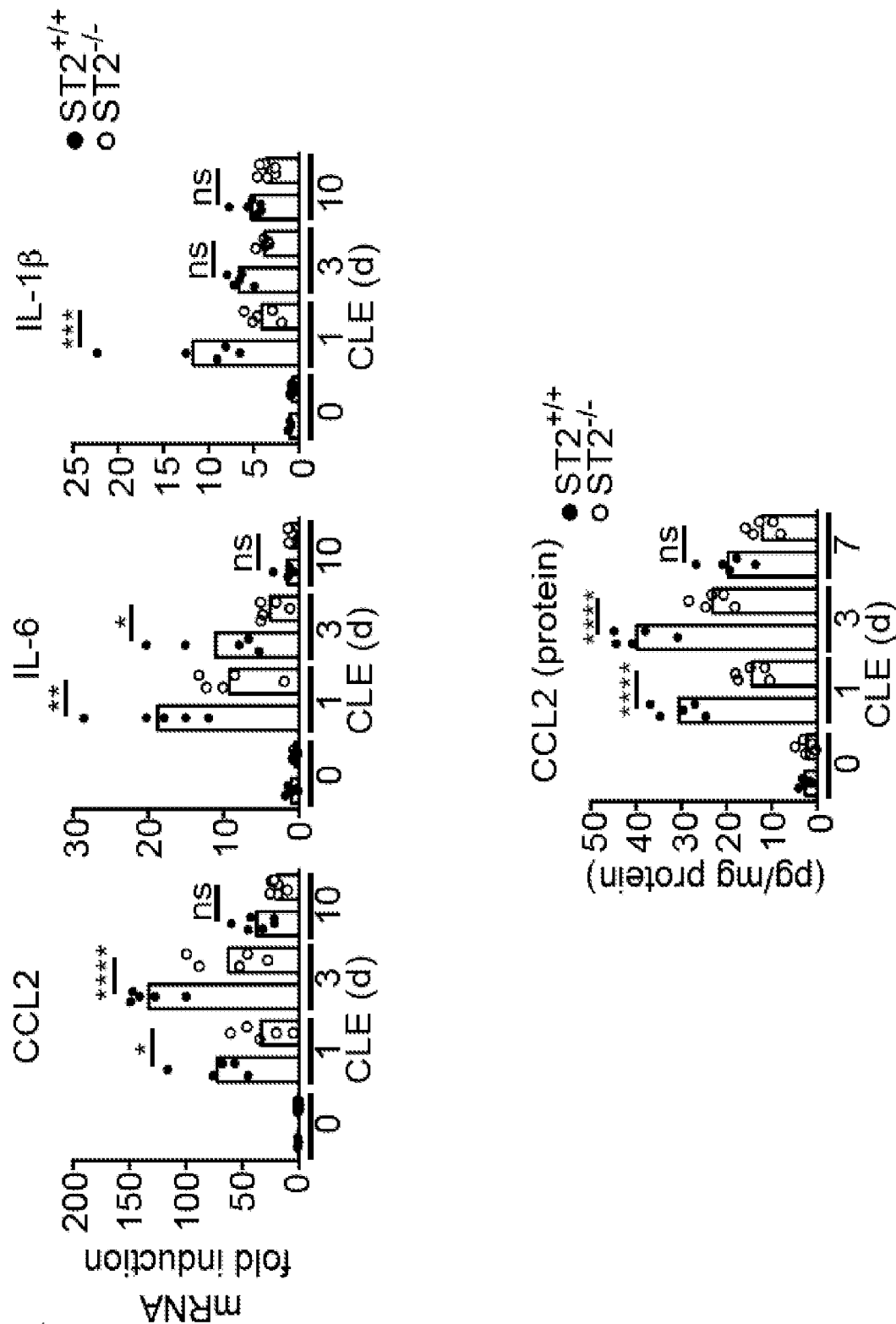


Figure 11D

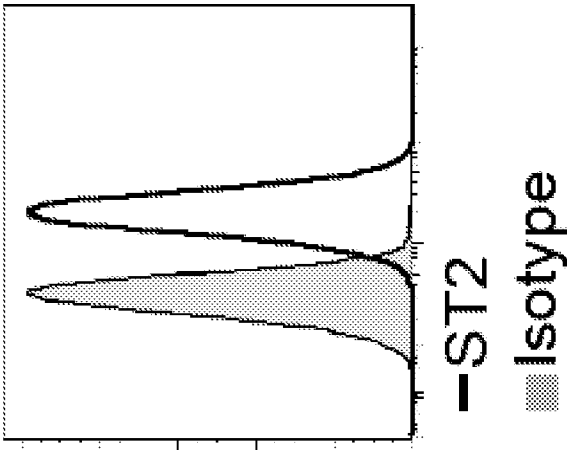
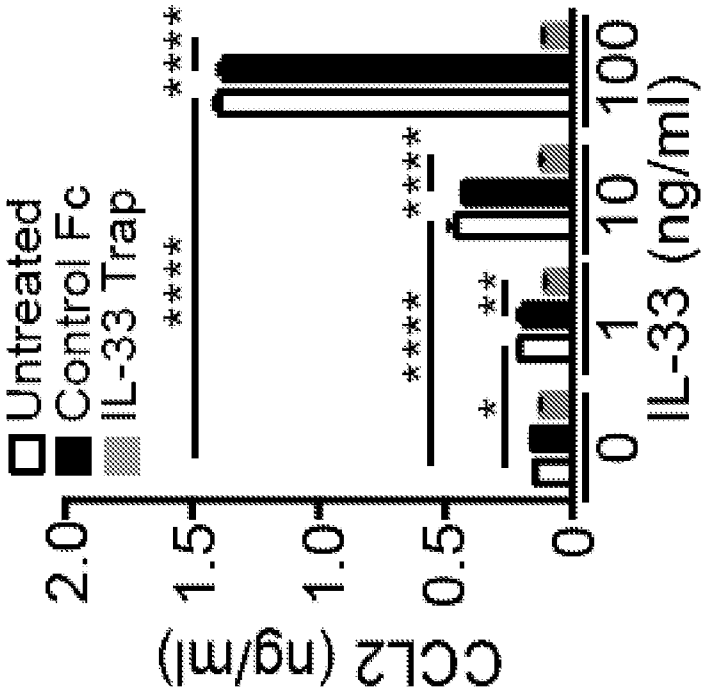


Figure 11E

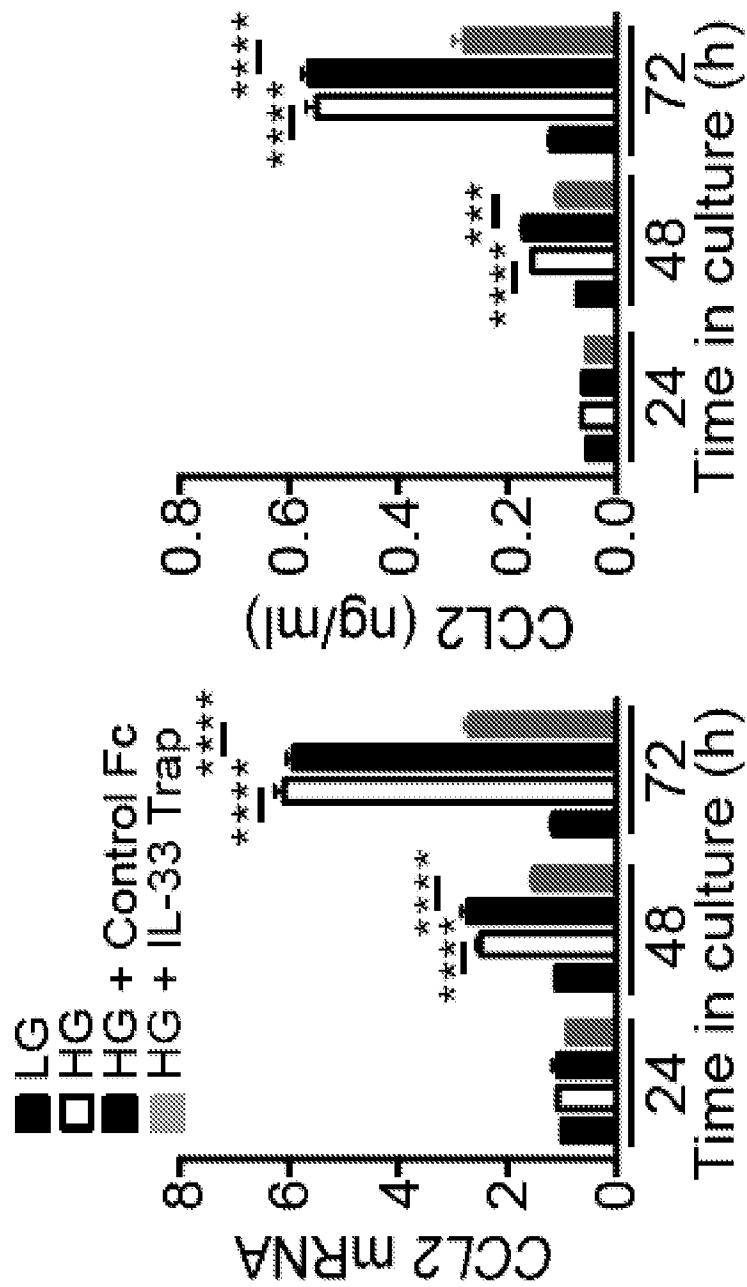


Figure 12A

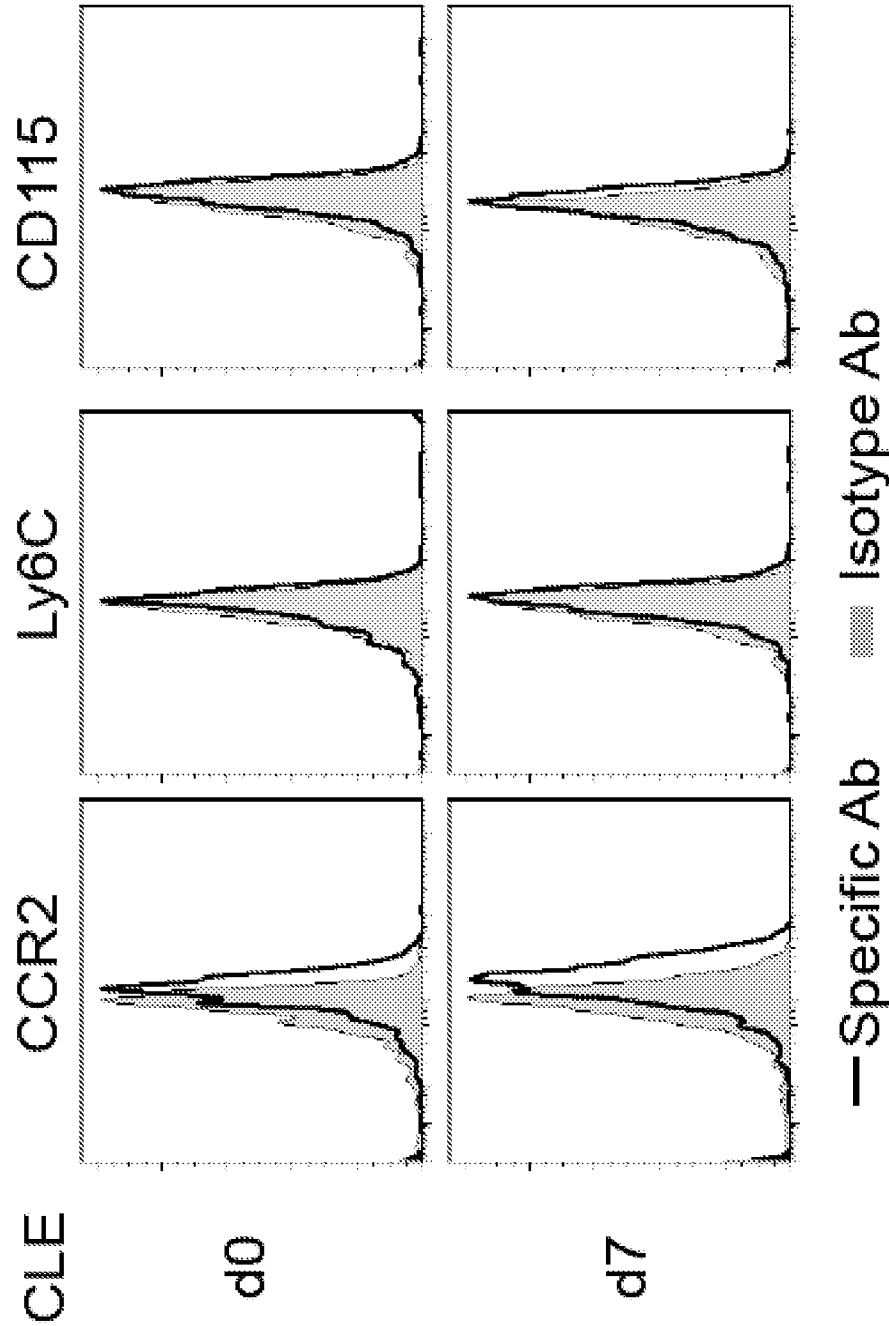


Figure 12B

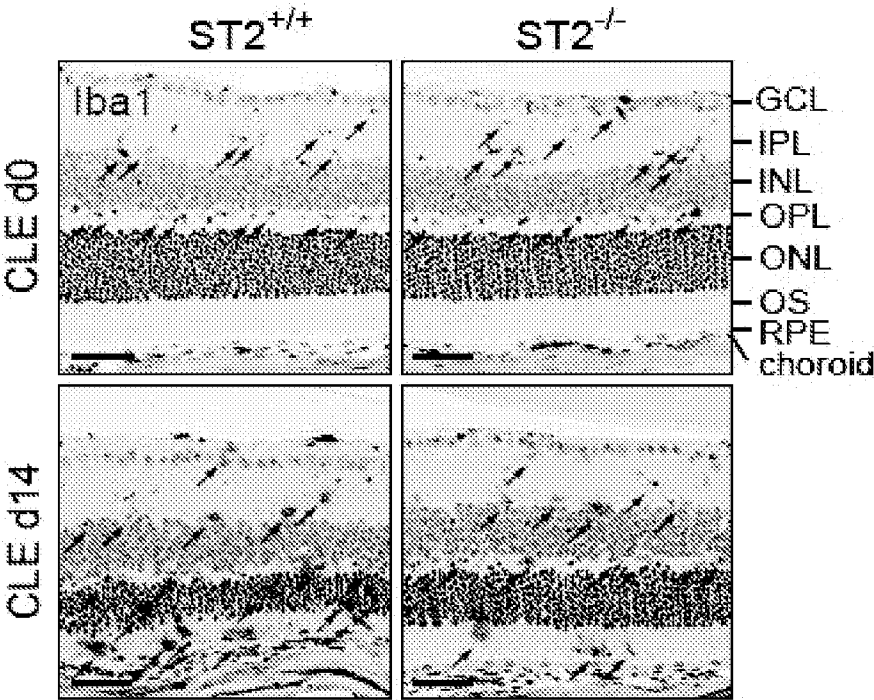


Figure 12C

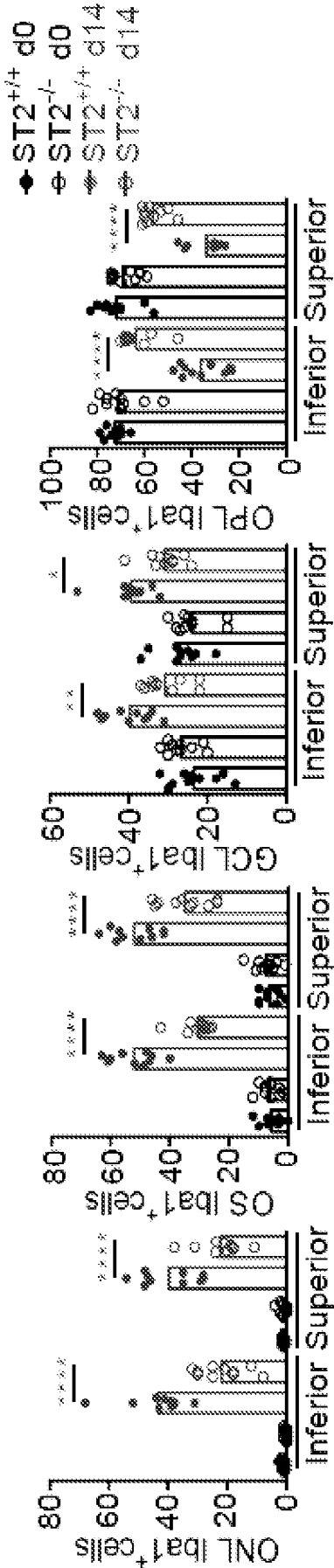


Figure 12D

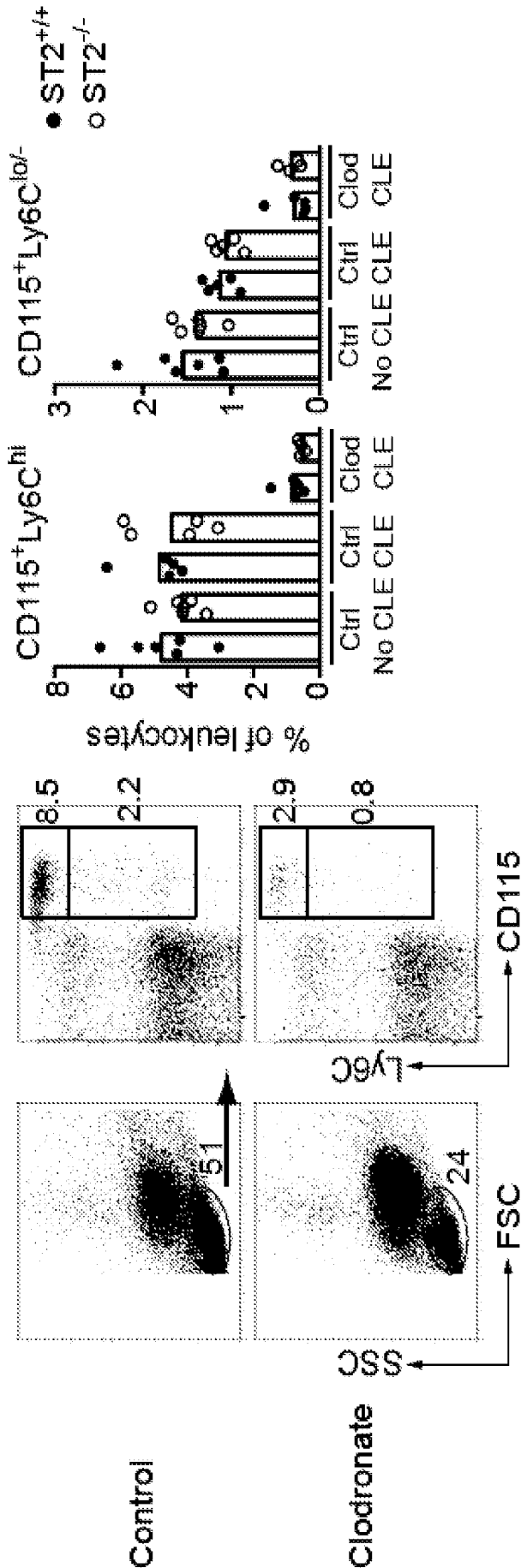


Figure 12E

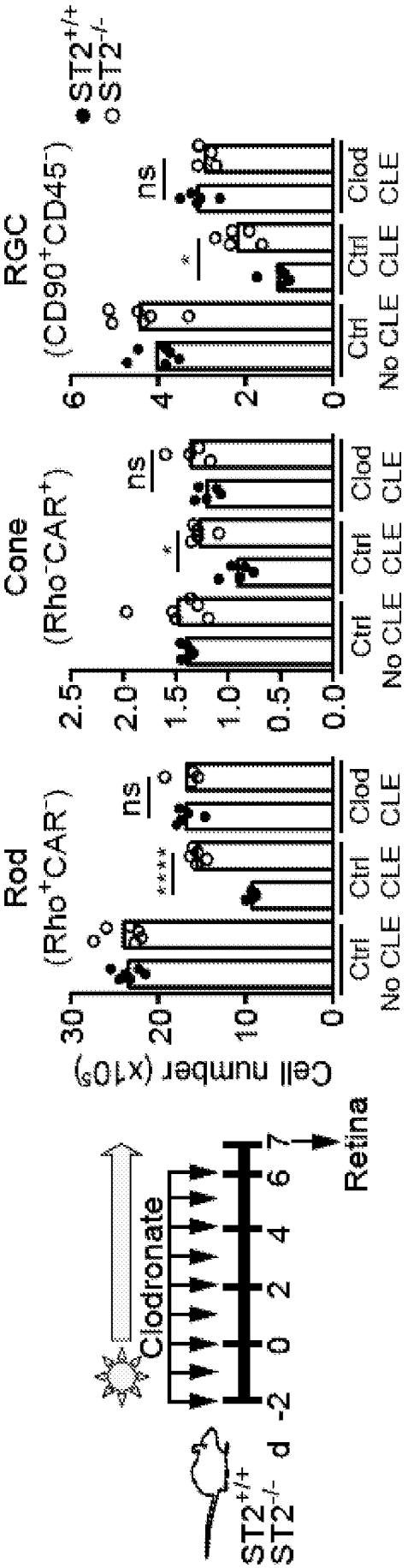


Figure 12F

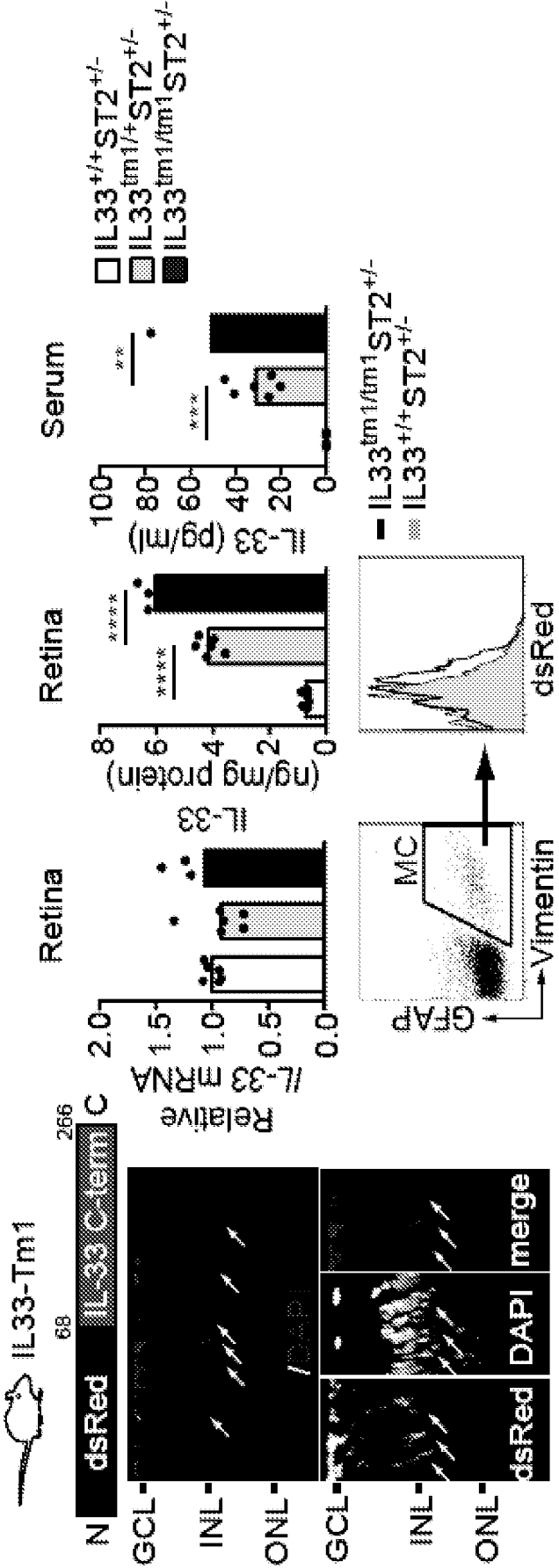


Figure 12G

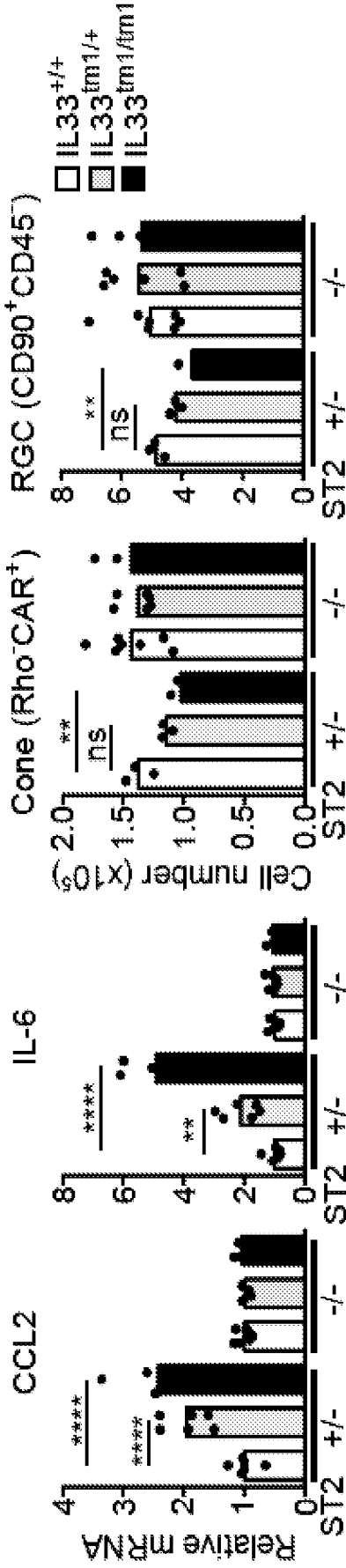


Figure 13A

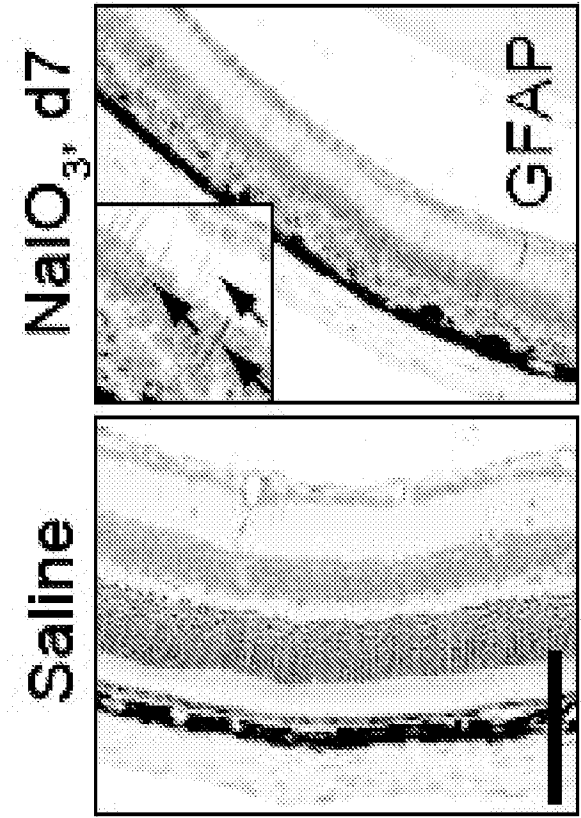


Figure 13B

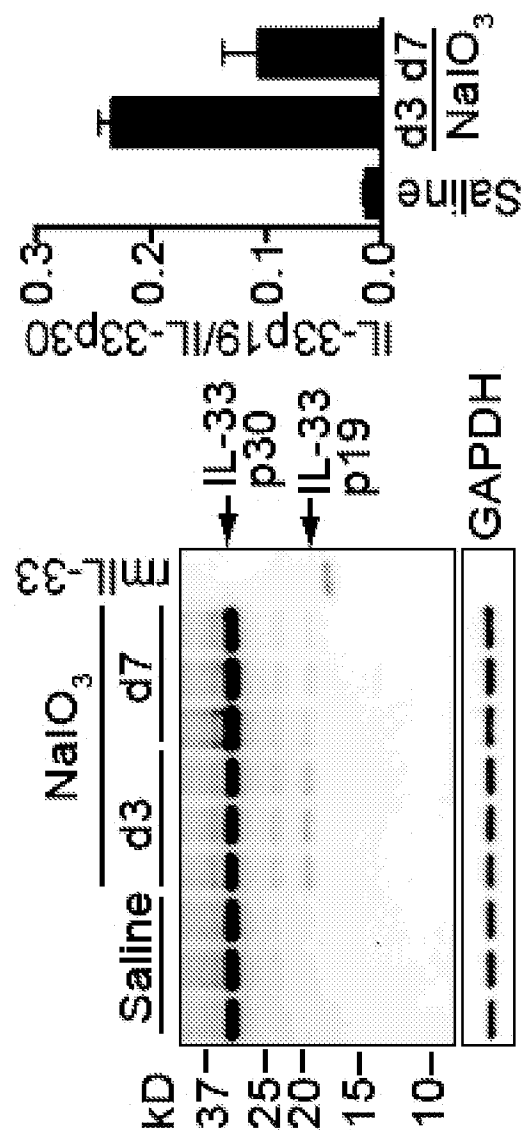
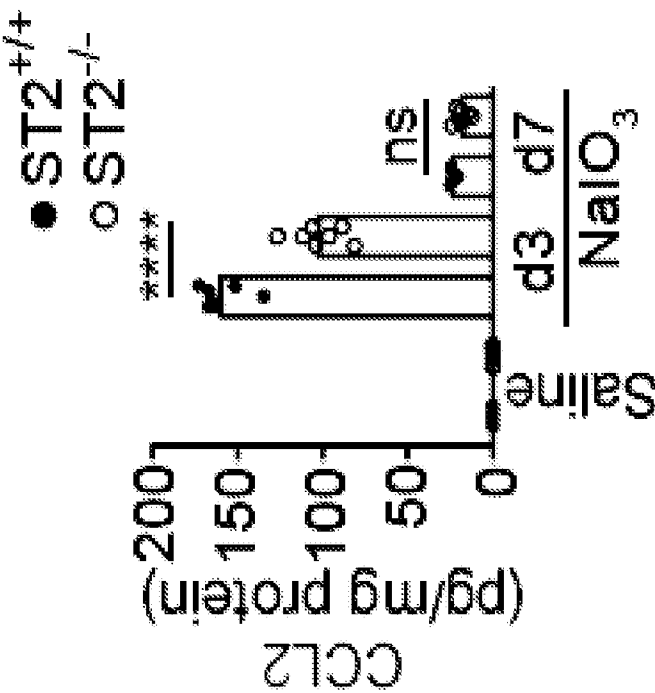


Figure 13C



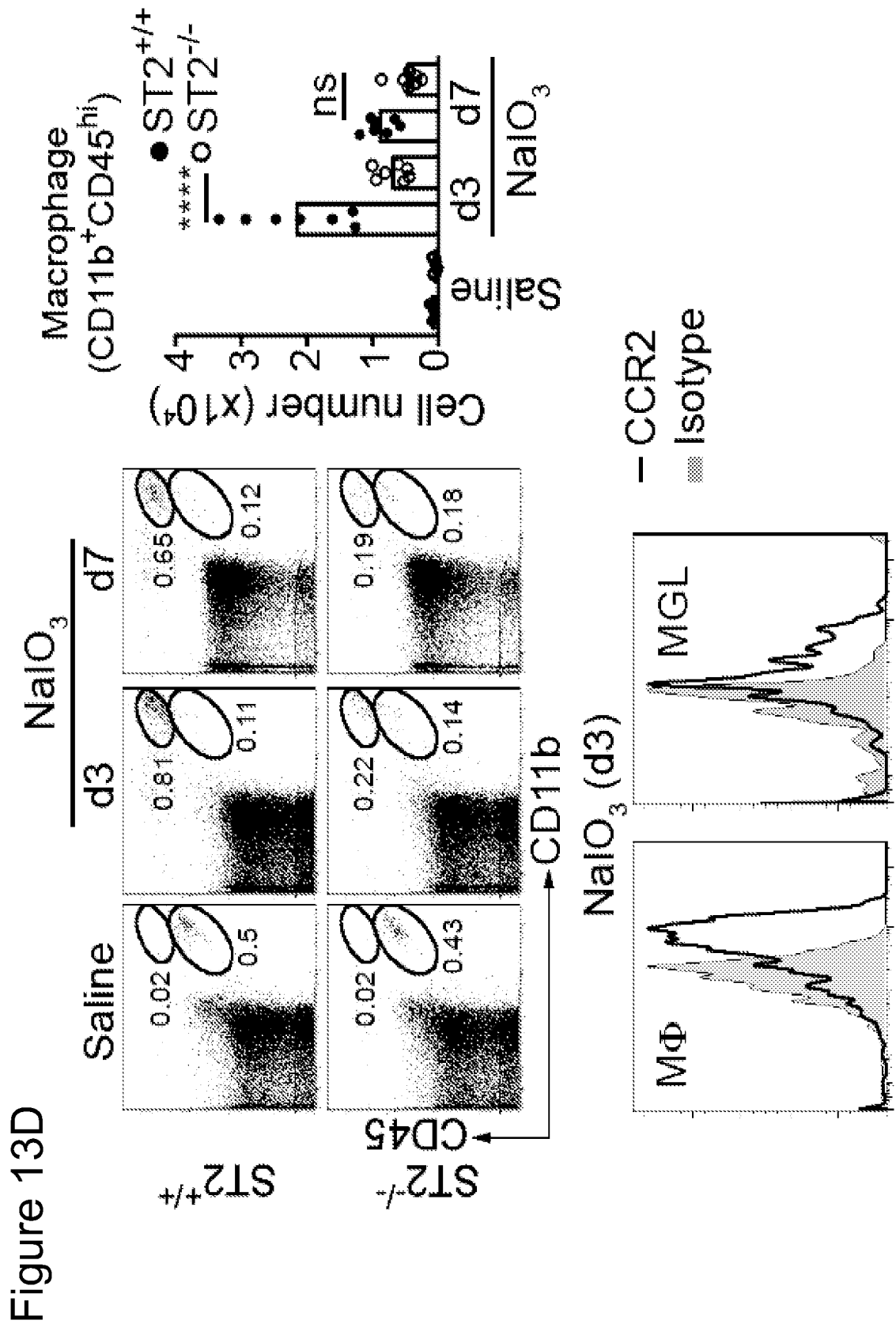


Figure 13E

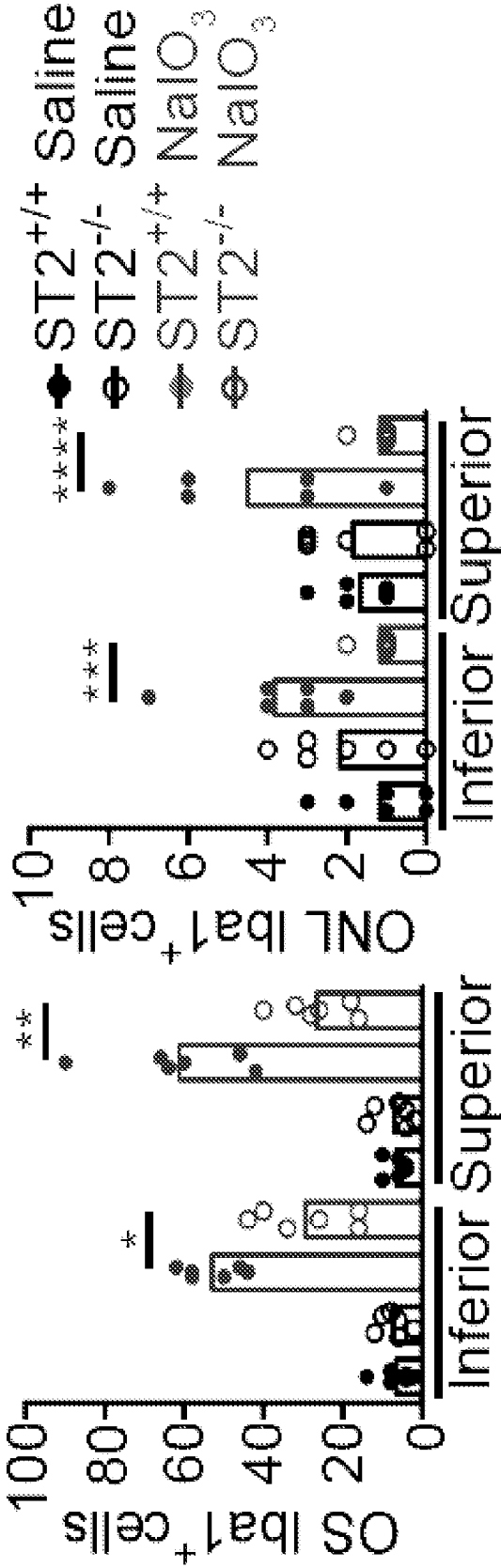
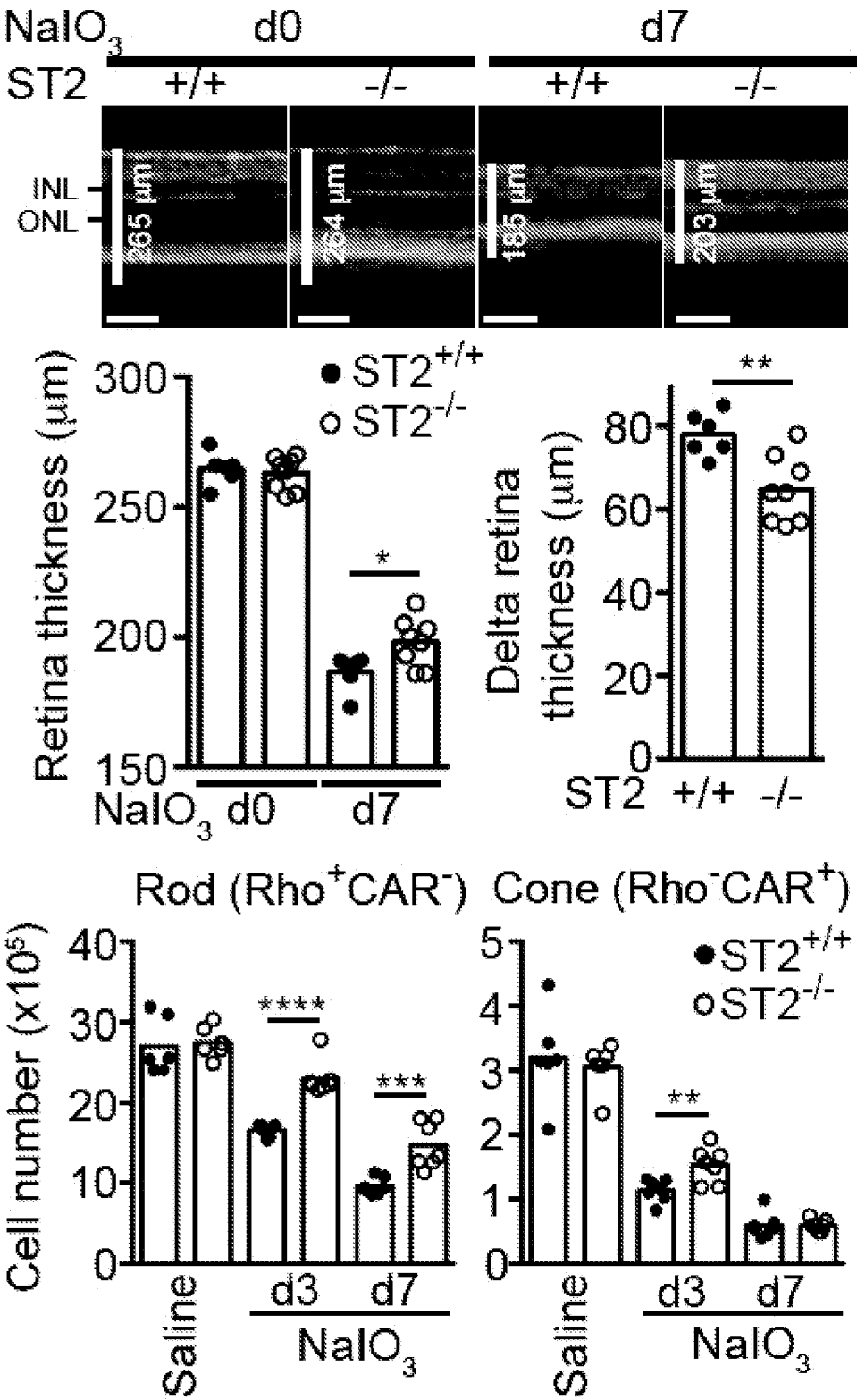


Figure 13F



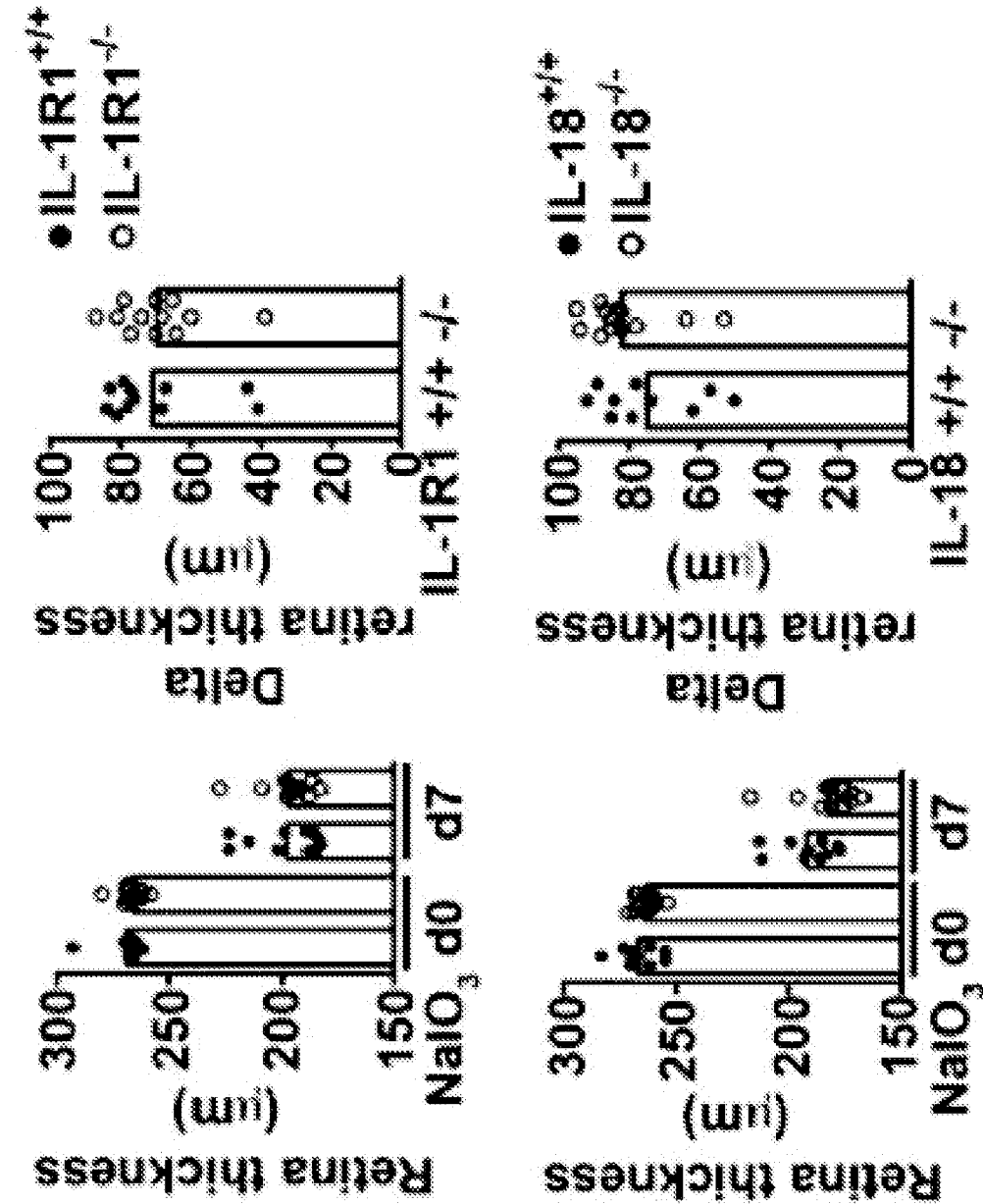


Figure 13G

Figure 13H

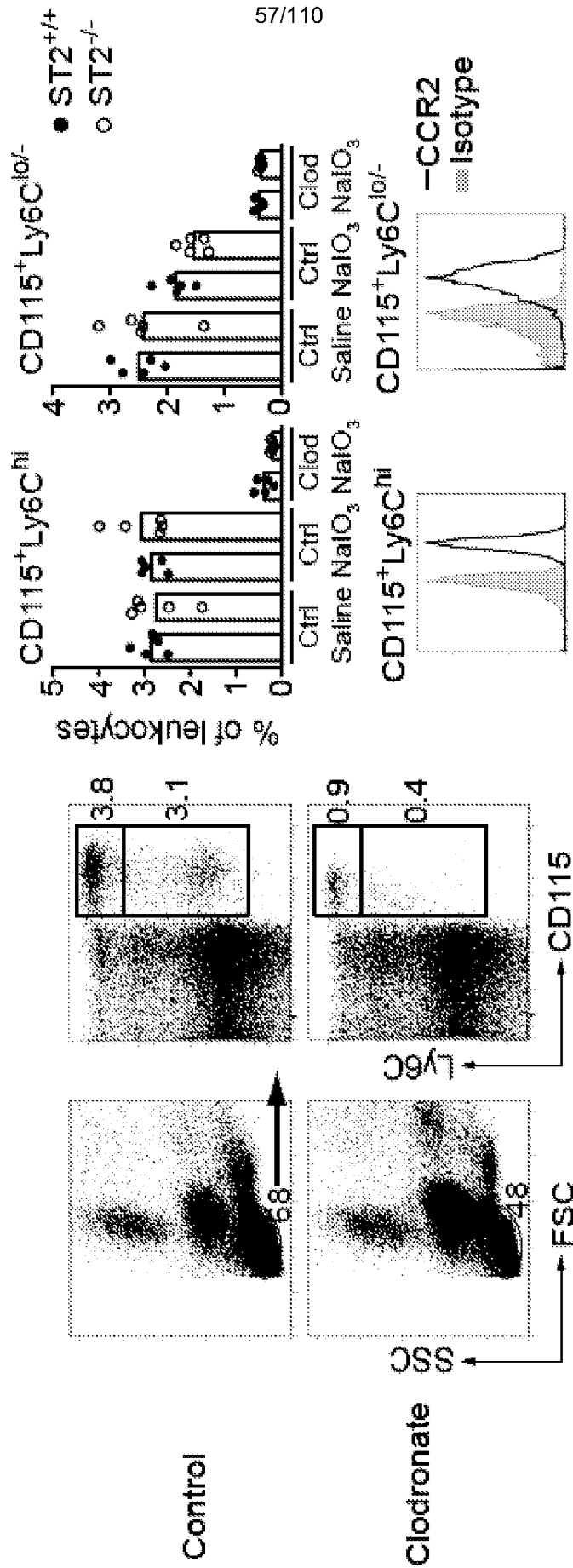


Figure 13I

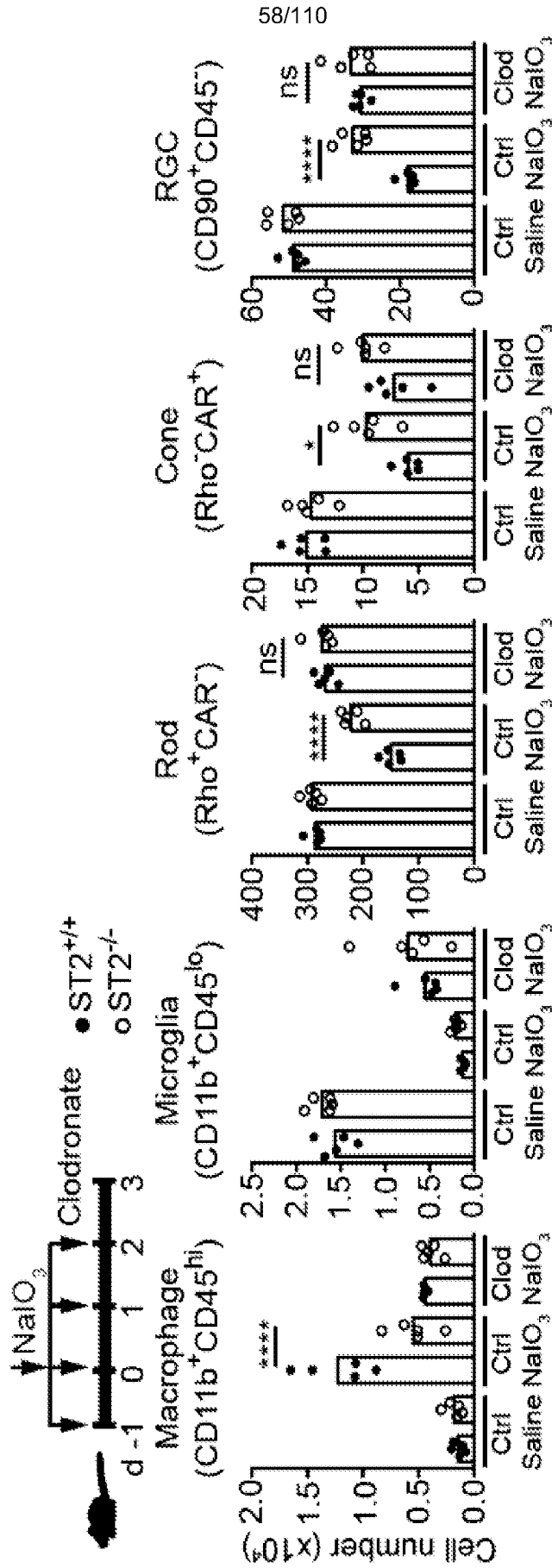


Figure 14A

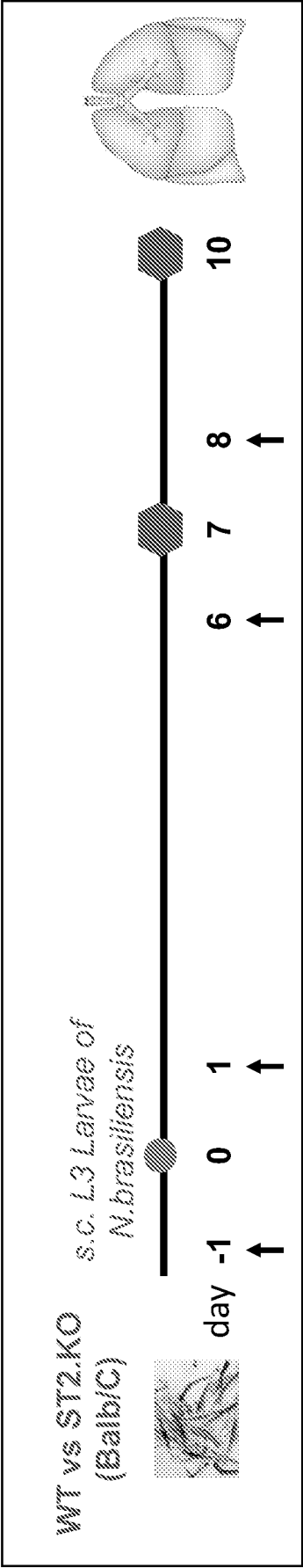
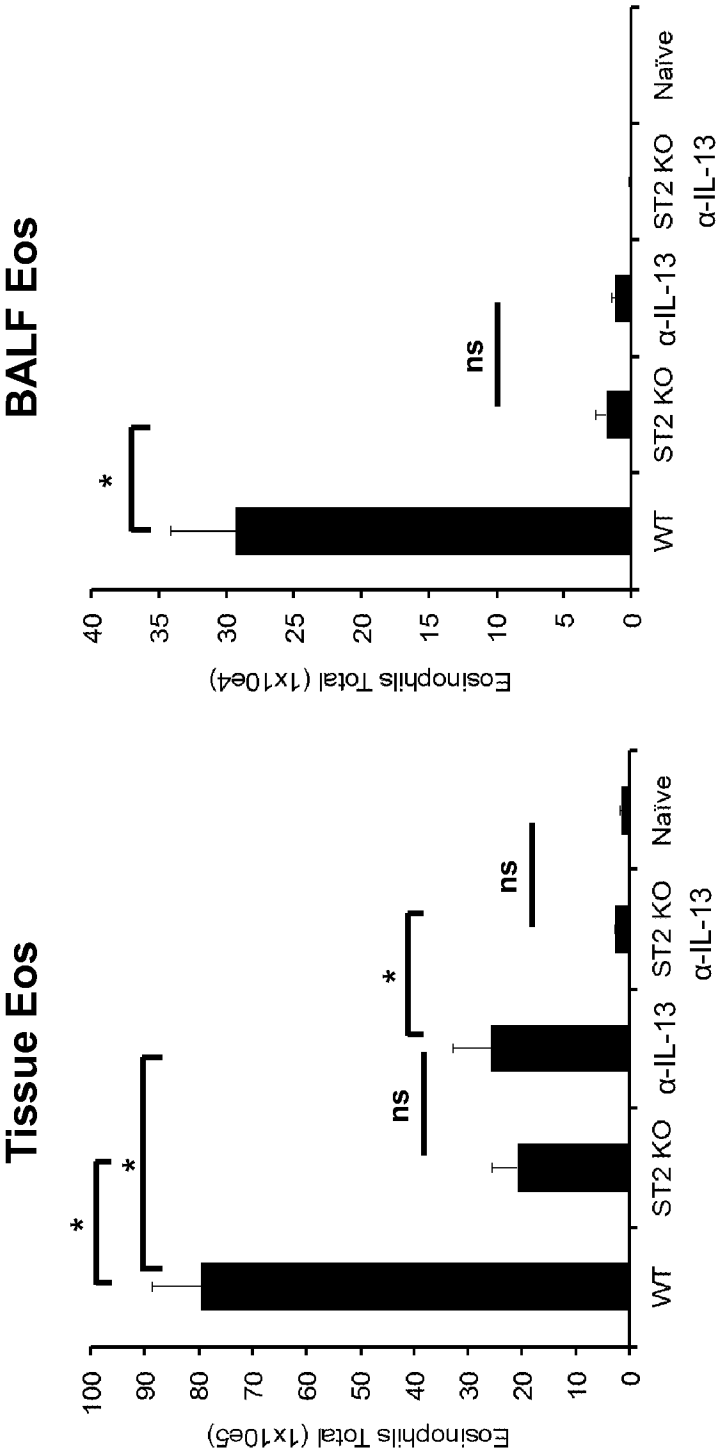
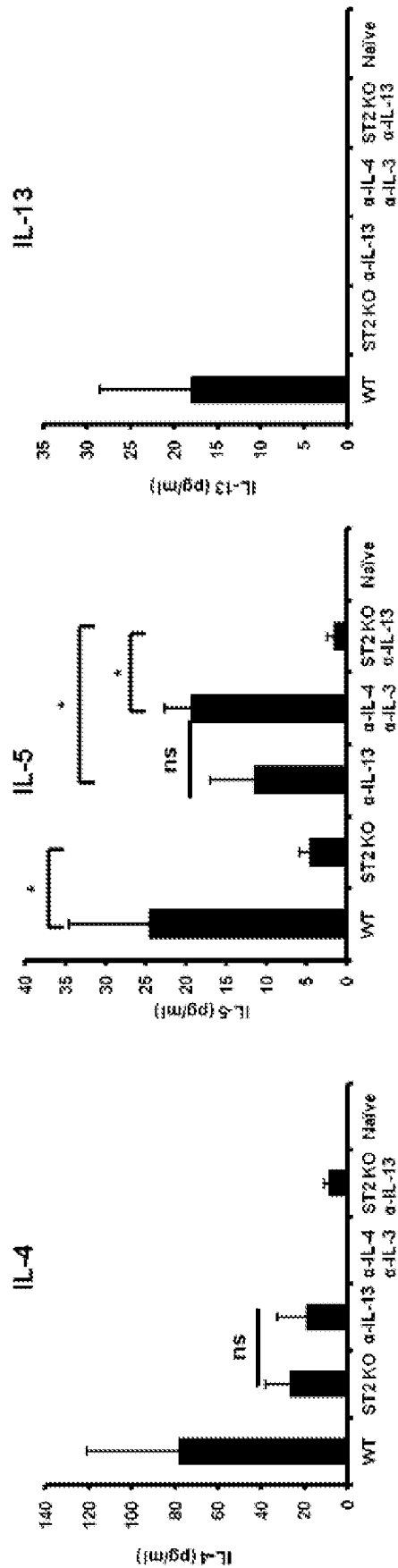


Figure 14B Lung flow cytometry analysis day 10 post-infection



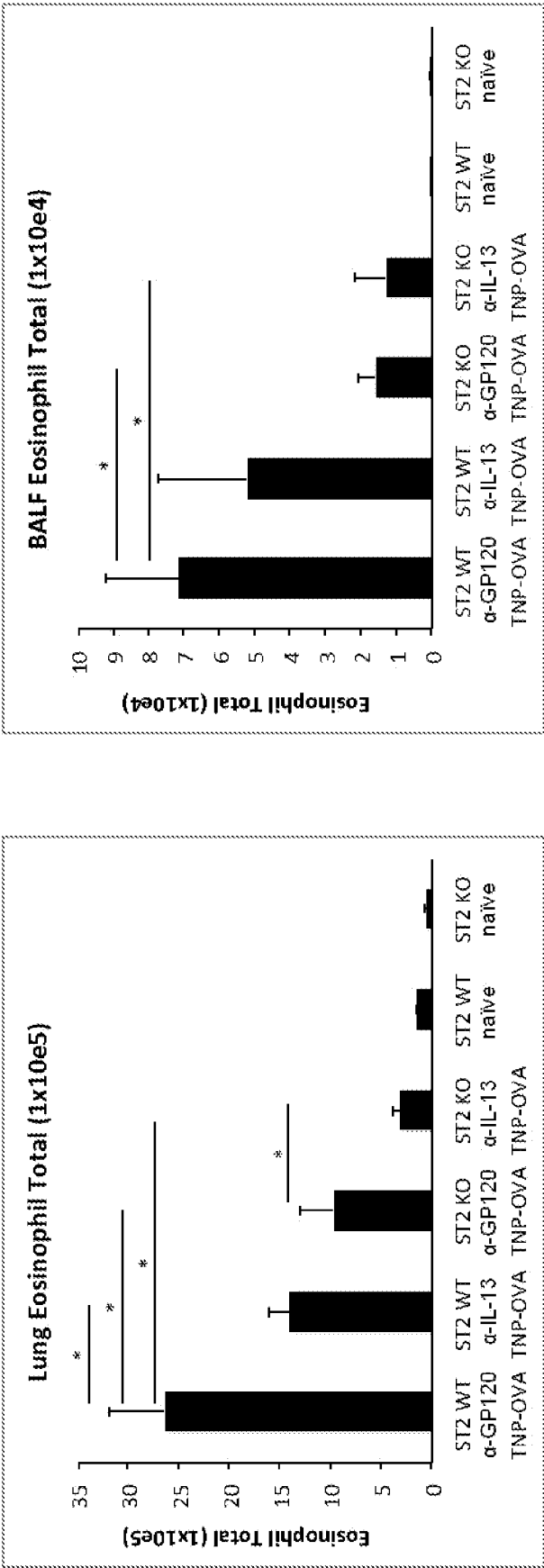
Group	Lung Day 10 Eosinophils (1x10e5)	BALF Day 10 Eosinophils (1x10e4)
WT	79.6 ± 9.1	29.3 ± 4.8
ST2 KO	20.8 ± 4.7	1.8 ± 0.8
α-IL-13	25.9 ± 6.9	1.2 ± 0.2
α-IL-13 ST2 KO	2.6 ± 0.1	0.1 ± 0.0
Naïve	1.6 ± 0.3	0.0 ± 0.0

Figure 14C
BALF cytokine analysis day 10 post-infection



Group	BALF Day 10 IL-4 (pg/ml)	BALF Day 10 IL-5 (pg/ml)	BALF Day 10 IL-13 (pg/ml)
WT	78 ± 42	25 ± 10	18 ± 11
ST2 KO	26 ± 11	5 ± 1	0 ± 0
α-IL-13	19 ± 13	11 ± 6	0 ± 0
α-IL-13 ST2 KO	9 ± 2	2 ± 1	0 ± 0
Naïve	0 ± 0	0 ± 0	0 ± 0

Figure 15A



Group	Lung Eosinophils (1x10e5)	BALF Eosinophils (1x10e4)
WT	26.5 ± 5.4	7.2 ± 2.0
α-IL-13	14.1 ± 2.0	5.2 ± 2.5
ST2 KO	9.7 ± 3.3	1.6 ± 0.5
α-IL-13 ST2 KO	3.2 ± 0.6	1.3 ± 0.9
WT Naïve	1.5 ± 0.1	0.0 ± 0.0
ST2 KO Naïve	0.5 ± 0.1	0.0 ± 0.0

Figure 15B

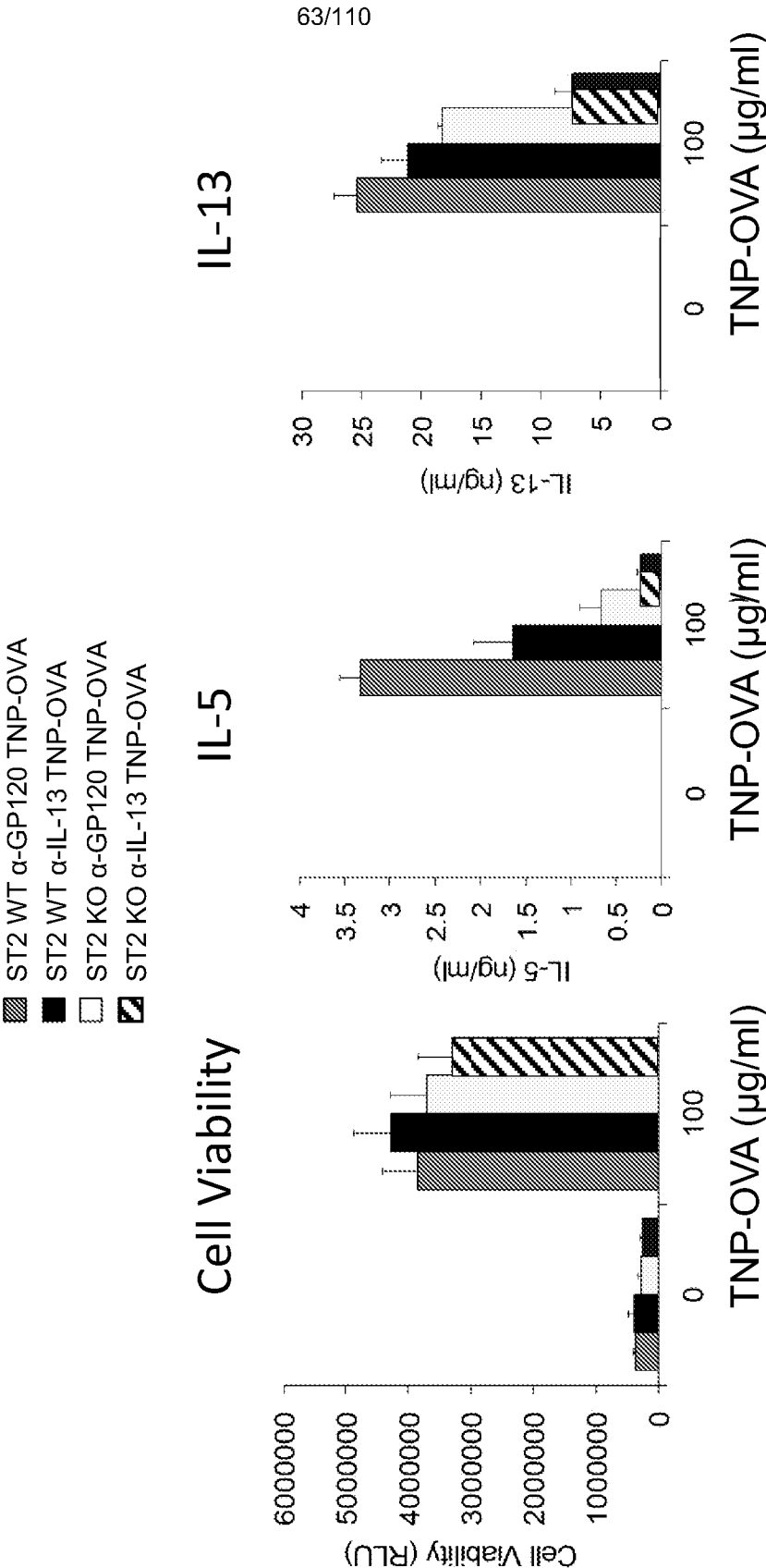


Figure 16A

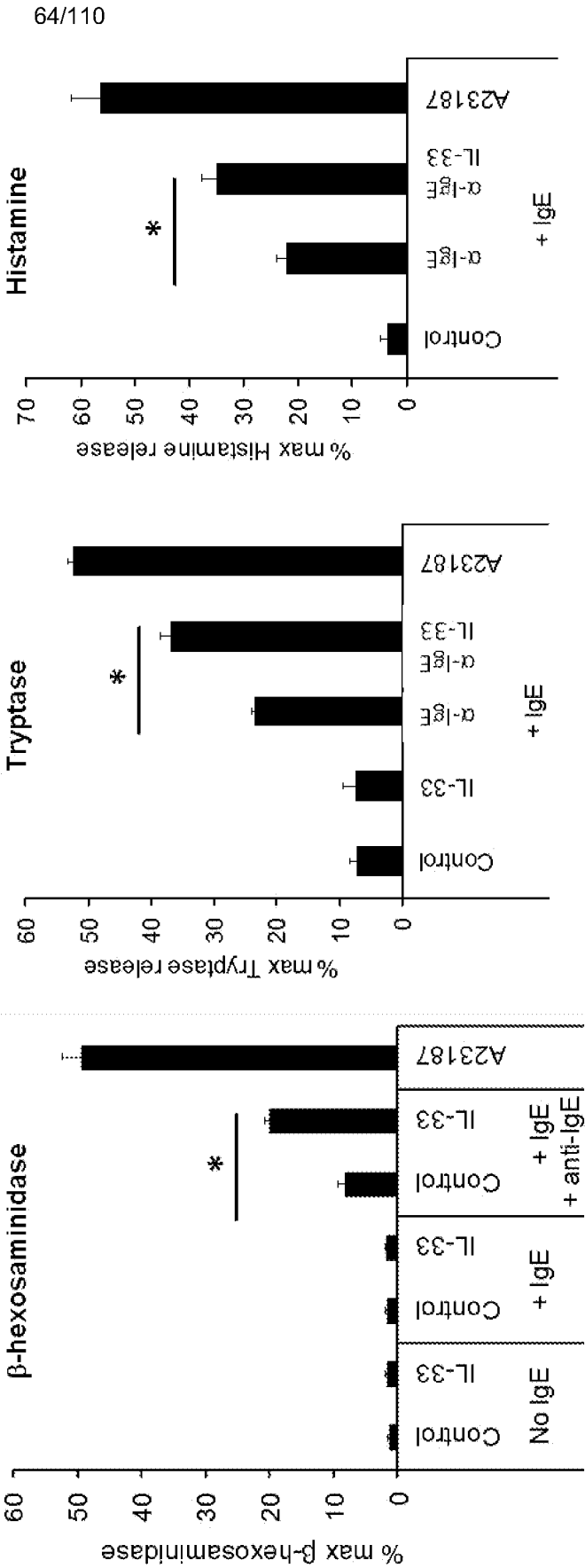
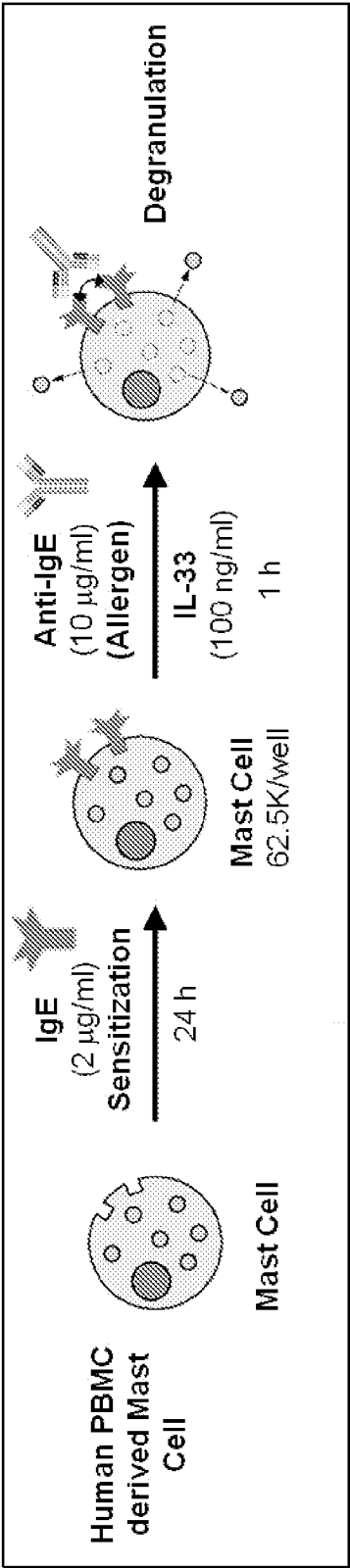
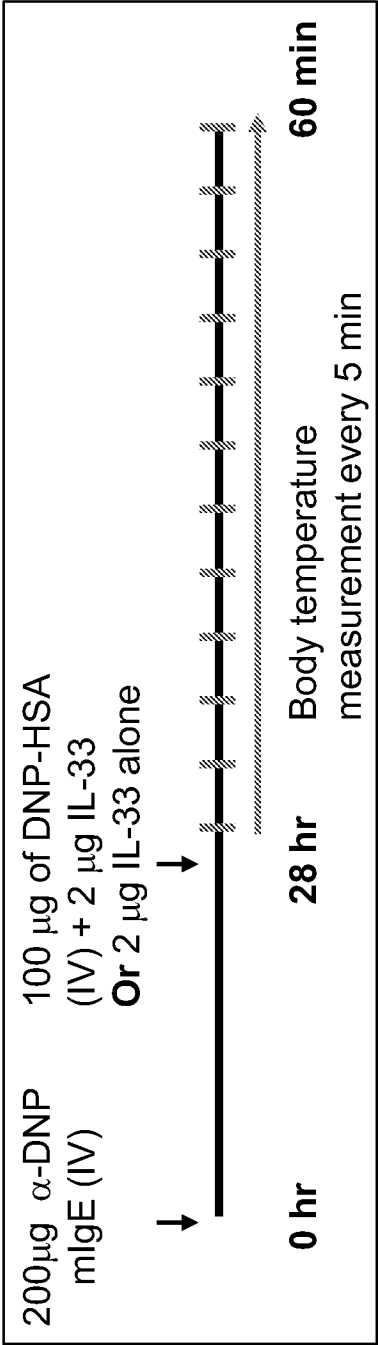
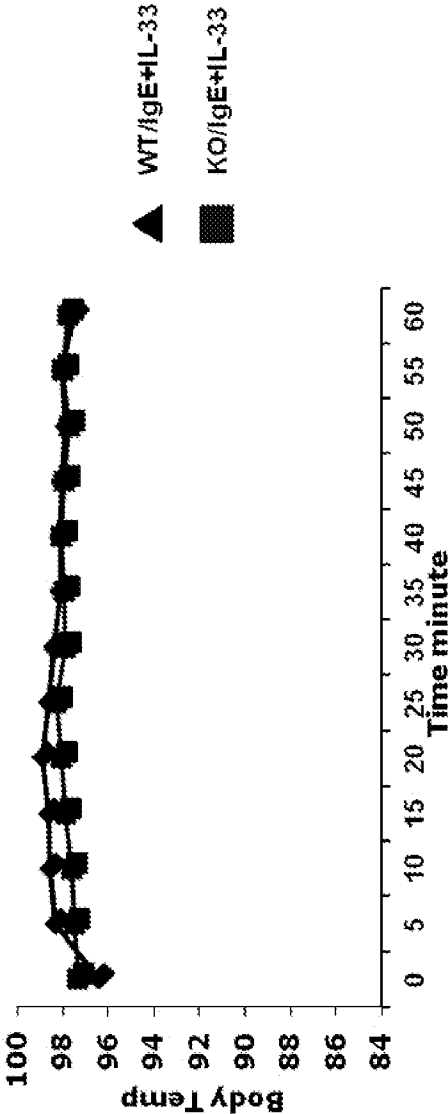


Figure 16B

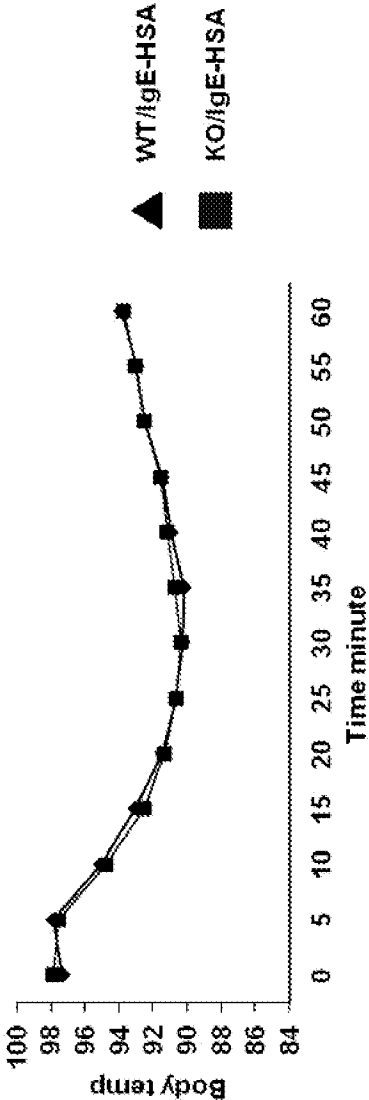


Figures 16C-16D

C.



D.



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Figure 16E

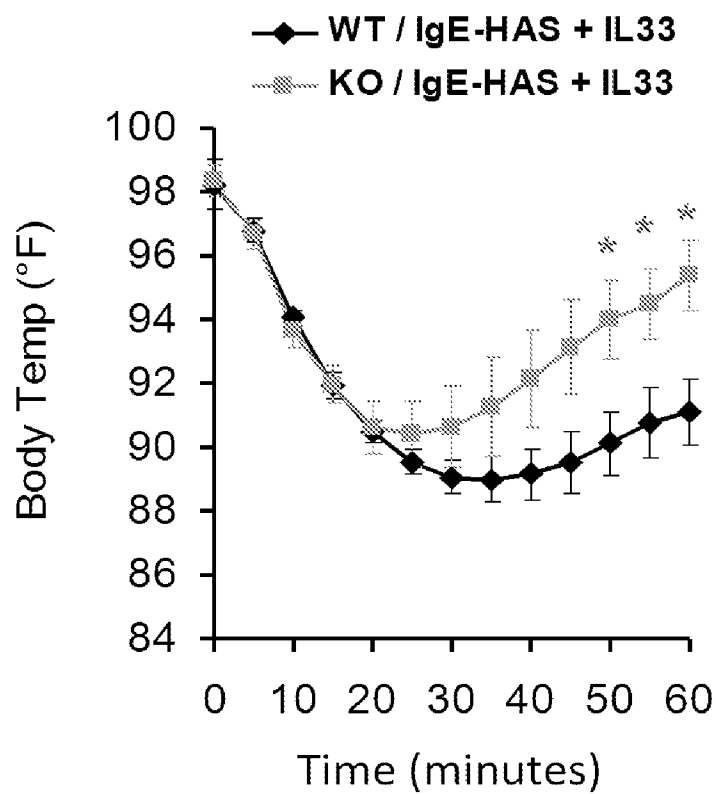
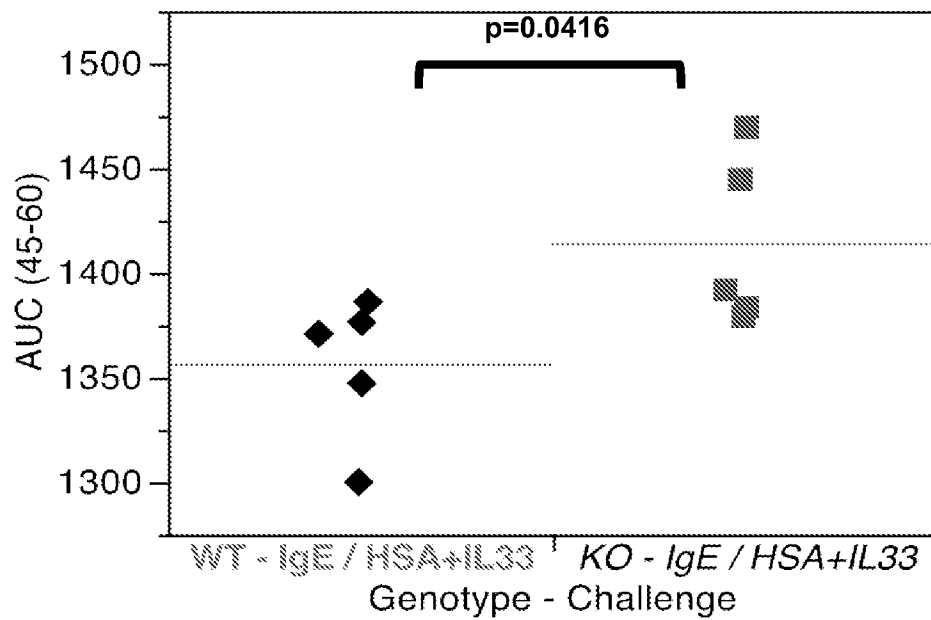


Figure 16F

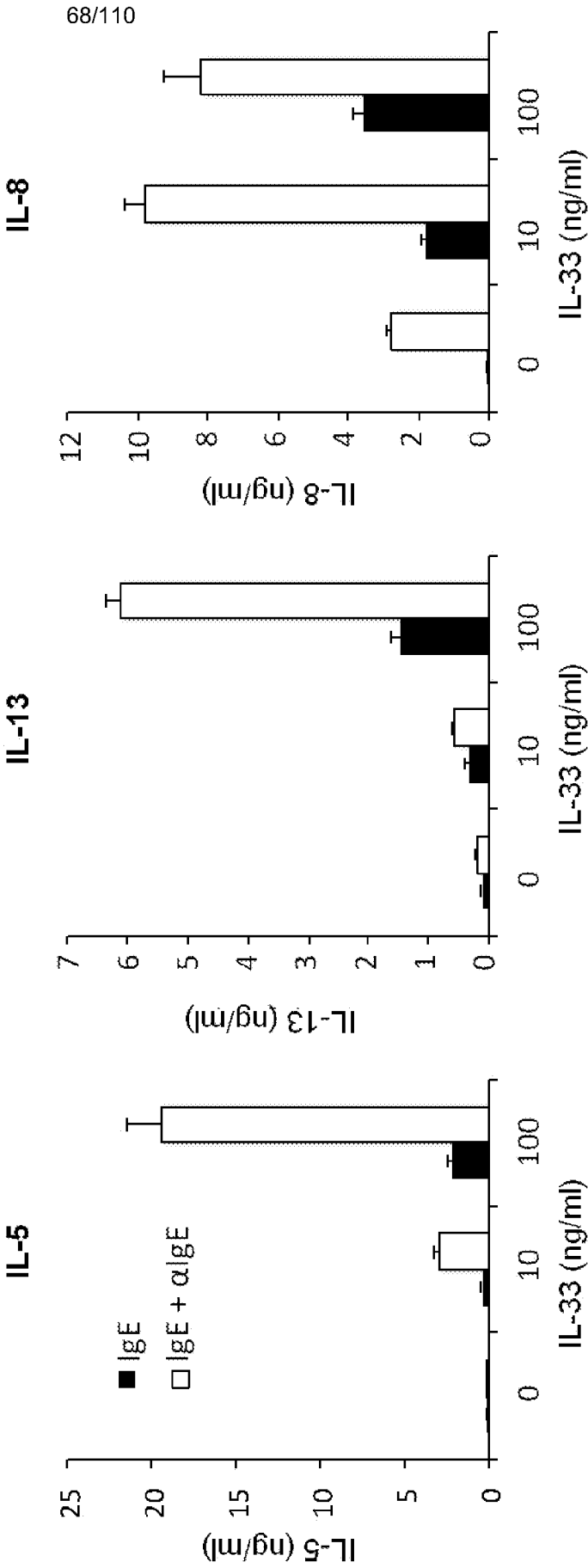
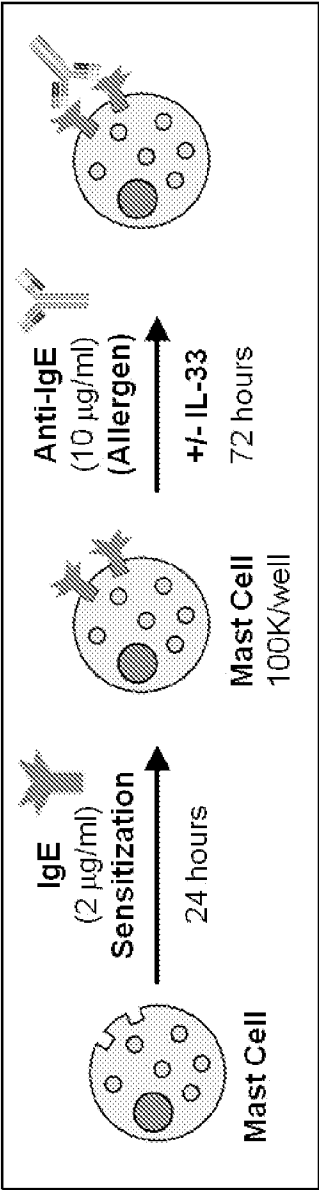


Figure 16G

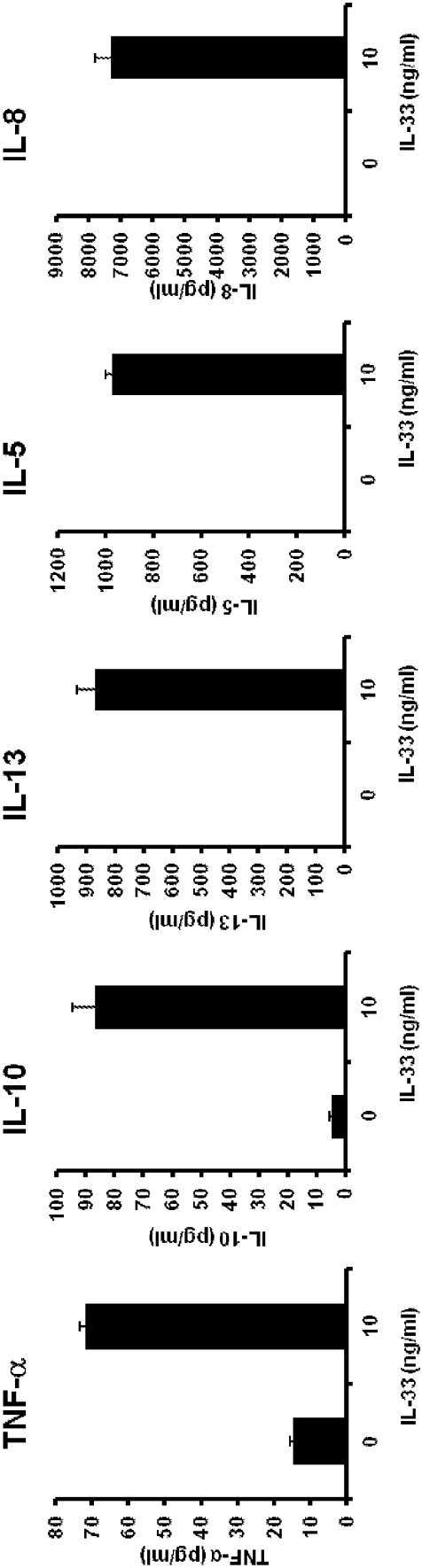
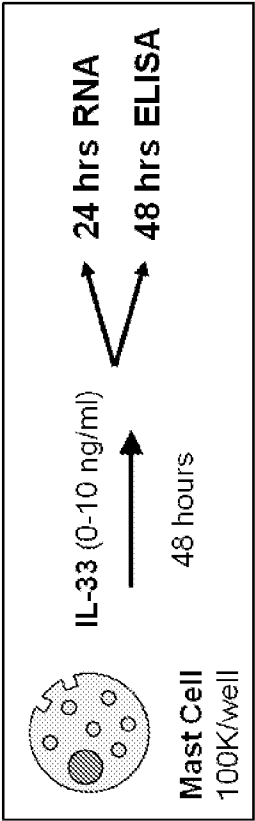


Figure 16H

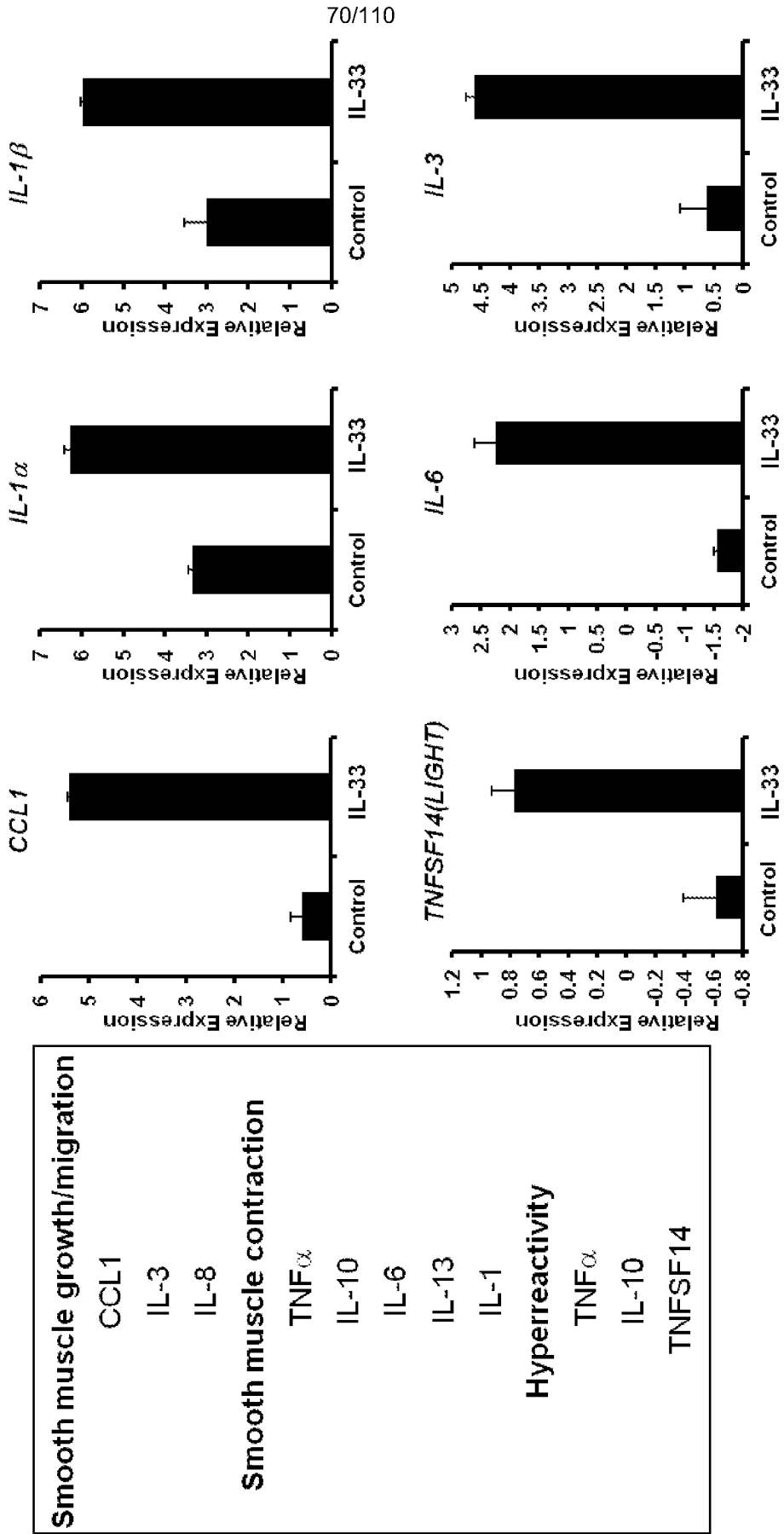


Figure 17A

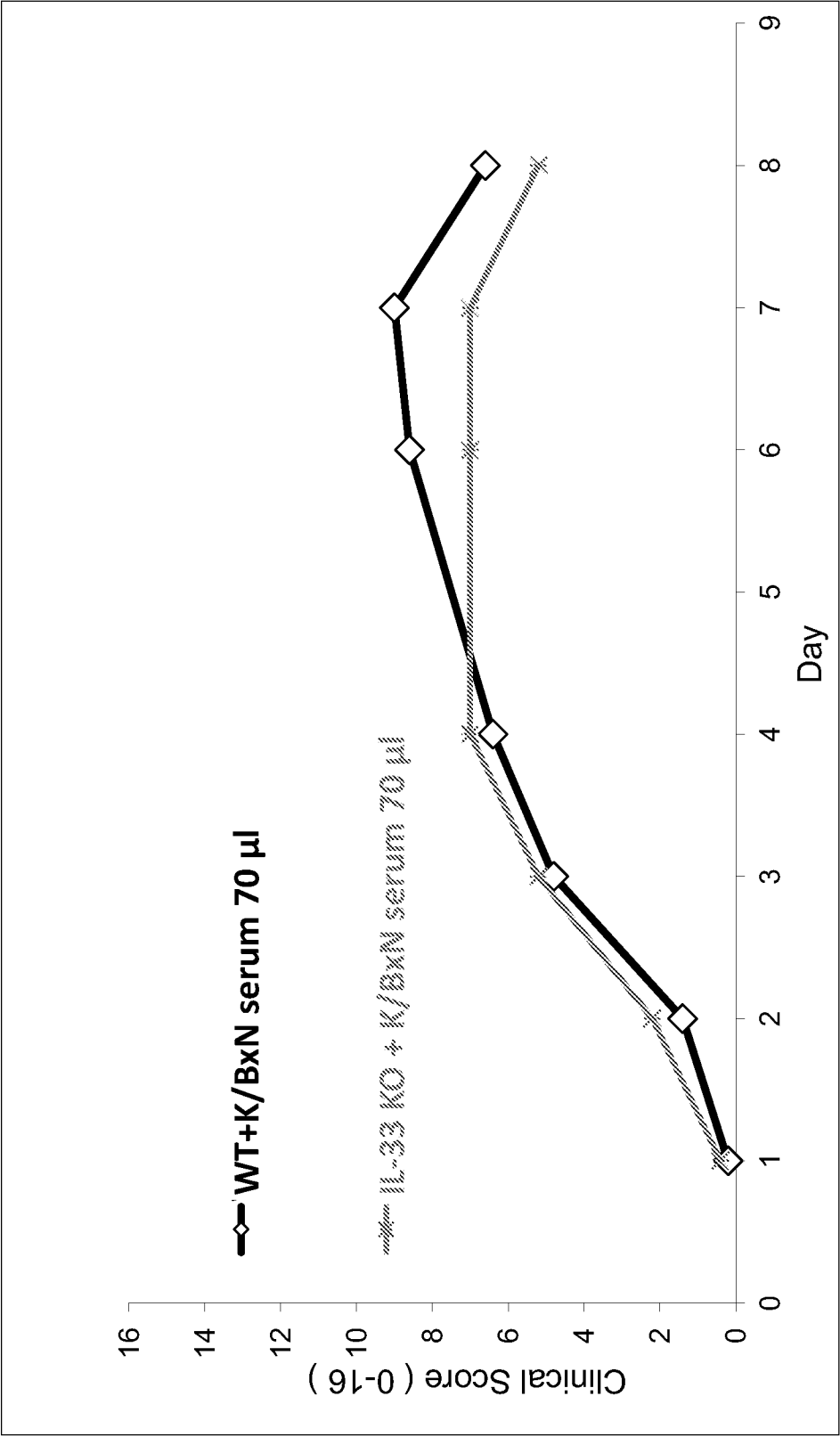
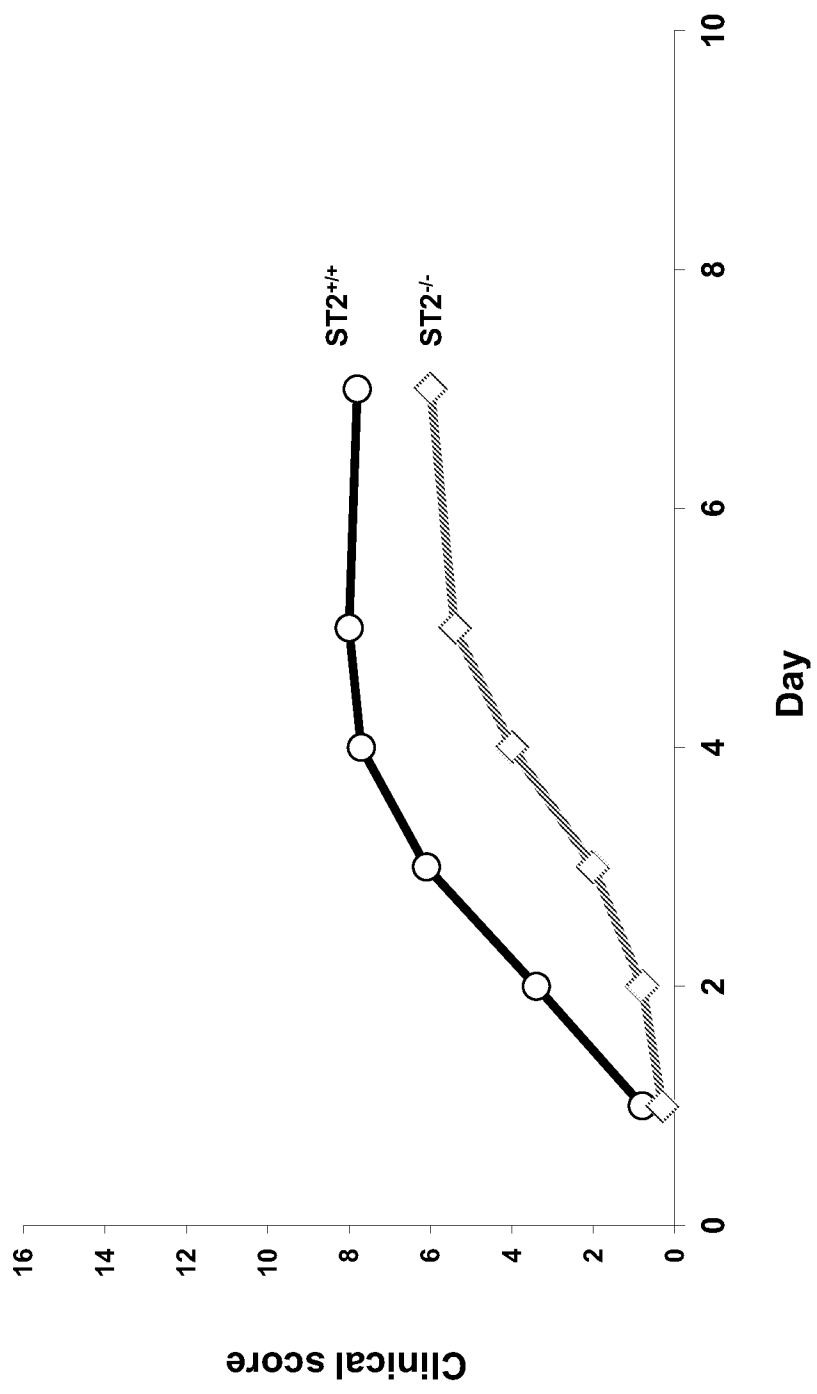
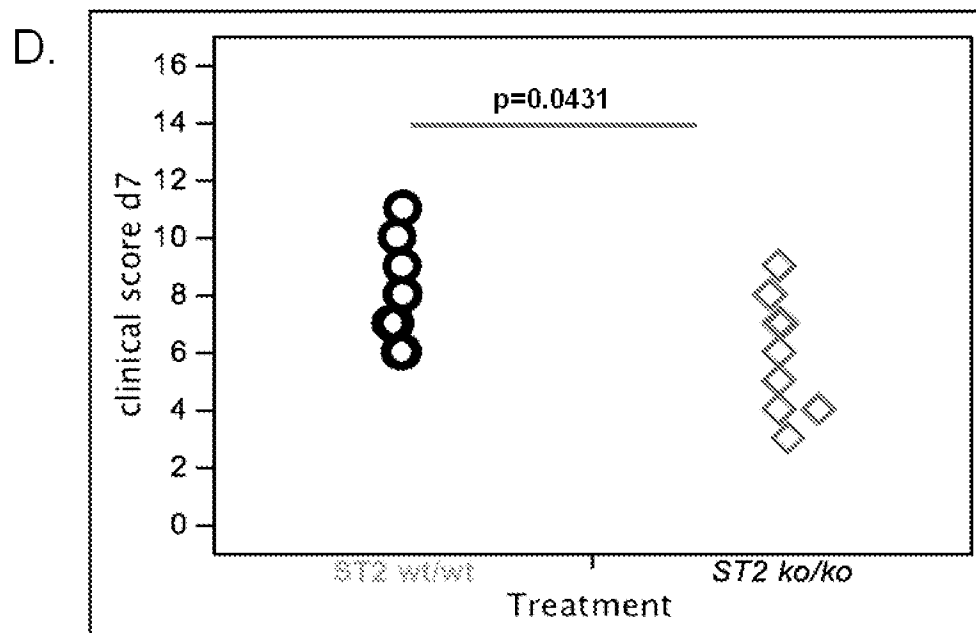
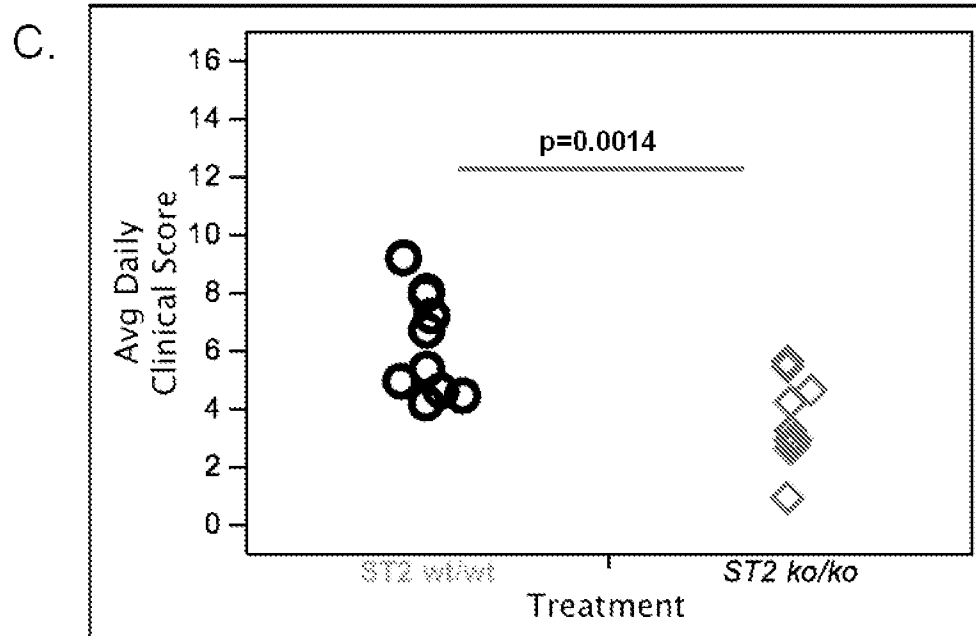


Figure 17B



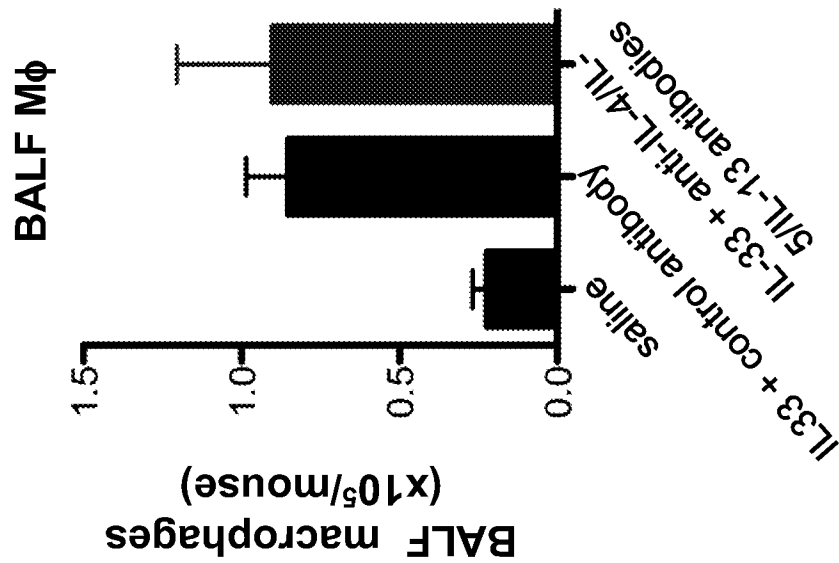
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Figures 17C-17D



Figures 18B-18C

B.



C.

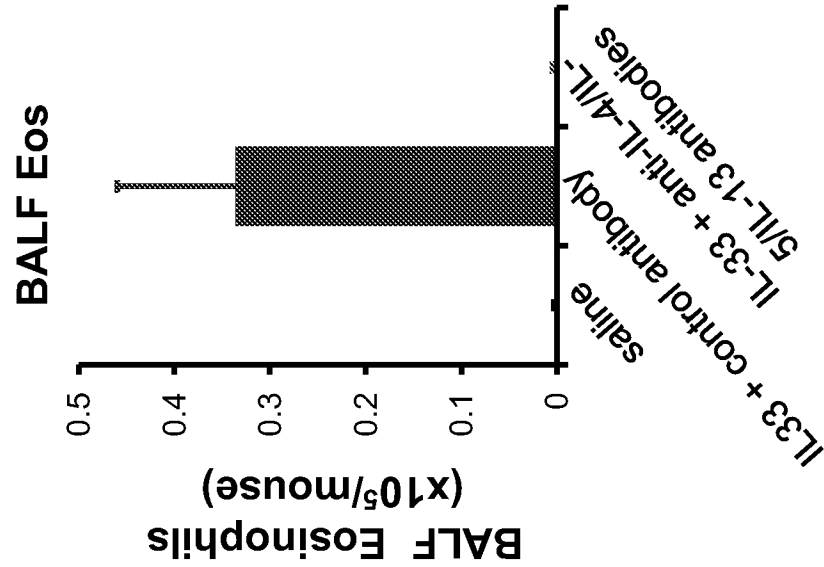
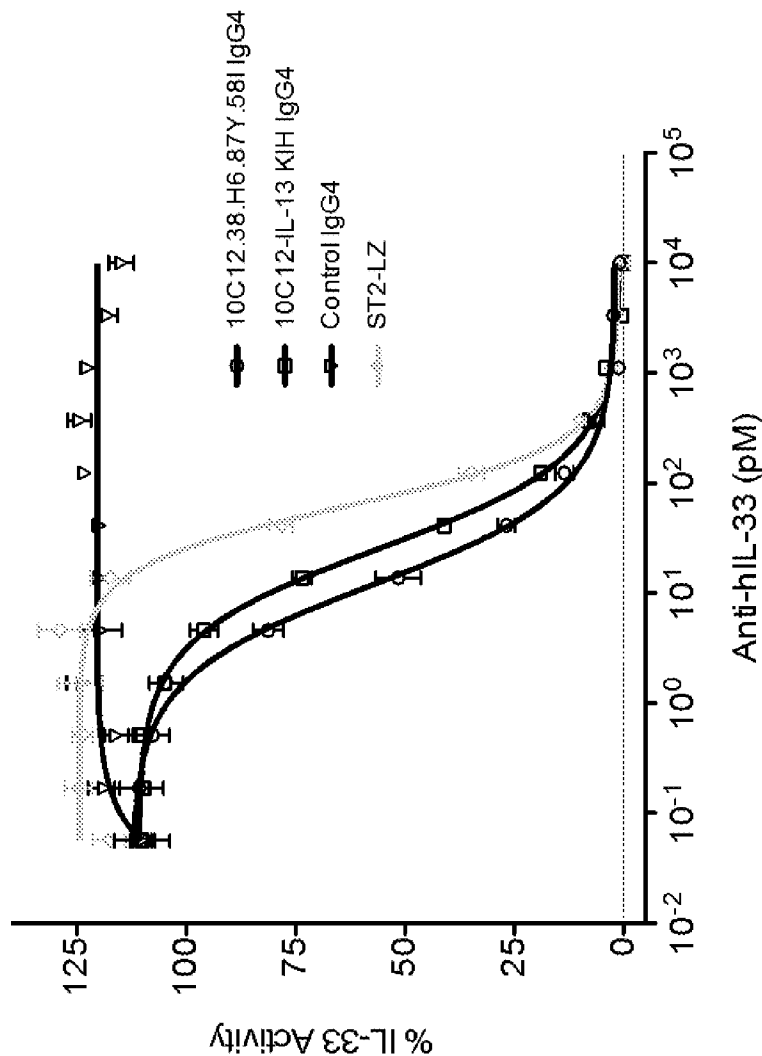


Figure 19A HEK-BLUE™ cell-based IL-33 blocking assay



IC90 (pM)	10C12.38.H6.87Y.58I IgG4	10C12-IL-13 KIH IgG4	Control IgG4	ST2-LZ
	102.1 (0.0153 µg/ml)	204.7 (0.0307 µg/ml)	1.082e-006	256.6

IC50 (pM)	10C12.38.H6.87Y.58I IgG4	10C12-IL-13 KIH IgG4	Control IgG4	ST2-LZ
	11.99	25.35	7.633e-006	62.11

Figure 19B

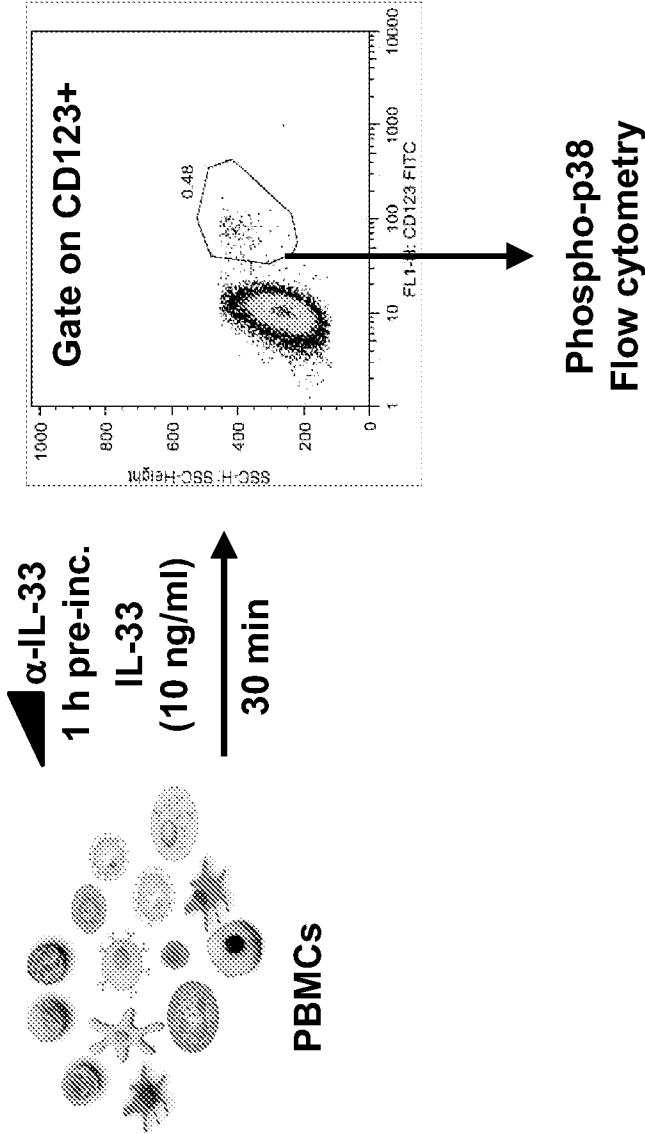


Figure 19C

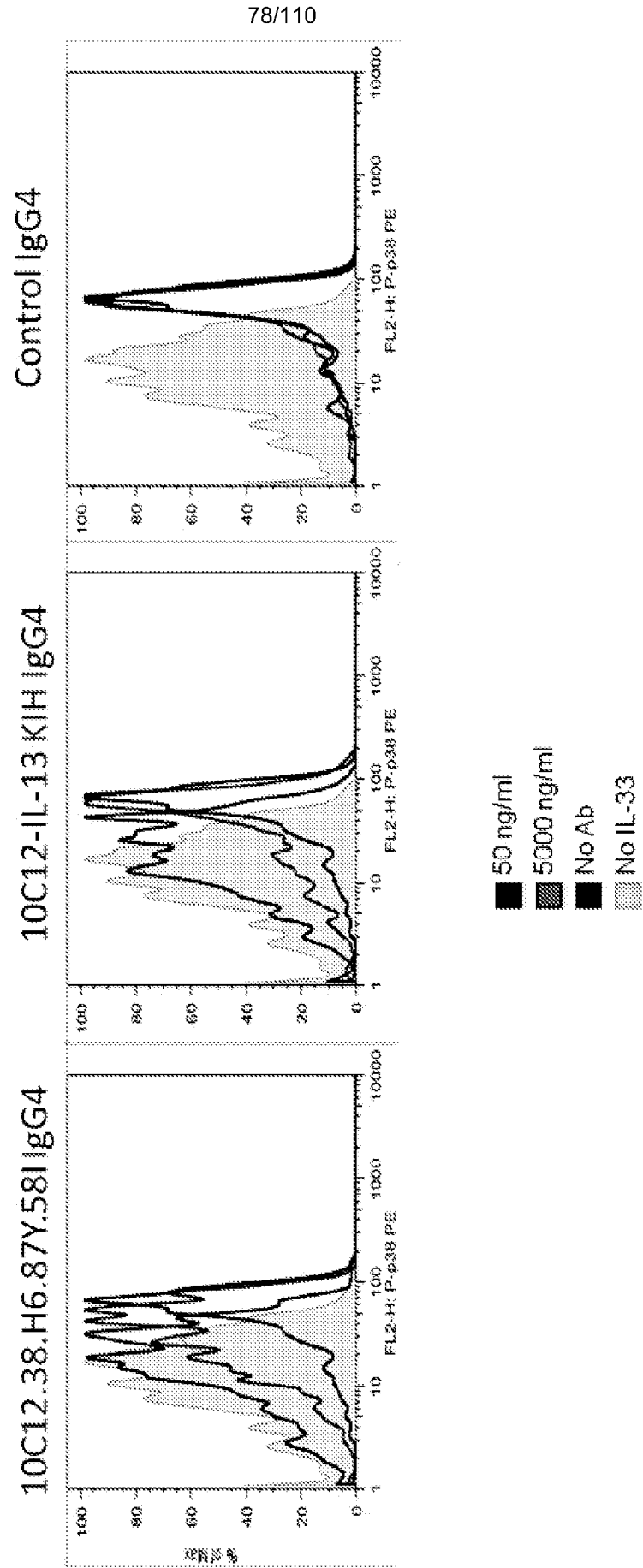


Figure 19D

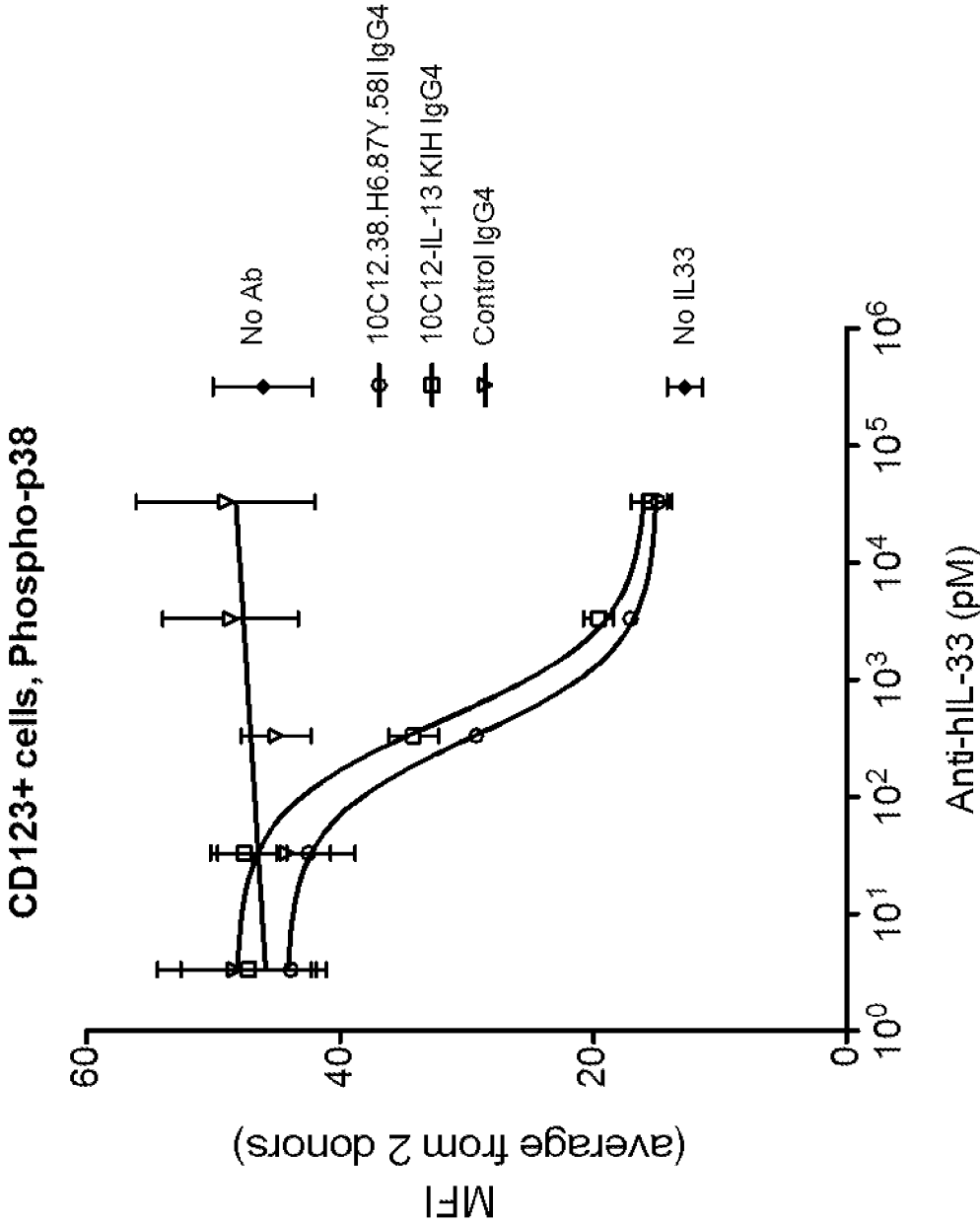


Figure 20

10C12.38.H6.87Y.58I/IL-13 IgG4 bispecific antibody

Lot	Human IL-33			Cyno IL-33			Human IL-13		
	k_{on} (1/Ms) (x10 ⁵)	k_{off} (1/s) (x10 ⁻⁴)	K_D (nM)	k_{on} (1/Ms) (x10 ⁵)	k_{off} (1/s) (x10 ⁻⁴)	K_D (nM)	k_{on} (1/Ms) (x10 ⁵)	k_{off} (1/s) (x10 ⁻⁴)	K_D (nM)
1	11.0	0.11	0.010	6.7	0.72	0.107	14.9	0.02	<0.010
2	11.4	0.30	0.026	6.5	0.40	0.062	14.7	0.04	<0.010
3	9.9	0.40	0.041	7.0	0.41	0.059	14.5	0.06	<0.010

Figure 21A

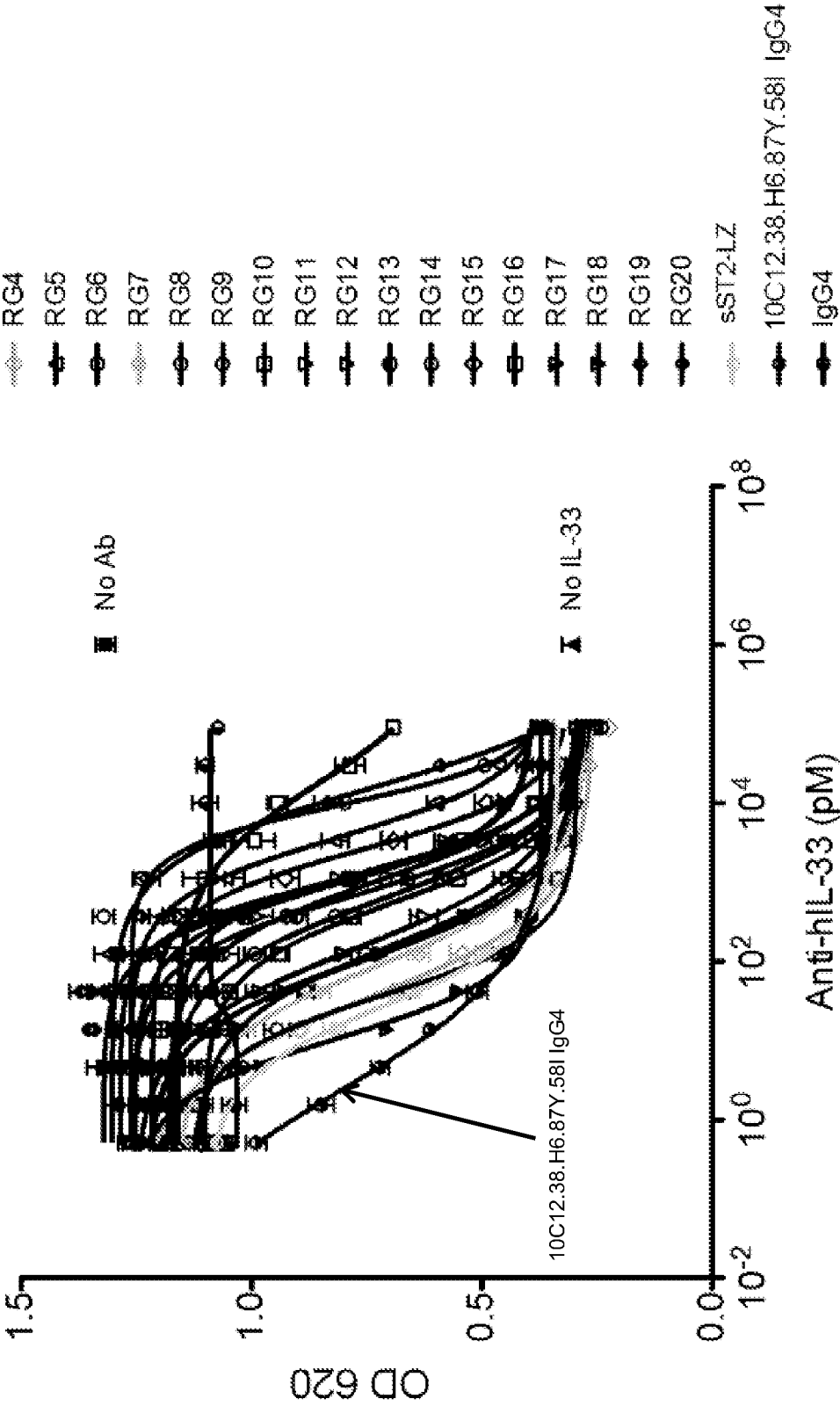


Figure 21B

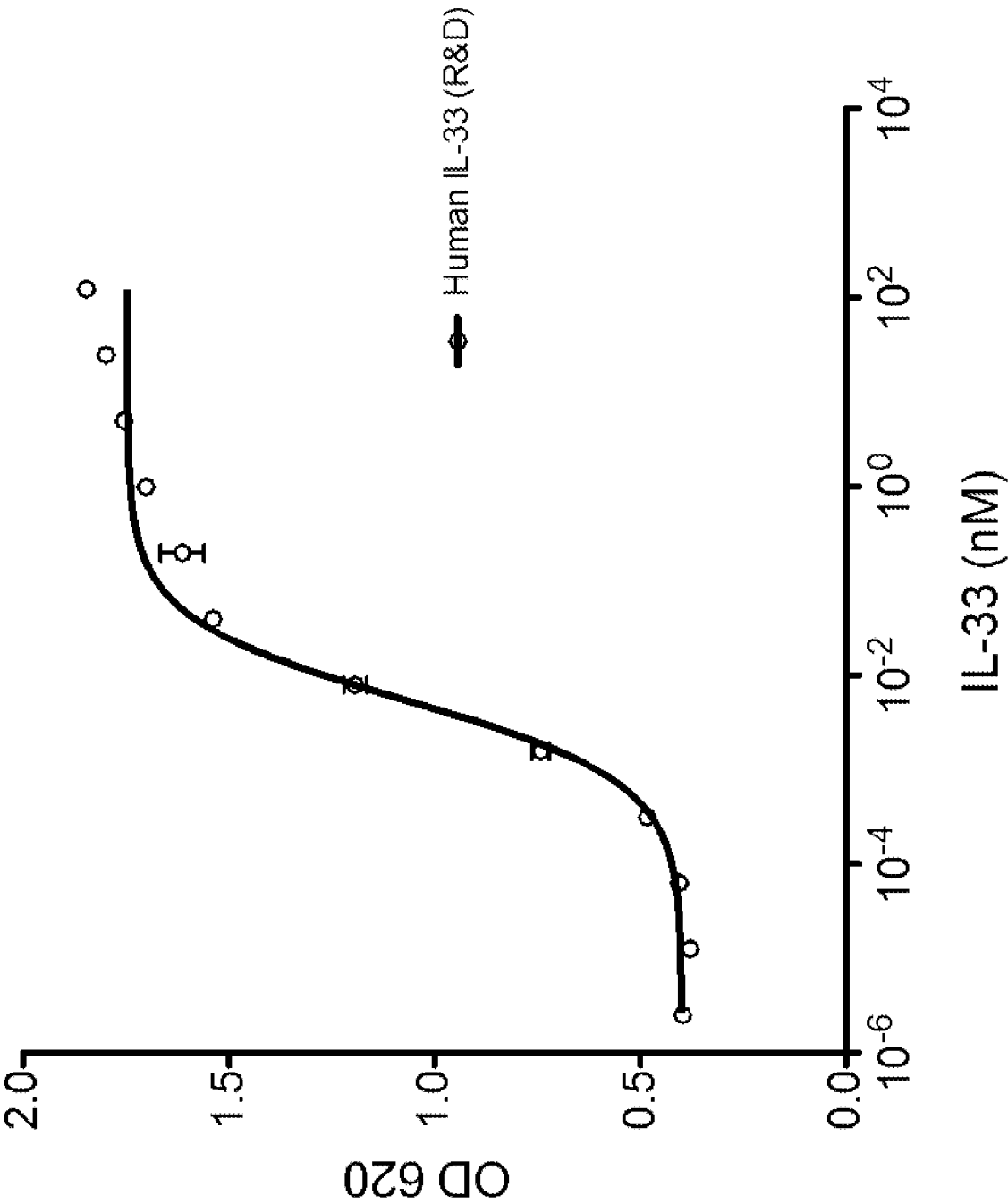


Figure 21C

Species	Human	Cyno
EC50 [M]	5.5E-12	2.1E-11
IL-33	10pM hIL-33	5pM cIL-33-Nhis
Ab	IC50 [M]	IC50 [M]
10C12.38.H6.87Y.58I IgG4	2.4E-12	4.2E-09
sST2	2.7E-11	3.0E-11
RG1	9.5E-09	non-blocking
RG2	1.7E-08	non-blocking
RG3	1.1E-10	2.9E-08
RG4	3.3E-11	non-blocking
RG5	3.7E-09	non-blocking
RG6	6.1E-10	non-blocking
RG7	9.2E-11	6.6E-08
RG8	3.8E-11	4.8E-08
RG9	1.5E-10	3.4E-08
RG10	1.5E-09	2.3E-08
RG11	1.5E-10	non-blocking
RG12	1.1E-09	1.1E-08
RG13	7.1E-10	non-blocking
RG14	1.0E-09	non-blocking
RG15	2.6E-09	non-blocking
RG16	5.7E-10	5.0E-08
RG17	9.8E-10	non-blocking
RG18	1.1E-11	5.7E-08
RG19	8.2E-10	non-blocking
RG20	1.6E-08	6.1E-09

Figure 21D

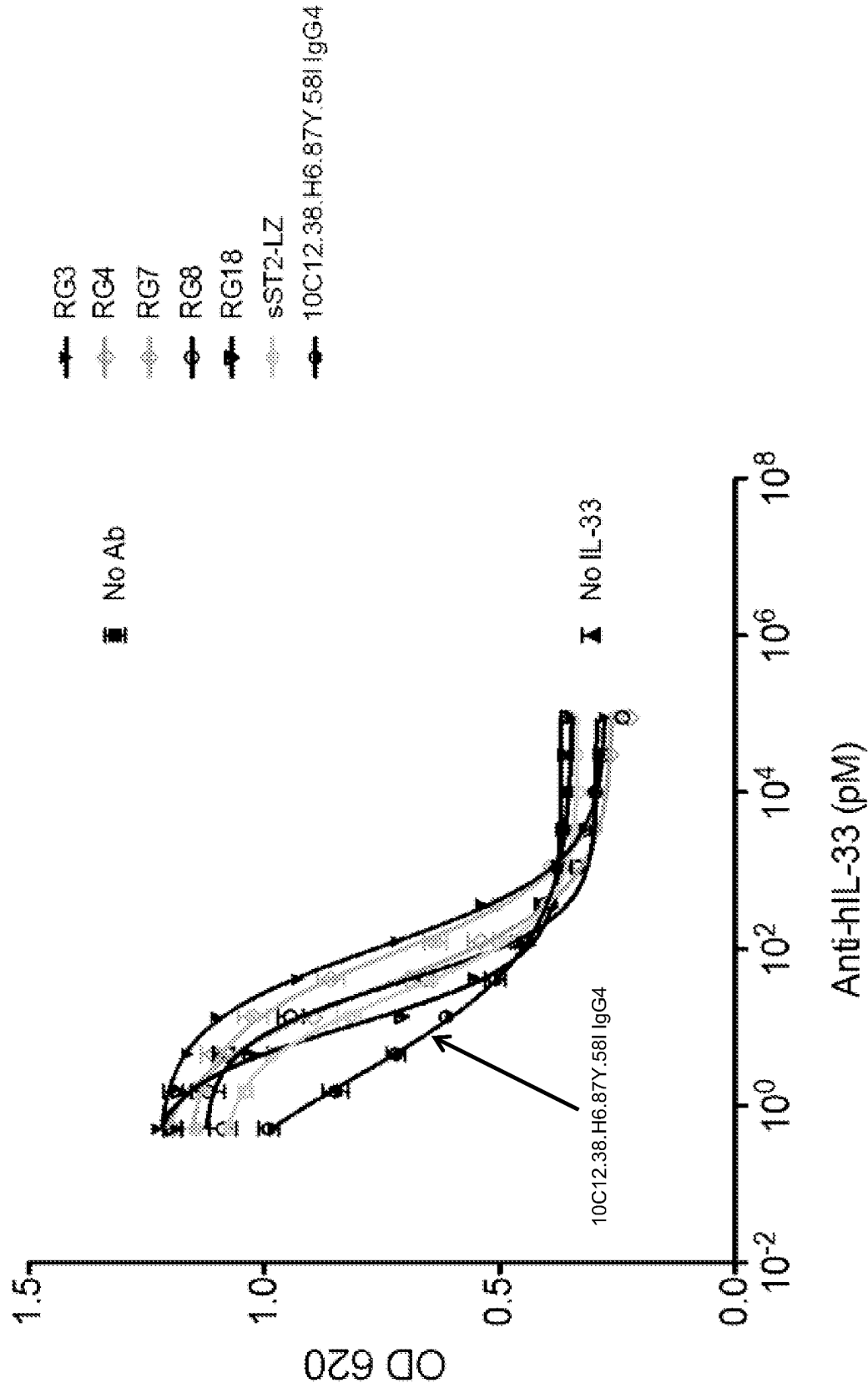
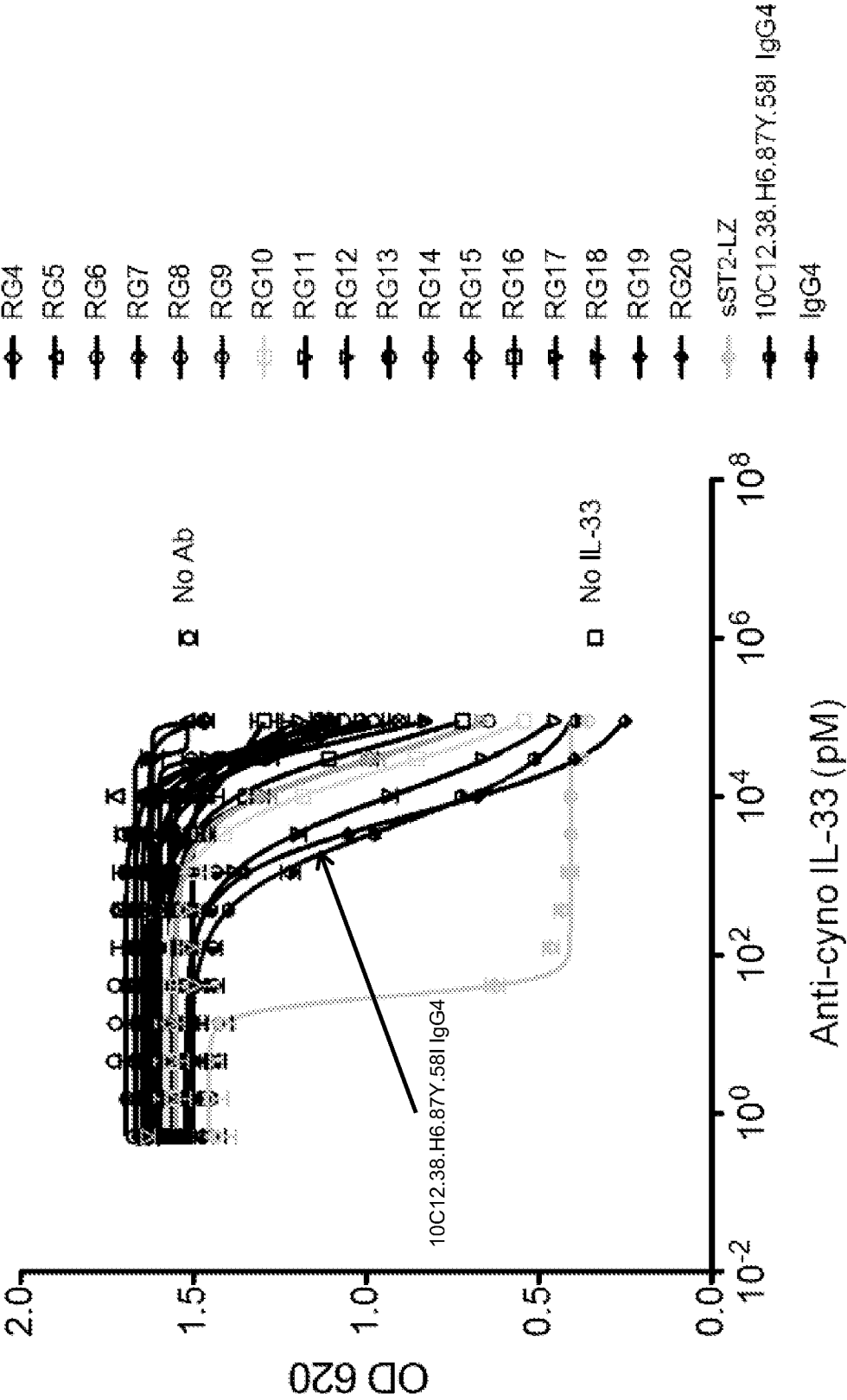


Figure 22A



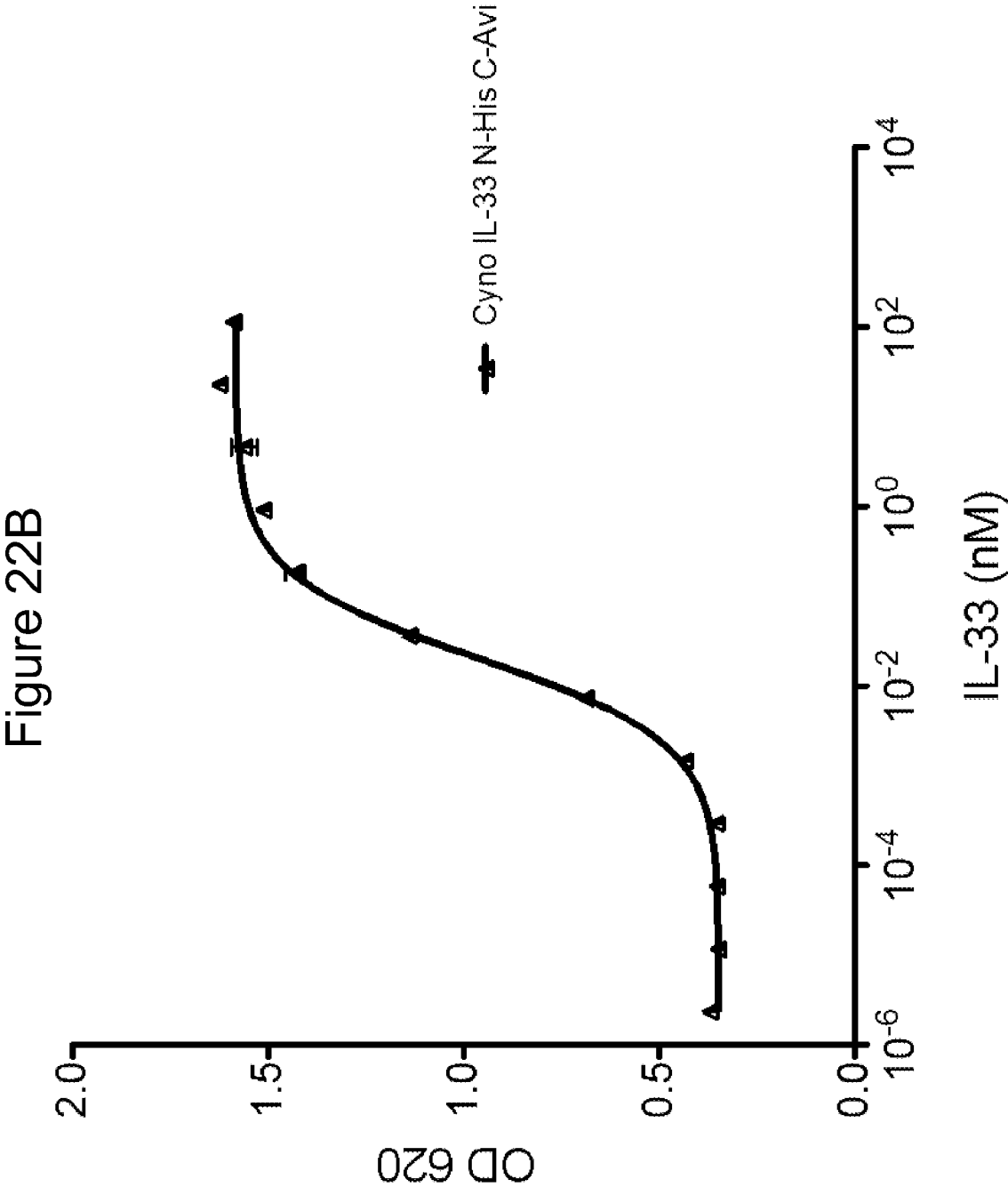
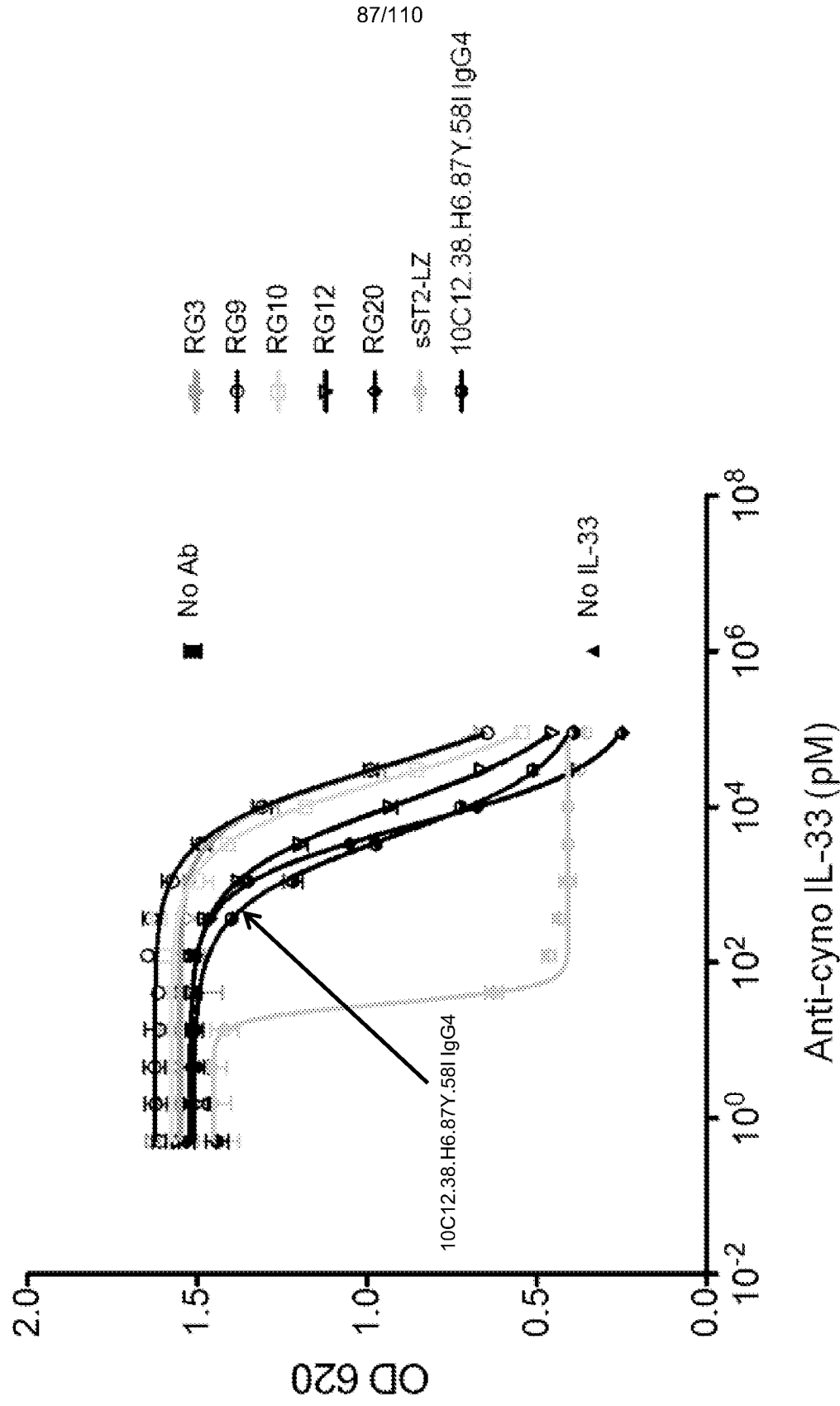


Figure 22C



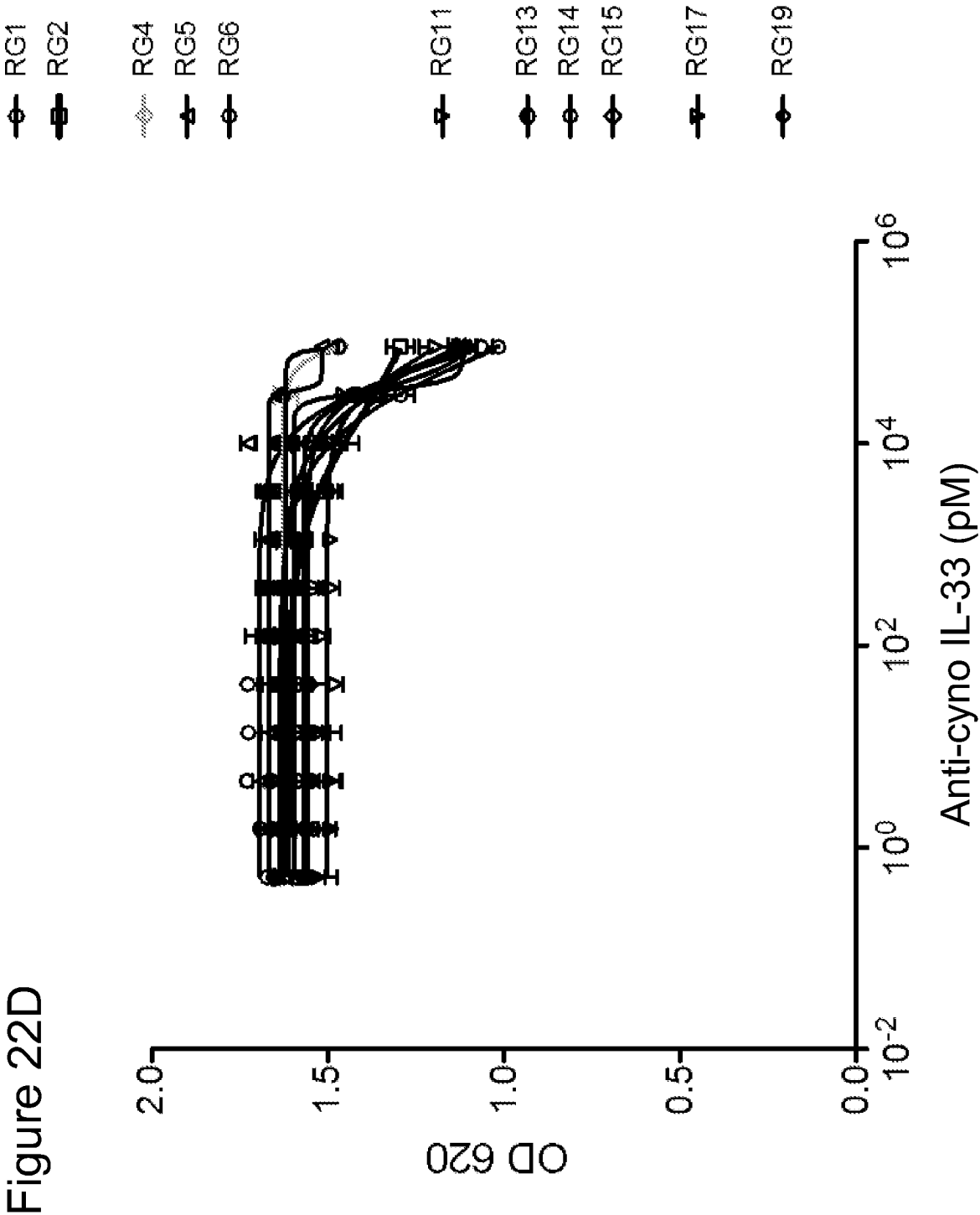


Figure 23A

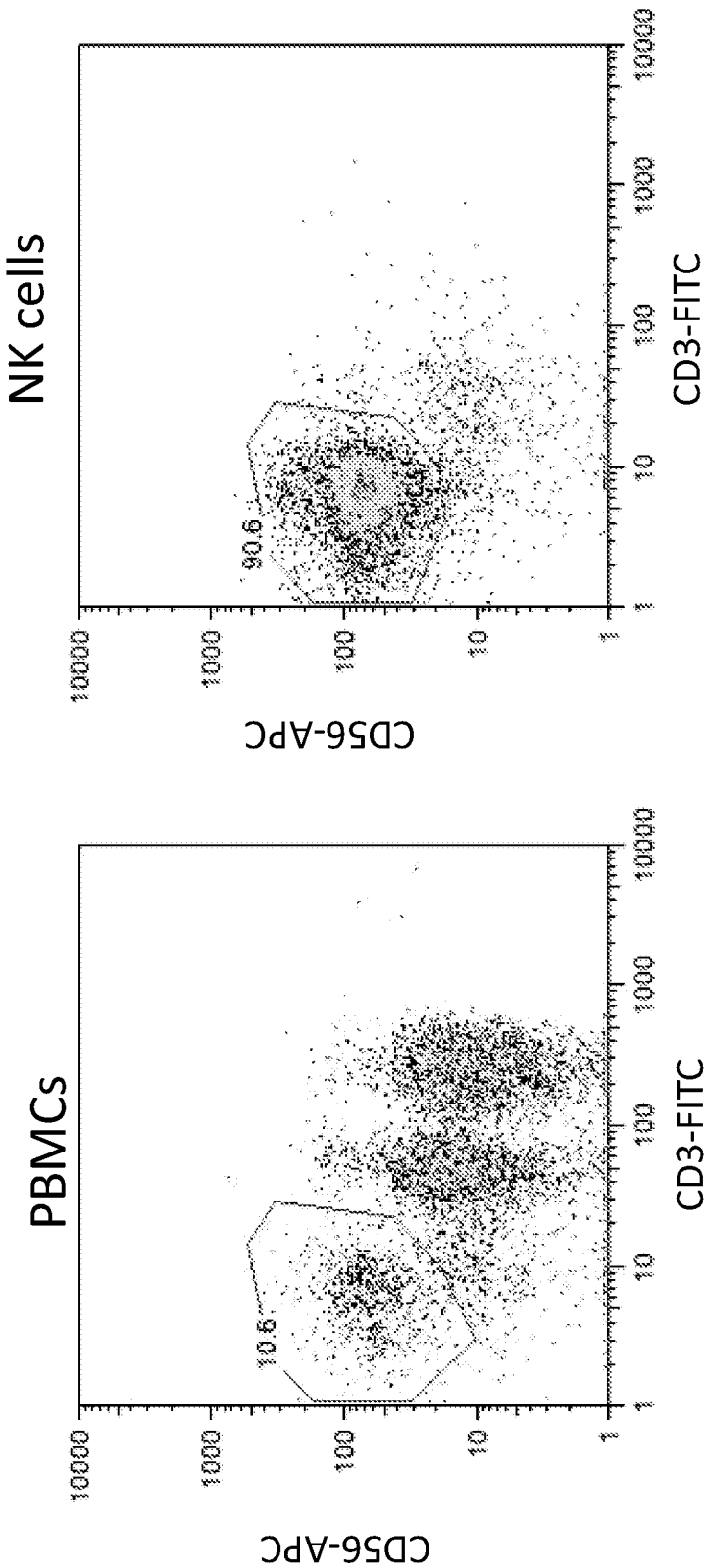


Figure 23B

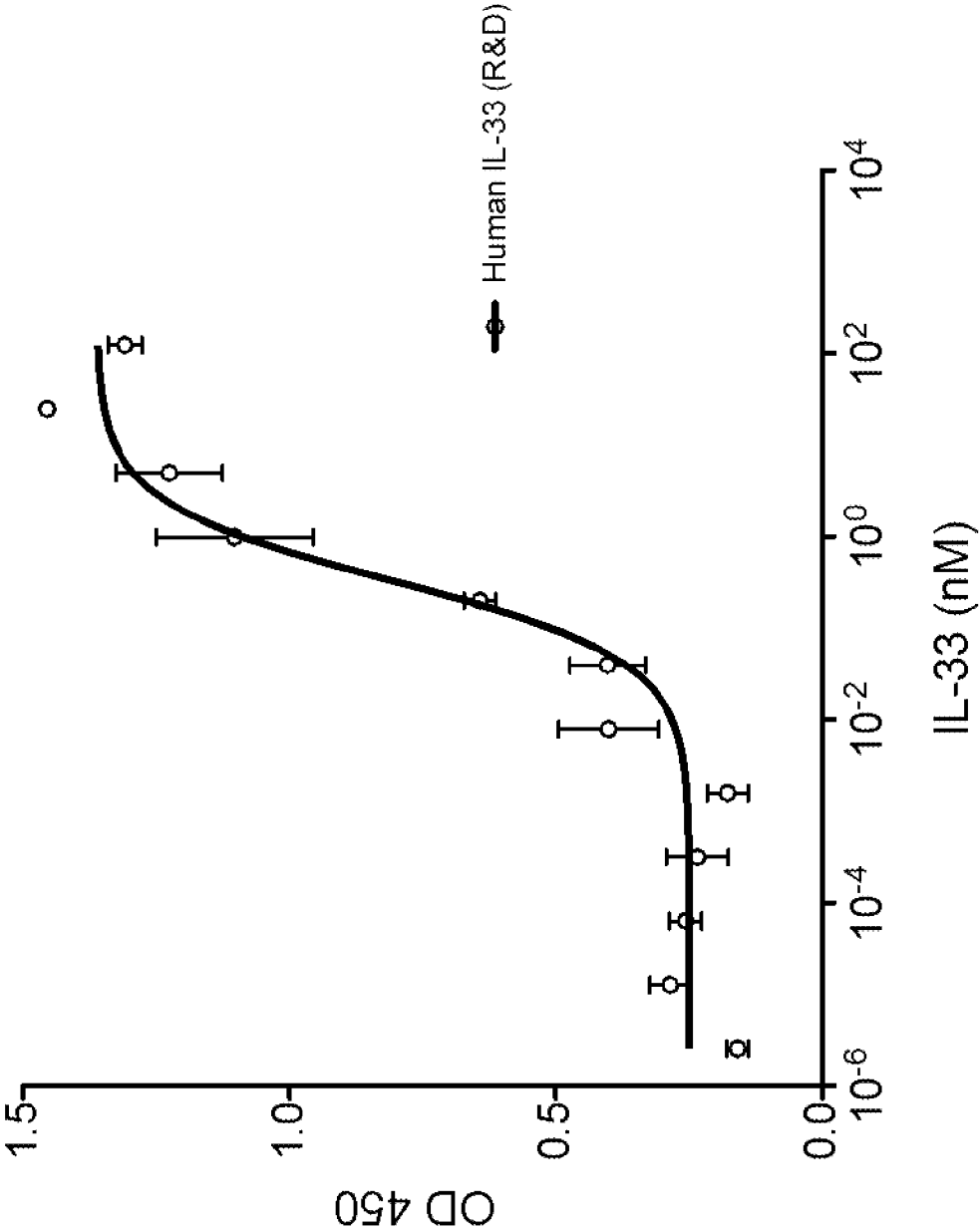


Figure 23C

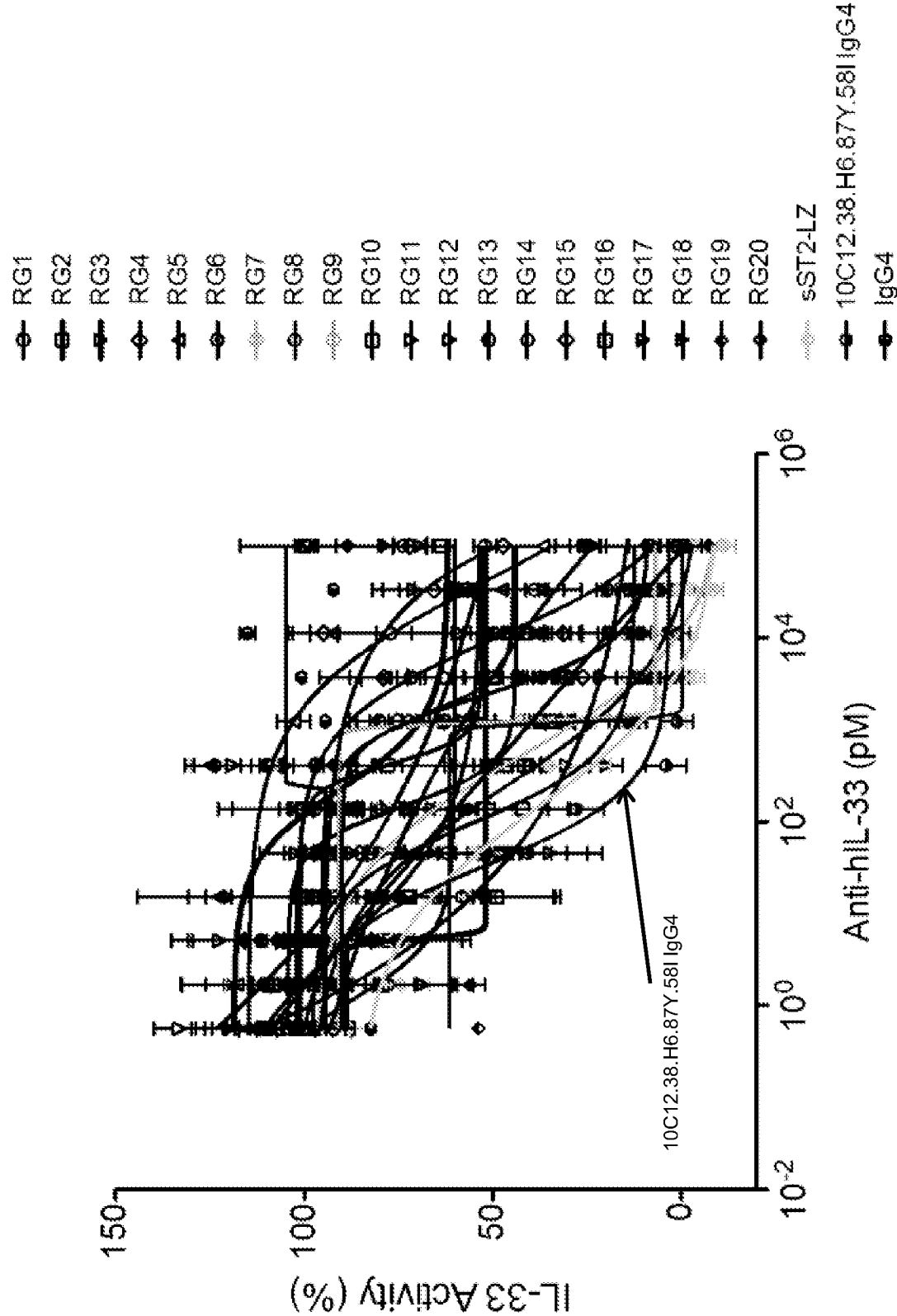


Figure 23D

NK assay

Species	Human
EC50 [M]	3.3E-10
IL-33	260pM hIL-33
Ab	IC50 [M]
10C12.38.H6.87Y.58I IgG4	3.3E-11
sST2	1.5E-10
RG1	non-blocking
RG2	non-blocking
RG3	non-blocking
RG4	non-blocking
RG5	4.1E-08
RG6	2.4E-09
RG7	5.1E-10
RG8	2.4E-10
RG9	1.2E-09
RG10	4.6E-09
RG11	non-blocking
RG12	non-blocking
RG13	1.0E-08
RG14	non-blocking
RG15	non-blocking
RG16	non-blocking
RG17	non-blocking
RG18	9.7E-11
RG19	1.2E-09
RG20	non-blocking

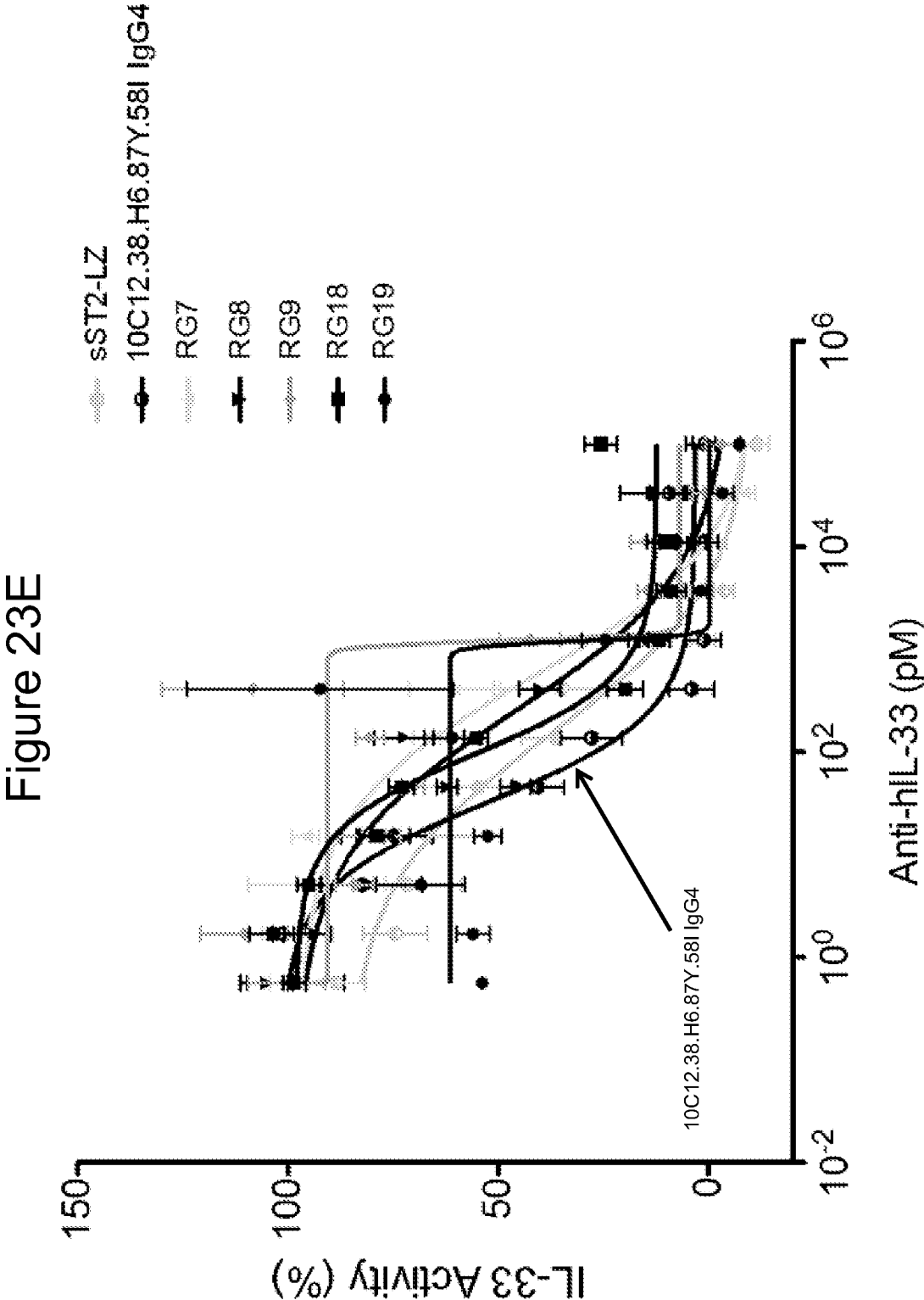


Figure 23F

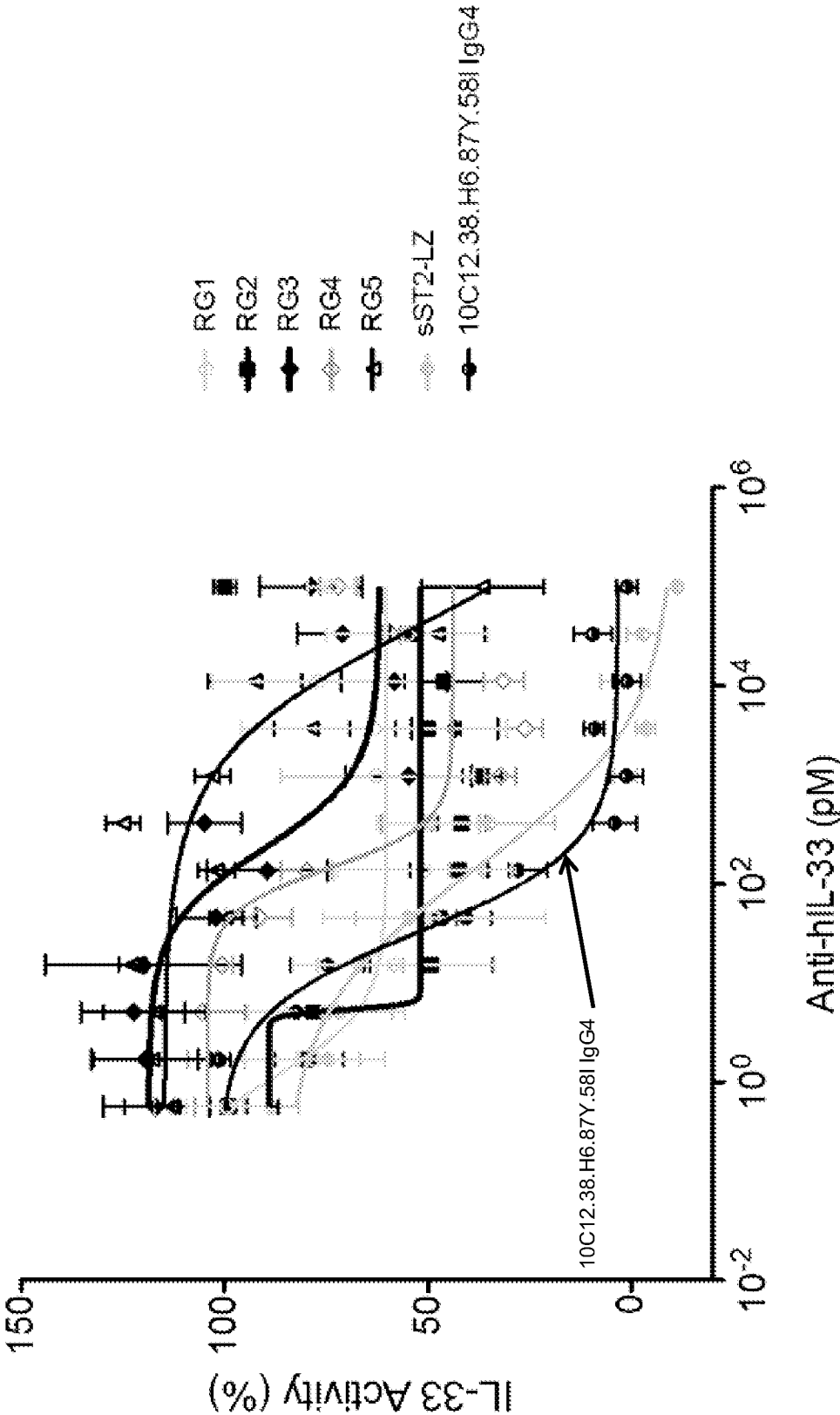


Figure 23G

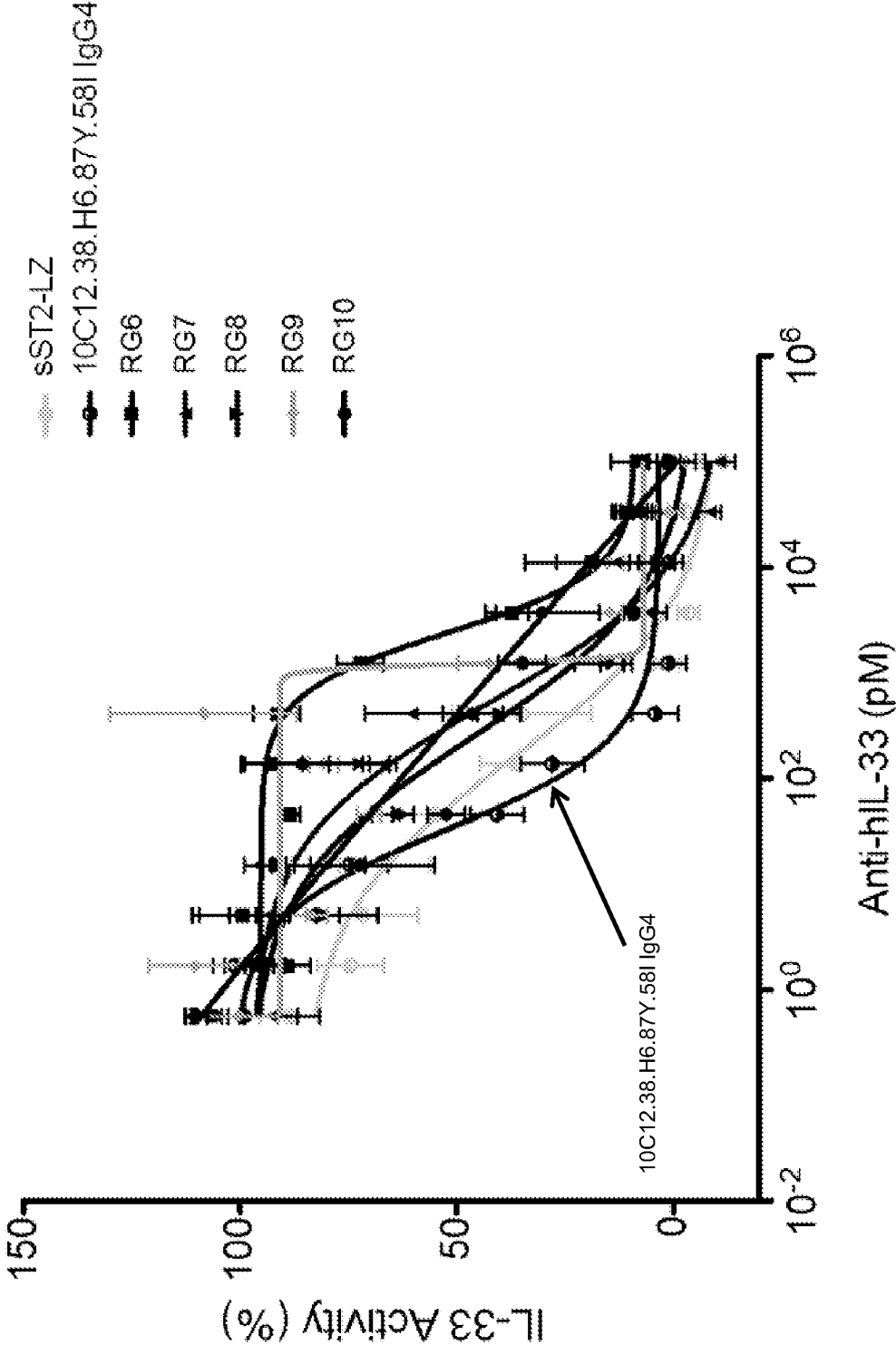


Figure 23H

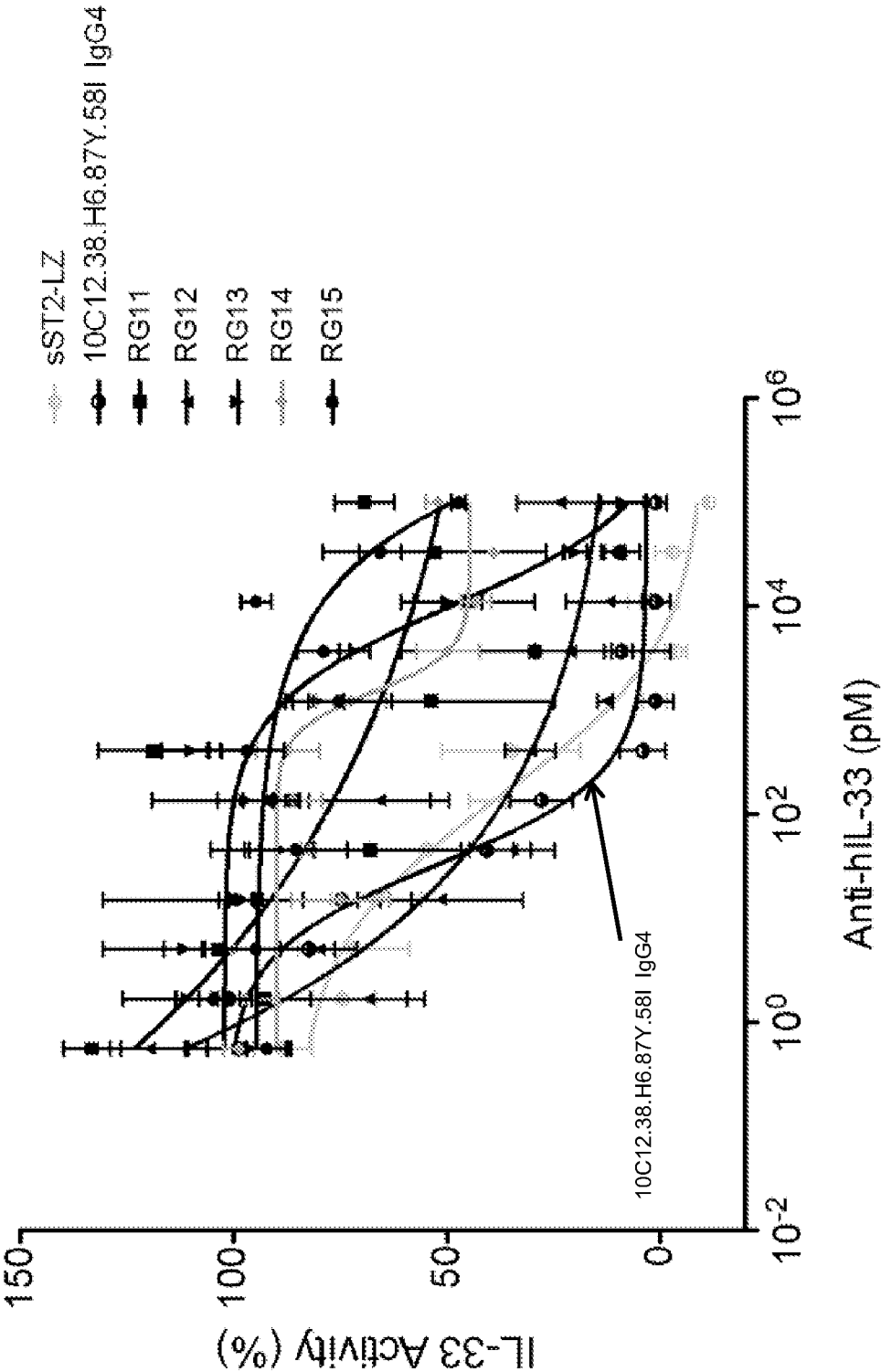


Figure 23I

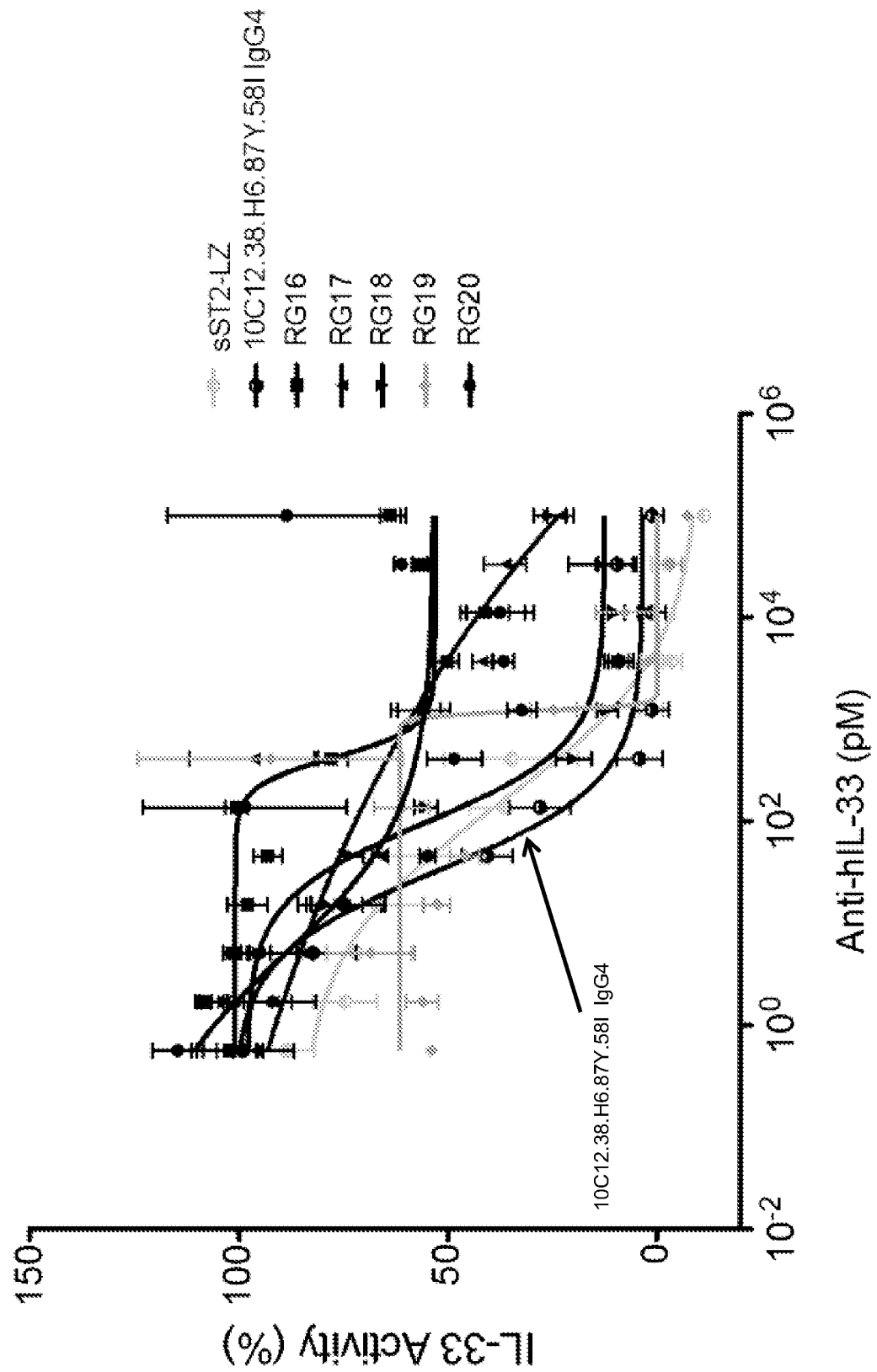


Figure 24A

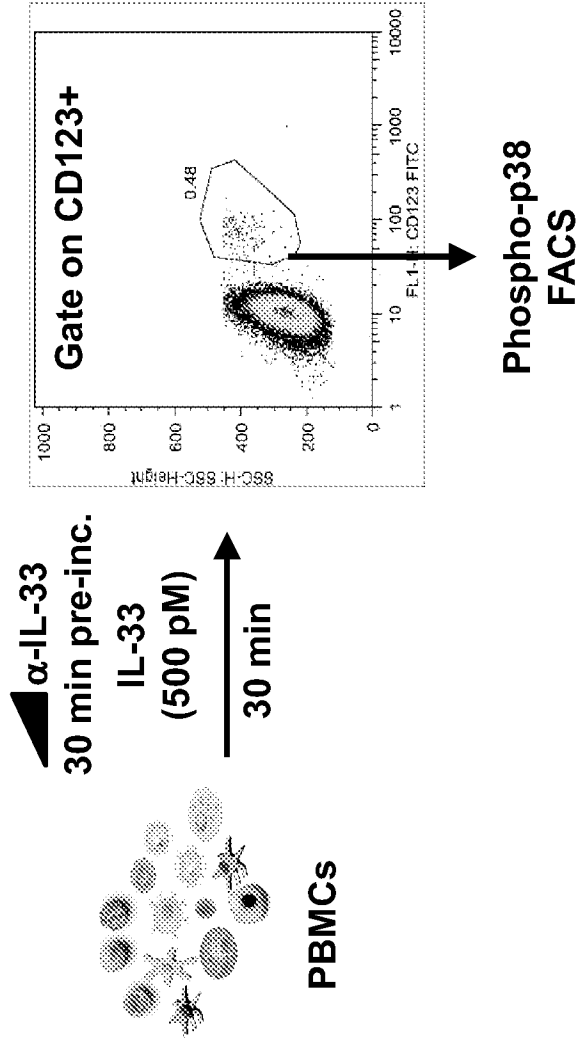


Figure 24B

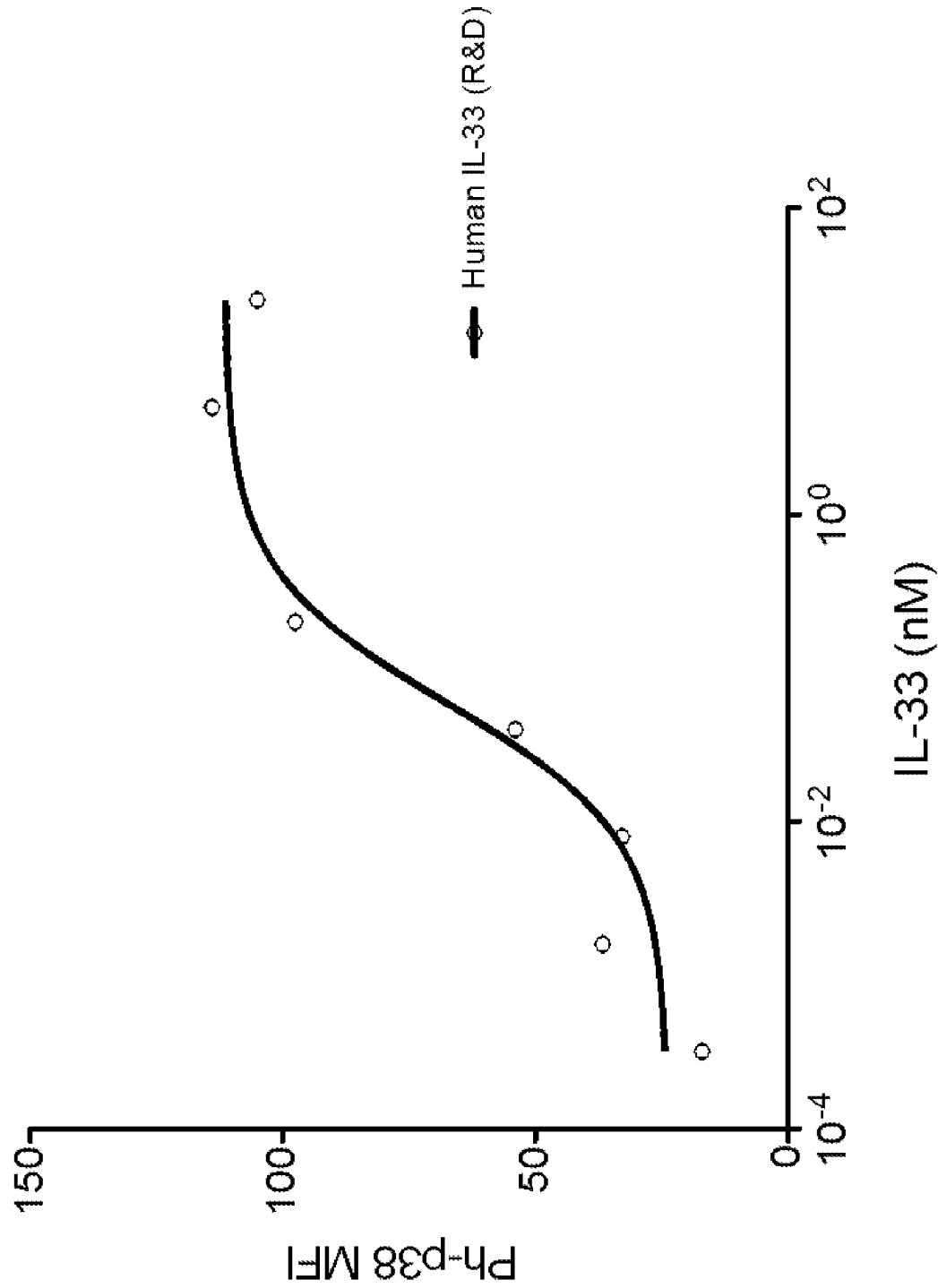
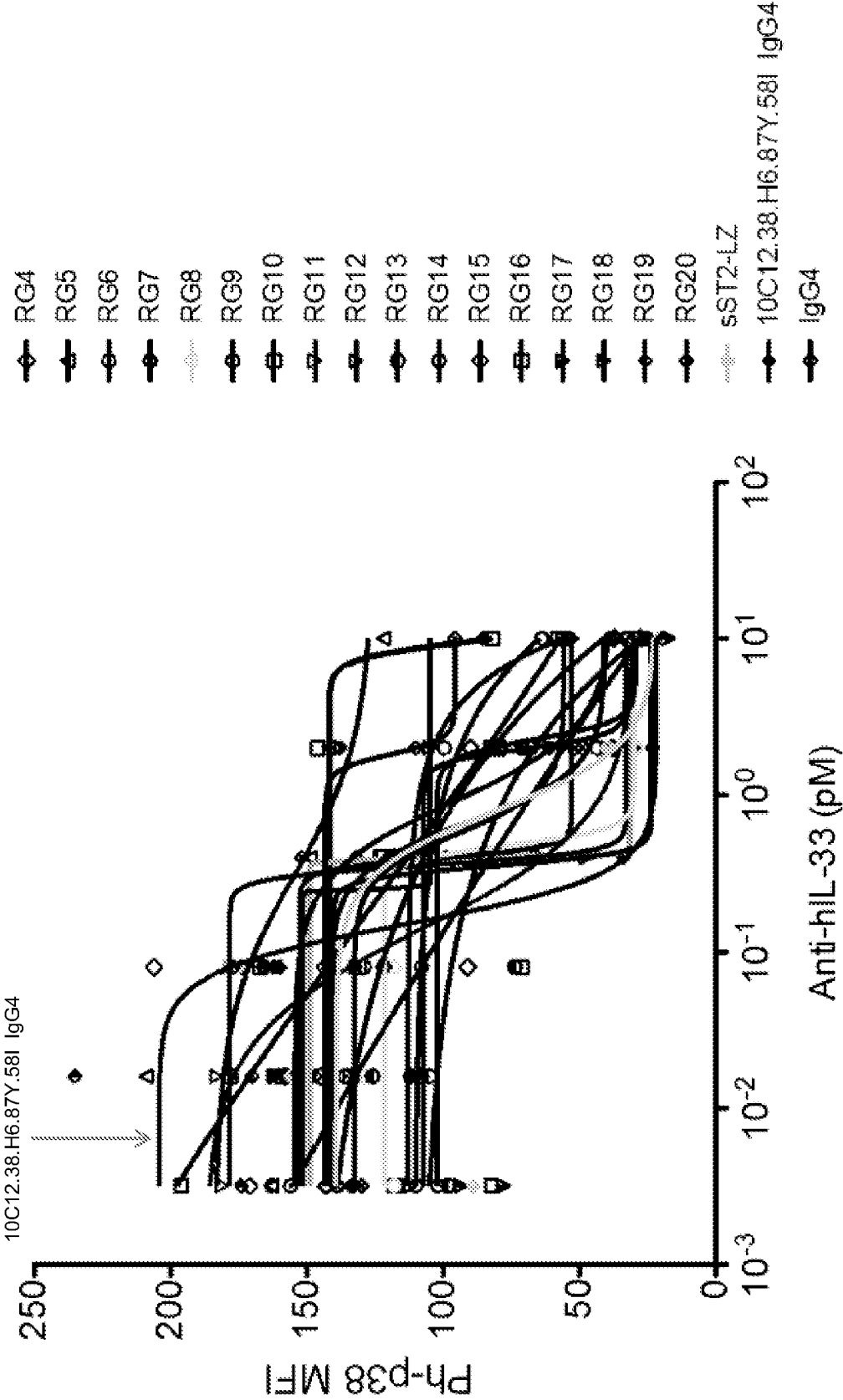


Figure 24C

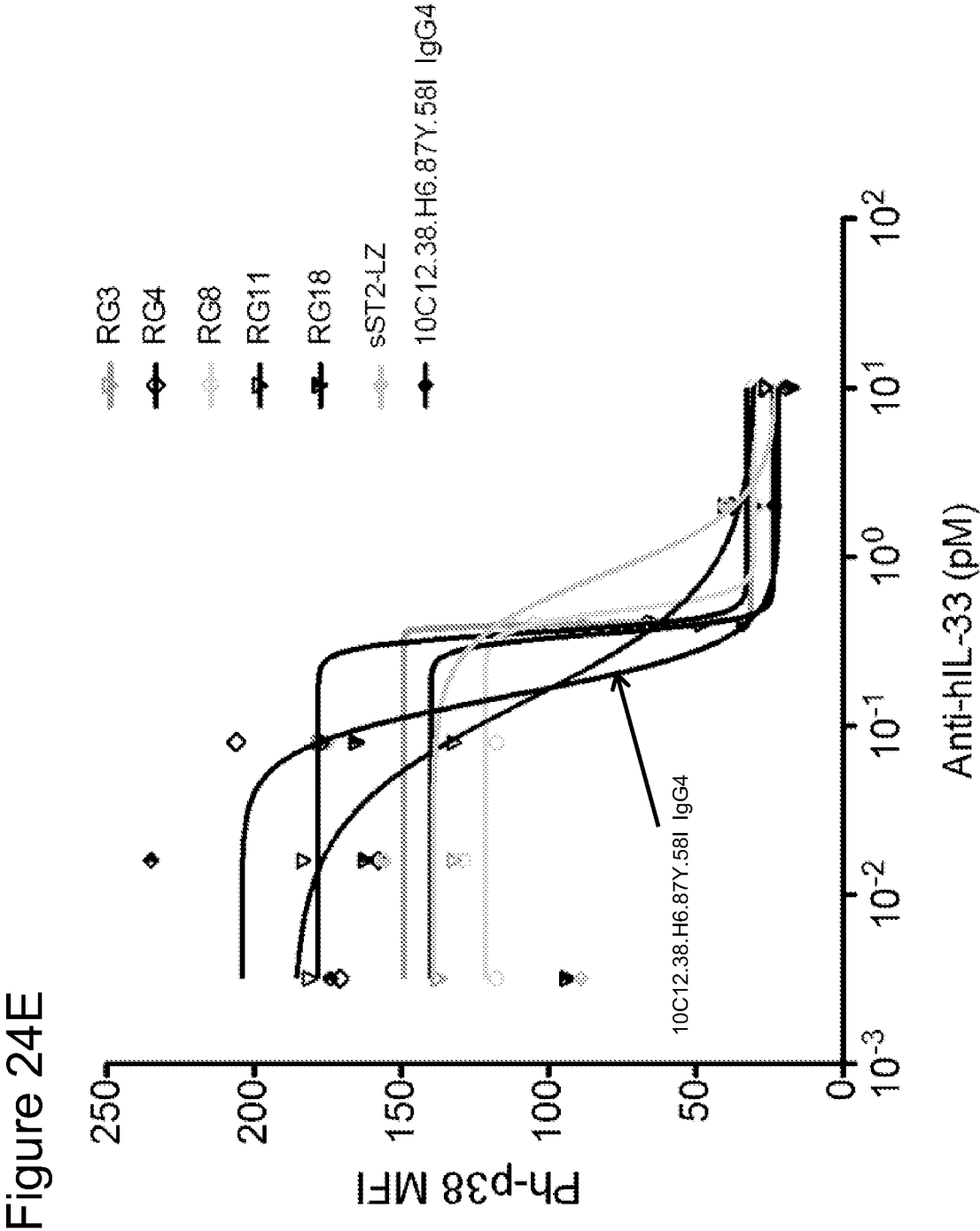


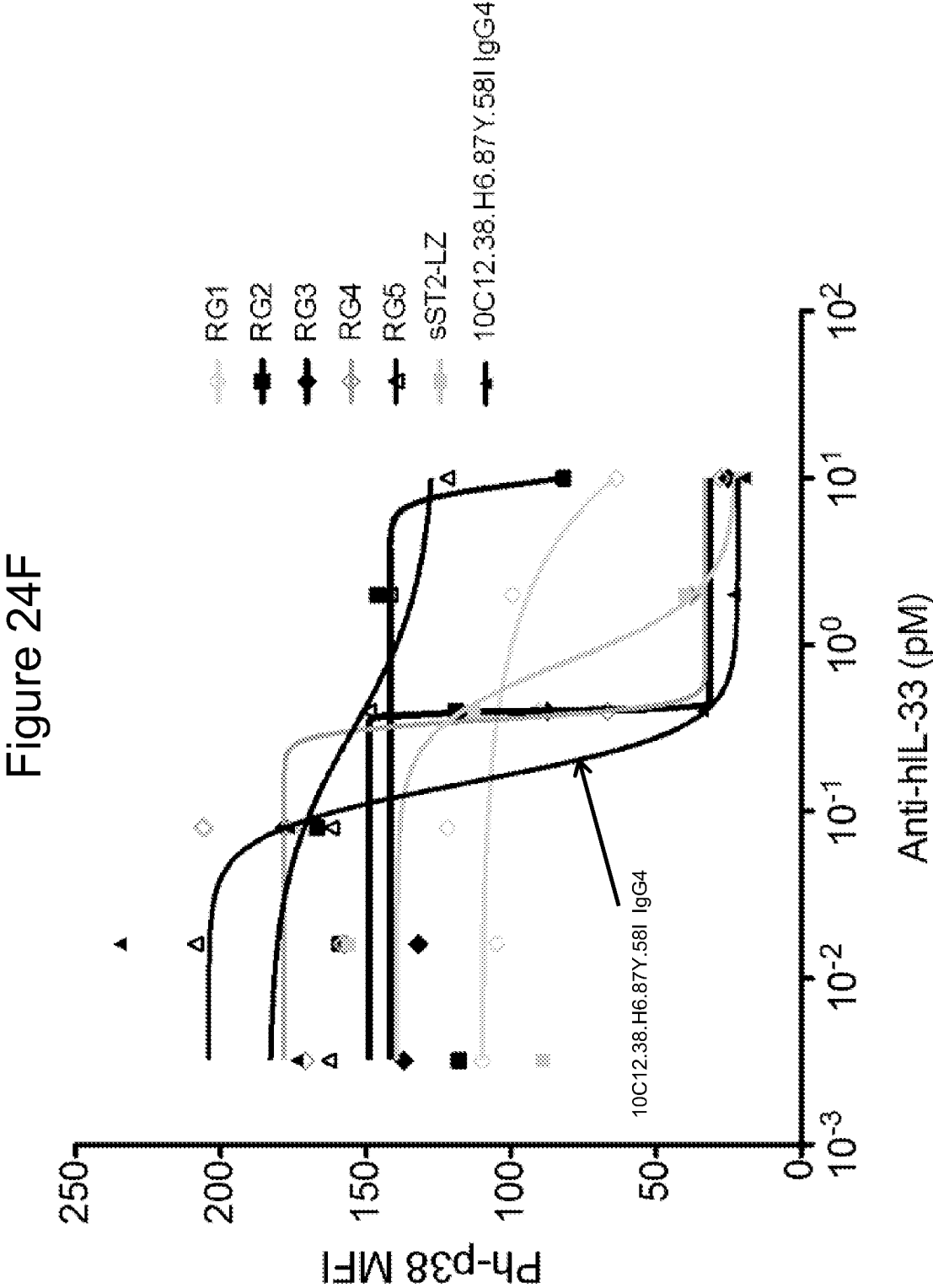
101/110

Figure 24D

Basophil assay

Species	Human
EC50 [M]	6.4E-11
IL-33	500pM hIL-33
Ab	IC50 [M]
10C12.38.H6.87Y.58I IgG4	1.5E-13
sST2	7.9E-13
RG1	non-blocking
RG2	non-blocking
RG3	4.0E-13
RG4	3.6E-13
RG5	non-blocking
RG6	3.9E-13
RG7	6.7E-13
RG8	4.8E-13
RG9	2.5E-09
RG10	partial-blocking
RG11	1.4E-13
RG12	2.4E-09
RG13	7.6E-06
RG14	2.0E-12
RG15	9.4E-03
RG16	2.3E-12
RG17	5.7E-13
RG18	3.5E-13
RG19	9.1E-13
RG20	non-blocking





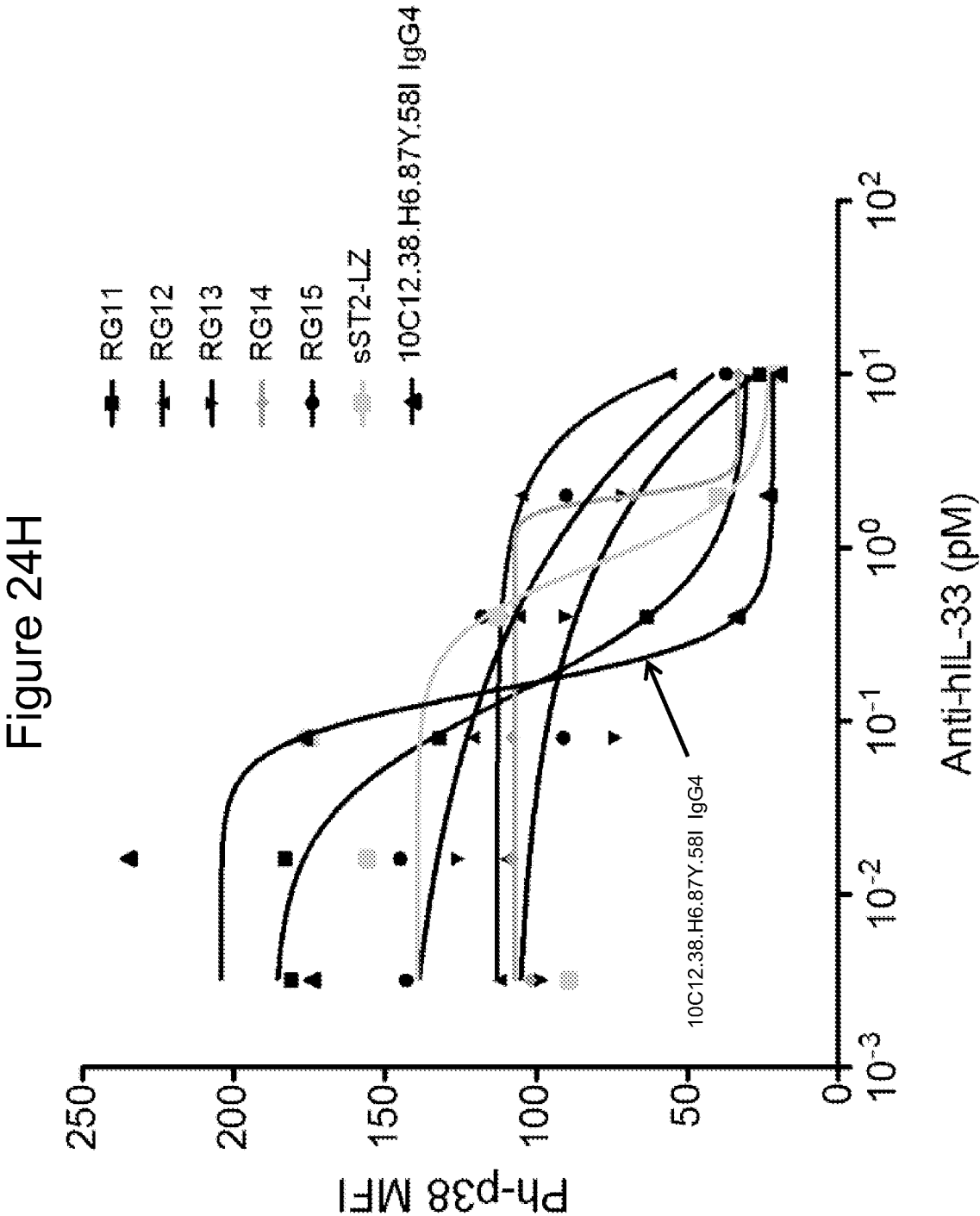
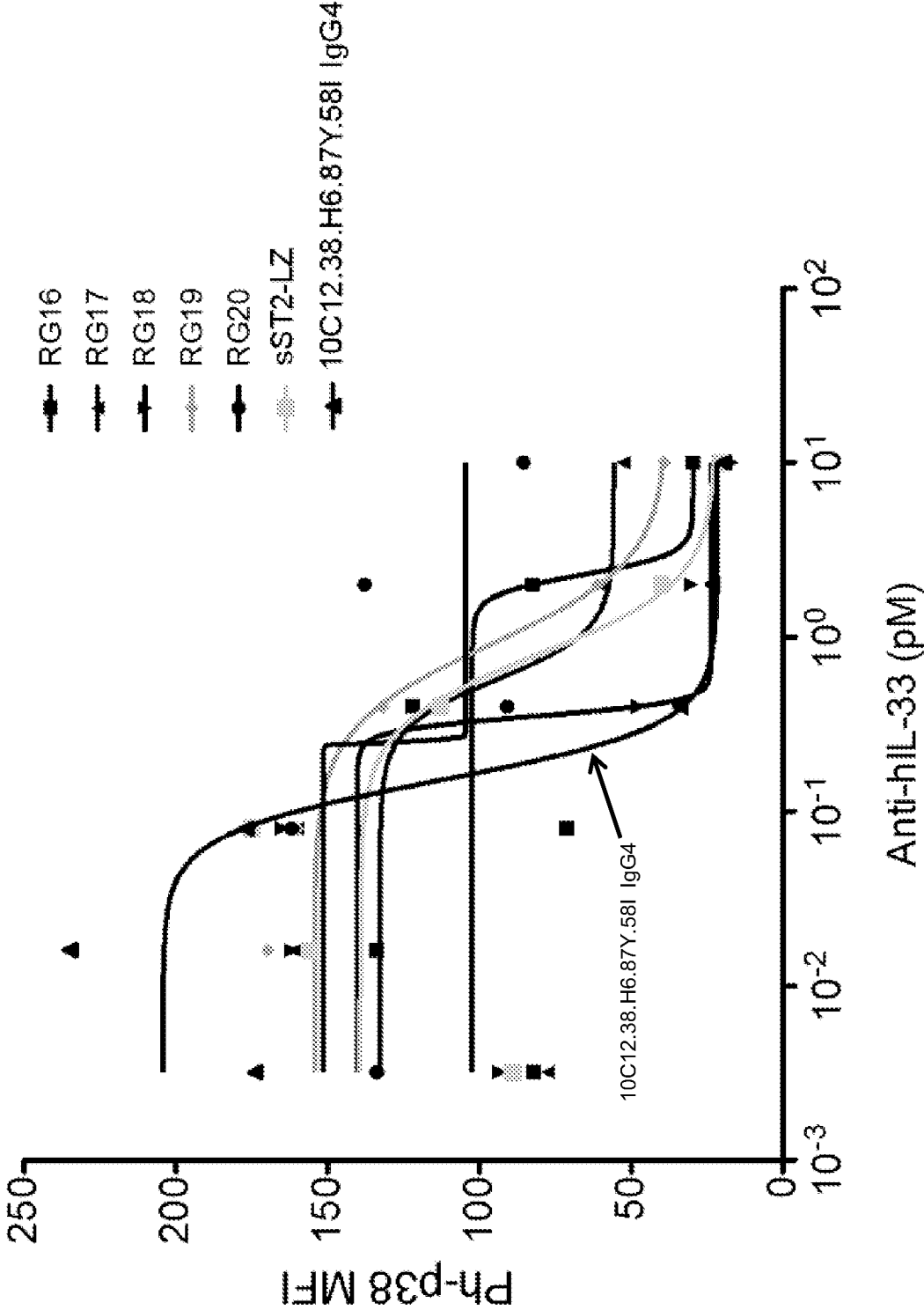


Figure 24I



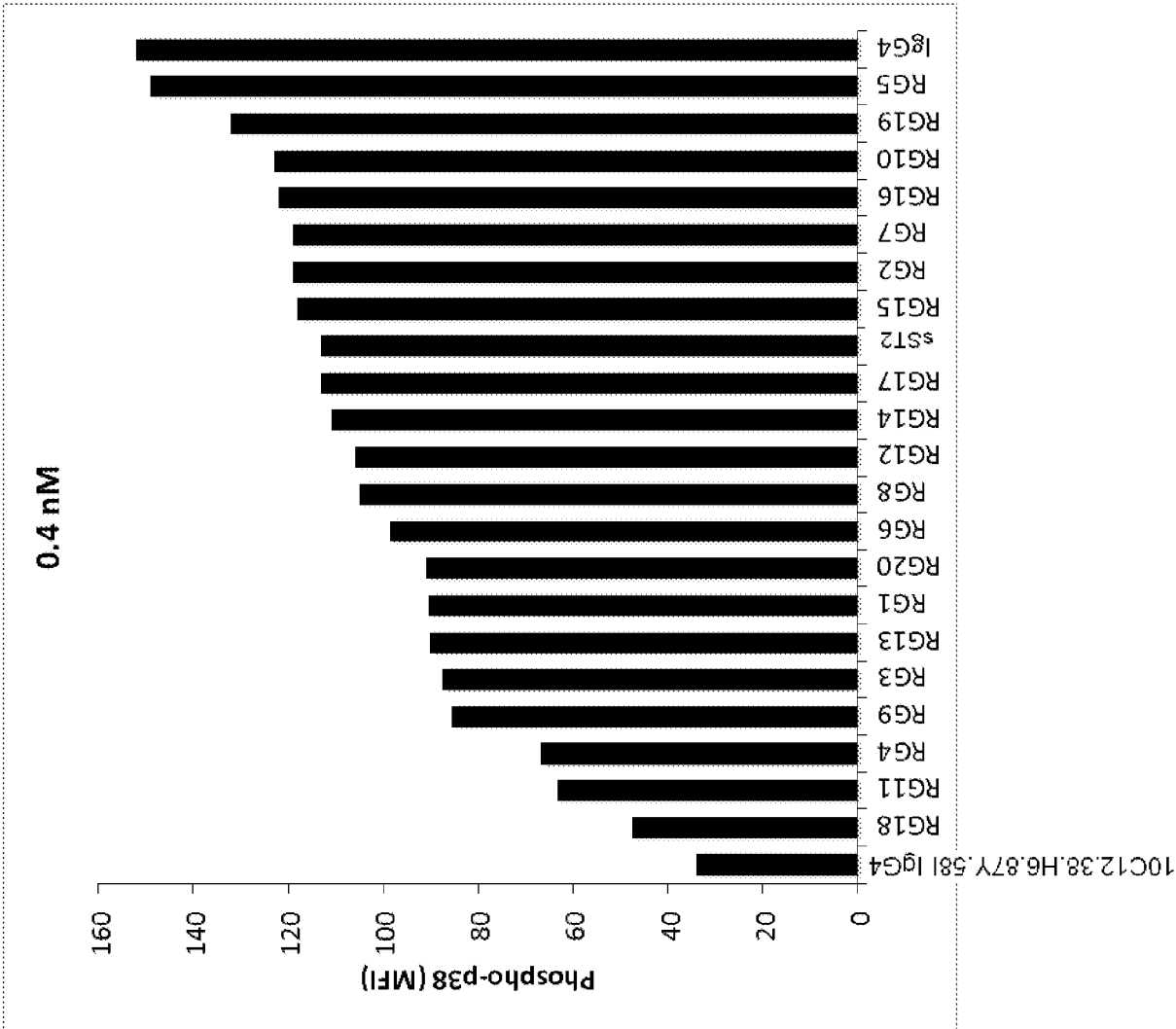
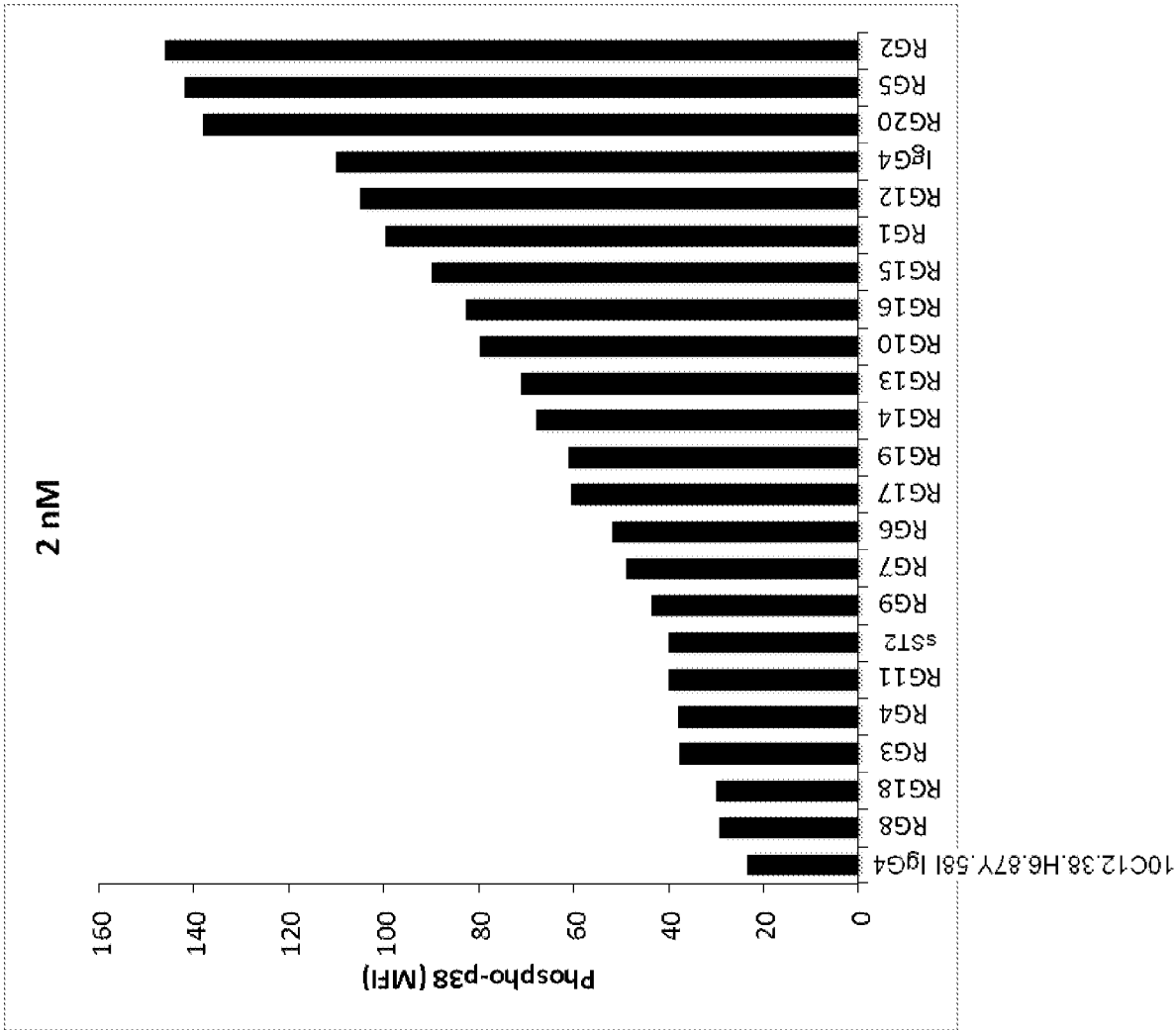


Figure 24J



2 nM Ab	Ph-p38 MFI
10C12.38.H6.87Y.581 IgG4	23
RG8	29
RG18	30
RG3	38
RG4	38
RG11	40
sST2	40
RG9	44
RG7	49
RG6	52
RG17	61
RG19	61
RG14	68
RG13	71
RG10	80
RG16	83
RG15	90
RG1	100
RG12	105
IgG4	110
RG20	138
RG5	142
RG2	146

Figure 24K

Figure 25A

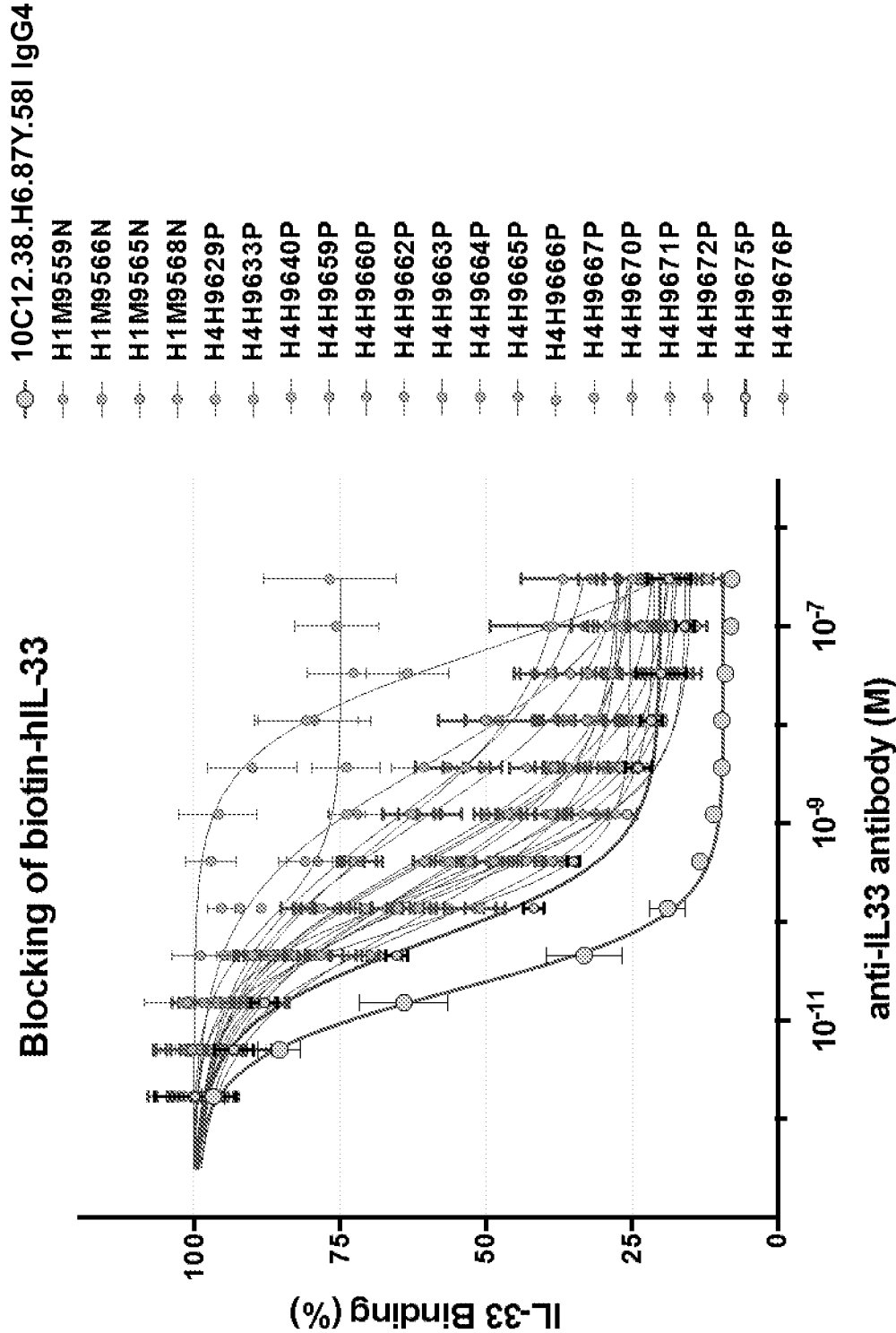
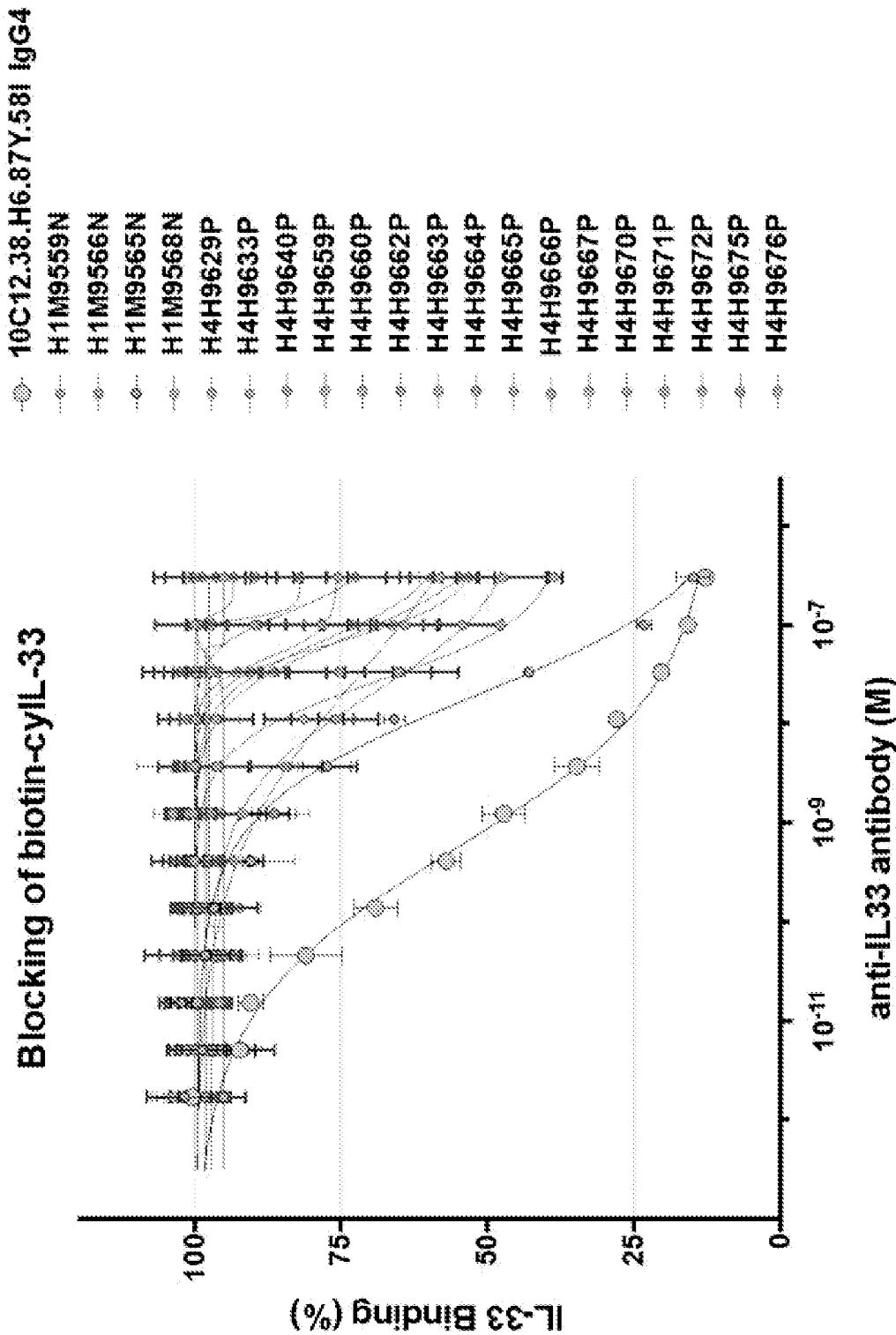


Figure 25B



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/060008

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07K16/24
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C07K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/164959 A2 (REGENERON PHARMA [US]) 9 October 2014 (2014-10-09) cited in the application paragraph [0115] - paragraph [0118]; examples 1-9 -----	23-30, 38-44, 221,223, 225, 227-348
X	WO 2005/079844 A2 (SCHERING CORP [US]; SCHMITZ JOCHEN [US]; OFT MARTIN [US]; KASTELEIN RO) 1 September 2005 (2005-09-01) paragraphs [0112] - [0115]; claims 1-7,10,11 ----- -/--	23-30, 38-44, 230-348



Further documents are listed in the continuation of Box C.



See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

17 February 2016

Date of mailing of the international search report

04/03/2016

Name and mailing address of the ISA/

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Authorized officer

Kalsner, Inge

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/060008

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>TAKESHI NABE: "Interleukin (IL)-33: New Therapeutic Target for Atopic Diseases", JOURNAL OF PHARMACOLOGICAL SCIENCES, vol. 126, no. 2, 1 January 2014 (2014-01-01), pages 85-91, XP055243800, JP</p> <p>ISSN: 1347-8613, DOI: 10.1254/jphs.14R12CP</p> <p>page 87, right-hand column, last paragraph - page 88, right-hand column, paragraph 2</p> <p>-----</p>	249-348
A	<p>LI, P., LIN, W., ZHENG, X: "IL-33 neutralization suppresses lupus disease in lupus-prone mice", INFLAMMATION, vol. 37, 3 June 2014 (2014-06-03), pages 824-832, XP002753811, abstract</p> <p>-----</p>	249-348
A	<p>KIM Y H ET AL: "Anti-IL-33 antibody has a therapeutic effect in a murine model of allergic rhinitis", ALLERGY (OXFORD), vol. 67, no. 2, February 2012 (2012-02), pages 183-190, XP002753812, abstract</p> <p>-----</p>	249-348

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/060008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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