



- (51) **International Patent Classification:**
C12N 5/0789 (2010.01)
- (21) **International Application Number:**
PCT/US2015/031959
- (22) **International Filing Date:**
21 May 2015 (21.05.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
62/002,101 22 May 2014 (22.05.2014) US
62/005,746 30 May 2014 (30.05.2014) US
- (71) **Applicants:** FRED HUTCHINSON CANCER RESEARCH CENTER [US/US]; 1100 Fairview Avenue North, Seattle, WA 98109 (US). BOARD OF REGENTS OF THE UNIVERSITY OF TEXAS SYSTEM [US/US]; 201 West 7th Street, Austin, TX 78701 (US).
- (72) **Inventors:** BERNSTEIN, Irwin, D.; 4949 Stanford Avenue NE, Seattle, WA 98105 (US). ZHANG, Chengcheng; 9835 N. MacArthur Blvd., #1704, Irving, TX 75063 (US).
- (74) **Agents:** ANTLER, Adriane, M. et al.; Jones Day, 222 East 41st Street, New York, NY 10017-6702 (US).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, 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).

[Continued on next page]

- (54)
- Title:**
- LILRB2 AND NOTCH-MEDIATED EXPANSION OF HEMATOPOIETIC PRECURSOR CELLS

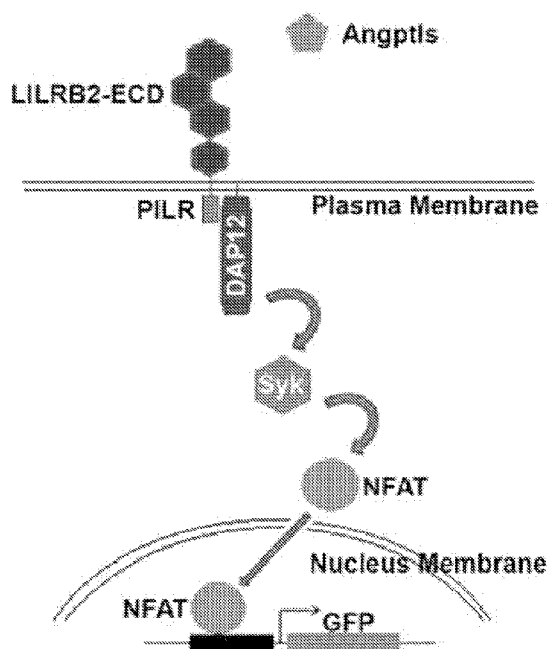


Fig. 1A

(57) **Abstract:** The current disclosure describes methods of expanding precursor cells for hematopoietic transplantation in subjects. The methods culture precursor cells in media containing an immobilized high molecular weight LILRB2 agonist or an LILRB2 agonist in combination with a Notch agonist. The expanded cells can be used to treat a variety of hematopoietic disorders.



Published:

- *with international search report (Art. 21(3))*
- *with sequence listing part of description (Rule 5.2(a))*
- *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))*

LILRB2 AND NOTCH-MEDIATED EXPANSION OF HEMATOPOIETIC PRECURSOR CELLS

[01] This application claims the benefit of U.S. provisional application No. 62/002,101, filed on May 22, 2014, and U.S. provisional application No. 62/005,746, filed on May 30, 2014, each of which is incorporated herein by reference in its entirety.

[02] This application incorporates by reference a Sequence Listing submitted with this application as a text file entitled “12674-012-228_SEQ.txt” created on May 21, 2015 and having a size of 80,894 bytes.

1. FIELD OF THE DISCLOSURE

[03] The current disclosure describes methods of expanding precursor cells for hematopoietic transplantation in subjects. The methods culture precursor cells in media containing an immobilized high molecular weight LILRB2 agonist or an LILRB2 agonist in combination with a Notch agonist. The expanded cells can be used to treat a variety of hematopoietic disorders.

2. BACKGROUND OF THE DISCLOSURE

[04] Hematopoietic stem cells (HSC) are pluripotent and ultimately gives rise to all types of terminally differentiated blood cells. HSC can self-renew or differentiate into more committed hematopoietic progenitor cells (HPC), which progenitor cells are irreversibly determined to be ancestors of only a few types of blood cell. For instance, HSC can differentiate into (i) myeloid progenitor cells, which myeloid progenitor cells ultimately give rise to monocytes and macrophages, neutrophils, basophils, eosinophils, erythrocytes, megakaryocytes/platelets, dendritic cells, or (ii) lymphoid progenitor cells, which lymphoid progenitor cells ultimately give rise to T-cells, B-cells, and lymphocyte-like cells called natural killer cells (NK-cells). Once the HSC differentiate into a myeloid progenitor cell, its progeny cannot give rise to cells of the lymphoid lineage, and, lymphoid cells cannot give rise to cells of the myeloid lineage. For a general discussion of hematopoiesis and HSC differentiation, see Chapter 17, Differentiated Cells and the Maintenance of Tissues, Alberts et al., 1989, Molecular Biology of the Cell, 2nd Ed., Garland Publishing, New York, NY; Chapter 2 of Regenerative Medicine, Department of Health and Human Services, August 5, 2006, and Chapter 5 of Hematopoietic

Stem Cells, 2009, Stem Cell Information, Department of Health and Human Services. Precursor cells can include HSC, HPC and/or mixtures of HSC and HPC.

[05] Precursor cell transplantation represents an important therapy due to these cell's capacity to restore blood and immune cells in transplant recipients. For example, transplantation of precursor cells can be used to treat subjects with inherited immuno-deficient or autoimmune diseases and diverse hematopoietic disorders. Precursor cell transplantation can also be used to treat chemotherapy and radiation-treatment patients because prolonged neutropenia and pancytopenia is common following these treatment regimens. As one example, and of particular concern, chemotherapeutic treatments for AML result in prolonged periods of profound neutropenia with infectious complications still common even in the setting of modern antimicrobial therapies with mortality rates as high as 20% in adolescent and young adults. Human bone marrow transplantation methods are also currently used as therapies for leukemia, lymphoma, and other life-threatening diseases.

[06] In transplantation, it has been observed that patients receiving greater numbers of expanded precursor cells have more rapid recovery of their neutrophils following transplantation. Accordingly, high doses of precursor cells are needed to achieve rapid and sustained engraftment that is critical for a patient's survival and recovery. These findings suggest a critical need for generating greater numbers of precursor cells that reliably enhance neutrophil recovery.

[07] Although progress toward efficient *ex vivo* expansion of precursor cells has been made, significant improvements in the efficacy and reproducibility of this technology are needed before it can be widely used. Accordingly, new approaches are needed.

3. SUMMARY OF THE DISCLOSURE

[08] Described herein are methods of expanding precursor cells *ex vivo*, comprising culturing said precursor cells with a LILRB2 agonist immobilized on a first solid phase, wherein the immobilized LILRB2 agonist is (i) an antibody to the LILRB2 receptor, or (ii) an antigen-binding fragment of said antibody; and wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells. In certain embodiments, the methods described herein comprise culturing said precursor cells with an immobilized LILRB2 agonist in combination with a Notch agonist. In specific embodiments, the precursor cells are human cells. In more specific embodiments, the precursor cells are obtained from bone marrow, umbilical cord blood,

placental blood, or Wharton's jelly. In more specific embodiments, the precursor cells are obtained from fetal or neonatal blood.

[009] In certain embodiments, the antibody to the LILRB2 receptor is a monoclonal antibody. In certain embodiments, the antibody to the LILRB2 receptor is a polyclonal antibody. In certain embodiments, the LILRB2 agonist is an Fv, Fab, Fab', F(ab')₂, Fc, or single chain Fv fragment (scFv). In certain embodiments, the antibody to LILRB2 is a human, humanized, synthetic, or chimeric antibody. In specific embodiments, the LILRB2 agonist binds to the Ig1 domain of LILRB2. In specific embodiments, the LILRB2 agonist binds to the Ig4 domain of LILRB2. In specific embodiments, the LILRB2 agonist binds to the Ig1 and Ig4 domains of LILRB2.

[010] In certain embodiments, the first solid phase is the surface of a tissue culture dish. In certain embodiments, the Notch agonist is immobilized on the first solid phase. In certain embodiments, the Notch agonist is immobilized on a second solid phase that is not the first solid phase. In certain embodiments, the Notch agonist is immobilized on the first solid phase, and the first solid phase is the surface of a tissue culture dish. In certain embodiments, the Notch agonist is immobilized on a second solid phase that is not the first solid phase, wherein the first solid phase is the surface of a tissue culture dish or flask, and the second solid phase is a bead. In certain embodiments, the Notch agonist is immobilized on a second solid phase that is not the first solid phase, wherein the first solid phase is a bead, and the second solid phase is the surface of a tissue culture dish or flask.

[011] In certain embodiments, the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein. In specific embodiments, the Notch agonist is human Delta-1. In specific embodiments, the Notch agonist is Delta^{ext-IgG}. In more specific embodiments, the Notch agonist is in dimeric form. In specific embodiments, the Notch agonist is an antibody that specifically binds to a Notch motif. In more specific embodiments, the Notch agonist is an antibody that specifically binds to Notch-1. In specific embodiments, the Notch agonist is an antibody that specifically binds to Notch-2.

[012] In certain embodiments, the culturing step is performed in the presence of a culture medium comprising stem cell factor (SCF), thrombopoietin (TPO), and Flt3-ligand. In specific embodiments, the culturing step is performed in the presence of a culture medium comprising 10-100 ng/mL SCF, 5-100 ng/mL TPO and 10/100 ng/mL Flt3-ligand. In certain embodiments, the culture medium comprises 50 ng/mL SCF. In certain embodiments, the culture medium

comprises 10 ng/mL TPO. In certain embodiments, the culture medium comprises 50 ng/mL Flt3-ligand. In certain embodiments, the culture medium comprises 50 ng/mL SCF, 10 ng/mL TPO and 50 ng/mL Flt3-ligand.

[013] In certain embodiments, the culturing step is performed in the presence of a culture medium comprising SCF, Flt3-ligand, interleukin-6 (IL-6), TPO, fibroblast growth factor-1 (FGF1), and interleukin-3 (IL-3). In specific embodiments, the culture medium comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3, and heparin. In certain embodiments, the culture medium comprises 1-100 ng/mL SCF, 1-100 ng/mL Flt3-ligand, 1-100 ng/mL IL-6, 1-100 ng/mL TPO, 1-100 ng/mL FGF1, and 1-100 ng/mL IL-3. In specific embodiments, the culture medium further comprises 1-100 µg/mL heparin. In certain embodiments, the culture medium comprises 50 ng/mL SCF, 50 ng/mL Flt3-ligand, 50 ng/mL IL-6, 50 ng/mL TPO, 20 ng/mL FGF1, and 10 ng/mL IL-3. In specific embodiments, the culture medium further comprises 10 µg/mL heparin.

[014] In certain embodiments, the culturing step is performed in the presence of a culture medium comprising retronectin. In specific embodiments, the culture medium comprises 1-100 µg/mL retronectin. In more specific embodiments, the culture medium comprises 5 µg/mL retronectin.

[015] The current disclosure provides improved methods to generate precursor cells through ex vivo expansion. The methods generate more precursor cells more quickly than previously-available methods and the generated precursor cells show enhanced early marrow repopulation in immuno-deficient subjects and improved long term repopulation following transplant. The methods disclosed herein are based on culturing precursor cells with an immobilized LILRB2 agonist or an LILRB2 agonist in combination with a Notch agonist.

4. BRIEF DESCRIPTION OF THE FIGURES

[016] **Figures 1A-H.** High molecular weight Angptl2 activates LILRB2 signaling. (A) Schematic of the chimeric LILRB2 receptor reporter system. (B) Representative flow cytometric profiles and summary showing that the Angptl2 conditioned medium stimulates GFP induction in the LILRB2 chimeric reporter system. The condition media of empty vector-transfected HEK-293T cells was used as control. (C) Left, secreted Angptl2 and HLA-G-ECD in condition medium detected by anti-FLAG antibody in Western blotting. Right, representative flow cytometric plots showing that Angptl2 binds to LILRB2 expressed on HEK-293T cells better

than the same amount of HLA-G-ECD. (D) The full-length (FL), coil-coil domain (CC), and fibrinogen domain (FBN) obtained from conditioned medium showed distinctive migration in reducing and non-reducing SDS-PAGE as determined by immunoblotting with anti-M2 Flag antibody. Protein extracted from equivalent amounts of condition media of empty vector-transfected HEK293T cells was used as control. (E) GST-human Angptl2 purified from bacterial expression system by Glutathione Sepharose was immediately fractionated through gel filtration FPLC. The molecular weight was determined by the peaks of Apoferritin (443 KD), Amylase (200 KD), Alcohol dehydrogenase (150 KD), Albumin (66 KD), Carbonic anhydrase (29 KD), and Cytochrome c (12.4 KD), respectively. (F) Equivalent amounts of indicated fractionated samples in FPLC were loaded on 10% native gel. Aggregated, monomeric, and cleaved GST-Angptl2 were visualized by silver staining. (G) Indicated FPLC fractionated samples were examined by Western blotting using antiM2 Flag antibody. The FLAG in cleaved GST-Angptl2 fragments (fraction 8; Fig. 1G) could not be detected by Western blotting. (H) Chimeric LILRB2 receptor reporter cells were treated with coated or soluble fraction 5 proteins for 48 hrs. In coated wells, 5 µg/ml GST-Angptl2 from fraction-5 was pre-coated onto wells of a 96-well plate for 3 hrs at 37°C. Equivalent amount of FPLC buffer was used as control. n.s. indicates not significant; ****, $p < 0.0001$.

[017] Figures 2A-B. Schematic of Angptl2, Angptl5, and HLA-G extracellular domain (ECD) expression constructs. (A) Constructs for secretable Angptl2, Angptl5, and HLA-G-ECD. Angptls without signal peptide (SP) or HLA-G ECD was fused to an optimized signal peptide (MWWRLWWLLLLLLLLLWPMVWA (SEQ ID NO: 1)) at the N terminus and a FLAG tag at the C terminus. (B) FACS plots showing the binding of Angptl5 to LILRB2 expressing 293T cells.

[018] Figure 3. Activation of the LILRB2 chimeric receptor reporter by Angptl2 is better than that by immobilized HLA-G. Chimeric LILRB2 receptor reporter cells were treated with coated 5 µg/ml GST-Angptl2 or 130 µg/ml human HLA-G for 24 hrs. Null receptor cells, which do not contain chimeric receptor, and PBS were used as controls.

[019] Figure 4. Expression of mAngptl2 in mouse tissues and organs. Whole cell lysates were extracted from mouse spleen, fat, muscle, heart, brain and kidney. Plasma and serum were extracted from peripheral blood via centrifugation with or without anti-clotting reagent, respectively. Fifty µg of each sample was loaded for western blot using rat anti-mouse Angptl2

antibody. The samples loaded were visualized by Coomassie Brilliant Blue staining (CBB). R, reduced; N, non-reduced; M, molecular weight marker. Arrows indicate the multimerized mouse Angptl2.

[020] Figures 5A-D. Immobilized anti-LILRB2 antibodies activated the chimeric LILRB2 reporter. (A) Representative flow cytometric profiles showing that the GFP induction by immobilized 5 $\mu\text{g/ml}$ Angptl2 was abolished by 5 $\mu\text{g/ml}$ anti-LILRB2 antibody. Chimeric LILRB2 receptor reporter cells were treated with indicated coated Angptl2 with or without soluble anti-LILRB2 pAb or mAb for 48 hrs. PBS was used as control. (B) Representative flow cytometric profiles showing that GFP was induced by immobilized anti-LILRB2 antibodies. Chimeric LILRB2 receptor reporter cells were treated with indicated coated (25 $\mu\text{g/ml}$ in 50 μl PBS) or soluble (5 $\mu\text{g/ml}$ in 250 μl cell culture media) antibodies for 48 hrs. The reporter cells not containing chimeric LILRB2 receptor were used as negative control. (C) Representative flow cytometric profiles showing that GFP expression was induced by cross-linked anti-LILRB2 antibodies. Chimeric LILRB2 receptor reporter cells were treated with 10 $\mu\text{g/ml}$ soluble anti-LILRB2 polyclone antibody (pAb) or equivalent crosslinked pAb for 48 hrs. Streptavidin alone was used as a negative control. (D) Representative confocal images of LILRB2 chimeric receptor reporter cells with or without coated anti-LILRB2 mAb showing that the distribution of LILRB2 protein on cell plasma membrane. Ten confocal scans from top to bottom of a cell were indicated from Layer-1 (L1) to Layer-10 (L10). Confocal images of the phase contrast, Cy3 (indicating LILRB2 expression), and GFP (indicating signaling activation) panels were merged.

[021] Figures 6A-I. Ig domains 1 and 4 in LILRB2 are critical for Angptl2 binding and signal activation. (A) Representative flow cytometry plots showing Angptl2 binding to full-length, individual Ig domain, Ig1+2, or Ig3+4 of LILRB2 that were expressed on 293T cells. $n = 3$. (B) Summary of data from panel A (C) Summary of Angptl2 binding abilities of WT and mutant LILRB2. Indicated mutations are described in Fig. 4B. (C) Schematic of the H*G*Y*C motifs in Ig1 and Ig4 of LILRB2. (D) Summary of Angptl2 binding abilities of WT and mutant Ig1+2 LILRB2. (E) Representative flow cytometry plots showing Angptl2 binding to Ig1+2 and mutant LILRB2. (F) Representative flow cytometry plots showing Angptl2 binding to WT and mutant LILRB2. (G) Comparison of Angptl2, Angptl5, and HLA-G binding abilities of WT and mutant LILRB2. MHC-S indicates HLA-G binding sites; MHC-S1, R59A/Y61A; MHC-S2, W90A/D200A/N202A/Y205A; MHC-S1+2, R59A/Y61A/W90A/D200A/N202A/Y205A. (H)

Summary of Angptl2-induced activation of the chimeric receptor reporter system by individual Ig domains, Ig1+2, or Ig3+4 of LILRB2. Indicated reporter cells were treated with 5 µg/ml coated GST-Angptl2 or polyclonal or monoclonal anti-LILRB2 antibodies. At least three independent experiments gave the similar results. (I) Summary of Angptl2-induced activation of the chimeric receptor reporter system by WT or mutant LILRB2. Reporter cells were treated with 10 µg/ml coated GST-Angptl2 or polyclonal or monoclonal anti-LILRB2 antibodies. At least three independent experiments were performed that gave similar results.

[022] Figure 7. Interaction of LILRB2 Ig domains with anti-LILRB2 antibodies. Mouse T hybridoma cells were infected with full-length LILRB4 ECD (1~4), individual Ig domains (1st, 2nd, 3rd and 4th Ig domain) and two-Ig domain combinations (1+2 and 3+4). The empty vector was used as negative control. These cells were stained by monoclonal (mAB) or polyclonal (pAB) anti-LILRB2 antibody for flow cytometry analysis.

[023] Figures 8A-C. Mutated residues of LILRB2 in the possible ligand binding interface based on the known structure of LILRB2 (SEQ ID NO. 2). Based on the PDB structure of Ig1-Ig2 domain (PDBID: 2GW5 and 2DYP) (surrounded by solid box in Fig. 8A) and Ig3-Ig4 domain (PDBID: 4LLA) (surrounded by dashed box in Fig. 8A) of human LILRB2, twenty-four large and hydrophobic residues in the possible ligand binding interface on each Ig domain were identified for mutagenesis study (underlined in Fig. 8A) and generated a series of mutant LILRB2 were generated (B). (C) Summary of Angptl2 binding abilities of WT and mutant LILRB2.

[024] Figure 9. The FL but not FBN domain of Angptl2 binds to the human cord blood (CB) LILRB2⁺ cells as determined by flow cytometry analysis. Human CB mononuclear cells were incubated with indicated FLAG-tagged full-length, CC domain, or FBN domain of Angptl2 followed by staining with anti-FLAGAPC and anti-human LILRB2-PE in a flow cytometry analysis.

[025] Figure 10. The activation of the LILRB2 chimeric receptor reporter by soluble or immobilized full-length, CC domain, or FBN domain of Angptl2. Chimeric LILRB2 receptor reporter cells were treated with indicated soluble or coated full-length, CC domain, or FBN domain of Angptl2 for 48 hrs. PBS was used as control. *, p<0.05; n.s., not significant.

[026] Figures 11A-E. Immobilized anti-LILRB2 antibodies promote the proliferation of human CB cells in vitro. (A) Human CD133⁺ umbilical CB cells were cultured in STF medium with or

without same amounts of coated (25 $\mu\text{g/ml}$ in 50 μl PBS) or soluble (5 $\mu\text{g/ml}$ in 250 μl StemSpan media) anti-LILRB2 pAb. Total cell expansion was assessed after 10 days of culture ($n = 3$). (B) Human CD133+ umbilical CB cells were cultured in STF medium with or without same amounts of coated (25 $\mu\text{g/ml}$ in 50 μl PBS) or soluble (5 $\mu\text{g/ml}$ in 250 μl StemSpan media) anti-LILRB2 mAb. Total cell expansion was assessed after 10 days of culture ($n = 3$). (C) Representative flow cytometric profiles showing the frequency of CD34+CD90+ cells after 10 days of culture. (D-E) Expansion of 250 input equivalent human CB CD133+ cells treated with or without anti-LILRB2 pAb (D) or mAb (E) were serially plated in CFU medium. Total CFUs were counted after 7 days in culture. n.s., not significant; *, $p < 0.05$; ***, $p < 0.001$.

[027] Figures 12A-L. Ex vivo expansion of human CB CD133+ cells by anti-LILRB2 polyclonal antibody as determined by NSG transplantation. (A) After 10 days of culture in STF medium with or without same amounts of coated (25 $\mu\text{g/ml}$ in 50 μl PBS) or soluble (5 $\mu\text{g/ml}$ in 250 μl StemSpan media) anti-LILRB2 pAb, expansion of 1×10^4 input equivalent human CB CD133+ cells were transplanted into NSG mice ($n=8$). Engraftment of human cells (human CD45+) in peripheral blood at indicated weeks are shown. n.s., not significant; ***, $p < 0.001$. (B) Engraftment of human CD45/CD71+ in bone marrow of mice described in panel A at 36 weeks. n.s., not significant; *, $p < 0.05$; $n=8$. (C) Multilineage contribution of cultured human umbilical CB CD133+ cells. Shown are representative flow cytometric profiles of bone marrow cells from one primary transplanted mouse of each group. Myeloid, CD45/CD71+CD15/CD66b+; lymphoid, CD19/CD20+; hematopoietic stem/progenitor cells, CD19/CD20-CD34+. (D-F) Summary of multilineage contributions from data shown in panel C. n.s., not significant; *, $p < 0.05$; **, $p < 0.01$; $n=8$. (G) Engraftment of human CD45+ cells in peripheral blood of secondarily transplanted mice at 3 and 7 weeks post-transplant are shown. n.s., not significant; **, $p < 0.01$; $n=3$. (H) Engraftments of human cells in bone marrow of secondarily transplanted mice at 8 weeks post-transplant are shown. n.s., not significant; *, $p < 0.05$; $n=3$. (I) Representative flow cytometric profiles showing multilineage contribution of human umbilical CB CD133+ cells in the bone marrow of secondarily transplanted mice at 8 weeks post-transplant. (J-L) Summary of multilineage contributions from data shown in panel I. n.s., not significant; *, $p < 0.05$; $n=3$.

[028] Figures 13A-D. Ex vivo expansion of human CB CD34+ cells by anti-LILRB2 polyclonal antibody as determined by NSG transplantation. (A) After 10 days culture in STF

medium with or without coated or soluble anti-LILRB2 polyclonal antibody, 1×10^4 input equivalent human CB CD34⁺ cells were transplanted into NSG mice. Engraftments of human CD45/CD71⁺ cells in bone marrow at 8 weeks are shown. n.s., not significant; *, $p < 0.05$; $n = 8$. (B-D) Multilineage contribution of cultured human umbilical CB CD34⁺ cells. n.s., not significant; *, $p < 0.05$; **, $p < 0.01$; $n = 8$.

[029] Figures 14A-L. Ex vivo expansion of human CB CD133⁺ cells by anti-LILRB2 monoclonal antibody in NSG mice as determined by NSG transplantation. (A) After 10 days culture in STF medium with or without same amounts of coated (25 $\mu\text{g/ml}$ in 250 μl PBS) or soluble (5 $\mu\text{g/ml}$ in 250 μl StemSpan media) anti-LILRB2 mAb, 1×10^4 input equivalent human CB CD133⁺ cells were transplanted into NSG mice. Engraftment of human CD45⁺ in peripheral blood at 3 and 7 weeks are shown. n.s., not significant; *, $p < 0.05$; $n = 4$. (B) Engraftments of human CD45/CD71⁺ in bone marrow of mice described in panel A at 8 weeks. n.s., not significant; $n = 4$. (C) Multilineage contribution of cultured human umbilical CB CD133⁺ cells. Shown are representative flow cytometric profiles of bone marrow cells from one primary transplanted mouse of each group. (D-F) Summary of multilineage contributions based on data shown in panel C. n.s., not significant; $n = 4$. (G) Engraftment of human CD45⁺ cells in peripheral blood of secondarily transplanted mice at 3, 7, 10, and 30 weeks. n.s., not significant; *, $p < 0.05$; $n = 3$. (H) Engraftment of human cells in bone marrow of secondarily transplanted mice at 30 weeks. n.s., not significant; $n = 3$. (I) Representative flow cytometric profiles showing multilineage contribution of human umbilical CB CD133⁺ cells in the bone marrow of secondarily transplanted mice at 8 weeks post-transplant. (J-L) Summary of multilineage contributions based on data from panel I. n.s., not significant; *, $p < 0.05$; $n = 3$.

[030] Figures 15A-I. Net ex vivo expansion of cultured human umbilical CB CD133⁺ cells as determined by limiting dilution analysis. (A-B) Numbers of total nucleated cells (A) and CD34⁺ cells (B) before and after culture with 25 $\mu\text{g/ml}$ coated anti-LILRB2 pAB. (C-D) Percentages of donor human CD45⁺ cells (C) in the peripheral blood at 1 and 2 months and (D) in bone marrow in recipient NSG mice transplanted with uncultured or expanded cells. (E) Net expansion of HSCs as determined by limiting dilution analysis. The numbers of input equivalent cells were used in the calculation. (F-I) Comparisons of multilineage repopulation of HSCs before and after ex vivo expansion. n.s., not significant; *, $p < 0.05$; **, $p < 0.01$; $n = 8$.

[031] Figure 16. Clinical grade culture of CB progenitors with Delta1 results in more rapid

neutrophil recovery in a myeloablative double CB transplant (CBT) setting. Individual and median times (solid line) to absolute neutrophil counts (ANC) of $\geq 500/\mu\text{l}$ for patients receiving double unit CB transplants with two non-manipulated units (“conventional”), one ex vivo expanded unit and one non-manipulated unit, or the “off-the-shelf” expanded product and a non-manipulated unit. Comparisons made using two-tailed t-test.

[032] Figure 17. Defining a CD34 Cell Dose for Early Myeloid Engraftment. CD34 cell dose versus time to neutrophil engraftment (ANC > 500) demonstrating cell doses above which more rapid early myeloid engraftment (before day 10) occurs. 6/7 patients with greater than 8 million CD34/kg (blue line) and 5/5 patients with greater than 10 million CD34/kg (red line) demonstrated early engraftment.

[033] Figure 18. Culture of human CB hematopoietic stem/progenitor cells (HSPC) in the presence of Angptl5 stimulates expansion of in vivo repopulating cells. Human repopulation in bone marrow of uncultured cells, cultured cells in the absence of Angptl5 (S+T+F) or cells cultured with Angptl5 (S+T+F+A5+I). Cell numbers transplanted are represented below conditions (for cultured cells number is progeny of cells generated in culture).

[034] Figure 19. Culture of CB HSPC in the presence of Delta1 and Angptl5 enhances early progenitor and myeloid precursor cell repopulation. CD34+ CB HSPC cultured in the presence of Delta1, Angptl5, or the combination were transplanted into immunodeficient mice (circles are individual mice, line is median engraftment for group) and progenitor (CD34) and myeloid (CD33) engraftment assessed at an early time point (2 weeks post-transplant). P-values represent two-tailed t-test.

[035] Figure 20. CD34-fold expansion of CB HSPC cultured in the presence of Notch alone, Angptl5 alone, or the combination. CD34+ CB HSPC were cultured for 16 days in the presence of Delta1, Angptl5, or the combination. CD34 fold expansion (CD34 cells generated/starting number CD34 cells) was calculated for time points represented (days 7, 10, 16).

[036] Figure 21. Significantly enhanced early marrow repopulation is seen when Delta is combined with Angptl5 and cultured in conditions optimized for Delta-mediated expansion.

[037] Figure 22. Longer-term repopulation is significantly enhanced as well; repopulation is multi-lineage showing significantly enhanced myeloid and lymphoid lineages. Cells did not have significant secondary engraftment when cultured in conditions previously optimized for Delta-mediated expansion.

[038] **Figures 23A and 23B** show that culture with Delta and Angptl5 with lower cytokine concentrations results in secondary engraftment previously not seen in Delta expanded cells suggesting maintenance/expansion of a longer-term repopulating cell when Delta is added to ANGPTL5 in these conditions.

[039] **Figure 24.** Culture with Delta and an antibody to the Angptl5 receptor (LILRB2 or CD85) trends towards enhanced early myeloid engraftment as compared to Delta alone. This trend is present at the highest dose of CD85 used in this experiment.

[040] **Figure 25.** When engraftment was assessed at a longer-term time point (16 wks after transplant), engraftment of cells cultured with Delta and antibody to the Angptl5 receptor (LILRB2 or CD85) had greater engraftment than Delta alone. These cells are able to repopulate both lymphoid and myeloid lineages.

[041] **Figure 26.** CD34⁺ cord blood hematopoietic stem/progenitor cells were cultured with Delta1 or a combination of Delta1 and anti-LILRB2 antibody (α LILRB2). The progeny of 10,000 starting cells were transplanted into NSG mice (circles = individual mice, lines = mean engraftment) and myeloid engraftment (y-axis: % CD33⁺ cells in total marrow) was assessed at 2 weeks. P-value represents two tailed t-test.

[042] **Figure 27.** CD34⁺ cord blood hematopoietic stem/progenitor cells were cultured with Delta1 or a combination of Delta1 and anti-LILRB2 antibody (α LILRB2). The progeny of 10,000 starting cells were transplanted into NSG mice (circles = individual mice, lines = mean engraftment) and progenitor engraftment (y-axis: % CD34⁺ cells in total marrow) was assessed at 10 weeks. P-value represents two tailed t-test.

[043] **Figure 28.** Cord blood CD34⁺ cells were cultured for 4 hrs in non-tissue culture wells coated with retronectin and either i) IgG (human), ii) anti-LILRB2 antibody (α LILRB2), iii) Delta1, or (iv) a combination of α LILRB2 and Delta1. HES1 expression was assessed by qPCR and normalized to expression of the β -glucuronidase (GUSB) reference gene. The y-axis presents the data as the fold increase in HES1 expression over the value obtained for wells coated with retronectin and human IgG.

[044] **Figure 29.** Cord blood CD34⁺ cells were cultured for 4 hrs in non-tissue culture wells coated with retronectin and also coated with either i) IgG (human), ii) a combination of anti-LILRB2 antibody (α LILRB2) and Delta1, or (iii) Delta1, in combination with anti-LILRB2 presented on microbeads. HES1 expression was assessed by qPCR and normalized to expression

of the β -glucuronidase (GUSB) reference gene. The y-axis presents the data as the fold increase in HES1 expression over the value obtained for wells coated with retronectin and human IgG.

5. DETAILED DESCRIPTION

[045] Hematopoietic precursor cell transplantation represents an important therapy due to these cell's capacity to restore blood and immune cells in transplant recipients. For example, transplantation of precursor cells can be used to treat subjects with inherited immunodeficient or autoimmune diseases and diverse hematopoietic disorders. Precursor cell transplantation can also be used to treat chemotherapy and radiation-treatment patients because prolonged neutropenia and pancytopenia is common following these treatment regimens. As one example, and of particular concern, chemotherapeutic treatments for AML result in prolonged periods of profound neutropenia with infectious complications still common even in the setting of modern antimicrobial therapies with mortality rates as high as 20% in adolescent and young adults. Human bone marrow transplantation methods are also currently used as therapies for leukemia, lymphoma, and other life-threatening diseases.

[046] Delayed myeloid engraftment is a known risk factor for cord blood (CB) transplant (CBT) recipients and is associated with low total nucleated cell count (TNC) and CD34+ cell doses provided in a single or double CB graft. The majority of non-relapse mortality in these patients occurs within the first 100 days post-transplant with infection being the most common cause of death.

[047] In transplantation, high doses of precursor cells are needed to achieve rapid and sustained engraftment that is critical for the patient's survival and recovery; this is especially true when CB precursor cells are used. Although progress toward efficient ex vivo expansion of precursor cells has been made, significant improvements in the efficacy and reproducibility of this technology are needed before it can be widely used.

[048] The present disclosure provides methods for producing immortalized cell populations of non-terminally differentiated precursor cells. In particular, the present disclosure provides methods of growing precursor cells in culture for a period beyond which the cells would otherwise stop proliferating and/or die, due to senescence and/or undergoing crisis leading to cell death.

[049] The current disclosure provides improved methods to expand precursor cells through ex

vivo expansion. The methods generate more precursor cells more quickly than previously-available methods and the generated precursor cells show enhanced early marrow repopulation in immune-deficient subjects and improved long term repopulation following transplant. The methods disclosed herein are based on culturing precursor cells with an immobilized LILRB2 agonist or an LILRB2 agonist in combination with a Notch agonist.

[050] Preferably, the technique used for expansion is one that has been shown to result in an increase in the number of precursor cells such as HSC e.g., CD34+ cells, in the expanded sample relative to the unexpanded HSC sample. In certain embodiments, the methods result in a 50-, 75-, 100-, 150-, 200-, 250-, 300-, 350-, 400-, 450-, 500-, 1000-, 2000-, 3000-, 4000-, 5000-fold (or more than) increase in the number of HSC in the expanded sample, relative to the unexpanded sample. The HSC can be positive for one or more of CD34, CD43, CD45RO, CD45RA, CD59, CD90, CD109, CD117, CD133, CD166, and HLA DR and/or negative for Lin and/or CD38. In a specific embodiment, the enhanced engraftment can be detected by detecting an increased percentage of human CD45+ cells in the bone marrow of mice infused with an aliquot of the expanded sample relative to mice infused with an aliquot of the unexpanded sample at, e.g., 10 days, 3 weeks or 9 weeks post-infusion (see Delaney et al., 2010, Nature Med. 16(2): 232-236). In some embodiments, the methods result in a 50-, 75-, 100-, 150-, 200-, 250-, 300-, 350-, 400-, 450-, 500-, 1000-, 2000-, 3000-, 4000-, 5000-fold (or more than) increase in the number of CD34+ HSC in the expanded sample, relative to the unexpanded sample. Cell populations are also preferably expanded until a sufficient number of cells are obtained to provide for at least one infusion into a human subject.

5.1 LILRB2 and Notch Agonists

[051] The present disclosure contemplates use of an immobilized LILRB2 agonist and/or an LILRB2 agonist in combination with a Notch agonist to expand precursor cells. An agonist is an agent that promotes, i.e., causes or increases, activation of LILRB2 and/or Notch pathway function. "LILRB2 pathway function" means a function mediated by the LILRB2 signaling (signal transduction) pathway, including inhibition mediated by immunoreceptor tyrosine-based inhibitory motifs (ITIMs) and/or recruitment of phosphatases SHP-1, SHP-2, or SHIP. "Notch pathway function" means a function mediated by the Notch signaling (signal transduction) pathway, including but not limited to nuclear translocation of the intracellular domain of Notch, nuclear translocation of RBP-JK or its Drosophila homolog Suppressor of Hairless; activation of

bHLH genes of the Enhancer of Split complex, e.g., Mastermind; activation of the HES-1 gene or the KBF2 (also called CBF1) gene; inhibition of *Drosophila* neuroblast segregation; and binding of Notch to a Delta protein, a Jagged/Serrate protein, Fringe, Deltex or RBP-JKI Suppressor of Hairless, or homologs or analogs thereof. See generally the review article by Kopan et al., 2009, *Cell* 137:216-233 for a discussion of the Notch signal transduction pathway and its effects upon activation; see also Jarriault et al., 1998, *Mol. Cell. Biol.* 18:7423-7431.

[052] Pathway activation is carried out by exposing a cell to one or more agonists. The agonists can be but are not limited to soluble molecules, molecules that are recombinantly expressed on a cell-surface, molecules on a cell monolayer to which the precursor cells are exposed, or molecules immobilized on a solid phase.

[053] Agonists of the present disclosure include but are not limited to proteins and analogs and derivatives (including fragments) thereof; proteins that are other elements of the LILRB2 or Notch pathway and analogs and derivatives (including fragments) thereof; activating antibodies thereto and fragments or other derivatives of such antibodies containing the binding region thereof; nucleic acids encoding the proteins and derivatives or analogs; as well as proteins and derivatives and analogs thereof which bind to or otherwise interact with LILRB2 or Notch proteins or other proteins in the LILRB2 or Notch pathways such that LILRB2 pathway activity or Notch pathway activity is promoted. Such agonists include but are not limited to proteins and derivatives thereof comprising relevant intracellular domains, nucleic acids encoding the foregoing, and proteins comprising the interacting domain of LILRB2 or Notch ligands. These proteins, fragments and derivatives thereof can be recombinantly expressed and isolated or can be chemically synthesized.

[054] Antibodies for use with the methods disclosed herein can include whole antibodies or binding fragments of an antibody, e.g., Fv, Fab, Fab', F(ab')₂, Fc, and single chain Fv fragments (ScFv) or any biologically effective fragments of an immunoglobulin that bind specifically to a LILRB2 or Notch motif.

[055] Antibodies or antigen binding fragments include all or a portion of polyclonal antibodies, monoclonal antibodies, human antibodies, humanized antibodies, synthetic antibodies, chimeric antibodies, bispecific antibodies, mini bodies, and linear antibodies.

[056] Antibodies from human origin or humanized antibodies have lowered or no immunogenicity in humans and have a lower number of non-immunogenic epitopes compared to

non-human antibodies. Antibodies and their fragments will generally be selected to have a reduced level or no antigenicity in human subjects.

[057] Antibodies that specifically bind an LILRB2 or Notch motif can be prepared using methods of obtaining monoclonal or polyclonal antibodies, methods of phage display, methods to generate human or humanized antibodies, or methods using a transgenic animal or plant engineered to produce antibodies as is known to those of ordinary skill in the art (see, for example, U.S. Patent Nos. 6,291,161 and 6,291,158). Phage display libraries of partially or fully synthetic antibodies are available and can be screened for an antibody or fragment thereof that can bind to an LILRB2 or Notch motif. For example, binding domains may be identified by screening a Fab phage library for Fab fragments that specifically bind to a target of interest (see Hoet et al., Nat. Biotechnol. 23:344, 2005). Phage display libraries of human antibodies are also available. Additionally, traditional strategies for hybridoma development using a target of interest as an immunogen in convenient systems (e.g., mice, HuMAb mouse®, TC mouse™, KM-mouse®, llamas, chicken, rats, hamsters, rabbits, etc.) can be used to develop binding domains. In particular embodiments, antibodies specifically bind an LILRB2 or Notch motif and do not cross react with nonspecific components or unrelated targets. Once identified, the amino acid sequence or polynucleotide sequence coding for the antibody can be isolated and/or determined.

[058] In another specific embodiment, the agonist is a cell which recombinantly expresses a protein or fragment or derivative thereof, which agonizes LILRB2 or Notch. The cell expresses the agonist in such a manner that it is made available to precursor cells in which LILRB2 or Notch signal transduction is to be activated, e.g., it is secreted, expressed on the cell surface, etc.

[059] In yet another specific embodiment, the agonist is a peptidomimetic or peptide analog or organic molecule that binds to a member of the LILRB2 or Notch signaling pathway. Such an agonist can be identified by the chimeric LILRB2 receptor reporter system described herein and/or by binding assays selected from those known in the art, for example the cell aggregation assays described in Rebay et al., 1991, Cell67:687-699 and in International Patent Publication No. WO 92119734.

[060] In a preferred embodiment the agonist is a protein including at least a fragment of a protein encoded by an LILRB2- or Notch-interacting gene which mediates binding to a protein or a fragment of LILRB2 or Notch, which fragment contains the region responsible for binding

to the agonist protein.

[061] In some embodiments, the agonist is recombinantly expressed from a nucleic acid introduced into the precursor cells. In specific embodiments, the recombinantly expressed agonist is a chimeric protein which includes an intracellular domain of a receptor and an extracellular domain of another ligand-binding surface receptor. In such embodiments, the LILRB2 or Notch pathway can be activated by exposure to a ligand of such another ligand-binding surface receptor. The recombinantly expressed agonist can be expressed by precursor cells from an inducible promoter. In certain embodiments, the expression of the nucleic acid encoding the agonist is under the control of Cre/Lox system or FLP/FRT system. In one embodiment, the agonist is flanked by Cre sites.

[062] In a specific embodiment, exposure of the cells to an agonist is not done by incubation with other cells recombinantly expressing a LILRB2 or Notch ligand on the cell surface (although in other embodiments, this method can be used), but rather is by exposure to a cell-free ligand, e.g., incubation with a cell-free ligand of LILRB2 or Notch, which ligand is immobilized on the surface of a solid phase, e.g., immobilized on the surface of a tissue culture dish.

[063] In some embodiments, cells are expanded by culturing the cells with an LILRB2 agonist immobilized on a first solid phase and a Notch agonist immobilized on a second solid phase, wherein the first and second solid phases are the same.

[064] In some embodiments, cells are expanded by culturing the cells with an LILRB2 agonist immobilized on a first solid phase and a Notch agonist immobilized on a second solid phase, wherein the second solid phase is not the first solid phase. In a specific embodiment, the first and second solid phases are different types of solid phases, selected from among any known in the art, including, but not limited to a culture dish, a culture flask, a culture plate, a bead, a particle, *etc.* In specific embodiments, the first solid phase is a surface of a tissue culture dish or flask, and the second solid phase is a bead, *e.g.* a magnetic microbead. In other specific embodiments, the first solid phase is a bead, *e.g.* a magnetic microbead, and the second solid phase is a surface of a tissue culture dish or flask. In an embodiment where the LILRB2 agonist and Notch agonist are immobilized on different solid phases, the precursor cells can be cultured with the LILRB2 agonist and the Notch agonist concurrently or sequentially.

5.2 LILRB2 Agonists

[065] The methods disclosed herein include LILRB2 agonists. In particular embodiments,

angiopoietins and angiopoietin-like proteins (Angptls) represent exemplary LILRB2 agonists. Until recently, Angptls were considered “orphan ligands” as no receptors were known. In 2012, a subset of the current inventors identified human leukocyte immunoglobulin-like receptor B2 (LILRB2) and its mouse ortholog paired Ig-like receptor (PirB) as receptors for several Angptls. Zheng et al., *Nature*. 2012;485:656-660. It was also found that LILRB2 and PirB are expressed by human and mouse HSCs, respectively, and support their ex vivo expansion. Zheng et al., *Nature*. 2012;485:656-660. LILRB2 sequence information includes: Accession: NP_001265335.2 (SEQ ID NO: 3); Accession: NP_001265334.2 (SEQ ID NO: 4); Accession: NP_001265333.2 (SEQ ID NO: 5); Accession: NP_001265332.2 (SEQ ID NO: 6); and Accession:AAH36827.1 (SEQ ID NO: 7).

[066] Several Angptls support the activity of precursor cells, such as HSCs in vitro and in vivo. For example, several Angptls inhibit differentiation and promote repopulation of HSCs in vitro and in vivo. Zheng et al., *Cell Stem Cell*. 2011;9:119-130; Zheng et al., *Blood*. 2011;117:470-479; Zhang and Lodish *Curr Opin Hematol*. 2008;15:307-311; and Zhang et al., *Blood*. 2008;111:3415-3423. LILRB2 and PirB are also required for leukemia development as they inhibit differentiation and promote self-renewal of leukemic progenitors. Zheng et al., *Nature*. 2012;485:656-660. It was further demonstrated that the binding of Angptls to LILRB2/PirB induces activation of SHP-2 and CAMKs, both types of factors known to be critical for supporting the activity of HSCs Kitsos et al., *J Biol Chem*. 2005;280:33101-33108; Chan et al., *Exp Hematol*. 2006;34:1230-1239.

[067] LILRB2 receptors contain ITIMs in their intracellular domains and are classified as inhibitory receptors because ITIM motifs can recruit phosphatases SHP-1, SHP-2, or SHIP to negatively regulate cell activation. Takai et al., *J Biomed Biotechnol*. 2011;2011:275302; Daeron et al., *Immunol Rev*. 2008;224:11-43. An important question is how Angptl binding leads to the activation of LILRB2. In Example 1, the molecular basis for the interaction between Angptls and LILRB2 is described. It is shown that mammalian-expressed Angptl2 exists as HMW species, which is needed for activation of LILRB2 and subsequent downstream signaling. A novel motif in the first and fourth Ig domains of LILRB2 that is critical to the Angptl2 binding was also identified. Moreover, that the binding of Angptl2 to LILRB2 is more potent and not completely overlapped with the binding of another ligand HLA-G is shown. Based on the new understanding of the Angptl/LILRB2 interaction, a serum-free culture containing defined cytokines and

immobilized antiLILRB2 antibodies that supports a stable and reproducible ex vivo expansion of repopulating human CB precursor cells was developed.

[068] Based on the foregoing, LILRB2 agonists of the current disclosure can particularly include high molecular weight agonists (above 200 kD; above 210 kD; above 215 kD; above 220 kD; above 225 kD; above 230 kD; above 235 kD; above 240 kD; above 245 kD; above 250 kD; above 255 kD; above 260 kD; above 265 kD; above 270 kD; above 275 kD; above 280 kD; above 285 kD; above 290 kD; above 295 kD; or above 300 kD) including high molecular weight Angptls. LILRB2 agonists can also include multimerized LILRB2 agonists, including multimerized Angptls.

[069] In particular embodiments, LILRB2 agonists bind a motif in the Ig1 domain of LILRB2, a motif in the Ig2 domain of LILRB2, a motif in the Ig3 domain of LILRB2, and/or a motif in the Ig4 domain of LILRB2. In more particular embodiments, the LILRB2 agonists bind motifs in the Ig1 and Ig4 domains of LILRB2. In more particular embodiments, the LILRB2 agonists bind amino acids at positions 92-100 of the Ig1 domain. In more particular embodiments, the LILRB2 agonists bind amino acids at positions 390-396 of the Ig4 domain. In more particular embodiments, the LILRB2 agonists bind amino acids at positions 92-100 of the Ig1 domain and amino acids at positions 390-396 of the Ig4 domain. In more particular embodiments, the LILRB2 agonists bind amino acids at positions 94, 95 and 96 of the Ig1 domain and amino acids at positions 392 and 394 of the Ig4 domain.

[070] Within the current disclosure, Angptls can be any member of a family of secreted glycosylated proteins that are similar in structure to angiopoietins (Oike et al., Int. J. Hematol. 80:21-8 (2004)). Similar to angiopoietins, Angptls contain an N-terminal CC domain and a C-terminal FBN-like domain. Unlike angiopoietins, Angptls do not bind to the tyrosine kinase receptor Tie2. Angptls include Angptls 2, 3, 4, 5, 6, and 7. Angptls also include microfibrillar-associated glycoprotein 4 (Mfap4), and analogs and equivalents thereof. Angptl2 has been described by Kim, et al. 1999, J Biol Chem 274, 26523-8). In addition, Angptls are available commercially (R&D Systems, Abnova Corp).

[071] Exemplary Angptls are provided, for example in GenBank as Accession Number AAH12368 (human Angptl2 precursor; SEQ ID NO: 8) Accession Number AAH58287 (human Angptl3 precursor; SEQ ID NO: 9) Accession Number AAH23647 (human Angptl4; SEQ ID NO: 10) and Accession Number AAH49170 (human Angptl5; SEQ ID NO: 11). An exemplary

sequence for Angptl7 is found in GenBank Accession No. AAH01881 (SEQ ID NO: 12). An exemplary sequence for Mfap4 is found in GenBank Accession No. NP002395 (SEQ ID NO: 13).

[072] Suitable equivalents for Angptls include proteins and polypeptides having similar biological activity to these factors as wild-type or purified Angptls (e.g., recombinantly produced). Suitable analogs of Angptls include fragments retaining the desired activity and related molecules. One preferred analog is a fragment of the Angptl containing the CC domain, for example, the CC domain of Angptl2. Another analog is the FBN-like domain. Fragments of Angptls such as the CC domain and the FBN-like domain may be easier to express and to purify compared to full-length protein. Molecules capable of binding the corresponding Angptl receptor and initiating one or more biological actions associated with Angptl binding to its receptor are also within the scope of the disclosure.

[073] Antibodies to the LILRB2 receptor can also be used. Exemplary commercially available antibodies include, anti-LILRB2 polyclonal antibody (pAb, #BAF2078, R&D systems) and anti-LILRB2 monoclonal antibody (mAb, #16-5149-85, eBioscience).

[074] Exemplary production methods of LILRB2 agonists are described in, for example, U.S. Patent Publication Nos. 2014/0017784 and 2011/0196343.

[075] In certain embodiments, to determine whether an LILRB2 binding protein, *e.g.*, an anti-LILRB2 antibody, is an LILRB2 agonist, precursor cells, *e.g.*, hematopoietic stem cells or hematopoietic progenitor cells, are cultured in the presence of the LILRB2 binding protein and then tested for increased Hes1 expression levels (relative to precursor cells cultured in the presence of a control molecule not having LILRB2 agonist activity), *e.g.*, by q-PCR, wherein increased Hes1 expression levels in the cells cultured in the presence of the LILRB2 binding protein indicates that the LILRB2 binding protein is an LILRB2 agonist. In other embodiments, to determine whether an LILRB2 binding protein, *e.g.*, an anti-LILRB2 antibody, is an LILRB2 agonist, precursor cells, *e.g.*, hematopoietic stem cells or hematopoietic progenitor cells, are cultured in the presence of the LILRB2 binding protein and then injected into NSG mice, wherein increased engraftment of the cells cultured in the presence of the LILRB2 binding protein in NSG mice (relative to precursor cells cultured in the presence of a control molecule not having LILRB2 agonist activity) indicates that the LILRB2 binding protein is an LILRB2 agonist.

5.3 Notch Agonists

[076] The current disclosure also describes stable and reproducible ex vivo expansion of precursor cells using a combination of Angptl agonists and Notch agonists.

[077] Members of the Notch family encode large transmembrane proteins that play central roles in cell-cell interactions and cell-fate decisions during early development in a number of invertebrate systems (Simpson, 1995, *Nature* 375:736-7; Artavanis-Tsakonis et al., 1995, *Science*. 268:225-232; Simpson, 1998, *Semin. Cell Dev. Biol.* 9:581-2; Go et al., 1998, *Development*. 125:2031-2040; Artavanis-Tsakonas and Simpson, 1991, *Trends Genet.* 7:403-408). The Notch receptor is part of a highly conserved pathway that enables a variety of cell types to choose between alternative differentiation pathways based on those taken by immediately neighboring cells. This receptor appears to act through an undefined common step that controls the progression of uncommitted cells toward the differentiated state by inhibiting their competence to adopt one of two alternative fates, thereby allowing the cell either to delay differentiation, or in the presence of the appropriate developmental signal, to commit to differentiate along the non-inhibited pathway.

[078] Genetic and molecular studies have led to the identification of a group of genes which define distinct elements of the Notch signaling pathway. While the identification of these various elements has come from *Drosophila* using genetic tools, initial guide, subsequent analyses have led to the identification of homologous proteins in vertebrate species including humans. The molecular relationships between the known Notch pathway elements as well as their subcellular localization are depicted in Artavanis-Tsakonas et al., 1995, *Science* 268:225-232; Artavanis-Tsakonas et al., 1999, *Science* 284:770-776; and in Kopan et al., 2009, *Cell* 137:216-233. Proteins of the Delta family and proteins of the Serrate (including Jagged, the mammalian homolog of Serrate) family are extracellular ligands of Notch. The portion of Delta and Serrate responsible for binding to Notch is called the DSL domain, which domain is located in the extracellular domain of the protein. Epidermal growth factor-like repeats (ELRs) 11 and 12 in the extracellular domain of Notch are responsible for binding to Delta, Serrate and Jagged. See Artavanis-Tsakonas et al., 1995, *Science* 268:225-232 and Kopan et al., 2009, *Cell* 137:216-233. Exemplary sequences relevant to Notch signaling include Accession Number: P46531.4 (SEQ ID NO: 14); Accession Number: AAG09716.1 (SEQ ID NO: 15); Accession Number: 2KB9_A (SEQ ID NO: 16) and Accession Number: 2VJ2_B (SEQ ID NO: 17).

[079] The present disclosure contemplates use of a Notch agonist. Contemplated for use in the present disclosure are any of the Notch agonists disclosed in U.S. Patent No. 7,399,633, or any other Notch agonists known in the art.

[080] Notch agonists include but are not limited to Notch proteins and derivatives thereof comprising the intracellular domain, Notch nucleic acids encoding the foregoing, and proteins comprising the Notch-interacting domain of Notch ligands (e.g., the extracellular domain of Delta or Serrate). Other agonists include but are not limited to RBP JKI Suppressor of Hairless or Deltex. Fringe can be used to enhance Notch activity, for example in conjunction with Delta protein. These proteins, fragments and derivatives thereof can be recombinantly expressed and isolated or can be chemically synthesized.

[081] In a preferred embodiment the agonist is a protein including at least a fragment of a protein encoded by a Notch-interacting gene which mediates binding to a Notch protein or a fragment of Notch, which fragment of Notch contains the region of Notch responsible for binding to the agonist protein, e.g., epidermal growth factor-like repeats 11 and 12 of Notch. Notch interacting genes mean the genes Notch, Delta, Serrate, Jagged, RBPJK, Suppressor of Hairless and Deltex, as well as other members of the Delta/Serrate family or Deltex family which may be identified by virtue of sequence homology or genetic interaction and more generally, members of the "Notch cascade" or the "Notch group" of genes, which are identified by molecular interactions (e.g., binding in vitro, or genetic interactions (as depicted phenotypically, e.g., in *Drosophila*). Exemplary fragments of Notch-binding proteins containing the region responsible for binding to Notch are described in U.S. Pat. Nos. 5,648,464; 5,849,869; and 5,856,441. The Notch agonists utilized by the methods of the disclosure can be obtained commercially, produced by recombinant expression, or chemically synthesized.

[082] In a specific embodiment, the Notch agonist is a dominant active mutant of a Notch protein (e.g., a Notch receptor lacking the extracellular, ligand binding domain). In another embodiment, the Notch agonist is not a dominant active mutant of a Notch protein.

[083] In some embodiments, the Notch agonist is recombinantly expressed from a nucleic acid introduced into the precursor cell. Methods that can be used for recombinantly expressing a Notch agonist are described in sec. 5.3 of U.S. Patent No. 7,399,633. In particular embodiments, the Notch agonist is a Notch protein (e.g., human or murine Notch-1, Notch-2, Notch-3 or Notch-4) including the intracellular domain of the Notch protein expressed recombinantly in

precursor cells. In specific embodiments, the recombinantly expressed Notch agonist is a chimeric Notch protein which includes the intracellular domain of Notch receptor and the extracellular domain of another ligand-binding surface receptor (e.g., the EGF receptor). In such embodiments, the Notch pathway can be activated by exposure to a ligand of such another ligand-binding surface receptor (e.g., EGF). The recombinantly expressed Notch agonist can be expressed by precursor cells from an inducible promoter. In certain embodiments, the expression of the nucleic acid encoding the Notch agonist is under the control of Cre/Lox system or FLP/FRT system. In one embodiment, the Notch agonist is flanked by Cre sites.

[084] In another specific embodiment, and as described in U.S. Pat. No. 5,780,300 to Artavanis-Tsakonas et al., Notch agonists include reagents that promote or activate cellular processes that mediate the maturation or processing steps required for the activation of Notch or a member of the Notch signaling pathway, such as the turin-like convertase required for Notch processing, Kuzbanian, the metalloprotease-disintegrin (ADAM) thought to be required for the activation of the Notch pathway upstream or parallel to Notch (Schlondorfiand Blobel, 1999, J. Cell Sci. 112:3603-3617), or, more generally, cellular trafficking and processing proteins such as the rab family of GTPases required for movement between cellular compartments (for a review on Rab GTPases, see Olkkonen and Stenmark, 1997, Int. Rev. Cytol. 176:1-85). The agonist can be any molecule that increases the activity of one of the above processes, such as a nucleic acid encoding a turin, Kuzbanian or rab protein, or a fragment or derivative or dominant active mutant thereof; or a peptidomimetic or peptide analog or organic molecule that binds to and activates the function of the above proteins.

[085] U.S. Pat. No. 5,780,300 further discloses classes of Notch agonist molecules (and methods of their identification) which can be used to activate the Notch pathway in the practice of the present disclosure, for example molecules that trigger the dissociation of the Notch ankyrin repeats with RBP-JK, thereby promoting the translocation of RBP-JK from the cytoplasm to the nucleus.

[086] Exemplary Notch agonists are the extracellular binding ligands Delta and Serrate (e.g., Jagged) which bind to the extracellular domain of Notch and activate Notch signal transduction, or a fragment (e.g., the extracellular domain) of Delta or Serrate (e.g., Jagged) that binds to the extracellular domain of Notch and activates Notch signal transduction. Nucleic acid and amino acid sequences of Delta family members and Serrate family members (e.g., Jagged family

members) have been isolated from several species, including human, are known in the art, and are disclosed in International Patent Publication Nos. WO 93/12141, WO 96/27610, WO 97/01571, Gray et al., 1999, Am. J. Path. 154:785-794. Jagged is a mammalian homologue of Serrate. As used in this application, Serrate shall encompass Jagged unless the context indicates otherwise. In one embodiment, the Notch agonist is Delta^{extIgG}, which is a fragment of a Delta protein consisting of the extracellular domain of the protein fused to the Fc portion of IgG.

[087] In certain embodiments, the Notch agonist is an anti-Notch antibody or antigen-binding fragment thereof. In specific embodiments, the Notch agonist is an anti-Notch-1 antibody or antigen-binding fragment thereof. In more specific embodiments, the Notch agonist is the anti-Notch-1 HMN1-519 antibody (commercially available from Biolegend, San Diego, CA). In other specific embodiments, the Notch agonist is an anti-Notch-2 antibody or antigen-binding fragment thereof. In more specific embodiments, the Notch agonist is the anti-Notch-2 HMN2-25 antibody (commercially available from Biolegend, San Diego, CA). In other specific embodiments, the Notch agonist is a combination of an anti-Notch-1 antibody and an anti-Notch-2 antibody.

[088] Sequence information provided by public databases can be used to identify nucleic acid sequences encoding proteins disclosed herein and vice versa. Variants of the sequences disclosed and referenced herein are also included. Variants of proteins can include those having one or more conservative amino acid substitutions. As used herein, a “conservative substitution” involves a substitution found in one of the following conservative substitutions groups: Group 1: Alanine (Ala or A), Glycine (Gly or G), Serine (Ser or S), Threonine (Thr or T); Group 2: Aspartic acid (Asp or D), Glutamic acid (Glu or Z); Group 3: Asparagine (Asn or N), Glutamine (Gln or Q); Group 4: Arginine (Arg or R), Lysine (Lys or K), Histidine (His or H); Group 5: Isoleucine (Ile or I), Leucine (Leu or L), Methionine (Met or M), Valine (Val or V); and Group 6: Phenylalanine (Phe or F), Tyrosine (Tyr or Y), Tryptophan (Trp or W).

[089] Additionally, amino acids can be grouped into conservative substitution groups by similar function or chemical structure or composition (e.g., acidic, basic, aliphatic, aromatic, sulfur-containing). For example, an aliphatic grouping may include, for purposes of substitution, Gly, Ala, Val, Leu, and Ile. Other groups containing amino acids that are considered conservative substitutions for one another include: sulfur-containing: Met and Cysteine (Cys or C); acidic: Asp, Glu, Asn, and Gln; small aliphatic, nonpolar or slightly polar residues: Ala, Ser, Thr, Pro,

and Gly; polar, negatively charged residues and their amides: Asp, Asn, Glu, and Gln; polar, positively charged residues: His, Arg, and Lys; large aliphatic, nonpolar residues: Met, Leu, Ile, Val, and Cys; and large aromatic residues: Phe, Tyr, and Trp. Additional information is found in Creighton (1984) *Proteins*, W.H. Freeman and Company.

[090] Variants of the protein sequences disclosed or referenced herein also include sequences with at least 70% sequence identity, at least 80% sequence identity, at least 85% sequence, at least 90% sequence identity, at least 95% sequence identity, at least 96% sequence identity, at least 97% sequence identity, at least 98% sequence identity, or at least 99% sequence identity to the protein sequences disclosed or referenced herein.

[091] "% sequence identity" refers to a relationship between two or more sequences, as determined by comparing the sequences. In the art, "identity" also means the degree of sequence relatedness between proteins as determined by the match between strings of such sequences. "Identity" (often referred to as "similarity") can be readily calculated by known methods, including (but not limited to) those described in: *Computational Molecular Biology* (Lesk, A. M., ed.) Oxford University Press, NY (1988); *Biocomputing: Informatics and Genome Projects* (Smith, D. W., ed.) Academic Press, NY (1994); *Computer Analysis of Sequence Data, Part I* (Griffin, A. M., and Griffin, H. G., eds.) Humana Press, NJ (1994); *Sequence Analysis in Molecular Biology* (Von Heijne, G., ed.) Academic Press (1987); and *Sequence Analysis Primer* (Gribskov, M. and Devereux, J., eds.) Oxford University Press, NY (1992). Preferred methods to determine identity are designed to give the best match between the sequences tested. Methods to determine identity and similarity are codified in publicly available computer programs. Sequence alignments and percent identity calculations may be performed using the Megalign program of the LASERGENE bioinformatics computing suite (DNASTAR, Inc., Madison, Wisconsin). Multiple alignment of the sequences can also be performed using the Clustal method of alignment (Higgins and Sharp *CABIOS*, 5, 151-153 (1989) with default parameters (GAP PENALTY=10, GAP LENGTH PENALTY=10). Relevant programs also include the GCG suite of programs (Wisconsin Package Version 9.0, Genetics Computer Group (GCG), Madison, Wisconsin); BLASTP, BLASTN, BLASTX (Altschul, et al., *J. Mol. Biol.* 215:403-410 (1990); DNASTAR (DNASTAR, Inc., Madison, Wisconsin); and the FASTA program incorporating the Smith-Waterman algorithm (Pearson, *Comput. Methods Genome Res.*, [Proc. Int. Symp.] (1994), Meeting Date 1992, 111-20. Editor(s): Suhai, Sandor. Publisher: Plenum, New York, N.Y..

Within the context of this disclosure it will be understood that where sequence analysis software is used for analysis, the results of the analysis are based on the "default values" of the program referenced. As used herein "default values" will mean any set of values or parameters which originally load with the software when first initialized.

5.4 Immobilized/Solid Support

[092] In some embodiments, during the culturing step, precursor cells are cultured in the presence of immobilized LILRB2 and/or Notch agonists, in particular embodiments the extracellular domains of an agonist, and in further particular embodiments, fused to a fusion partner. In specific embodiments, during the culturing step, precursor cells are cultured on a solid phase coated with LILRB2 and/or Notch agonists.

[093] In certain embodiments, the isolated precursor cells are expanded in the presence of a fibronectin or a fragment thereof (e.g., CH-296; (Dao et al., 1998, Blood 92(12):4612-21)) or RetroNectin® (a recombinant human fibronectin fragment; Clontech Laboratories, Inc., Madison, WI)). In certain embodiments, fibronectin is excluded from the tissue culture dishes or is replaced by another extracellular matrix protein. See also U.S. Patent No. 7,399,633 to Bernstein et al. for additional exemplary culture conditions for precursor cell expansion. For example, the isolated precursor cells can be expanded in the presence of an immobilized fibronectin or a fragment thereof (e.g., immobilized on the same solid phase as LILRB2 and/or Notch agonist), or immobilized on a solid phase that is different from the solid phase on which the LILRB2 and/or Notch agonist is immobilized.

5.5 Growth Factors & Other Culture Components

[094] In some embodiments, precursor cells are expanded in the presence of one or more growth factors, two or more growth factors, three or more growth factors, or four or more growth factors (e.g., in a fluid medium).

[095] In some embodiments, the amount or concentration of growth factors suitable for expanding precursor cells of the present disclosure is the amount or concentration effective to promote proliferation of HSC but substantially no differentiation of HSC.

[096] Exposing precursor cells to one or more growth factors can be done prior to, concurrently with, or following exposure of the cells to a LILRB2 and/or Notch agonist. In some embodiments, precursor cells are exposed to one or more growth factors for at least a portion of the time or the minimal culture time, most preferably the majority or all of the time, that

precursor cells are exposed to a LILRB2 and/or Notch agonist. The minimal culture time is the amount of time at which the cell would die or stop proliferating in the absence of LILRB2 and/or Notch agonist and the growth factors (e.g., 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 7 weeks, 8 weeks, 9 weeks, 10 weeks, 11 weeks, 12 weeks, 13 weeks, 14 weeks, 15 weeks, 16 weeks, 17 weeks, 18 weeks, 19 weeks, 20 weeks, 21 weeks, 22 weeks, 23 weeks, 24 weeks, or 25 weeks). In specific embodiments, the minimal culture time is from 3 to 4 weeks.

[097] In specific exemplary embodiments, the growth factors present in the expansion medium include one or more of the following growth factors: stem cell factor (SCF; also known as the c-kit ligand or mast cell growth factor), Flt-3 ligand (Flt-3L), interleukin-6 (IL-6), interleukin-3 (IL-3), interleukin-7 (IL-7), interleukin-11 (IL-11), thrombopoietin (TPO), granulocyte-macrophage colony stimulating factor (GM-CSF), granulocyte colony stimulating factor (G-CSF), insulin growth factor-2 (IGF-2), and fibroblast growth factor-1 (FGF-1).

[098] In some embodiments, the growth factors present in the expansion medium include one or more of the following growth factors: IL-1, IL-3, IL-6, IL-11, G-CSF, GM-CSF, SCF, Flt3-L, TPO, erythropoietin and analogs thereof (wherein the analogs include any structural variants of the growth factors having the biological activity of the naturally occurring growth factor and cytokine receptor agonists, e.g., agonist antibody against the TPO receptor such as VB22B sc(Fv)2 described in WO 20071145227) (see page 13 of U.S. Patent Publication No. 2010/0183564). In one embodiment, SCF, Flt3-L and TPO are used in the expansion methods provided herein. In another embodiment, IL-6, SCF, Flt3-L and TPO are used in the expansion methods provided herein. In some embodiments, one or more growth factors are used in a serum-free medium.

[099] The amount or concentration of growth factors suitable for expanding precursor cells of the present disclosure will depend on the activity of the growth factor preparation, and the species correspondence between the growth factors and precursor cells, etc. The amount of growth factors can be in the range of 5-1000 ng/ml. Generally, when the growth factor(s) and precursor cells are of the same species, the total amount of growth factor in the culture medium ranges from 1 ng/ml to 100 µg/ml, more preferably from 5 ng/ml to 1 µg/ml, and most preferably from about 5 ng/ml to 250 ng/ml.

[0100] In certain embodiments, the foregoing growth factors are present in the culture condition for expanding precursor cells at the following concentrations: 25-300 ng/ml SCF, 25-300 ng/ml

Flt-3 ligand, 25-100 ng/ml TPO, 25-100 ng/ml IL-6 and 10 ng/ml IL-3. In more specific embodiments, 50, 100 or 200 ng/ml SCF, 50, 100 or 200 ng/ml of Flt-3 ligand, 50 or 100 ng/ml TPO, 50 or 100 ng/ml IL-6 and about 10 ng/ml IL-3 can be used.

[0101] In one embodiment, precursor cells are expanded by exposing precursor cells to an LILRB2 agonist and 50 ng/ml SCF; 10 ng/ml TPO; and 50 ng/ml FLT3-ligand. In one embodiment, precursor cells are expanded by exposing precursor cells to an LILRB2 agonist and 50 ng/ml SCF; 10 ng/ml TPO; and 50 ng/ml FLT3-ligand in StemSpan media (Stemcell Technologies, Inc.). In another embodiment, precursor cells are expanded by exposing precursor cells to an LILRB2 agonist and 50 ng/ml SCF; 10 ng/ml TPO; and 50 ng/ml FLT3-ligand for 10 days.

[0102] In further embodiments, precursor cells are expanded by exposing precursor cells to an LILRB2 agonist, a Notch agonist and 50 ng/ml SCF; 50 ng/ml Flt-3 ligand; 50 ng/ml interleukin-6 (IL-6); 50 ng/ml TPO; 20 ng/ml FGF1; 10 ng/ml interleukin-3 (IL-3); and 10 µg/ml heparin. In one embodiment, precursor cells are expanded by exposing precursor cells to an LILRB2 agonist, a Notch agonist and 50 ng/ml SCF; 50 ng/ml Flt-3 ligand; 50 ng/ml interleukin-6 (IL-6); 50 ng/ml TPO; 20 ng/ml FGF1; 10 ng/ml interleukin-3 (IL-3); and 10 µg/ml heparin in StemSpan media (Stemcell Technologies, Inc.).

[0103] Exposing precursor cells to a Notch agonist can be done prior to, concurrently with, or following exposure of the cells to an LILRB2 agonist. In one embodiment, precursor cells are exposed to both an LILRB2 agonist and a Notch agonist for the entire period of ex vivo expansion of precursor cells. In some embodiments, precursor cells are exposed to both an LILRB2 agonist and a Notch agonist for more than 80%, 85%, 90%, 95%, 98%, or 99% of the period of ex vivo expansion of precursor cells. In another embodiment, precursor cells are exposed to an LILRB2 agonist and a Notch agonist for less than the entire period of ex vivo expansion of precursor cells. In yet another embodiment, precursor cells are exposed to an LILRB2 agonist for the entire period of ex vivo expansion of precursor cells, but are exposed to a Notch agonist for less than the entire period of ex vivo expansion (e.g., for less than 100%, 99%, 98%, 95%, 90%, 85%, 80%, 75%, 70%, 60%, or 50% of the ex vivo expansion period). Alternatively, precursor cells are exposed to a Notch agonist for the entire period of ex vivo expansion of precursor cells, but are exposed to an LILRB2 agonist for less than the entire period of ex vivo expansion (e.g., for less than 100%, 99%, 98%, 95%, 90%, 85%, 80%, 75%, 70%,

60%, or 50% of the ex vivo expansion period).

[0104] Culturing precursor cells can take place under any suitable culture medium/conditions described in U.S. Patent Publication No. 2004/0067583, U.S. Patent No. 7,399,633, or U.S. Patent Publication No. 2010/0183564 or as is known in the art (see, e.g., Freshney Culture of Animal Cells, Wiley-Liss, Inc., New York, NY (1994)). The time in culture is a time sufficient to produce an expanded precursor cell population. For example, precursor cells can be cultured in a serum-free medium in the presence of an LILRB2 agonist and/or a Notch agonist, and, optionally, one or more growth factors or cytokines for 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, or 35 days; or, preferably, for at least 10 or at least 15 days or at least 16 days. Optionally, at any point during the culturing period, the culture medium can be replaced with fresh medium or fresh medium can be added. In one embodiment, the fresh culture medium is added every 3 or 4 days.

[0105] In other embodiments, precursor cells are cultured for 1 week, 2 weeks, 3 weeks, 4 weeks, 5 weeks, 6 weeks, 7 weeks, 8 weeks, 9 weeks or 10 weeks; or, preferably, the precursor cells are cultured for at least 3 or 4 weeks (in the presence of the combination of an LILRB2 agonist and/or a Notch agonist, and, optionally, one or more growth factors). In yet other embodiments, precursor cells are cultured for less than 4 weeks (in the presence of an LILRB2 agonist and/or a Notch agonist, and, optionally, one or more growth factors). In yet other embodiments, precursor cells are cultured for more than 10 weeks, e.g., 12, 15, 18, 20 or 25 weeks (in the presence of an LILRB2 agonist and/or a Notch agonist, and, optionally, one or more growth factors).

5.6 Source, Collection, Isolation and Treatment of Precursor Cells for Expansion

[0106] The present disclosure provides methods for immortalizing and optionally differentiating precursor cells, by circumventing or delaying the entry of the precursor cells into cell cycle arrest or into a nonreplicative phase. Precursor cells for immortalization according to the disclosure are non-terminally-differentiated cells and can be from any species, including but not limited to human, animal, plant, mammal, primate, mouse, rat, dog, cat, horse, cow, fowl, insect, *Drosophila*, and *C. elegans*. Most preferably, the precursor cells are vertebrate, more preferably mammalian, and most preferably human. In a preferred embodiment, the precursor cells have not gone through a "crisis" or "senescence" phase resulting in cell line characteristics (e.g.

transformation resulting in a stable phenotypic change (see Freshney, 1994, In "Culture of Animal Cells--A manual of Basic Technique," 3rd Edition at p. 12, John Wiley & Sons, Inc.). In a preferred embodiment, the precursor cells are primary cells. The term "primary cells" indicates that the cells have not been through a subculture following their explantation from a tissue source, such as a mammalian subject.

[0107] Generally, though not necessarily, the precursor cells are pluripotent stem cells or multipotent progenitor cells. In one embodiment, the precursor cells are stem cells. In another embodiment, the precursor cells are progenitor cells. The precursor cells can be isolated from a cell population, if desired, before or after immortalization.

[0108] In a specific embodiment, the precursor cells are hematopoietic stem cells. In a specific embodiment, the precursor cells are hematopoietic progenitor cells.

[0109] In a specific embodiment, the precursor cells are a population of cells enriched for hematopoietic stem cells. In another embodiment, the precursor cells are a population of cells enriched for hematopoietic stem and progenitor cells.

[0110] Sources of precursor cells include but are not limited to: umbilical CB, placental blood, peripheral blood (e.g., mobilized peripheral blood), bone marrow (e.g., from femurs, hips, ribs, sternum and other bones), embryonic cells (including embryonic stem cells and hematopoietic precursors of HSC derived from embryonic stem cells, induced pluripotent stem cells or HSC or hematopoietic precursors derived by reprogramming (see Gazit et al., Stem Cell Reports, Vol. 1, 266-280, 2013), aortal-gonadal-mesonephros derived cells, lymph, liver (e.g., fetal liver), thymus, and spleen. Sources of precursor cells further include fetal blood, neonatal blood (from an infant in the first 28 days after birth), blood from an infant under 12 months of age, blood from a toddler between 1 year and 3 years of age, blood from a child between 3 and 18 years of age, and adult blood (i.e., derived from a subject who is older than 18 years of age). As will be understood by one of ordinary skill in the art, all collected samples can be screened for undesirable components and discarded, treated or used according to accepted current standards.

[0111] Umbilical CB and/or placental blood can be obtained by any method known in the art. The use of cord or placental blood as a source of CB stem cells provides numerous advantages, including that the cord and placental blood can be obtained easily and without trauma to the donor. See, e.g., U.S. Patent No. 5,004,681 for a discussion of collecting cord and placental blood at the birth of a human. In one embodiment CB collection is performed by the method

disclosed in U.S. Patent No. 7,147,626.

[0112] Collections should be made under sterile conditions. Immediately upon collection, cord or placental blood should be mixed with an anticoagulant. Such an anticoagulant can be any known in the art, including but not limited to CPO (citrate-phosphate-dextrose), ACD (acid citrate-dextrose), Alsever's solution (Alsever et al., 1941, N.Y. St. J. Med. 41:126), De Gowin's Solution (De Gowin, et al., 1940, J. Am. Med. Ass. 114:850), Edglugate-Mg (Smith, et al., 1959, J. Thorac. Cardiovasc. Surg. 38:573), Rous-Turner Solution (Rous and Turner, 1916, J. Exp. Med. 23:219), other glucose mixtures, heparin, ethyl biscoumacetate, etc. See, generally, Hum, 1968, Storage of Blood, Academic Press, New York, pp. 26-160. In particular embodiments, ACD can be used.

[0113] The CB can preferably be obtained by direct drainage from the cord and/or by needle aspiration from the delivered placenta at the root and at distended veins. See, generally, U.S. Patent No. 5,004,681. Preferably, the collected human CB and/or placental blood is free of contamination.

[0114] In certain embodiments, HSC are obtained from the fetal blood from the fetal circulation at the placental root with the use of needle guided ultrasound, by placentocentesis, or by fetoscopy as described in sec. 5.4.5 of U.S. Patent No. 7,399,633. In specific embodiments, HSC are obtained from Wharton's jelly as described in sec. 5.4.5 of U.S. Patent No. 7,399,633.

[0115] Peripheral blood is preferably mobilized prior to its collection. Peripheral blood can be mobilized by any method known in the art. Peripheral blood can be mobilized by treating the subject from whom precursor cells are to be collected with any agent(s), described herein or known in the art, that increase the number of precursor cells circulating in the peripheral blood of a subject. For example, in some embodiments, peripheral blood is mobilized by treating the subject from whom precursor cells are to be collected with one or more cytokines or growth factors (e.g., G-CSF, kit ligand (KL), IL-1, IL-7, IL-8, IL-11, Flt3 ligand, SCF, thrombopoietin, or GM-CSF (such as sargramostim)). Different types of G-CSF that can be used in the methods for mobilization of peripheral blood include, without limitation, filgrastim and longer acting G-CSF-pegfilgrastim. In certain embodiments, peripheral blood is mobilized by treating the subject from whom precursor cells are to be collected with one or more chemokines (e.g., macrophage inflammatory protein-1 α (MIP1 α /CCL3)), chemokine receptor ligands (e.g., chemokine receptor

2 ligands GROP and GROPM), chemokine receptor analogs (e.g., stromal cell derived factor-1 α (SDF-1 α) peptide analogs such as CTCE-0021, CTCE-0214, or SDF-1 α such as Met-SDF-1 α), or chemokine receptor antagonists (e.g., chemokine (C-X-C motif) receptor 4 (CXCR4) antagonists such as AMD3100). In some embodiments, peripheral blood is mobilized by treating the subject from whom precursor cells are to be collected with one or more anti-integrin signaling agents (e.g., function blocking anti-very late antigen 4 (VLA-4) antibody, or anti-vascular cell adhesion molecule 1 (VCAM-1)). In other embodiments, peripheral blood is mobilized by treating the subject from whom precursor cells are to be collected with one or more cytotoxic drugs such as cyclophosphamid, etoposide or paclitaxel. In particular embodiments, peripheral blood can be mobilized by administering to a subject one or more of the agents listed above for a certain period of time. For example, the subject can be treated with one or more agents (e.g., G-CSF) via injection (e.g., subcutaneous, intravenous or intraperitoneal), once daily or twice daily, for 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 or 14 days prior to collection of precursor cells. In specific embodiments, precursor cells are collected within 1, 2, 3, 4, 5, 6, 7, 8, 12, 14, 16, 18, 20 or 24 hours after the last dose of an agent used for mobilization of peripheral blood. In some embodiments, peripheral blood is mobilized by treating the subject from whom precursor cells are to be collected with two or more different types of agents described above or known in the art, such as a growth factor (e.g., G-CSF) and a chemokine receptor antagonist (e.g., CXCR4 receptor antagonist such as AMD3100), or a growth factor (e.g., G-CSF or KL) and an anti-integrin agent (e.g., function blocking VLA-4 antibody). In particular embodiments, different types of mobilizing agents are administered concurrently or sequentially. Methods of mobilization of peripheral blood are known in the art (see, e.g., Craddock et al., 1997, *Blood* 90(12):4779-4788; Jin et al., 2008, *Journal of Translational Medicine* 6:39; Pelus, 2008, *Curr. Opin. Hematol.* 15(4):285-292; Papayannopoulou et al., 1998, *Blood* 91(7):2231-2239; Tricot et al., 2008, *Haematologica* 93(11):1739-1742; Weaver et al., 2001, *Bone Marrow Transplantation* 27(2):S23-S29).

[0116] Precursor cells from bone marrow can be obtained, e.g., directly from bone marrow from the posterior iliac crest by needle aspiration (see, e.g., Kodo et al., 1984, *J. Clin Invest.* 73:1377-1384), or from the blood following pre-treatment with cytokines (such as G-CSF) that induce cells to be released from the bone marrow compartment. Precursor cells from peripheral blood can be collected from the blood through a syringe or catheter inserted into a subject's vein. For

example, the peripheral blood can be collected using an apheresis machine. Blood flows from the vein through the catheter into an apheresis machine, which separates the precursor cells from the rest of the blood and then returns the blood to the subject's body. Apheresis can be performed for several days (e.g., 1 to 5 days) until enough precursor cells have been collected.

[0117] Once precursor cells are isolated or collected, the blood can be processed to produce an enriched precursor cells population. Enriched precursor cells produced from umbilical CB or placental blood can form a population of CB stem cells. Preferably, the enriched precursor cells are enriched in CD34⁺ HSC (and, thus, T cell depleted). Enrichment thus can refer to a process wherein the percentage of HSC in the sample is increased (relative to the percentage in the sample before the enrichment procedure). Purification is one example of enrichment. In certain embodiments, the increase in the number of CD34⁺ cells (or other suitable antigen-positive cells) as a percentage of cells in the enriched sample, relative to the sample prior to the enrichment procedure, is at least 25-, 50-, 75-, 100-, 150-, 200, 250-, 300-, 350-fold, and preferably is 100-200 fold. In a preferred embodiment, the CD34⁺ cells are enriched using a monoclonal antibody to CD34, which antibody is conjugated to a magnetic bead, and a magnetic cell separation device to separate out the CD34⁺ cells. In some embodiments, using anti-CD34 antibodies, HSC are enriched from 1-2% of a normal bone marrow cell population to approximately 50-80% of the population, as described in sec. 5.4.1.1 of U.S. Patent No. 7,399,633.

[0118] Any technique known in the art for cell separation/selection can be used to carry out enrichment for a cell type such as HSC. For example, methods which rely on differential expression of cell surface markers can be used.

[0119] Procedures for separation may include magnetic separation, using antibody-coated magnetic beads; fluorescence activated cell sorting (FACS); affinity chromatography; cytotoxic agents joined to a monoclonal antibody or used in conjunction with a monoclonal antibody, e.g., complement and cytotoxins; and "panning" with antibody attached to a solid matrix, e.g., plate, or other convenient technique. Techniques providing accurate separation/selection include fluorescence activated cell sorters, which can have varying degrees of sophistication, e.g., a plurality of color channels, low angle and obtuse light scattering detecting channels, impedance channels, etc.

[0120] Antibodies may be conjugated with markers, such as magnetic beads, which allow for direct separation, biotin, which can be removed with avidin or streptavidin bound to a support,

fluorochromes, which can be used with a fluorescence activated cell sorter, or the like, to allow for ease of separation of the particular cell type. Any technique may be employed which is not unduly detrimental to the viability of the remaining cells. In one embodiment, the enrichment of HSC is affected by contacting a precursor cell sample with a solid substrate (e.g., beads, flask, magnetic particles) to which antibodies are bound, and by removing any unbound cells, wherein the HSC can be found either in the cells bound to the solid substrate or in the unbound cells depending on the antibodies used.

[0121] In one embodiment of the present disclosure, a precursor cell sample (e.g., a fresh CB unit) is processed to select for, i.e., enrich for, CD34⁺ cells using anti-CD34 antibodies directly or indirectly conjugated to magnetic particles in connection with a magnetic cell separator, for example, the CliniMACS® Cell Separation System (Miltenyi Biotec, Bergisch Gladbach, Germany), which employs nano-sized super-paramagnetic particles composed of iron oxide and dextran coupled to specific monoclonal antibodies. The CliniMACS® Cell Separator is a closed sterile system, outfitted with a single-use disposable tubing set.

[0122] Similarly, CD133⁺ cells can be enriched using anti-CD133 antibodies. In a specific embodiment, CD34⁺CD90⁺ cells are enriched for. Similarly, cells expressing CD43, CD45RO, CD45RA, CD59, CD90, CD109, CD117, CD166, HLA DR, or a combination of the foregoing, can be enriched for using antibodies against the antigen.

[0123] In one embodiment, HSC express CD34 (CD34⁺) and lack CD38 expression (CD38⁻). In some embodiments, HSC are selected and/or enriched for CD34⁺CD38⁻ cells. In specific embodiments, HSC are CD34⁺ and CD3T⁺, CD38⁻, HLA DK and/or Thy-1^{lo}. In some embodiments, HSC are selected and/or enriched for CD34⁺ and CD33⁺, CD38⁻, HLA DK and/or Thy-1^{lo} cells. In particular embodiments, human HSC are CD45Ra⁻, CD19⁻ and/or c-kit⁺. In some embodiments, HSC are selected and/or enriched for CD45Ra⁻, CD19⁻ and/or c-kit⁺ cells. In one embodiment, HSC express vascular endothelial growth factor receptor 2 (VEGFR2). In some embodiments, HSC are selected and/or enriched for VEGFR2, which can be used as a marker for HSC.

[0124] HSC can also be enriched as described in sec. 5.4.1.1 of U.S. Patent No. 7,399,633. In particular, human HSC can be enriched by incubating a sample with antibodies that recognize one or more of glycophorin A, CD3, CD24, CD16, CD14, CD34, CD45Ra, CD36, CD56, CD2, CD19, CD20, CD66a and CD66b, and separating the antibody-bound cells from non-antibody

bound cells. In some of these embodiments, the non-antibody bound cell population would be enriched for HSC. In some embodiments My10 and HLA-DR are used to obtain enriched HSC. In some embodiments, T lymphocyte depletion is used to enrich for HSC, e.g., by pretreating cells with a monoclonal antibody that recognizes a T cell antigen plus complement. In one embodiment, glycophorin A antibody is used to select for or against erythrocytes. In other embodiments, antibodies against CD14, CD16, CD66a and CD66b are used to select for or against monocytes. In other embodiments, antibodies against CD24, CD3, CD19, CD20, CD56, CD2 are used to select for or against B and T lymphocytes and NK cells. In yet another embodiment, antibodies against CD45RA and CD36 are used to select for or against T-cells, B-cells, granulocytes, platelets, monocytes, differentiated erythroid precursors, and some committed mature progenitors. Markers of pre-B progenitor cells can be MHC class II antigens. CD21 is a marker of mature B cells. In specific embodiments, antibodies which can be used for enrichment of HSC include My-10 and 3C5 (which recognize CD34), or RFB-1 (which recognizes CD99 and identifies populations of BFU-E cells). Other antibodies against the above-mentioned hematopoietic antigens are disclosed in U.S. Pat. No. 5,877,299.

[0125] The above-mentioned antibodies can be used alone or in combination with procedures such as "panning" (Broxmeyer et al., 1984, J. Clin. Invest. 73:939-953) or fluorescence activated cell-sorting (FACS) (Williams et al., 1985, J. Immunol. 135:1004; Lu et al., 1986, Blood 68(1):126-133) to isolate the cells containing surface determinants recognized by these antibodies, as described in sec. 5.4.1.1 of U.S. Patent No. 7,399,633.

[0126] In a specific embodiment, the HSC (e.g., from umbilical CB and/or placental blood) sample are red cell depleted, and the number of CD34+ cells in the red cell depleted fraction is calculated. Preferably, the HSC (e.g. umbilical CB and/or placental blood) samples containing more than 3.5 million CD34+ cells are enriched by the enrichment methods described above. After HSC have been isolated according to the enrichment methods described above or other methods known in the art, the enriched HSC can be expanded in order to increase the number of HSC, e.g., CD34+ cells. In less preferred embodiments, the methods described herein can be applied without prior enrichment, or prior to enrichment.

[0127] In some embodiments, precursor cells that are subjected to expansion using the methods described herein are fresh, i.e., they have not been previously cryopreserved and thawed. In other embodiments, precursor cells that are subjected to expansion using the

methods described herein have been cryopreserved and thawed. The precursor cells can be derived, e.g., from peripheral blood (such as mobilized peripheral blood), bone marrow, umbilical CB, or placental blood.

5.7 Methods of Use

[0128] Methods disclosed herein include treating subjects (humans, veterinary animals (dogs, cats, reptiles, birds, etc.) livestock (horses, cattle, goats, pigs, chickens, etc.) and research animals (monkeys, rats, mice, fish, etc.) with precursor cells expanded as disclosed herein. Treating subjects includes delivering therapeutically effective amounts. Therapeutically effective amounts include those that provide effective amounts, prophylactic treatments and/or therapeutic treatments.

[0129] An "effective amount" is the amount of precursor cells necessary to result in a desired physiological change in the subject. Effective amounts are often administered for research purposes. In particular embodiments, an effective amount results in an increased number of SCID repopulating cells in an expanded sample determined by limiting-dilution analysis as shown by enhanced engraftment in NOD/SCID mice infused with the expanded sample, relative to that seen with the unexpanded sample, where the unexpanded sample and expanded sample are from different aliquots of the same sample, wherein the expanded sample but not the unexpanded sample is subjected to the expansion technique. Effective amounts can also be determined using animal models for long-term engrafting potential of HSC such as the SCID-hu bone model (Kyoizumi et al. (1992) *Blood* 79:1704; Murray et al. (1995) *Blood* 85(2) 368-378) and the in utero sheep model (Zanjani et al. (1992) *J. Clin. Invest.* 89:1179)). For a review of animal models of human hematopoiesis, see Srour et al. (1992) *J. Hematother.* 1:143-153 and the references cited therein. Effective amounts can also be assessed in vitro models such as the long-term culture-initiating cell (LTCIC) assay, based on a limiting dilution analysis of the number of clonogenic cells produced in a stromal co-culture after 5 to 8 weeks (Sutherland et al. (1990) *Proc. Nat'l Acad. Sci.* 87:3584-3588). The LTCIC assay has been shown to correlate with another commonly used stem cell assay, the cobblestone area forming cell (CAFC) assay, and with long-term engrafting potential in vivo (Breems et al. (1994) *Leukemia* 8:1095).

[0130] A "prophylactic treatment" includes a treatment administered to a subject who does not display signs or symptoms of a deficient cell population or displays only early signs or symptoms of a deficient cell population such that treatment is administered for the purpose of

diminishing, preventing, or decreasing the risk of developing the deficient cell population further. Thus, a prophylactic treatment functions as a preventative treatment against a deficient cell population.

[0131] A "therapeutic treatment" includes a treatment administered to a subject who displays symptoms or signs of a deficient cell population and is administered to the subject for the purpose of diminishing or eliminating those signs or symptoms of the deficient cell population. The therapeutic treatment can reduce, control, or eliminate the presence of the deficient cell population.

[0132] For administration, therapeutically effective amounts (also referred to herein as doses) can be initially estimated based on results from in vitro assays and/or animal model studies. The actual dose amount administered to a particular subject can be determined by a physician, veterinarian or researcher taking into account parameters such as physical and physiological factors including target, body weight, severity of cell deficiency, previous or concurrent therapeutic interventions, idiopathy of the subject and route of administration.

[0133] Therapeutically effective amounts can include as few as several hundred cells (or fewer) to as many as several million or more. In specific embodiments, therapeutically effective amounts range from 10^3 to 10^8 cells per 100 kg. In additional embodiments, and in human subjects, therapeutically effective amounts can include between 10^3 to 10^8 cells per 100 kg per infusion; 10^4 to 10^9 cells per 100 kg per infusion; or 10^5 and 10^{13} cells per 100 kg per infusion. In another embodiment, therapeutically effective amounts can include 1×10^8 to 5×10^{12} cells per 100 kg per infusion. In another embodiment, therapeutically effective amounts can include between 1×10^9 and 5×10^{11} cells per 100 kg person per infusion. For example, dosages such as 4×10^9 cells per 100 kg and 2×10^{11} cells can be infused per 100 kg.

[0134] In some embodiments, a single administration of precursor cells are provided. In other embodiments, multiple administrations are used. Multiple administrations can be provided over periodic time periods such as an initial treatment regime of 3 to 7 consecutive days, and then repeated at other times.

[0135] Methods of introduction include but are not limited to intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, and epidural routes. The precursor cells may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (e.g., oral mucosa, rectal and intestinal

mucosa, etc.) and may be administered together with other biologically active agents. Intravenous administration also affords ease, convenience and comfort at higher levels than other modes of administration. In certain applications, systemic administration by intravenous infusion is more effective overall. In another embodiment, the precursor cells are administered to an individual by infusion into the superior mesenteric artery or celiac artery. The precursor cells may also be delivered locally by irrigation down the recipient's airway or by direct injection into the mucosa of the intestine.

[0136] The expanded precursor cells can be used for a variety of applications. In one embodiment, the precursor cells are used for transplantation, sometimes referred to as cell-based therapies or cell replacement therapies, such as bone marrow transplants, gene therapies, tissue engineering, and in vitro organogenesis. As one example, hematopoietic progenitor cell expansion for bone marrow transplantation is a potential application of human bone marrow cultures. Human autologous and allogeneic bone marrow transplantation are currently used as therapies for diseases such as leukemia, lymphoma, and other life-threatening diseases. For these procedures, however, a large amount of donor bone marrow must be removed to ensure that there are enough cells for engraftment. The methods of the present disclosure circumvent this problem. Methods of transplantation are known to those skilled in the art.

[0137] Several terms are used herein with respect to transplantation therapies, also known as cell-based therapies or cell replacement therapy. The terms autologous transfer, autologous transplantation, autograft and the like refer to treatments wherein the cell donor is also the recipient of the cell replacement therapy. The terms allogeneic transfer, allogeneic transplantation, allograft and the like refer to treatments wherein the cell donor is of the same species as the recipient of the cell replacement therapy, but is not the same individual. A cell transfer in which the donor's cells have been histocompatibly matched with a recipient is sometimes referred to as a syngeneic transfer. The terms xenogeneic transfer, xenogeneic transplantation, xenograft and the like refer to treatments wherein the cell donor is of a different species than the recipient of the cell replacement therapy.

[0138] Transplantation of precursor cells may be useful in the treatment of hematopoietic disorders and diseases. In one embodiment, the precursor cells are used to treat or prevent a hematopoietic disorder or disease characterized by a failure or dysfunction of normal blood cell production and maturation cell. In another embodiment, the precursor cells are used to treat or

prevent a hematopoietic disorder or disease resulting from a hematopoietic malignancy. In yet another embodiment, the precursor cells are used to treat or prevent a hematopoietic disorder or disease resulting from immunosuppression, particularly immunosuppression in subjects with malignant, solid tumors. In yet another embodiment, the precursor cells are used to treat or prevent an autoimmune disease affecting the hematopoietic system. In yet another embodiment, the precursor cells are used to treat or prevent a genetic or congenital hematopoietic disorder or disease.

[0139] Additional examples of particular hematopoietic diseases and disorders which can be treated by precursor cells expanded by the methods disclosed herein include: (i) diseases resulting from a failure or dysfunction of normal blood cell production and maturation (e.g., hyperproliferative stem cell disorders; aplastic anemia; pancytopenia; agranulocytosis; thrombocytopenia; red cell aplasia; Blackfan-Diamond syndrome due to drugs, radiation, or infection idiopathic); (ii) Hematopoietic malignancies (e.g., acute lymphoblastic (lymphocytic) leukemia; chronic lymphocytic leukemia; acute myelogenous leukemia; chronic myelogenous leukemia; acute malignant myelosclerosis; multiple myeloma; polycythemia vera; agnogenic myelometaplasia; Waldenstrom's macroglobulinemia; Hodgkin's lymphoma; non-Hodgkin's lymphoma); (iii) immunosuppression in patients with malignant, solid tumors (e.g., malignant melanoma; carcinoma of the stomach; ovarian carcinoma; breast carcinoma; small cell lung carcinoma; retinoblastoma; testicular carcinoma; glioblastoma; rhabdomyosarcoma; neuroblastoma; Ewing's sarcoma; lymphoma); (iv) autoimmune diseases (e.g., rheumatoid arthritis; diabetes type I; chronic hepatitis; multiple sclerosis; systemic lupus erythematosus); (v) genetic (congenital) disorders (e.g., anemias; familial aplastic; Fanconi's syndrome; Bloom's syndrome; pure red cell aplasia (PRCA); dyskeratosis congenital; Blackfan-Diamond syndrome; congenital dyserythropoietic syndromes I-IV; Chwachmann-Diamond syndrome; dihydrofolate reductase deficiencies; formamino transferase deficiency; Lesch-Nyhan syndrome; congenital spherocytosis; congenital elliptocytosis; congenital stomatocytosis; congenital Rh null disease; paroxysmal nocturnal hemoglobinuria; G6PD (glucose-6-phosphate dehydrogenase) variants 1, 2, 3; pyruvate kinase deficiency; congenital erythropoietin sensitivity deficiency; sickle cell disease and trait; thalassemia alpha, beta, gamma; met-hemoglobinemia; congenital disorders of immunity; severe combined immunodeficiency disease (SCID); bare lymphocyte syndrome; ionophore-responsive combined immunodeficiency; combined immunodeficiency with a capping

abnormality; nucleoside phosphorylase deficiency; granulocyte actin deficiency; infantile agranulocytosis; Gaucher's disease; adenosine deaminase deficiency; Kostmann's syndrome; reticular dysgenesis; congenital leukocyte dysfunction syndromes); (vi) others (e.g., osteopetrosis; myelosclerosis; acquired hemolytic anemias; acquired immunodeficiencies; infectious disorders causing primary or secondary immunodeficiencies bacterial infections (e.g., Brucellosis, Listerosis, tuberculosis, leprosy); parasitic infections (e.g., malaria, Leishmaniasis); fungal infections; disorders involving disproportions in lymphoid cell sets and impaired immune functions due to aging; phagocyte disorders; Kostmann's agranulocytosis; chronic granulomatous disease; Chediak-Higachi syndrome; neutrophil actin deficiency; neutrophil membrane GP-180 deficiency; metabolic storage diseases; mucopolysaccharidoses; mucopolipidoses; miscellaneous disorders involving immune mechanisms; Wiskott-Aldrich Syndrome; α 1-antitrypsin deficiency).

[0140] Expanded precursor cells are also useful as a source of cells for specific hematopoietic lineages. The maturation, proliferation and differentiation of expanded hematopoietic cells into one or more selected lineages may be effected through culturing the cells with appropriate factors including, but not limited to, erythropoietin (EPO), colony stimulating factors, e.g., GM-CSF, G-CSF, or M-CSF, SCF, interleukins, e.g., IL-1, -2, -3, -4, -5, -6, -7, -8, -13, etc., or with stromal cells or other cells which secrete factors responsible for stem cell regeneration, commitment, and differentiation. As is understood by one of ordinary skill in the art, differentiated precursor cells may be used in accordance with the methods of use described herein.

[0141] The disclosure includes formulating expanded precursor cells for administration to a subject as a pharmaceutical composition comprising a therapeutically effective amount of the precursor cells. In one embodiment, the precursor cells are substantially purified. Formulation of pharmaceutical compositions is well known in the art. In particular embodiments, pharmaceutical compositions can include pharmaceutically acceptable carrier or excipients such as saline, buffered saline, dextrose, water, glycerol, ethanol, and combinations thereof. Pharmaceutical compositions can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. The pharmaceutical composition can be a liquid solution, suspension, or emulsion. In particular embodiments, pharmaceutical compositions can also include a solubilizing agent and/or a local anesthetic such as lignocaine to ease pain at a site of the

injection.

6. EXEMPLARY EMBODIMENTS

1. A method for expanding precursor cells comprising culturing the precursor cells in the presence of a media comprising an immobilized LILRB2 agonist with a molecular weight of at least 225 kD wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an immobilized LILRB2 agonist with a molecular weight of at least 225 kD stop proliferating and/or die.
2. A method of embodiment 1 wherein the LILRB2 agonist has a molecular weight of at least 250 kD
3. A method of embodiment 1 or 2 wherein the LILRB2 agonist is multimerized.
4. A method of embodiments 1, 2 or 3 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.
5. A method of embodiment 4 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.
6. A method of embodiment 4 or 5 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.
7. A method of embodiment 1 wherein the LILRB2 agonist is an LILRB2 receptor antibody.
8. A method of embodiment 7 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.
9. A method of any one of embodiments 1 - 8 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.
10. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.
11. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.
12. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.
13. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.

14. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.
15. A method of any of embodiments 1 - 8 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.
16. A method of any of embodiments 1 - 15 wherein the media is serum free.
17. A method of any of embodiments 1 - 16 wherein the media comprises 1-100 µg/ml immobilized LILRB2 agonist.
18. A method of embodiment 17 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.
19. A method of embodiment 17 or 18 wherein the media further comprises SCF; TPO and Flt3-ligand.
20. A method of embodiment 17 or 18 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF; 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO and 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand.
21. A method of embodiment 20 wherein the media comprises 10 ng/ml SCF.
22. A method of embodiment 20 wherein the media comprises 5 ng/ml TPO.
23. A method of embodiment 20 wherein the media comprises 10 ng/ml Flt3-ligand.
24. A method of embodiment 20 wherein the media comprises growth factors: 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
25. A method of any one of embodiments 1 - 25 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
26. A method of any one of embodiments 1 - 25 wherein the precursor cells are hematopoietic stem cells.
27. A method of any one of embodiments 1 - 25 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
28. A method of any one of embodiments 1 - 25 wherein the precursor cells are obtained from fetal or neonatal blood.
29. A method for expanding precursor cells comprising culturing the precursor cells in the

presence of a media comprising an LILRB2 agonist and a Notch agonist wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an LILRB2 agonist and a Notch agonist stop proliferating and/or die.

30. A method of embodiment 29 wherein the LILRB2 agonist is immobilized in the culture media.

31. A method of embodiment 29 or 30 wherein the Notch agonist is immobilized in the culture media.

32. A method of embodiment 29, 30 or 31 wherein the LILRB2 agonist has a molecular weight of at least 225 kD or at least 250 kD.

33. A method of any one of embodiments 29 - 32 wherein the LILRB2 agonist is multimerized.

34. A method of any one of embodiments 29 - 33 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.

35. A method of embodiment 34 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.

36. A method of embodiment 34 or 35 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.

37. A method of any one of embodiments 29 - 33 wherein the LILRB2 agonist is an LILRB2 receptor antibody.

38. A method of embodiment 37 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

39. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.

40. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

41. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.

42. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.

43. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.
44. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.
45. A method of any one of embodiments 29 - 38 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.
46. A method of any one of embodiments 29 - 45 wherein the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein.
47. A method of any one of embodiments 29 - 45 wherein the Notch agonist is Delta^{ext-IgG}.
48. A method of any one of embodiments 29 - 45 wherein the Notch agonist is in dimeric form.
49. A method of any one of embodiments 29 - 49 wherein the media is serum free.
50. A method of any one of embodiments 29 - 50 wherein the media comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml immobilized LILRB2 agonist.
51. A method of embodiment 50 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.
52. A method of embodiment 50 wherein the media comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.08 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml immobilized LILRB2 agonist.
53. A method of any one of embodiments 29 - 52 wherein the media comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml Notch agonist.
54. A method of embodiment 53 wherein the media comprises 0.5 to 2.5 µg/ml Notch agonist.
55. A method of any one of embodiments 29 - 52 wherein the media further comprises SCF; TPO and Flt3-ligand.
56. A method of embodiment 55 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF; 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO and 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand.

57. A method of embodiment 56 wherein the media comprises 10 ng/ml SCF.
58. A method of embodiment 56 wherein the media comprises 5 ng/ml TPO.
59. A method of embodiment 56 wherein the media comprises 10 ng/ml Flt3-ligand.
60. A method of embodiment 56 wherein the media comprises 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
61. A method of any one of embodiments 29 - 52 wherein the media further comprises SCF, Flt3-ligand, IL-6, TPO, FGF1 and IL-3.
62. A method of embodiment 61 wherein the media comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3 and heparin.
63. A method of embodiment 61 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml IL-6, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml FGF1 and 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml IL-3.
64. A method of embodiment 63 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml heparin.
65. A method of embodiment 61 wherein the media further comprises 50 ng/ml SCF, 50 ng/ml Flt3-ligand, 50 ng/ml IL-6, 50 ng/ml TPO, 20 ng/ml FGF1 and 10 ng/ml IL-3.
66. A method of embodiment 65 wherein the media further comprises 10 µg/ml heparin.
67. A method of any one of embodiments 29 - 66 wherein the media further comprises retronectin.
68. A method of embodiment 67 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml retronectin.
69. A method of embodiment 68 wherein the media further comprises 5 µg/ml retronectin.

70. A method of any one of embodiments 29-69 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
71. A method of any one of embodiments 29-69 wherein the precursor cells are hematopoietic stem cells.
72. A method of any one of embodiments 29-69 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
73. A method any one of embodiments 29-69 wherein the precursor cells are obtained from fetal or neonatal blood.
74. A method for producing precursor cells for hematopoietic transplantation comprising culturing the precursor cells in the presence of a media comprising an immobilized LILRB2 agonist with a molecular weight of at least 225 kD wherein the culturing is effective to produce precursor cells suitable able to treat a subject when formulated for administration and administered in an effective amount.
75. A method of embodiment 74 wherein the LILRB2 agonist has a molecular weight of at least 250 kD
76. A method of embodiment 74 or 75 wherein the LILRB2 agonist is multimerized.
77. A method of embodiment 74, 75 or 76 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.
78. A method of embodiment 77 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.
79. A method of embodiment 77 or 78 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.
80. A method of embodiment 74 wherein the LILRB2 agonist is an LILRB2 receptor antibody.
81. A method of embodiment 80 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.
82. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.
83. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

84. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.
85. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.
86. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.
87. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.
88. A method of any one of embodiments 74-81 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.
89. A method of any one of embodiments 74-88 wherein the media is serum free.
90. A method of any one of embodiments 74-89 wherein the media comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml immobilized LILRB2 agonist.
91. A method of embodiment 90 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.
92. A method of embodiment any one of embodiments 74-91 wherein the media further comprises SCF; TPO and Flt3-ligand.
93. A method of embodiment 92 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF; 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO and 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand.
94. A method of embodiment 93 wherein the media comprises 10 ng/ml SCF.
95. A method of embodiment 93 wherein the media comprises 5 ng/ml TPO.
96. A method of embodiment 93 wherein the media comprises 10 ng/ml Flt3-ligand.
97. A method of embodiment 93 wherein the media comprises 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
98. A method of any one of embodiments 74-97 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.

99. A method of any one of embodiments 74-97 wherein the precursor cells are hematopoietic stem cells.
100. A method of any one of embodiments 74-97 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
101. A method of any one of embodiments 74-97 wherein the precursor cells are obtained from fetal or neonatal blood.
102. A method for expanding precursor cells comprising culturing the precursor cells in the presence of a media comprising an LILRB2 agonist and a Notch agonist wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an LILRB2 agonist and a Notch agonist stop proliferating and/or die.
103. A method of embodiment 102 wherein the LILRB2 agonist is immobilized in the culture media.
104. A method of embodiment 102 or 103 wherein the Notch agonist is immobilized in the culture media.
105. A method of embodiment 102, 103 or 104 wherein the LILRB2 agonist has a molecular weight of at least 225 kD or at least 250 kD.
106. A method of any one of embodiments 102-105 wherein the LILRB2 agonist is multimerized.
107. A method of any one of embodiments 102-106 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.
108. A method of any one of embodiments 102-107 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.
109. A method of any one of embodiments 102-108 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.
110. A method of any one of embodiments 102-106 wherein the LILRB2 agonist is an LILRB2 receptor antibody.
111. A method of embodiment 110 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

112. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.
113. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.
114. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.
115. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.
116. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.
117. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.
118. A method of any one of embodiments 102-111 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.
119. A method of any one of embodiments 102-118 wherein the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein.
120. A method of any one of embodiments 102-118 wherein the Notch agonist is Delta^{ext-IgG}.
121. A method of any one of embodiments 102-118 wherein the Notch agonist is in dimeric form.
122. A method of any one of embodiments 102-121 wherein the media is serum free.
123. A method of any one of embodiments 102-122 wherein the media comprises 0.025-100 µg/ml immobilized LILRB2 agonist.
124. A method of embodiment 123 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.
125. A method of embodiment any one of embodiments 102-124 wherein the media comprises 0.08 to 25 µg/ml immobilized LILRB2 agonist.
126. A method of any one of embodiments 102-125 wherein the media comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml Notch agonist.
127. A method of embodiment 126 wherein the media comprises 0.5 to 2.5 µg/ml Notch agonist.

128. A method of any one of embodiments 102-127 wherein the media further comprises SCF; TPO and Flt3-ligand.
129. A method of embodiment 128 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF; 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO and 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand.
130. A method of embodiment 129 wherein the media comprises 10 ng/ml SCF.
131. A method of embodiment 129 wherein the media comprises 5 ng/ml TPO.
132. A method of embodiment 129 wherein the media comprises 10 ng/ml Flt3-ligand.
133. A method of embodiment 129 wherein the media comprises: 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
134. A method of any one of embodiments 102-127 wherein the media further comprises SCF, Flt3-ligand, IL-6, TPO, FGF1 and IL-3.
135. A method of embodiment 134 wherein the media comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3 and heparin.
136. A method of any one of embodiments 102-127 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml SCF, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml Flt3-ligand, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml IL-6, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml TPO, 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 ng/ml FGF1 and 1-100 ng/ml IL-3.
137. A method of embodiment 136 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml heparin.
138. A method of embodiment 136 or 137 wherein the media further comprises 50 ng/ml SCF, 50 ng/ml Flt3-ligand, 50 ng/ml IL-6, 50 ng/ml TPO, 20 ng/ml FGF1 and 10 ng/ml IL-3.

139. A method of embodiment 138 wherein the media further comprises 10 µg/ml heparin.
140. A method of any one of embodiments 102-139 wherein the media further comprises retronectin.
141. A method of embodiment 140 wherein the media further comprises 0.025, 0.050, 0.075, 0.01, 0.05, 0.1, 0.5, 0.75, 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100 µg/ml retronectin.
142. A method of embodiment 141 wherein the media further comprises 5 µg/ml retronectin.
143. A method of any one of embodiments 102-142 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
144. A method of any one of embodiments 102-142 wherein the precursor cells are hematopoietic stem cells.
145. A method of any one of embodiments 102-142 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
146. A method of any one of embodiments 102-142 wherein the precursor cells are obtained from fetal or neonatal blood.
147. A chimeric receptor reporter system comprising cells expressing a fusion protein comprising at least one extracellular domain of LILRB2 and transmembrane and cytoplasmic domains of PILRβ wherein binding of an activating ligand to the extracellular domain of LILRB2 results in reporter gene expression.
148. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 is the Ig1 domain, the Ig2 domain, the Ig3 domain and/or the Ig4 domain.
149. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 is the Ig1 domain.
150. A chimeric receptor reporter system of embodiment 147 wherein the Ig1 domain includes amino acids 24-119 of LILB2.
151. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 is the Ig2 domain.
152. A chimeric receptor reporter system of embodiment 147 wherein the Ig2 domain includes amino acids 120-219 of LILB2.
153. A chimeric receptor reporter system of embodiment 147 wherein the at least one

extracellular domain of LILRB2 is the Ig3 domain.

154. A chimeric receptor reporter system of embodiment 147 wherein the Ig3 domain includes amino acids 221-320 of LILRB2.

155. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 is the Ig4 domain.

156. A chimeric receptor reporter system of embodiment 147 wherein the Ig4 domain includes amino acids 321-458 of LILRB2.

157. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 includes the Ig1 domain and the Ig2 domain.

158. A chimeric receptor reporter system of embodiment 147 wherein the Ig1 domain and the Ig2 domain includes amino acids 24-219 of LILRB2.

159. A chimeric receptor reporter system of embodiment 147 wherein the at least one extracellular domain of LILRB2 includes the Ig3 domain and the Ig4 domain.

160. A chimeric receptor reporter system of embodiment 147 wherein the Ig3 domain and the Ig4 domain includes amino acids 221-458 of LILRB2.

161. A chimeric receptor reporter system of embodiment 147 wherein the fusion protein includes amino acids 24-458 of LILRB2.

162. A chimeric receptor reporter system of any one of embodiments 147-161 wherein the cells are T cell hybridoma cells.

163. A chimeric receptor reporter system of embodiment 162 wherein reporter gene expression results from NFAT activation.

164. A chimeric receptor reporter system of embodiment 162 or 163 wherein reporter gene expression is under the control of a NFAT-responsive promoter.

165. A method of any one of embodiments 1 - 25 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

166. A method of any one of embodiments 29-69 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

167. A method of any one of embodiments 74-97 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced

pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

168. A method of any one of embodiments 102-142 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

[0142] The Examples below are included to demonstrate particular embodiments of the disclosure. Those of ordinary skill in the art should recognize in light of the present disclosure that many changes can be made to the specific embodiments disclosed herein and still obtain a like or similar result without departing from the spirit and scope of the disclosure.

7. EXAMPLES

7.1 Example 1

[0143] A better understanding of the interaction between extrinsic factors and surface receptors on HSC will greatly benefit stem cell research and applications. Recently it was shown that several Angptls bind and activate the immune inhibitory receptor LILRB2 to support ex vivo expansion of HSC. However, the molecular basis for the interaction between Angptls and LILRB2 was unclear. Example 1 demonstrates that Angptl2 expressed in mammalian cells forms high molecular weight (HMW) species, and ligand multimerization is required for activation of LILRB2 for downstream signaling. A novel motif in the first and fourth Ig domains of LILRB2 was identified that is necessary for the receptor to be bound and activated by Angptl2. The binding of Angptl2 to LILRB2 is more potent than and not completely overlapped with the binding of another ligand HLA-G. Immobilized anti-LILRB2 antibodies induce a more potent activation of LILRB2 than Angptl2. Example 1 describes a serum-free culture containing defined cytokines and immobilized anti-LILRB2 that supports a net expansion of repopulating human CB HSCs. The elucidation of the mode of Angptl binding to LILRB2 enabled the development of this new approach for ex vivo expansion of human HSCs.

7.1.1. Example 1 - Methods

[0144] Chimeric receptor reporter cells. The chimeric receptors including individual or all Ig-domains or their mutants of the extracellular domain of LILRB2 and the transmembrane and cytoplasmic domains of activating PILR β were infected into mouse T cell hybridoma cells carrying NFAT-GFP reporter gene and DAP12 by using a retrovirus vector. Amino acid 24-458 of hLILRB2 was used to construct the full-length LILRB2 chimeric reporter. The amino acid

sequences for the individual Ig domains or Ig combinations are: Ig1 (aa 24-119), Ig2 (aa 120-219), Ig3 (aa 221-320), Ig4 (aa 321-458), Ig1+2 (aa 24-219), and Ig3+4 (aa 221-458). These chimeric LILRB2-PILR β receptor reporter cells (5×10^4 /well) were incubated with ligands for indicated time, and GFP was analyzed by flow cytometry. Purified Angptl2-FLAG by M2 resin or Angptl2 in conditioned medium collected from transfected 293T cells were used as indicated. For experiments using coated wells, indicated bacterially-expressed GST-Angptl2, anti-LILRB2 polyclonal antibody (pAb, #BAF2078, R&D systems), or anti-LILRB2 monoclonal antibody (mAb, #16-5149-85, eBioscience) or control antibody was pre-coated on 96 well-plates for 3 hrs in 37°C unless otherwise indicated. When antibodies were cross-linked, 10 μ g/ml pAb was incubated with 10 μ g/ml streptavidin at 4 °C overnight.

[0145] Mice. NOD/SCID IL2R gamma $^{-/-}$ (NSG) mice were purchased and maintained at the University of Texas Southwestern Medical Center animal facilities. All animal experiments were performed with the approval of UT Southwestern Committee on Animal Care.

[0146] Plasmids and proteins. Wild-type or mutant LILRB2s were constructed into pLVX-IRES-ZsGreen (Clontech). Plasmid CMV-Kozak-human Angptl2 encoding Angptl2 or HLA-G extracellular domain (ECD) with a FLAG tag at the C-terminus was transfected into 293T cells using Lipofectamine 2000, and the conditioned medium at 48 h was collected. Angptl2-FLAG was purified using M2 resin. Bacterially-expressed GST-Angptls-FLAG was constructed in pGEX vector, and expressed and purified from bacteria. Concentrations of Angptl proteins were adjusted to the same level for flow cytometry-based binding experiments. Purified recombinant HLA-G was purchased from Origene (#TP305216).

[0147] SDS-PAGE and native polyacrylamide gel electrophoresis (PAGE). For reduced SDS-PAGE, samples were mixed with 4 $\times$ loading buffer with β mercaptoethanol (BME) and loaded on 10% SDS gels. For non-reduced SDS-PAGE, samples were mixed with 4 $\times$ loading buffer without BME and loaded on 10% SDS gels. For native PAGE, the PAGE gel did not contain SDS. Samples were mixed with 4 $\times$ loading buffer without BME.

[0148] Fast protein liquid chromatography (FPLC). Purified GST-Angptl2 expressed from bacteria was loaded onto a 16/60 Superdex 200 gel filtration column and eluted with PBS and 2mM EDTA. Fractions (0.6 ml) were collected, and the amount of Angptl2 in each fraction was analyzed by western blot analysis.

[0149] Human cell culture. Fresh and cryopreserved human CB cells were purchased from

AllCells. All of the cells were from pooled donors. Purities of CD34⁺ or CD133⁺ cells as analyzed by flow cytometry were higher than 90%. After thawing, the cell viability tested by trypan blue exclusion was higher than 72%. The thawed cells were centrifuged and resuspended in StemSpan medium before being aliquoted for immediate transplantation or culture. StemSpan supplemented with 50 ng/ml human SCF, 10 ng/ml human TPO, and 50 ng/ml human Flt3-L with soluble or immobilized anti-LILRB2 monoclonal antibody (#165149-85, eBioscience) or polyclonal antibody (#BAF2078, R&D Systems) was used as culture medium. Fresh human CB CD34⁺ cells or cryopreserved CD133⁺ cells as indicated were plated at 5×10^3 cells/well in one well of a U-bottom 96-well plate (3799; Corning) with 200 μ l of the indicated medium for 2 days. On day 3, cells were pooled from individual wells and transferred to 6-well plates at 5×10^4 cells/ml. Fresh medium was added at days 4 and 7 to keep the cell density at 2×10^5 cells/ml (day 4) or 7×10^5 cells/ml (day 7). Cells were cultured at 37°C in 5% CO₂ and normal O₂ or 5% O₂ (low O₂) levels. For transplantation, cells from all the culture wells were pooled before the indicated numbers of cells were transplanted into each mouse.

[0150] NSG transplant. Uncultured or cultured progenies of human CB CD133⁺ or CD34⁺ cells at indicated days were pooled together and the indicated portions were injected intravenously via the retro-orbital route into sub-lethally irradiated (250 rad) 8-10 week old NSG mice. Eight weeks or as indicated after transplantation, bone marrow nucleated cells from transplanted animals were analyzed by flow cytometry for the presence of human cells. For secondary transplantations, bone marrow aspirates from one hind leg of a primary recipient were used to transplant two secondary recipients as described in Bryder et al., *Am J Pathol.* 2006; 169:338-346. Calculation of long-term repopulating cells (competitive repopulating unit, CRU) in limiting dilution experiments was conducted using L-Calc software (StemCell Technologies). See, for example, Brunstein and Wagner, *Annu Rev Med.* 2006;57:403-417; Chou et al., *Cell Stem Cell.* 2010;7:427-428; and Delaney et al., *Nat Med.* 2010;16:232-236.

[0151] For limiting dilution analysis, mice were considered to be positive for human HSC engraftment when at least 1% (for primary transplantation) or 0.1% (for secondary transplantation) CD45/71⁺ human cells were detected among the mouse bone marrow cells, unless otherwise indicated.

[0152] Flow cytometry. To measure Angptl2/LILRB2 binding, plasmids for expression of LILRB2 or mutants driven from a CMV promoter were transfected into 293T cells. Cells were

harvested at 48 h for analysis. Alternatively, mononuclear human CB cells were incubated with Fc block and equal amounts of FLAG-tagged Angptl2 at 4°C for 60 min, followed by staining with anti-Flag-APC and propidium iodide. Anti-LILRB2-PE was used as indicated. Cells were analyzed using either a FACSCalibur or FACS Aria instrument (Becton Dickinson).

[0153] Human hematopoietic engraftment in NSG mice was assessed following the protocol described in Himburg et al., Nat Med. 2010;16:475-482. Briefly, bone marrow cells from recipient NSG mice were stained with antihuman CD45-PE, CD71-PE, CD15-FITC, and CD66b-FITC to quantify the total human hematopoietic (CD45/71+) cell population as well as the subset of exclusively granulopoietic (CD15/66b+) cells within this population. Cells were stained with antihuman CD34-FITC and anti-human CD19-PE and CD20-PE to quantify human progenitor (CD34+) and B-lineage (CD34-CD19/20+) populations. Anti-human CD3 was used to analyze human T-lineage reconstitution. Anti-human CD34-FITC and anti-human CD90-APC was used to quantitate CD34+ or CD34+CD90+ cells in culture. All antihuman antibodies were purchased from Becton Dickinson.

[0154] Retrovirus infection. The retroviral plasmids with PCL-ECO (2:1) were transfected using Lipofectamine 2000 (Invitrogen) into 293T cells. The resulting retroviral supernatant was collected 48-72 hours later and was used for infection. Target cells were resuspended in viral supernatants (1×10^5 cells/ml) with 4 µg/ml polybrene and centrifuged at 2000 rpm for 120 min before culturing for 24 hours in RPMI-1640 medium (Sigma) plus 10% FBS and 100 U/ml penicillin/streptomycin. Cells were then resuspended in viral supernatant for another round of infection.

[0155] Live cell immunofluorescence and confocal microscopy. The LILRB2 chimeric receptor reporter cells were treated with PBS or coated monoclonal anti-LILRB2 antibody for 6 hours at 37°C. These cells were washed by PBS twice and stained with rat anti-human LILRB2 antibody for 15 minutes at 4 °C. The cells were further stained with goat anti-rat Cy3 for 15 minutes at 4 °C and mounted on a slide for examination by a Zeiss LSM 710 confocal microscope. Each image was scanned in Z-series from top to bottom of cells.

7.1.2. Example 1 - Results

[0156] Multimerized Angptl2 activates LILRB2. Because there is no definitive downstream reporter for LILRB-mediated signaling, a stable reporter cell system was employed to test whether Angptl2 can bind to and activate LILRB2. In this chimeric receptor reporter system, the

extracellular domain (ECD) of LILRB2 is fused with transmembrane/intracellular domains of paired immunoglobulin-like receptor β (PILR β) that associates with the adaptor protein DAP12 containing ITAM. When the chimeric receptor is activated by Angptl2 binding to the ECD of LILRB2, ZAP70 or Syk kinase is recruited to the ITAM of the adaptor DAP12 and activates the nuclear factor of activated T cells (NFAT) to promote GFP expression driven by the NFAT responsive promoter (Fig. 1A). The establishment of this reporter was inspired by a LILRB1 reporter system (Arase et al., Science. 2002;296:1323-1326; Ohtsuka et al., Proc Natl Acad Sci U S A. 2004;101:8126-8131) and it serves as a surrogate and sensitive system to enable study of the signaling-induction abilities of different forms of Angptl2 (including soluble, immobilized, monomeric, and oligomeric) and to screen additional agonists and antagonists.

[0157] To test whether Angptl2 expressed in mammalian cells can activate signaling through LILRB2, LILRB2 reporter cells were incubated with conditioned medium collected from 293T cells transfected with a plasmid designed to express Angptl2 (2 μ g/ml) (schematic in Fig. 2). Conditioned medium from mock transfected 293T cells served as the control. After 24 h, Angptl2-treated LILRB2 reporter cells induced a significantly greater GFP expression than the control cells ($18.95 \pm 0.95\%$ versus $5.34 \pm 1.19\%$; Fig. 1B). The potential binding/activation of LILRB2 by the immobilized HLA-G was also measured using the same LILRB2 reporter cells. GFP activation was not detected by as much as 130 μ g/ml HLA-G (Fig. 3). This suggests that Angptl2 is capable of binding and activating LILRB2, with a significantly greater ability than HLAG. In parallel, the binding of Angptl2/LILRB2 to HLA-G-LILRB2 using flow cytometry analysis. To this end, a secretable HLA-G-ECD expression vector was constructed with the same signal peptide as Angptl2 expression vector (Fig. 2) and collected the same amount of soluble HLA-G-ECD and Angptl2 for binding to LILRB2 expressed on the surface of transiently transfected 293T cells. Similar to the result of the chimeric reporter system, Angptl2 binds to LILRB2 with a significantly greater affinity than HLAG (Fig. 1C).

[0158] In the described characterization of Angptl2 expressed in 293T cells, full-length (FL), coiled-coil domain (CC), and FBN-like domain of Angptl2 with or without β -mecaptoethanol (BME) treatment were compared. BME treatment reduces disulfide bonds that stabilize a HMW form of Angptl2. When analyzed by SDS-PAGE, full-length and CC domain preparations of Angptl2 ran partially or exclusively, respectively, as a HMW band (larger than 250 kD), whereas the FBN domain migrated as a 37 kD band, corresponding to the expected size of the FBN

monomer (Fig. 1D). The HMW species was likely in a multimerization state. Similarly, multimerized Angptl2 exists in mouse serum and plasma (Fig. 4).

[0159] A bacterial expression system enabled production and purification of a large amount of GST-tagged Angptl2 (Zheng et al. *Nature*. 2012;485:656-660). The monomer GST-Angptl2 was purified by size exclusion chromatography and the product was detected in native-PAGE and western blotting (Fig. 1E-G). Because the multimerized ligand can induce the clustering of surface receptor (Arase et al., *Science*. 2002;296:1323-1326; Ohtsuka et al., *Proc Natl Acad Sci U S A*. 2004;101:8126-8131) and immobilized ligand may also cluster the receptor, the abilities of the soluble and immobilized monomeric GST-Angptl2 to activate the LILRB2 reporter cells were compared. The monomeric GST-Angptl2 was immobilized on the wells of the tissue culture plate or added into the medium, and LILRB2 reporter cells were added. Only the immobilized monomeric form, and not the soluble monomer, induced GFP expression ($20 \pm 2.65\%$ versus $3.56 \pm 0.98\%$; Fig. 1H). Because the natively multimerized form of Angptl2 and the immobilized monomer Angptl2 activated LILRB2 but the soluble monomeric Angptl2 did not, it was concluded that Angptl2 must be multimerized to become an active ligand of LILRB2.

[0160] To further study whether a multimerized form of Angptl2 is needed to activate LILRB2, the effects of monoclonal and polyclonal anti-LILRB2 antibodies on the LILRB2 reporter cells were tested. Both soluble monoclonal and polyclonal anti-LILRB2 blocked the activation of LILRB2 by the immobilized Angptl2 (from 19.9% to 0.81 or 2.31%; Fig. 5A), supporting the idea that the binding between Angptl2 and LILRB2 is not as potent as that between anti-LILRB2 and LILRB2. Whereas neither the control antibody nor the soluble anti-LILRB2 stimulated GFP expression, both immobilized monoclonal and polyclonal anti-LILRB2 efficiently induced upregulation of GFP (from 3.88% to 33.7 or 87%; Fig. 5B). Moreover, cross-linking of biotin-conjugated anti-LILRB2 by streptavidin-

activated GFP expression (from 3.1% to 36.4%; Fig. 5C). Although anti-LILRB2 has a higher binding affinity for LILRB2 than does Angptl2, only immobilized but not soluble antibodies activated LILRB2. To determine if immobilized ligands induce receptor clustering, the LILRB2 localization on the cell surface with or without immobilized monoclonal anti-LILRB2 treatment was examined. Without treatment, the majority of LILRB2 chimeric reporter cells (81.2%) exhibited an even distribution of LILRB2-ECD on the cell membrane, with a "Ring"-like shape under confocal microscopy observation (Fig. 5D). By contrast, after treatment with immobilized

antibodies, the distribution of LILRB2-ECD was changed from the “Ring”-to the “Spot”-like shape in 97.8% signaling activated cells (indicated as GFP induced cells) (Fig. 5D). These results further support the conclusion that multimerized ligands induce the clustering of the receptor LILRB2 for signaling activation.

[0161] A motif in Ig domains of LILRB2 is critical for the effects of Angptl2 in binding and receptor activation. LILRB2 contains four extracellular immunoglobulin (Ig)-like domains. Takai et al., J Biomed Biotechnol. 2011;2011:275302. It was hypothesized that one or more of these Ig-domains bind to Angptl2. To test this hypothesis, a number of domain and site-specific mutations of LILRB2 were generated for the flow cytometry-based cell surface ligand binding assay and chimeric reporter assay. To start with, Angptl2 binding abilities of a number of domain mutations of LILRB2 were screened. Although individual Ig domains of LILRB2 do not bind to Angptl2, Ig1 and 2 in combination, and Ig3 and Ig4 in combination displayed about 50% and 10%, respectively, of the maximal binding between the full-length LILRB2 and Angptl2 (Fig. 6A-B, Fig. 7). This suggests that the major Angptl2 binding site resides in Ig1 and Ig2 of LILRB2 and that Ig3 and Ig4 facilitate binding of C-terminal domains of the protein.

[0162] Next a series of site-specific mutations in amino acids potentially critical to the binding of ligand to LILRB2 based on the structure of LILRB2 28 (PDB structure 2GY7) were designed. Based on the physical mapping data of LILRB2, both Ig1-Ig2 and Ig3-Ig4 combination can maintain its binding activity with Angptl2, which indicates that the single interface on each Ig domain is not essential for LILRB2 binding affinity. For this type of Ig structure, the binding interface is possibly located at flexible and variable loops rather than rigid and conserved beta-sheets. Based on the PDB structure of Ig1-Ig2 domain (PDBID: 2GW5 and 2DYP) and Ig3-Ig4 domain (PDBID: 4LLA), the possible interface on each Ig domain was designed (Fig. 8). Because the overall geometry of four Ig domains is highly flexible and each one of it is not essential, the point mutation on each Ig domain may not block the overall binding between LILRB2 and Angptl2. Therefore, some additional large and hydrophobic residues were identified for mutagenesis study (Fig. 8A-B). However, these mutant LILRB2 do not significantly decrease Angptl2 binding (Fig. 8C). These results suggest that Angptl2 may have somewhat different binding pockets in LILRB2 than HLA-G (see below for additional data).

[0163] The bioinformatical analysis and mutagenesis study results were combined to find that AA 92-100 in Ig1 is critical for Angptl2 binding. The Ig1+2 fragment with mutations in this

region (Mut-8 aa) did not bind to Angptl2, and Angptl2 binding of the full-length LILRB2 with the same mutation was decreased by more than 50% relative to the wild-type protein (Fig. 6C-D). Further experiments showed that single mutations in G94, R95, or Y96 each decreased the Angptl2 binding of full-length LILRB2 by half (Fig. 6E), indicating these three amino acids are essential for Angptl2 binding in Ig1. A similar motif, AA 390-396, exists in Ig4 (Fig. 6C). A single mutation in Y394 decreased Angptl2 binding of full-length LILRB2 by about 30% (Fig. 6E). Furthermore, when combined with Y96A, G392D or Y394A mutations totally abrogated the Angptl2 binding of full-length LILRB2 (Fig. 6E-F). Therefore, these results indicate that Ig2 helps Ig1 to form the major Angptl2 binding site, Ig4 further facilitates Ig1+2 binding, and the H*G*Y*C motifs in Ig1 and Ig4 are critical for LILRB2 to bind Angptl2.

[0164] To further investigate whether Angptl2, Angptl5, and HLA-G bind to the same regions in LILRB2, the bindings of these ligands to mutant LILRB2 were compared. HLA-G binds to a number of mutant LILRB2 including H92S, T93A, G94D, R95E, Q99R, G392D, T393E, and HLA-G binding site 1 (MHC-S1) (from the structures by Shiroishi et al., Proc Natl Acad Sci U S A. 2006;103:16412-16417; Shiroishi et al., Proc Natl Acad Sci U S A. 2003;100:8856-8861) with lower affinity than Angptl2. Angptl5 binds to mutant LILRB2 generally more similar to Angptl2 than to HLA-G (Fig. 6G, Fig. 2B). Together with the result in Fig. 8C, the data suggest that the binding of Angptl2 or HLA-G to LILRB2 is partially but not completely overlapped.

[0165] In addition to the flow cytometry-based binding analysis, the activation of various LILRB2 mutants treated with immobilized antibodies or Angptl2 in the chimeric reporter system was measured. It was found that only Ig1 and Ig2 domains in combination could bind and be activated by ligands (Fig. 6H). Moreover, a single mutation in Y96 led to a dramatic decrease of GFP induction, and the combined mutations of Y96A with either G392D or Y394A totally abrogated the GFP induction by immobilized Angptl2 (Fig. 6I). Therefore the results in using chimeric reporter system confirmed that the H*G*Y*C motifs in Ig1 and Ig4 are essential for LILRB2 to bind Angptl2. Furthermore, they suggest that the indicated motifs are critical for LILRB2 activation.

[0166] To identify the sites in Angptls that bind to LILRB2, the binding of full-length with CC and FBN domains of Angptl2 to LILRB2 was compared. The full-length protein, but not the CC or the FBN domain of Angptl2, bound to 293T cells that expressed LILRB2 21. The full-length protein and the CC domain (but not FBN domain) of Angptl2 bound to LILRB2+ human CB

mononuclear cells (Fig. 9). The full-length Angptl2, the FBN domain, and a high concentration of soluble CC domain were able to activate LILRB2 reporter cells (Fig. 10). It is speculated that the actual concentration of the CC domain coated on the plastic dish might be lower than that of the soluble CC domain, and therefore this immobilized CC domain was not sufficiently high to activate the LILRB2 chimeric reporter. These results suggest that both CC and FBN of Angptl2 are needed for optimal binding and activation of LILRB2.

[0167] Anti-LILRB2 antibodies support ex vivo expansion of human CB HSCs. Although numerous conditions have been used for expansion of HSCs in culture, the optimal mixture of growth factors and cytokines to allow expansion sufficient for clinical applicability has not yet been determined. See, for example, Chou et al., *Cell Stem Cell*. 2010;7:427-428; Delaney et al., *Nat Med*. 2010;16:232-236; Himburg et al., *Nat Med*. 2010;16:475-482; Zheng et al., *Cell Stem Cell*. 2011;9:119-130; Boitano et al., *Science*. 2010;329:1345-1348; Butler et al., *Cell Stem Cell*. 2010;6:251-264; North et al., *Nature*. 2007;447:1007-1011; Antonchuk et al., *Cell*. 2002;109:39-45; Dahlberg et al., 2011;117:6083-6090; Kirouac et al., *Curr Opin Biotechnol*. 2006;17:538-547; and Robinson et al., *Cytotherapy*. 2005;7:243-250.

[0168] Previously Angptls were identified as growth factors for HSC expansion. Zheng et al., *Blood*. 2011;117:470-479; Zhang et al., *Blood*. 2008;111:3415-3423 and Zhang et al., *Nat Med*. 2006;12:240-245. However, because Angptls are large glycosylated proteins that are readily degraded and form aggregates, they are difficult to express and purify and thus are not ideal components for use in culture. Molecules with enhanced stability and higher activities that mimic the effects of the Angptls would lead to the development of a more efficient HSC expansion system. Based on the finding that immobilized antibody to LILRB2 mimicked Angptl2-stimulated receptor signaling (Fig. 5), whether immobilized anti-LILRB2 antibody would support ex vivo expansion of human CB HSCs was tested.

[0169] Culture of human CB CD133+ cells in STF medium, medium with soluble anti-LILRB2, and medium with immobilized either polyclonal (pAb) or monoclonal (mAb) anti-LILRB2 antibody was first compared. 1×10^4 cryopreserved human CB CD133+ cells were plated in indicated medium; after 10 days of culture the total numbers of cells were determined. More expansion resulted from culture with immobilized pAb or mAb than either in STF medium or STF medium containing soluble antibodies (230% and 125% of the STF sample value, respectively; Figure 4A-B). It is of note that the levels of CD34+CD90+ cells that may be

enriched in cultured HSCs were similar in these conditions (Fig. 11C).

[0170] Colony-forming assays were next performed. Concordant with the cell growth results, samples of cells treated with the immobilized antibodies had significantly increased colony forming units (CFUs) in both primary and secondary colony forming assays than the STF sample or the soluble antibody sample (Fig. 11D-E). In particular, the immobilized polyclonal and monoclonal antibody treated samples had more than 3-fold and 1.6-fold of CFUs, respectively, than the STF samples in the secondary replating.

[0171] Finally, cells cultured in these same conditions were transplanted into sublethally irradiated NSG mice (1×10^4 input equivalent cells per mouse). CD133+ cells cultured with immobilized anti-LILRB2 pAb had a significantly greater average chimerism in peripheral blood and bone marrow than the counterparts without antibody treatment or than cells treated with soluble antibody at the analyzed post-transplant time points (3-36 weeks, Figure 5A-B). Figure 5C shows human hematopoietic engraftment at 36 weeks in representative mice that were transplanted with differently cultured human CB CD133+ cells. Mice that were transplanted with cells cultured in immobilized antibody displayed a much higher engraftment of total hematopoietic (CD45/71+) ($52.48 \pm 5.41\%$ versus $23.13 \pm 7.93\%$; Fig. 12B), myeloid (CD15/66b+) ($3.29 \pm 0.41\%$ versus $1.16 \pm 0.38\%$; Fig. 12D), B-lymphoid (CD34-CD19/20+) ($27.43 \pm 5.15\%$ versus $8.52 \pm 2.58\%$; Fig. 12E), and primitive (CD34+) ($0.93 \pm 0.24\%$ versus $0.26 \pm 0.10\%$; Fig. 12F) human cells than mice transplanted with STF cultured cells or cells cultured with soluble antibody (Fig. 12B, D-F).

[0172] To measure the self-renewal potential of SCID-repopulating cells (SRCs) after culture, bone marrow was collected from the primary mice and transplanted into sublethally irradiated secondary recipients. Engraftment of secondary recipients with cells cultured in STF medium or in soluble antibody was barely detectable. In contrast, the cells cultured with immobilized antibody showed positive engraftment of myeloid, B-lymphoid, and primitive cells after the secondary transplantation (Fig. 12G-L). Similar results were obtained from another independent experiment using human CB CD34+ cells for culture (Fig. 13).

[0173] CD133+ cells cultured with soluble or immobilized anti-LILRB2 mAb were also transplanted into sublethally irradiated NSG mice (1×10^4 input equivalent cells per mouse). In the primary transplantation, engraftment with immobilized monoclonal anti-LILRB2 treated cells was detectable but not significantly different from cells cultured without antibody treatment or

with soluble anti-LILRB2 (Fig. 14A-F). In the secondary transplantation, however, only cells treated with immobilized anti-LILRB2 showed positive engraftment (Fig. 14G-L). Together, the data indicate a net expansion of HSCs during the initial culture period, and it is thus concluded that immobilized anti-LILRB2 antibodies support extensive ex vivo expansion of human SRCs.

[0174] A limiting dilution assay was performed to quantitate the SRC frequencies before and after culture. Human CB CD133⁺ cells cultured with immobilized anti-LILRB2 antibody-cultured for 10 days had a 112-fold increase in total nucleated cells (TNCs) and a 19-fold increase in CD34⁺ cells relative to input cells (Fig. 15A-B). Cultured cells had greater average chimerism than in peripheral blood (Fig. 15C) and bone marrow (Fig. 15D). As part of the limiting dilution assay, the engraftment by 700-4,000 uncultured CD133⁺ cells, and the progenies of these cells after culture was measured. All mice transplanted with the cultured progenies of 4,000 CD133⁺ cells engrafted at a level greater than 1%. Figure 7E shows that the frequency of repopulating cells (CRU) from uncultured CD133⁺ cells is 1 per 4557 cells (95% confidence interval for mean: 3222 to 6445, n = 24). That is, as calculated from Poisson statistics, injection of an average of 4,557 cells from this lot of uncultured human CD133⁺ cells would be sufficient to repopulate 63% (= 1-1/e) of transplanted mice. In contrast, the CRU after culture was 1 per 932 input equivalent cells (95% confidence interval for mean: 689 to 1261, n = 24). There was a 4.9 -fold increase in the number of SRCs after cultured in STF medium with immobilized anti-LILRB2 polyclonal antibody. These cultured cells had much greater levels of multi-lineage engraftment than uncultured cells (Fig. 15F-I).

[0175] It has previously been shown that several Angptls support ex vivo expansion of HSCs (Zhang et al., Blood. 2008;111:3415-3423; Zhang et al., Nat Med. 2006;12:240-245; and Huynh et al., Stem Cells. 2008;26:1628-1635) but the mechanism responsible for this activity was unknown. Here it has been demonstrated that mammalian-expressed Angptl2 exists as HMW species, and ligand multimerization is required for activation of LILRB2 for downstream signaling. Motifs in the Ig domains of LILRB2 that are critical for the Angptl2 binding and signaling activation were also identified. It was shown that the binding of Angptl2 to LILRB2 is greater than and not completely overlapped with the binding of another ligand HLA-G. In an attempt to identify agonists of LILRB2 that are more potent and stable than Angptl to support ex vivo expansion of human HSCs, it was found that immobilized polyclonal anti-LILRB2 supports consistent ex vivo expansion of human CB HSCs. This study thus started to uncover the

molecular basis for Angptl/LILRB2 interaction. It also provides functional evidence that manipulation the binding between the ligands and LILRB2 on HSCs supports the repopulating activity of HSCs, and demonstrated a novel approach for efficient expansion of HSCs that may find utility in HSC-based cell therapies.

[0176] While the bona fide signaling reporter of LILRB2 is not available, a chimeric receptor surrogate reporter system was developed that can evaluate the ability of a ligand to bind and activate LILRB2. As shown in the described studies, this reporter cell line can serve as a sensitive system to enable comparison of the signaling-induction abilities of different forms of ligands. This chimeric receptor reporter system will also be useful to screen additional agonists and antagonists of ITIM-containing receptors. It is envisioned that the agonists of ITIM-containing receptors may facilitate stem cell-based regenerative medicine, and the antagonists may serve as inhibitors of cancer development.

[0177] The critical factors that contribute to LILRB2 activation by Angptl2 were identified. First, it was determined that mammalian-expressed Angptl2 forms HMW species that appear to be important for its binding to the receptor. Angptl2 contains both CC and FBN domains. Based on several pieces of evidence, neither the CC domain nor the FBN domain of Angptl2 alone bind to LILRB2 as potently as the full-length Angptl2. Both the CC domain and full-length LILRB2 exist as HMW species, whereas the FBN domain does not. Concordantly, a previous study showed that the CC domain of Angptl4 mediates multimerization. Ge et al., J. Biol Chem. 2004;279:2038-2045. These data suggest that both CC and FBN domains contribute to the receptor binding and that the CC domain-mediated multimerization significantly enhances the binding of the full-length Angptl2 to LILRB2. Although Angptls are observed as soluble hormones in serum, they can also be enriched on the plasma membrane in vitro (data not shown). In addition to the soluble multimerized form, it is speculated that clustered, cell surface-bound Angptls exist in vivo and activate LILRB2.

[0178] The features of LILRB2 important for Angptl2 binding were further identified. Novel H*G*Y*C motifs in the first and fourth Ig domains of LILRB2 are essential to Angptl2 binding. The critical necessity of this motif in Angptl2/LILRB2 binding is supported by the effects of the site-specific mutations at G94, R95, and Y96 in Ig1 that reduced Angptl2 binding by 50%. Similarly, a single mutation in Y394 in Ig4 decreased Angptl2 binding of full-length LILRB2 by 40%. In addition to Angptls, LILRB2 is known to have other ligands including various MHC

class I molecules. Shiroishi et al., Proc Natl Acad Sci U S A. 2003;100:8856-8861. An important question is whether Angptl and MHC class I molecules bind to LILRB2 in a similar or different manner. As the flow cytometry-based ligand binding assay showed, Angptl2 has a greater binding than HLA-G to LILRB2. This result is supported by the described reporter cell assay. In contrast to Angptl2, a much greater dose of the immobilized HLA-G cannot induce GFP expression of the LILRB2 reporter cells. Therefore, the Angptl2 activation of the LILRB2 chimeric receptor reporter cells is much more potent than HLA-G; however, Angptl2 is not efficiently to compete the HLA-G binding to LILRB2 (data not shown). Whereas HLA-G binds to the first two Ig domains of LILRB2 28, Angptl2 binds to both Ig1 and Ig4 of LILRB2. Interestingly, the H*G*Y*C motif that is critical for Angptl2 binding to LILRB2 is not within either of the two MHC binding sites or at the typical interfacial loop region, but within the beta-sheet structure, as revealed by a crystallographic study. Shiroishi et al., Proc Natl Acad Sci U S A. 2006;103:16412-16417. Based on the described binding and activation results, this motif should be required for the conformational stability of the Ig domains of LILRB2 that is needed for binding and activation by Angptl2. Together, these results suggest that, 1) Angptl2 binds and activates LILRB2 with a greater ability than MHC class I, and 2) Angptl2 and MHC class I molecules may not directly compete for binding to the same sites, and these two types of molecules may be able to act individually or even cooperatively so that the signaling of LILRB2 may be co-regulated. Nevertheless, the binding of each of the two ligands may somewhat require common conformational alterations. For example, while the mutations of most of the MHC-I binding sites of LILRB2 did not affect Angptl2 binding, it was observed that the mutation G94D, R95E, or Y394A in LILRB2 that is within the H*G*Y*C motif and decreases Angptl2 binding also showed lower HLA-G binding.

[0179] Interestingly, while all LILRBs contain a G*Y*C motif, Angptl2 only binds LILRB2. This suggests that the H*G*Y*C motif is necessary but not sufficient for maintaining the LILRB2 conformation for Angptl2 binding and activation.

[0180] Based on the described identification of the binding sites of Angptl2 to LILRB2, an improved strategy to use immobilized anti-LILRB2 for ex vivo expansion of human HSCs was developed. Immobilized antibodies bind to the same region of LILRB2 as Angptl2. The serum-free culture system containing defined cytokines and immobilized anti-LILRB2 supports a net expansion of repopulating human CB HSCs, as determined by the serial NSG transplantation and

limiting dilution analysis. The polyclonal anti-LILRB2 antibody demonstrated a greater ability to support ex vivo expansion of HSCs than monoclonal anti-LILRB2, suggesting the possibility of multiple ligand binding sites in LILRB2 activation. In addition, the internalization signal YXXphi of LILRB2 (Kozik et al., *Traffic*. 2010;11:843-855) suggests that LILRB2 can undergo endocytosis, possibly after ligand binding. Because the immobilized antibodies may prevent this event and thus prolong the receptor activation, the ex vivo expansion of HSCs may also be enhanced by the immobilized antibodies. Together, because the anti-LILRB2 polyclonal antibodies are easier to be expressed and purified and more stable than Angptls, and importantly, bind and activate LILRB2 with a greater ability than Angptl2, this system may have greater advantages to use in ex vivo expansion of HSCs.

7.2 Example 2

[0181] Previous studies have led to Notch-induced ex vivo expansion of hematopoietic stem cells (HSC) and their successful use for reducing the prolonged post-transplant neutropenia encountered in patients undergoing CB stem cell transplantation (see Figures 16 and 17). More recently a relationship between the number of expanded, partially HLA-matched CD34+ cells infused and time to neutrophil recovery has been observed, suggesting a critical need for greater expansion of CB HSPC to reliably enhance early neutrophil recovery.

[0182] To alleviate the risks associated with delayed myeloid recovery, methods for ex vivo expansion of CB HSPC that are infused along with one or two non-manipulated CB units in the setting of myeloablative hematopoietic stem cell transplantation (HSCT) have been developed. These methods are based on previously described studies of the role for the Notch receptor family in regulation of hematopoiesis and on pre-clinical development of a Notch-mediated expansion system for hematopoietic progenitors using the Notch ligand Delta1. Milner et al., *Blood*. 1994; 83(8): 2057-2062; Varnum-Finney et al., *Nat Med*. 2000; 6(11): 1278-1281; Varnum-Finney et al., *Blood*. 2003; 101(5): 1784-1789; Delaney et al., *Blood*. 2005; 106(9): 2693-2699. Clinical translation of this work resulted in a Phase I CBT trial using ex vivo expanded CB progenitor cells following myeloablative conditioning. Results of this trial showed both safety of this approach as well as significant decrease in time to neutrophil engraftment. An update of these studies since the initial publication (Delaney et al. *Nat Med*. 2010; 16(20): 232-237) shows reduction in median time to initial ANC $\geq 500/\mu\text{l}$ of 11 days compared with a

concurrent cohort of patients (N=29) with the same treatment regimen ($p < 0.0001$, Figure 16). Significantly, achievement of $ANC > 100/\mu l$, an indicator of risk of day +100 mortality (Dahlberg et al. Blood. 2011; 118(21): 3033) occurred at 7 days as compared to 19 days in the conventional double CBT group ($p = 0.0002$). Moreover a relationship between number of HSPC infused and time to engraftment, with 6 out of 7 patients who received greater than 8×10^6 CD34+ cells/kg achieving an $ANC \geq 500/\mu l$ within 10 days (Figure 17) was observed, findings unique with respect to cell-therapy based reduction of neutropenia. This observed dose-relationship is reflective of studies in non-manipulated CBT indicating that higher cell doses of CD34+ cells/kg are required to overcome increased HLA disparity and allow engraftment in partially-HLA matched CBT recipients.

Laughlin et al. N Engl J Med. 2001; 344(24): 1815-1822; Wagner et al. Blood. 2002; 100(5): 1611-1618.

[0183] Aspects of the current disclosure are based on the hypothesis that inhibition of differentiation by induction of endogenous Notch signaling in combination with factor(s) able to enhance stem self-renewal and/or survival will lead to generation of greater numbers of rapidly repopulating CD34+ HSPC. One such factor is angiopoietin agonists including, for example, Angptl5. Angptl5 a member of the Angiopoietin-like family of proteins previously shown to enhance the generation of hematopoietic repopulating cells in preclinical studies.

[0184] For example, in vitro culture with Angptls 2, 3, 5, and 7 and cytokines significantly increases repopulating activities of murine long-term HSC. Zhang et al., Nat Med. 2006; 12(2): 240-245. Culture of CB HSPC with ANGPTL5 and growth factors (SCF, TPO, FGF-1, heparin, and IGFBP2) led to significantly improved in vivo reconstitution in NOD/SCID mice at 2 months post-transplant (39.5% engraftment v. 0.2-2% in the non-cultured group, Figure 18) as well as enhanced secondary transplantation. Zhang et al. Blood. 2008; 111(7): 3415-3423. Moreover, whereas Notch signaling inhibits differentiation allowing HSPC self-renewal, Angptl proteins enhance in vivo HSPC repopulation in the absence of in vitro evidence demonstrating altered differentiation or HSC expansion. Aspects of the current disclosure are accordingly based on the hypothesis that because these physiologic ligands function by two distinct mechanisms, the combination may result in generation of more effective repopulating cells. This hypothesis was tested in Example 2 to further examine whether combined effects of Delta1- and Angptls, such as Angptl5, enhance HSC expansion, allowing improvement over current cellular therapies

relevant for clinical applications.

[0185] Based in part on the described data and hypotheses, the Notch agonist Delta 1 in combination with Angptl5 was selected for further study. However, culture conditions optimized for Delta^{Ext-IgG} and Angptl5 are quite distinct. Optimal Delta^{Ext-IgG}-induced expansion was found following 16-17 days culture in StemSpan serum-free media in the presence of SCF, Flt3-ligand (Flt3L), TPO, IL-6 and IL-3, with immobilized Delta^{Ext-IgG} and retronectin. By contrast, Angptl5-induced expansion was optimal following 10 days culture in StemSpan media, but with low-doses of the cytokines SCF, TPO as well as FGF1, heparin, and IGFBP2. Accordingly, success of the combination could not be predicted.

7.2.1. Example 2- Methods

[0186] Cell Isolation. Human CB for research was obtained from normal deliveries under Swedish Medical Center Institutional Review Board (Seattle) approval after consent was obtained. Samples were incubated in ammonium chloride red blood cell lysis buffer, washed, and suspended in phosphate-buffered saline (PBS) with 2% human type AB serum. Cells were incubated with CD34+ immunomagnetic beads (Miltenyi Biotec) and purified using a Miltenyi AutoMACS and then frozen. CD34+ cells were then thawed for individual experiments.

[0187] Generation and immobilization of Delta^{Ext-IgG} protein and LILRB2 antibody (anti-CD85d). Generation of the construct encoding the extracellular domain of Delta1 fused to the fc domain of human IgG1 and purification of Delta^{Ext-IgG} protein from culture medium of NSO cells electroporated with the construct have been previously described (Varnum-Finney, J Cell Sci. 2000; 113(pt23): 4313-4318). Human CD85d biotinylated antibody (polyclonal goat IgG) or normal goat IgG biotinylated control were obtained from R&D Systems. Wells of non-tissue culture-treated culture plates or non-tissue culture-treated flasks were incubated with Delta^{Ext-IgG} (0.5 or 2.5 µg/ml), CD85d biotinylated antibody (range 0.08 to 25 µg/ml), or IgG control diluted in PBS together with 5 µg/ml retronectin, incubated overnight at 4 °C, and washed generously with PBS.

[0188] Cell Cultures. Cells were cultured in serum-free medium (Stemspan Serum Free Expansion Medium; StemCell Technologies) with 50ng/ml human stem cell factor (SCF), human Flt3-ligand, human interleukin 6 (IL-6), thrombopoietin (TPO), 10 ng/ml human interleukin 3 (IL-3), FGF1 20ng/ml, and heparin 10µg/ml. Cultures for transplant were initiated in 25cm² non-

tissue cultured treated flasks with between 1 and 1.2×10^5 starting CD34⁺ cells/flask. Cells were expanded to 75 and 125 cm² non-tissue cultured treated flasks when cell density reached approximately $1-1.5 \times 10^6$ cells/ml. Fresh medium with cytokines was added every 3-4 days.

[0189] Transplantation of human hematopoietic cells into NOD/SCID gamma null mice. Sublethally irradiated (275 rad) NOD-SCID IL-2R γ -null mice (NSG) approved for use by the Fred Hutchinson Cancer Research Center Institutional Animal Care and Use Committee were used for transplant. Single mice (5-8 mice/group) were infused with the progeny generated from 1×10^5 started CD34⁺ cells. Repopulating ability (percent human CD45⁺ or CD45⁺33⁺, CD45⁺19⁺, CD45⁺34⁺ in marrow) was assessed at 2 and 8 weeks after transplantation using bone marrow aspirated from the femur of anesthetized recipient mice.

[0190] Statistical Analysis. Unpaired, two-tailed t-tests were used to make comparisons between groups

7.2.2. Example 2 - Results

[0191] The combined effects of Delta1 and Angptl5 enhanced generation of CB-derived CD34⁺ cells that rapidly repopulate the marrow of immune deficient mice with hematopoietic precursors and differentiating myeloid cells. Particularly, in studies combining Delta1 and Angptl5, significantly enhanced rapid (2 week) repopulation of NSG mice by CD34⁺ precursors ($p=.04$) and a clear trend towards enhanced repopulation by immature, CD33⁺ myeloid precursors ($p=0.08$ two-tailed t-test, $p=0.04$ Mann-Whitney test for possible non-Gaussian distribution) was found compared to using Delta1 or Angptl5 alone (Figure 19). Importantly, this occurred despite overall similar CD34-fold expansion with CB HSPC cultured on Delta1 alone (Figure 20). Additionally, there was no difference in generation of CD34⁺CD90^{lo} or CD49f cells suggesting generation of greater numbers of rare, rapidly repopulating cells, or cells with altered cell-cycle, apoptotic, or transcriptional or epigenetic properties. Of note, this combination maintained multi-lineage engraftment 8 weeks after transplant suggesting maintenance or expansion of longer term repopulating cells.

[0192] Figure 21 shows significantly enhanced early marrow repopulation when Delta is combined with Angptl5 and cultured in conditions optimized for Delta-mediated expansion.

[0193] Figure 22 shows longer-term repopulation is significantly enhanced when Delta is combined with Angptl5 and cultured in conditions optimized for Delta-mediated expansion; repopulation is multi-lineage showing significantly enhanced myeloid and lymphoid lineages.

Cells did not have significant secondary engraftment when cultured in conditions previously optimized for Delta-mediated expansion.

[0194] Figures 23A and 23B show that culture with Delta and Angptl5 with lower cytokine concentrations results in secondary engraftment previously not seen in Delta expanded cells suggesting maintenance/expansion of a longer-term repopulating cell when Delta is added to Angptl5 in these conditions.

[0195] Figure 24. Culture with Delta and an antibody to the Angptl5 receptor (LILRB2 or CD85) trends towards enhanced early myeloid engraftment as compared to Delta alone. This trend is present at the highest dose of CD85 used in this experiment.

[0196] Figure 25. When engraftment was assessed at a longer-term time point (16 wks after transplant), engraftment of cells cultured with Delta and CD85 had greater engraftment than Delta alone. These cells are able to repopulate both lymphoid and myeloid lineages.

[0197] Accordingly, Example 2 demonstrates the development of culture conditions for expanding HSC using Delta1 and Angptl5 with cytokine compositions and time in culture. Significantly enhanced early marrow repopulation in immune-deficient mice from CB hematopoietic stem/progenitor cells (HSPC) cultured with Delta1 and Angptl5 as compared to Delta1 alone is demonstrated. Further, data demonstrating improved longer-term repopulation of CB HSPC following culture with Delta1 and Angptl5 as compared to either approach alone is provided.

7.3 Example 3

[0198] The focus of this Example is on optimizing generation of CB hematopoietic stem/progenitor cells (HSPC) by investigating not only culture conditions but also presentation of Delta1 and anti-LILRB2 antibody.

[0199] Use of an immobilized antibody against LILRB2 (CD85d), an Angiopoietin-like (ANGPTL) protein receptor, was investigated. Interaction of LILRB2 and ANGPTL protein allows for the *ex vivo* expansion of CB HSPC, including those with *in vivo* repopulating ability. In initial studies, combination of immobilized Delta1 with an intermediate concentration of anti-LILRB2 antibody led to the increased generation of CD34⁺ and CD34⁺CD90^{lo} cells (CD90^{lo} cells were those cells expressing low amounts of CD90, as determined by a gated cut-off amount) compared to culture with Delta1 or anti-LILRB2 antibody alone (data not shown). Transplantation experiments into NSG mice to optimize culture conditions for maximal

generation of rapid myeloid repopulating cells demonstrated improved generation of cells using previously established cytokine culture conditions and immobilized anti-LILRB2 antibody at concentration of 1.25 $\mu\text{g/ml}$ (data not shown). Upon transplant into NSG mice, the combined activation of Notch and LILRB2 receptors enhanced the generation of rapidly repopulating myeloid precursors compared to Delta1 alone (29.3% vs. 18.6% total human CD33+ cells in NSG mice at 2 weeks post-transplant, $p=0.05$) (Fig. 26). Culture in these conditions may also enhance generation of longer-term repopulating cells as shown by greater progenitor cell engraftment with the combination (2.9% vs. 1.7% total human CD34+ cells in NSG mice at 10 weeks post-transplant) (Fig. 27).

[0200] Enhanced Hes1 (a Notch target gene) expression was observed in cells cultured with the combination of Delta1 and anti-LILRB2 antibody over Delta1 alone, with all reagents immobilized on the plastic of the culture dish (Fig. 28).

[0201] Studies investigating alternate methods of agonist presentation were performed, specifically comparing the effectiveness of agonist immobilized on magnetic protein A-microbeads with immobilization to the culture flask. Data suggest that presentation of Delta1 and anti-LILRB2 antibodies induced greater Hes1 expression when the two agonists were presented by alternate means, e.g. Delta1 immobilized on plastic and anti-LILRB2 antibody immobilized on beads (Fig. 29).

[0202] Amplification in the production of CD7+ cells accompanying the increased Hes1 expression has not been observed, suggesting that the expression of T cell genes are unaffected. Without being bound by any particular theory, these data suggest that the activation of the ANGPTL5/LILRB2 pathway is not amplifying the effects of Notch signaling, but acts in parallel with Notch, perhaps at the Hes1 gene level, to inhibit myeloid differentiation and enhance HSPC self-renewal.

[0203] As will be understood by one of ordinary skill in the art, each embodiment disclosed herein can comprise, consist essentially of or consist of its particular stated element, step, ingredient or component. Thus, the terms “include” or “including” should be interpreted to recite: “comprise, consist of, or consist essentially of.” As used herein, the transition term “comprise” or “comprises” means includes, but is not limited to, and allows for the inclusion of unspecified elements, steps, ingredients, or components, even in major amounts. The transitional

phrase “consisting of” excludes any element, step, ingredient or component not specified. The transition phrase “consisting essentially of” limits the scope of the embodiment to the specified elements, steps, ingredients or components and to those that do not materially affect the embodiment. As used herein, a material effect would cause a statistically significant reduction in precursor cell expansion by the methods disclosed herein as measured by an assay described in relation to effective amounts.

[0204] Unless otherwise indicated, all numbers used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. When further clarity is required, the term “about” has the meaning reasonably ascribed to it by a person skilled in the art when used in conjunction with a stated numerical value or range, i.e. denoting somewhat more or somewhat less than the stated value or range, to within a range of $\pm 20\%$ of the stated value; $\pm 19\%$ of the stated value; $\pm 18\%$ of the stated value; $\pm 17\%$ of the stated value; $\pm 16\%$ of the stated value; $\pm 15\%$ of the stated value; $\pm 14\%$ of the stated value; $\pm 13\%$ of the stated value; $\pm 12\%$ of the stated value; $\pm 11\%$ of the stated value; $\pm 10\%$ of the stated value; $\pm 9\%$ of the stated value; $\pm 8\%$ of the stated value; $\pm 7\%$ of the stated value; $\pm 6\%$ of the stated value; $\pm 5\%$ of the stated value; $\pm 4\%$ of the stated value; $\pm 3\%$ of the stated value; $\pm 2\%$ of the stated value; or $\pm 1\%$ of the stated value.

[0205] Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical value, however, inherently contains certain errors necessarily resulting from the standard deviation found in their respective testing measurements.

[0206] The terms “a,” “an,” “the” and similar referents used in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Recitation of ranges of values herein is merely intended to serve as a shorthand method of

referring individually to each separate value falling within the range. Unless otherwise indicated herein, each individual value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention otherwise claimed. No language in the specification should be construed as indicating any non-claimed element essential to the practice of the invention.

[0207] Groupings of alternative elements or embodiments of the invention disclosed herein are not to be construed as limitations. Each group member may be referred to and claimed individually or in any combination with other members of the group or other elements found herein. It is anticipated that one or more members of a group may be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is deemed to contain the group as modified thus fulfilling the written description of all Markush groups used in the appended claims.

[0208] Certain embodiments of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Of course, variations on these described embodiments will become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventor expects skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

[0209] Furthermore, numerous references have been made to publications, patents and/or patent applications (collectively “references”) throughout this specification. Each of the cited references is individually incorporated herein by reference for their particular cited teachings.

[0210] In closing, it is to be understood that the embodiments of the invention disclosed herein are illustrative of the principles of the present invention. Other modifications that may be employed are within the scope of the invention. Thus, by way of example, but not of limitation,

alternative configurations of the present invention may be utilized in accordance with the teachings herein. Accordingly, the present invention is not limited to that precisely as shown and described.

[0211] The particulars shown herein are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of various embodiments of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for the fundamental understanding of the invention, the description taken with the drawings and/or examples making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

[0212] Definitions and explanations used in the present disclosure are meant and intended to be controlling in any future construction unless clearly and unambiguously modified in the examples or when application of the meaning renders any construction meaningless or essentially meaningless. In cases where the construction of the term would render it meaningless or essentially meaningless, the definition should be taken from Webster's Dictionary, 3rd Edition or a dictionary known to those of ordinary skill in the art, such as the Oxford Dictionary of Biochemistry and Molecular Biology (Ed. Anthony Smith, Oxford University Press, Oxford, 2004).

[0213] Various references such as patents, patent applications, and publications are cited herein, the disclosures of which are hereby incorporated by reference herein in their entireties.

What is claimed is:

1. A method of expanding precursor cells *ex vivo*, comprising culturing said precursor cells with a LILRB2 agonist immobilized on a first solid phase, wherein the immobilized LILRB2 agonist is (i) an antibody to the LILRB2 receptor, or (ii) an antigen-binding fragment of said antibody; and wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
2. The method of claim 1, which comprises culturing said precursor cells with an immobilized LILRB2 agonist in combination with a Notch agonist.
3. The method of claim 1 or claim 2, wherein the precursor cells are human cells.
4. The method of claim 3, wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
5. The method of claim 3, wherein the precursor cells are obtained from fetal or neonatal blood.
6. The method of claim 1 or claim 2, wherein the antibody to the LILRB2 receptor is a monoclonal antibody.
7. The method of claim 1 or claim 2, wherein the antibody to the LILRB2 receptor is a polyclonal antibody.
8. The method of claim 1 or claim 2, wherein the LILRB2 agonist is an Fv, Fab, Fab', F(ab')₂, Fc, or single chain Fv fragment (scFv).
9. The method of claim 1 or claim 2, wherein the antibody to LILRB2 is a human, humanized, synthetic, or chimeric antibody.
10. The method of claim 1 or claim 2, wherein LILRB2 agonist binds to the Ig1 domain of LILRB2.
11. The method of claim 1 or claim 2, wherein LILRB2 agonist binds to the Ig4 domain of LILRB2.

12. The method of claim 1 or claim 2, wherein LILRB2 agonist binds to the Ig1 and Ig4 domains of LILRB2.
13. The method of claim 1 or claim 2, wherein the first solid phase is the surface of a tissue culture dish.
14. The method of claim 2, wherein the Notch agonist is immobilized on the first solid phase.
15. The method of claim 2, wherein the Notch agonist is immobilized on a second solid phase that is not the first solid phase.
16. The method of claim 14, wherein the first solid phase is the surface of a tissue culture dish.
17. The method of claim 15, wherein the first solid phase is the surface of a tissue culture dish or flask, and the second solid phase is a bead.
18. The method of claim 15, wherein the first solid phase is a bead, and the second solid phase is the surface of a tissue culture dish or flask.
19. The method of claim 2, wherein the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein.
20. The method of claim 2, wherein the Notch agonist is human Delta-1.
21. The method of claim 2, wherein the Notch agonist is Delta^{ext-IgG}.
22. The method of claim 2, wherein the Notch agonist is in dimeric form.
23. The method of claim 2, wherein the Notch agonist is an antibody that specifically binds to a Notch motif.
24. The method of claim 2, wherein the Notch agonist is an antibody that specifically binds to Notch-1.

25. The method of claim 2, wherein the Notch agonist is an antibody that specifically binds to Notch-2.

26. The method of claim 1 or claim 2, wherein the culturing step is performed in the presence of a culture medium comprising stem cell factor (SCF), thrombopoietin (TPO), and Flt3-ligand.

27. The method of claim 1 or claim 2, wherein the culturing step is performed in the presence of a culture medium comprising 10-100 ng/mL SCF, 5-100 ng/mL TPO and 10/100 ng/mL Flt3-ligand.

28. The method of claim 27, wherein the culture medium comprises 50 ng/mL SCF.

29. The method of claim 27, wherein the culture medium comprises 10 ng/mL TPO.

30. The method of claim 27, wherein the culture medium comprises 50 ng/mL Flt3-ligand.

31. The method of claim 27, wherein the culturing step is performed in the presence of a culture medium comprising 50 ng/mL SCF, 10 ng/mL TPO and 50 ng/mL Flt3-ligand.

32. The method of claim 2, wherein the culturing step is performed in the presence of a culture medium comprising SCF, Flt3-ligand, interleukin-6 (IL-6), TPO, fibroblast growth factor-1 (FGF1), and interleukin-3 (IL-3).

33. The method of claim 32, wherein the culture medium comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3, and heparin.

34. The method of claim 32, wherein the culture medium comprises 1-100 ng/mL SCF, 1-100 ng/mL Flt3-ligand, 1-100 ng/mL IL-6, 1-100 ng/mL TPO, 1-100 ng/mL FGF1, and 1-100 ng/mL IL-3.

35. The method of claim 34, wherein the culture medium further comprises 1-100 µg/mL heparin.

36. The method of claim 32, wherein the culture medium comprises 50 ng/mL SCF, 50 ng/mL Flt3-ligand, 50 ng/mL IL-6, 50 ng/mL TPO, 20 ng/mL FGF1, and 10 ng/mL IL-3.

37. The method of claim 36, wherein the culture medium further comprises 10 µg/mL heparin.

38. The method of claim 2, the culturing step is performed in the presence of a culture medium comprising retronectin.

39. The method of claim 38, wherein the culture medium comprises 1-100 µg/mL retronectin.

40. The method of claim 39, wherein the culture medium comprises 5 µg/mL retronectin.

41. A method for expanding precursor cells comprising culturing the precursor cells in the presence of a media comprising an immobilized LILRB2 agonist with a molecular weight of at least 225 kD wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an immobilized LILRB2 agonist with a molecular weight of at least 225 kD stop proliferating and/or die.

42. A method of claim 41 wherein the LILRB2 agonist has a molecular weight of at least 250 kD

43. A method of claim 41 wherein the LILRB2 agonist is multimerized.

44. A method of claims 41 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.

45. A method of claim 44 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.

46. A method of claim 44 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment

thereof.

47. A method of claim 41 wherein the LILRB2 agonist is an LILRB2 receptor antibody.

48. A method of claim 47 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

49. A method of claim 41 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.

50. A method of claim 41 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

51. A method of any of claim 41 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.

52. A method of claim 41 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.

53. A method of claim 41 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.

54. A method of claim 41 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.

55. A method of claim 41 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.

56. A method of claim 41 wherein the media is serum free.

57. A method of claim 41 wherein the media comprises 1-100 µg/ml immobilized LILRB2 agonist.

58. A method of claim 57 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.

59. A method of claim 57 wherein the media further comprises SCF; TPO and Flt3-ligand.
60. A method of claim 57 wherein the media further comprises 10-100 ng/ml SCF; 5-100 ng/ml TPO and 10-100 ng/ml Flt3-ligand.
61. A method of claim 60 wherein the media comprises 10 ng/ml SCF.
62. A method of claim 60 wherein the media comprises 5 ng/ml TPO.
63. A method of claim 60 wherein the media comprises 10 ng/ml Flt3-ligand.
64. A method of claim 60 wherein the media comprises growth factors: 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
65. A method of claim 41 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
66. A method of claim 41 wherein the precursor cells are hematopoietic stem cells.
67. A method of claim 41 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
68. A method of claim 41 wherein the precursor cells are obtained from fetal or neonatal blood.
69. A method for expanding precursor cells comprising culturing the precursor cells in the presence of a media comprising an LILRB2 agonist and a Notch agonist wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an LILRB2 agonist and a Notch agonist stop proliferating and/or die.
70. A method of claim 69 wherein the LILRB2 agonist is immobilized in the culture media.
71. A method of claim 69 wherein the Notch agonist is immobilized in the culture

media.

72. A method of claim 69 wherein the LILRB2 agonist has a molecular weight of at least 225 kD or at least 250 kD.

73. A method of claim 69 wherein the LILRB2 agonist is multimerized.

74. A method of claim 69 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.

75. A method of claim 74 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.

76. A method of claim 74 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.

77. A method of claim 69 wherein the LILRB2 agonist is an LILRB2 receptor antibody.

78. A method of claim 77 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

79. A method of claim 69 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.

80. A method of claim 69 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

81. A method of claim 69 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.

82. A method of claim 69 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.

83. A method of claim 69 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.

84. A method of claim 69 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.

85. A method of claim 69 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.

86. A method of claim 69 wherein the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein.

87. A method of claim 69 wherein the Notch agonist is Delta^{ext-IgG}.

88. A method of claim 69 wherein the Notch agonist is in dimeric form.

89. A method of claim 69 wherein the media is serum free.

90. A method of claim 69 wherein the media comprises 0.025-100 µg/ml immobilized LILRB2 agonist.

91. A method of claim 90 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.

92. A method of claim 90 wherein the media comprises 0.08 to 25 µg/ml immobilized LILRB2 agonist.

93. A method of claim 69 wherein the media comprises 0.025 to 5 µg/ml Notch agonist.

94. A method of claim 93 wherein the media comprises 0.5 to 2.5 µg/ml Notch agonist.

95. A method of claim 69 wherein the media further comprises SCF; TPO and Flt3-ligand.

96. A method of claim 95 wherein the media further comprises 10-100 ng/ml SCF; 5-

100 ng/ml TPO and 10-100 ng/ml Flt3-ligand.

97. A method of claim 96 wherein the media comprises 10 ng/ml SCF.
98. A method of claim 96 wherein the media comprises 5 ng/ml TPO.
99. A method of claim 96 wherein the media comprises 10 ng/ml Flt3-ligand.
100. A method of claim 96 wherein the media comprises 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
101. A method of claim 69 wherein the media further comprises SCF, Flt3-ligand, IL-6, TPO, FGF1 and IL-3.
102. A method of claim 101 wherein the media comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3 and heparin.
103. A method of claim 101 wherein the media further comprises 1-100 ng/ml SCF, 1-100 ng/ml Flt3-ligand, 1-100 ng/ml IL-6, 1-100 ng/ml TPO, 1-100 ng/ml FGF1 and 1-100 ng/ml IL-3.
104. A method of claim 103 wherein the media further comprises 1-100 µg/ml heparin.
105. A method of claim 101 wherein the media further comprises 50 ng/ml SCF, 50 ng/ml Flt3-ligand, 50 ng/ml IL-6, 50 ng/ml TPO, 20 ng/ml FGF1 and 10 ng/ml IL-3.
106. A method of claim 105 wherein the media further comprises 10 µg/ml heparin.
107. A method of claim 69 wherein the media further comprises retronectin.
108. A method of claim 107 wherein the media further comprises 1-100 µg/ml retronectin.
109. A method of claim 108 wherein the media further comprises 5 µg/ml retronectin.
110. A method of claim 69 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.

111. A method of claim 69 wherein the precursor cells are hematopoietic stem cells.
112. A method of claim 69 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
113. A method of claim 69 wherein the precursor cells are obtained from fetal or neonatal blood.
114. A method for producing precursor cells for hematopoietic transplantation comprising culturing the precursor cells in the presence of a media comprising an immobilized LILRB2 agonist with a molecular weight of at least 225 kD wherein the culturing is effective to produce precursor cells suitable able to treat a subject when formulated for administration and administered in an effective amount.
115. A method of claim 114 wherein the LILRB2 agonist has a molecular weight of at least 250 kD
116. A method of claim 114 wherein the LILRB2 agonist is multimerized.
117. A method of claim 114 wherein the LILRB2 agonist is an angiopoietin-like protein (Angptl) or fragment thereof.
118. A method of claim 117 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.
119. A method of claim 117 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.
120. A method of claim 114 wherein the LILRB2 agonist is an LILRB2 receptor antibody.
121. A method of claim 120 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

122. A method of claim 114 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.

123. A method of claim 114 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

124. A method of claim 114 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.

125. A method of claim 114 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.

126. A method of claim 114 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.

127. A method of claim 114 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.

128. A method of claim 114 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.

129. A method of claim 114 wherein the media is serum free.

130. A method of claim 114 wherein the media comprises 1-100 µg/ml immobilized LILRB2 agonist.

131. A method of claim 130 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.

132. A method of claim 114 wherein the media further comprises SCF; TPO and Flt3-ligand.

133. A method of claim 132 wherein the media further comprises 10-100 ng/ml SCF; 5-100 ng/ml TPO and 10-100 ng/ml Flt3-ligand.

134. A method of claim 133 wherein the media comprises 10 ng/ml SCF.

135. A method of claim 133 wherein the media comprises 5 ng/ml TPO.
136. A method of claim 133 wherein the media comprises 10 ng/ml Flt3-ligand.
137. A method of claim 133 wherein the media comprises 10 ng/ml SCF; 5 ng/ml TPO; and 10 ng/ml Flt3-ligand.
138. A method of claim 114 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.
139. A method of claim 114 wherein the precursor cells are hematopoietic stem cells.
140. A method of claim 114 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.
141. A method of claim 114 wherein the precursor cells are obtained from fetal or neonatal blood.
142. A method for expanding precursor cells comprising culturing the precursor cells in the presence of a media comprising an LILRB2 agonist and a Notch agonist wherein the culturing is effective to maintain expansion of the precursor cells beyond a time at which precursor cells cultured in the media lacking an LILRB2 agonist and a Notch agonist stop proliferating and/or die.
143. A method of claim 142 wherein the LILRB2 agonist is immobilized in the culture media.
144. A method of claim 142 wherein the Notch agonist is immobilized in the culture media.
145. A method of claim 142 wherein the LILRB2 agonist has a molecular weight of at least 225 kD or at least 250 kD.
146. A method of claim 142 wherein the LILRB2 agonist is multimerized.
147. A method of claim 142 wherein the LILRB2 agonist is an angiopoietin-like

protein (Angptl) or fragment thereof.

148. A method of claim 142 wherein the Angptl or fragment thereof comprises the coiled-coil domain of the Angptl.

149. A method of claim 142 wherein the LILRB2 agonist is Angptl 1 or a fragment thereof, Angptl2 or a fragment thereof, Angptl3 or a fragment thereof, Angptl4 or a fragment thereof, Angptl5 or a fragment thereof, Angptl7 or a fragment thereof, or Mfap4 or a fragment thereof.

150. A method of claim 142 wherein the LILRB2 agonist is an LILRB2 receptor antibody.

151. A method of claim 150 wherein the LILRB2 antibody is a monoclonal antibody or a polyclonal antibody.

152. A method of claim 142 wherein the LILRB2 agonist binds the Ig1 domain of LILRB2.

153. A method of claim 142 wherein the LILRB2 agonist binds the Ig4 domain of LILRB2.

154. A method of claim 142 wherein the LILRB2 agonist binds the Ig1 domain and the Ig4 domain of LILRB2.

155. A method of claim 142 wherein the LILRB2 agonist binds the amino acids at positions 92-100 of LILRB2 within the Ig1 domain.

156. A method of claim 142 wherein the LILRB2 agonist binds the amino acids at positions 94, 95 and/or 96 of LILRB2 within the Ig1 domain.

157. A method of claim 142 wherein the LILRB2 agonist binds the amino acids at positions 390-396 of LILRB2 within the Ig4 domain.

158. A method of claim 142 wherein the LILRB2 agonist binds the amino acids at 392 and 393 of LILRB2 within the Ig4 domain.

159. A method of claim 142 wherein the Notch agonist is an extracellular, Notch-interacting domain of a Delta protein.
160. A method of claim 142 wherein the Notch agonist is Delta^{ext-IgG}.
161. A method of claim 142 wherein the Notch agonist is in dimeric form.
162. A method of claim 142 wherein the media is serum free.
163. A method of claim 142 wherein the media comprises 0.025-100 µg/ml immobilized LILRB2 agonist.
164. A method of claim 163 wherein the media comprises 25 µg/ml immobilized LILRB2 agonist.
165. A method of claim 142 wherein the media comprises 0.08 to 25 µg/ml immobilized LILRB2 agonist.
166. A method of claim 142 wherein the media comprises 0.025 to 5 µg/ml Notch agonist.
167. A method of claim 166 wherein the media comprises 0.5 to 2.5 µg/ml Notch agonist.
168. A method of claim 102 wherein the media further comprises SCF; TPO and Flt3-ligand.
169. A method of claim 168 wherein the media further comprises 10-100 ng/ml SCF; 5-100 ng/ml TPO and 10-100 ng/ml Flt3-ligand.
170. A method of claim 169 wherein the media comprises 10 ng/ml SCF.
171. A method of claim 169 wherein the media comprises 5 ng/ml TPO.
172. A method of claim 169 wherein the media comprises 10 ng/ml Flt3-ligand.
173. A method of claim 169 wherein the media comprises: 10 ng/ml SCF; 5 ng/ml

TPO; and 10 ng/ml Flt3-ligand.

174. A method of claim 142 wherein the media further comprises SCF, Flt3-ligand, IL-6, TPO, FGF1 and IL-3.

175. A method of claim 174 wherein the media comprises SCF, Flt3-ligand, IL-6, TPO, FGF1, IL-3 and heparin.

176. A method of claim 142 wherein the media further comprises 1-100 ng/ml SCF, 1-100 ng/ml Flt3-ligand, 1-100 ng/ml IL-6, 1-100 ng/ml TPO, 1-100 ng/ml FGF1 and 1-100 ng/ml IL-3.

177. A method of claim 176 wherein the media further comprises 1-100 µg/ml heparin.

178. A method of claim 176 wherein the media further comprises 50 ng/ml SCF, 50 ng/ml Flt3-ligand, 50 ng/ml IL-6, 50 ng/ml TPO, 20 ng/ml FGF1 and 10 ng/ml IL-3.

179. A method of claim 178 wherein the media further comprises 10 µg/ml heparin.

180. A method of claim 142 wherein the media further comprises retronectin.

181. A method of claim 180 wherein the media further comprises 1-100 µg/ml retronectin.

182. A method of claim 181 wherein the media further comprises 5 µg/ml retronectin.

183. A method of claim 142 wherein the precursor cells are hematopoietic stem cells or hematopoietic progenitor cells.

184. A method of claim 142 wherein the precursor cells are hematopoietic stem cells.

185. A method of claim 142 wherein the precursor cells are obtained from bone marrow, umbilical cord blood, placental blood, or Wharton's jelly.

186. A method of claim 142 wherein the precursor cells are obtained from fetal or neonatal blood.

187. A chimeric receptor reporter system comprising cells expressing a fusion protein comprising at least one extracellular domain of LILRB2 and transmembrane and cytoplasmic domains of PILR β wherein binding of an activating ligand to the extracellular domain of LILRB2 results in reporter gene expression.

188. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 is the Ig1 domain, the Ig2 domain, the Ig3 domain and/or the Ig4 domain.

189. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 is the Ig1 domain.

190. A chimeric receptor reporter system of claim 187 wherein the Ig1 domain includes amino acids 24-119 of LILB2.

191. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 is the Ig2 domain.

192. A chimeric receptor reporter system of claim 187 wherein the Ig2 domain includes amino acids 120-219 of LILB2.

193. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 is the Ig3 domain.

194. A chimeric receptor reporter system of claim 187 wherein the Ig3 domain includes amino acids 221-320 of LILB2.

195. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 is the Ig4 domain.

196. A chimeric receptor reporter system of claim 187 wherein the Ig4 domain includes amino acids 321-458 of LILB2.

197. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 includes the Ig1 domain and the Ig2 domain.

198. A chimeric receptor reporter system of claim 187 wherein the Ig1 domain and the Ig2 domain includes amino acids 24-219 of LILRB2.

199. A chimeric receptor reporter system of claim 187 wherein the at least one extracellular domain of LILRB2 includes the Ig3 domain and the Ig4 domain.

200. A chimeric receptor reporter system of claim 187 wherein the Ig3 domain and the Ig4 domain includes amino acids 221-458 of LILRB2.

201. A chimeric receptor reporter system of claim 187 wherein the fusion protein includes amino acids 24-458 of LILRB2.

202. A chimeric receptor reporter system of claim 187 wherein the cells are T cell hybridoma cells.

203. A chimeric receptor reporter system of claim 202 wherein reporter gene expression results from NFAT activation.

204. A chimeric receptor reporter system of claim 203 wherein reporter gene expression is under the control of a NFAT-responsive promoter.

205. A method of claim 41 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

206. A method of claim 69 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

207. A method of claim 114 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem cells; or HSC or hematopoietic precursors derived by reprogramming.

208. A method of claim 142 wherein the precursor cells are embryonic stem cells; hematopoietic precursors of HSC derived from embryonic stem cells; induced pluripotent stem

cells; or HSC or hematopoietic precursors derived by reprogramming.

1/63

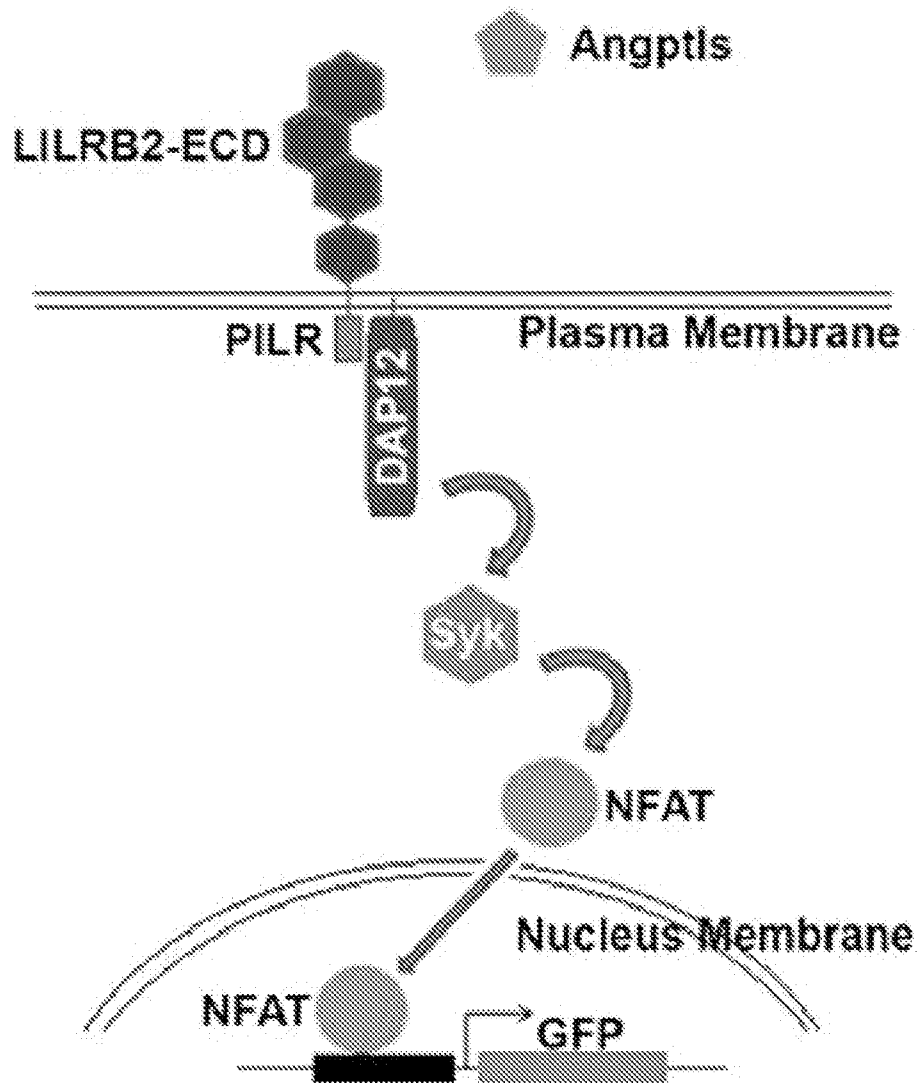


Fig. 1A

2/63

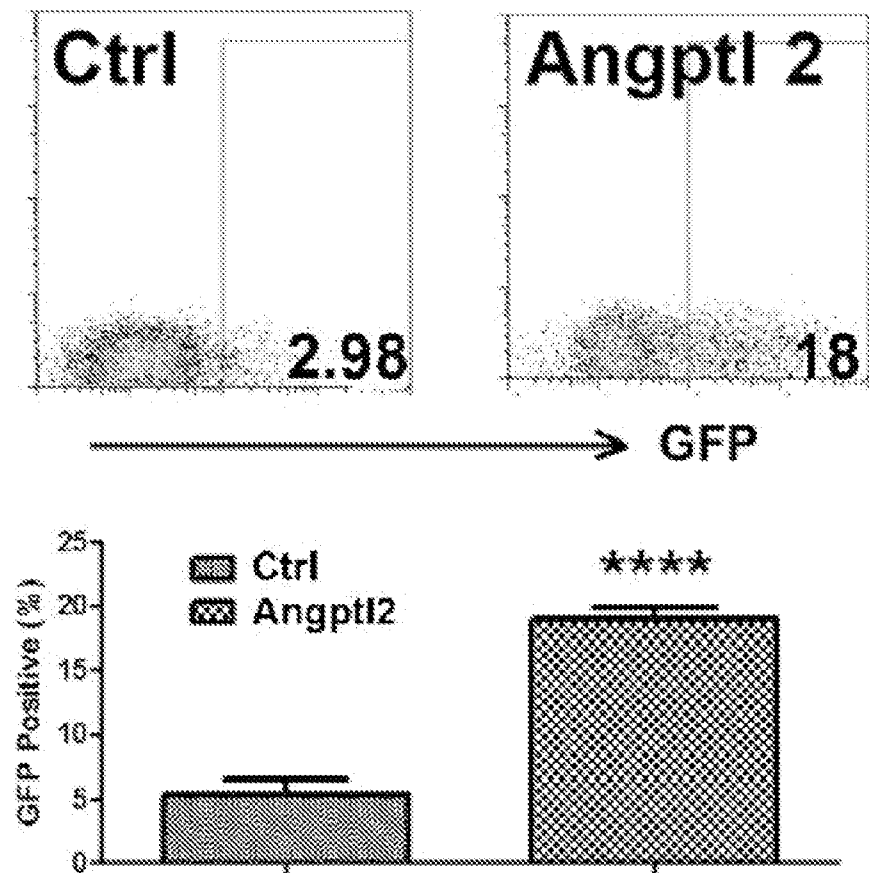


Fig. 1B

3/63

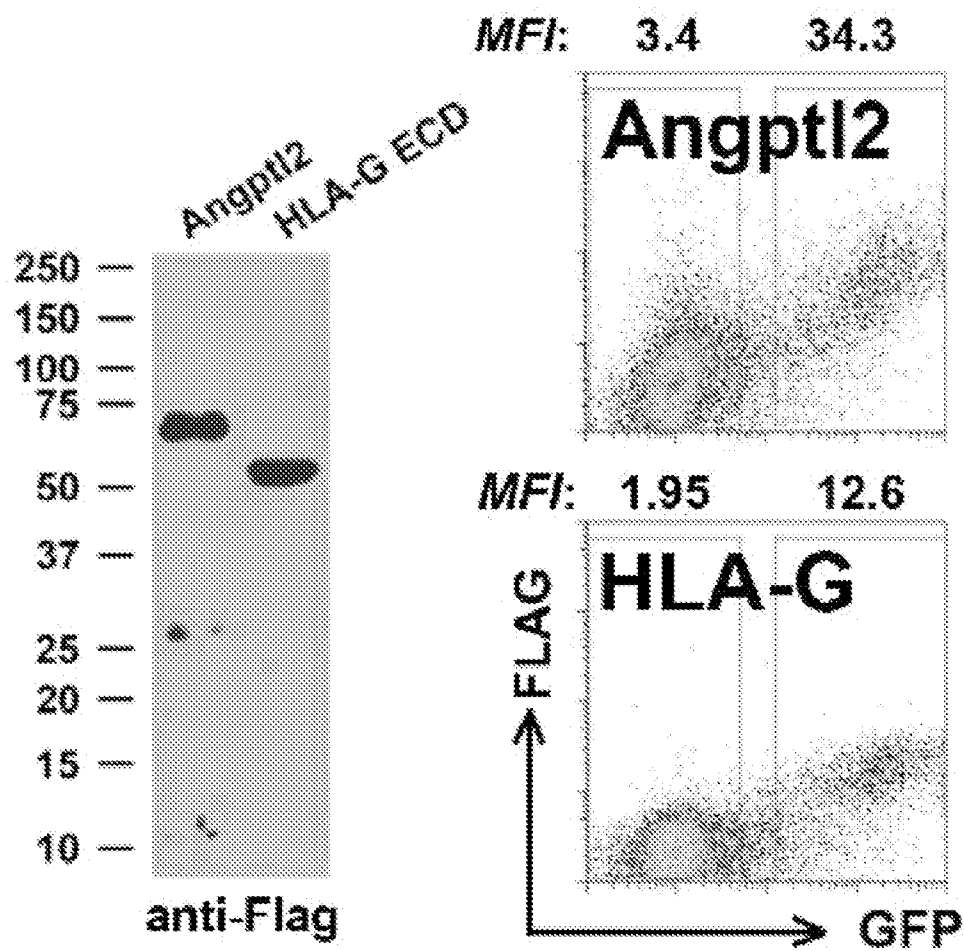


Fig. 1C

4/63

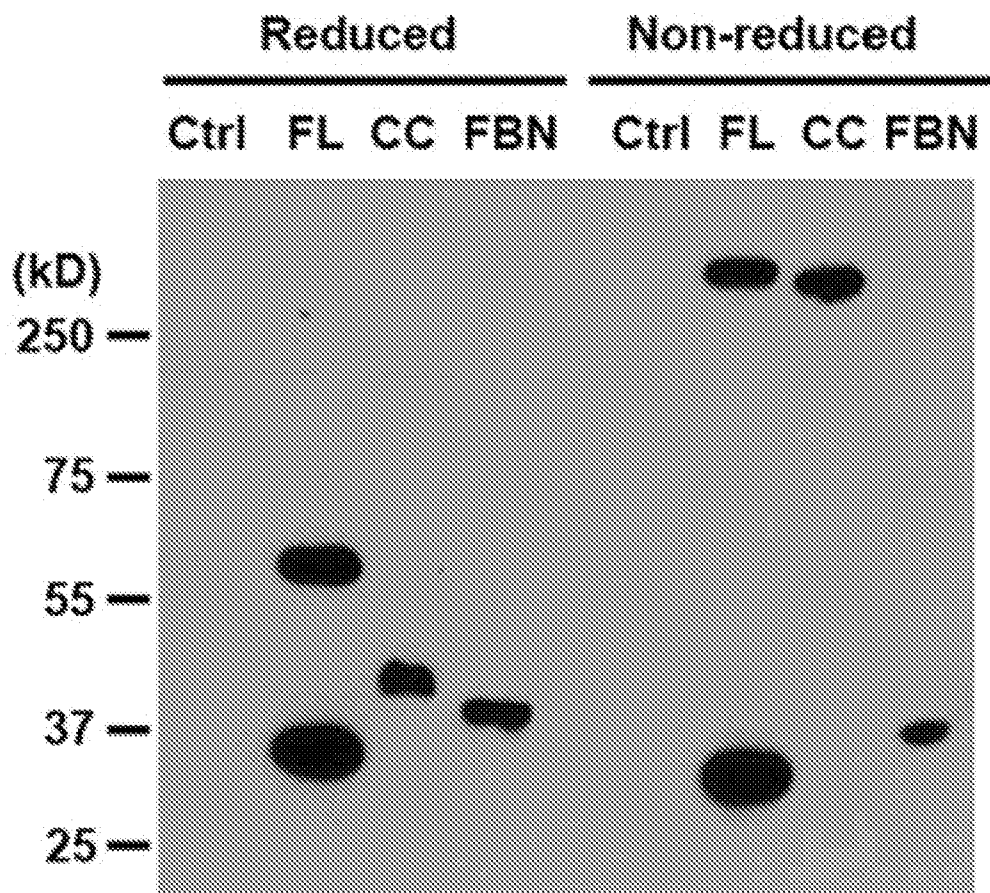


Fig. 1D

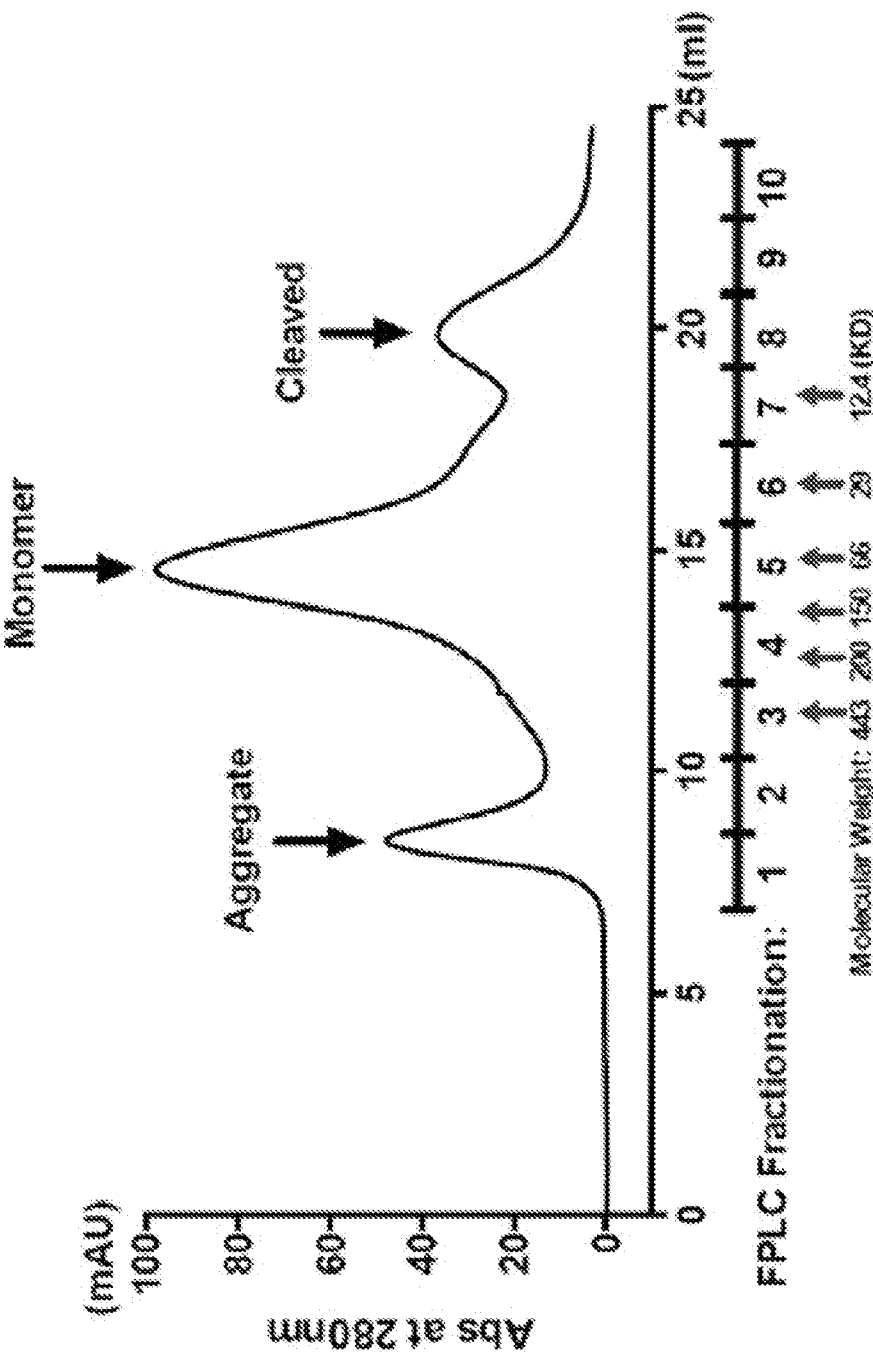


Fig. 1E

6/63

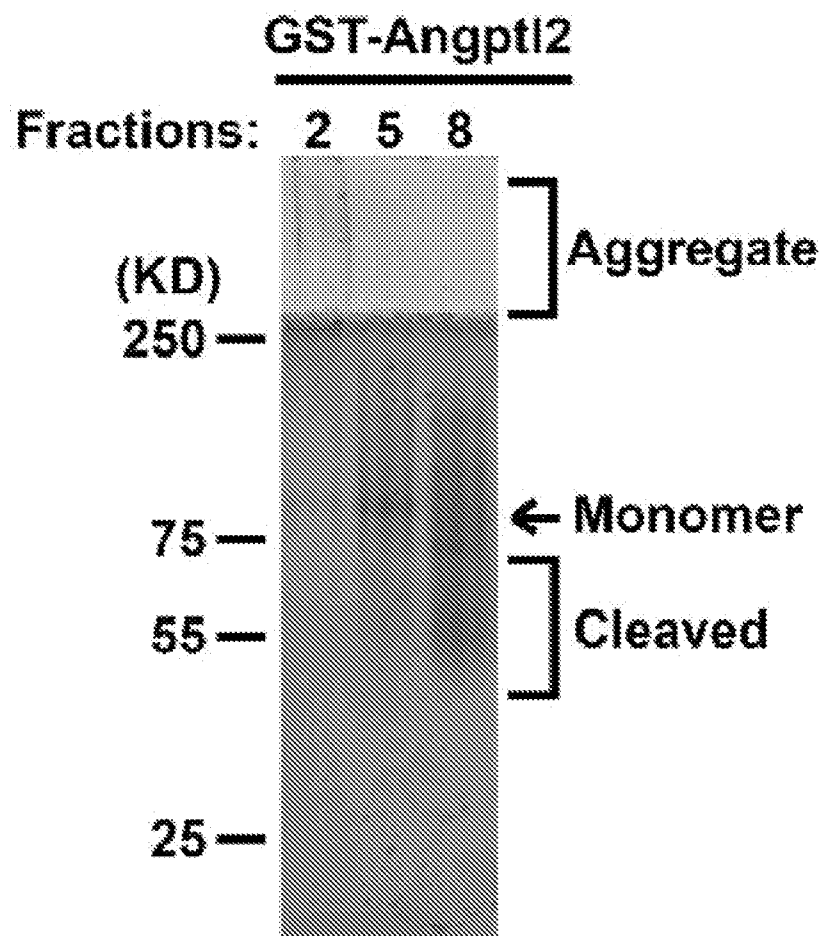


Fig. 1F

7/63

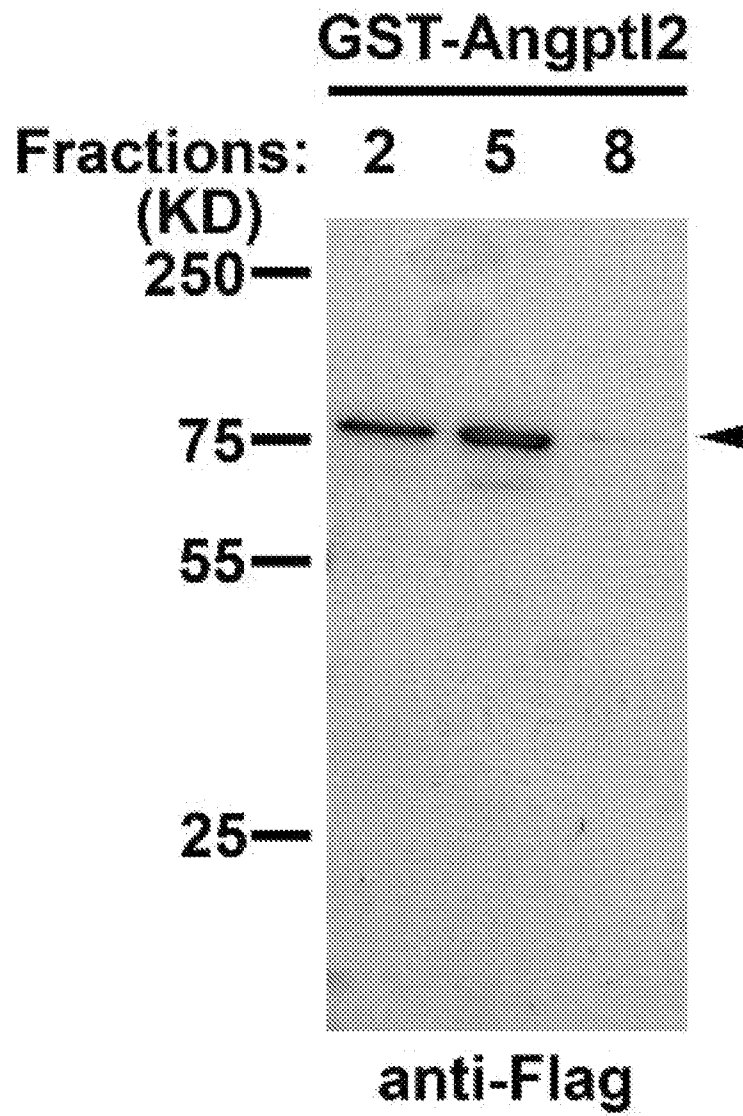


Fig. 1G

8/63

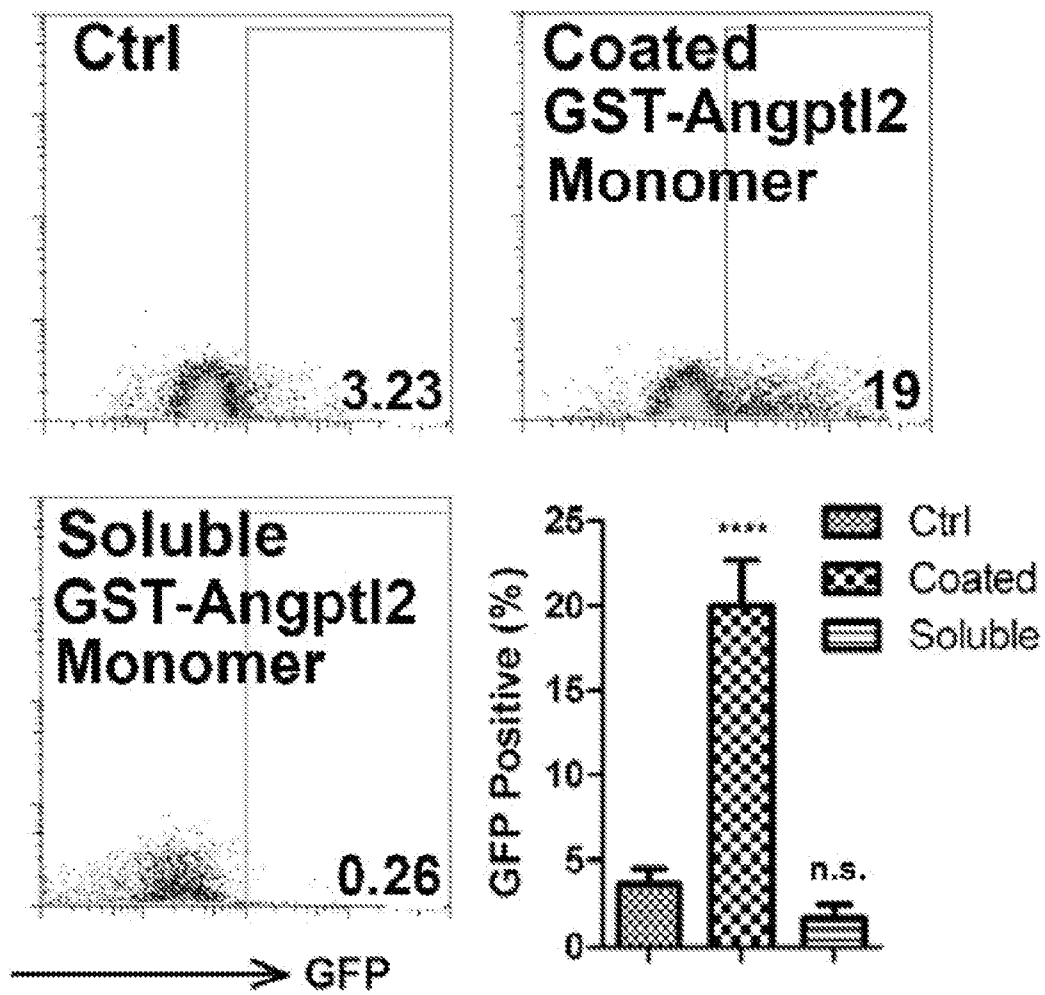


Fig. 1H

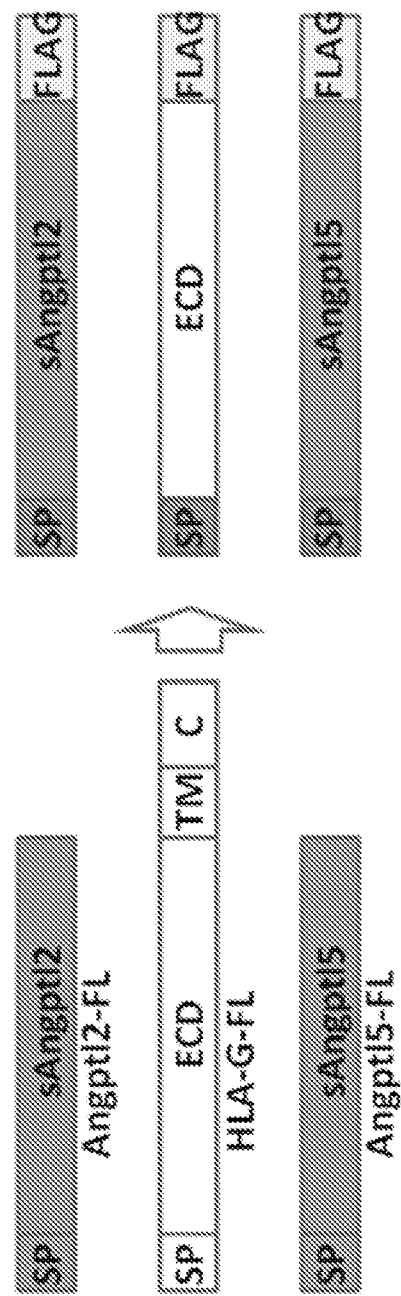


Fig. 2A

10/63

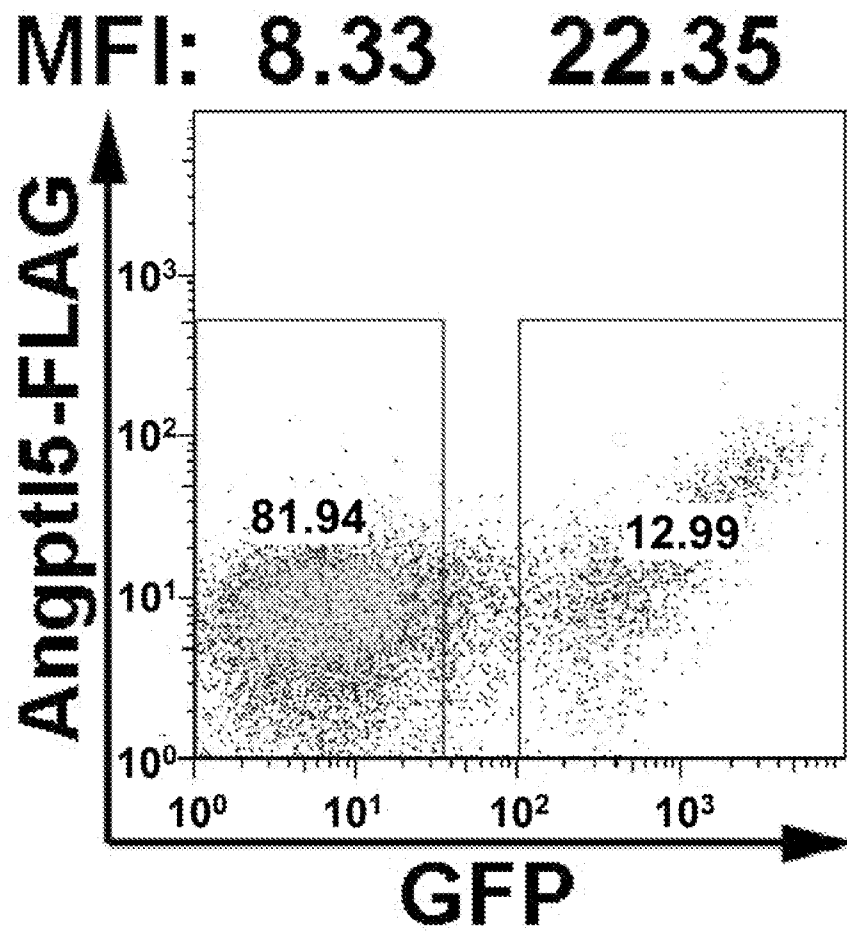


Fig. 2B

11/63

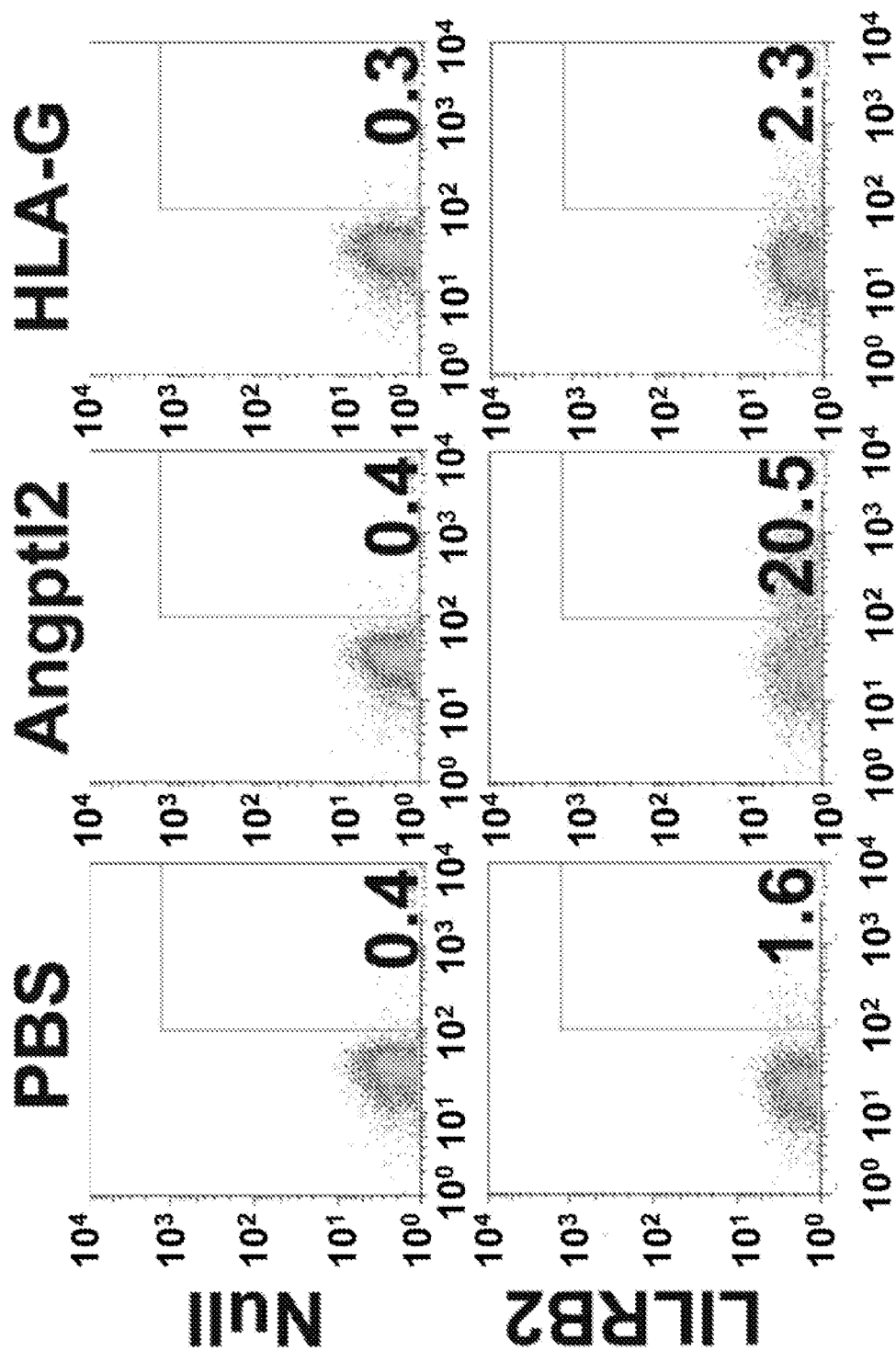


Fig. 3

12/63

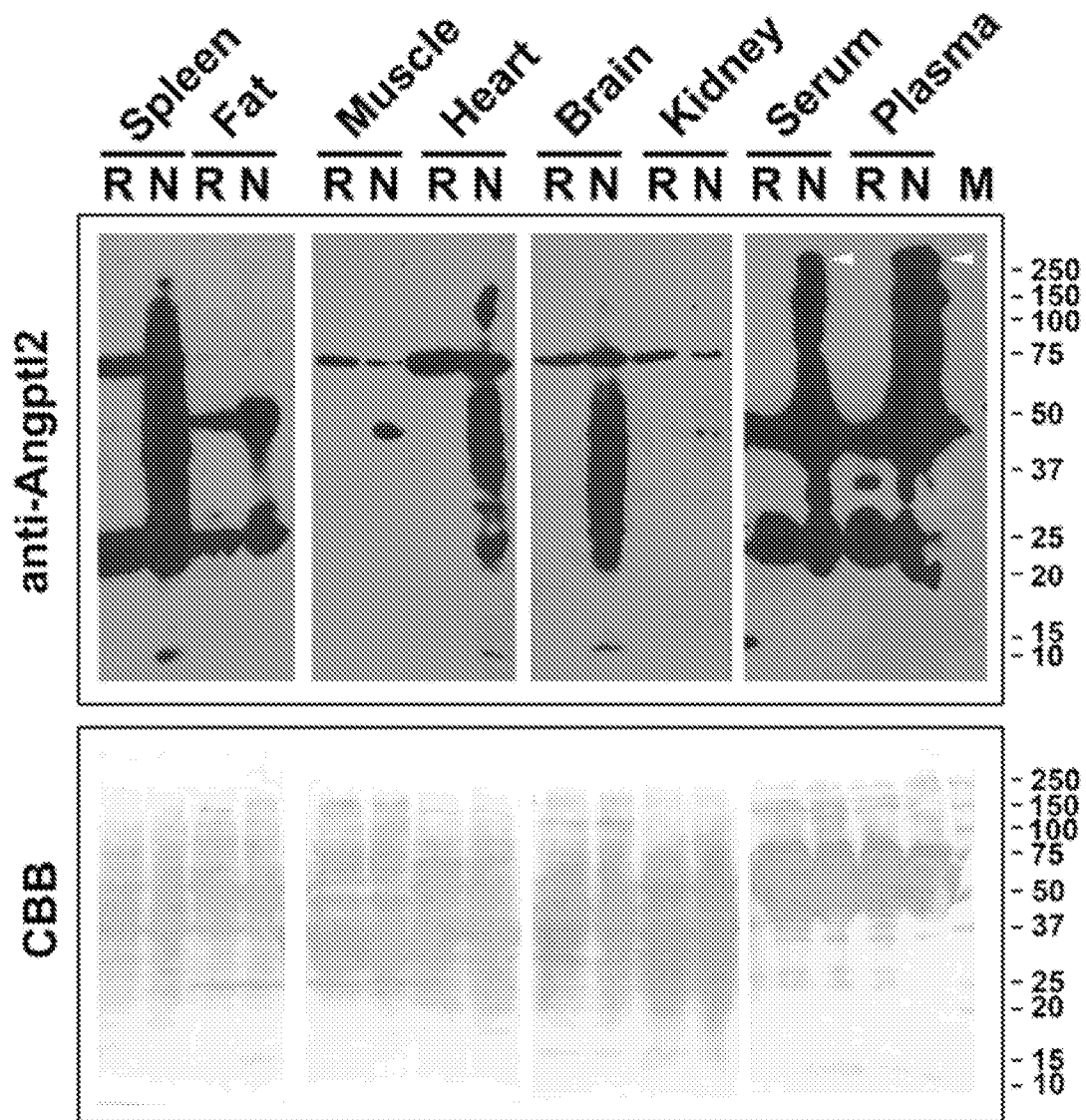


Fig. 4

13/63

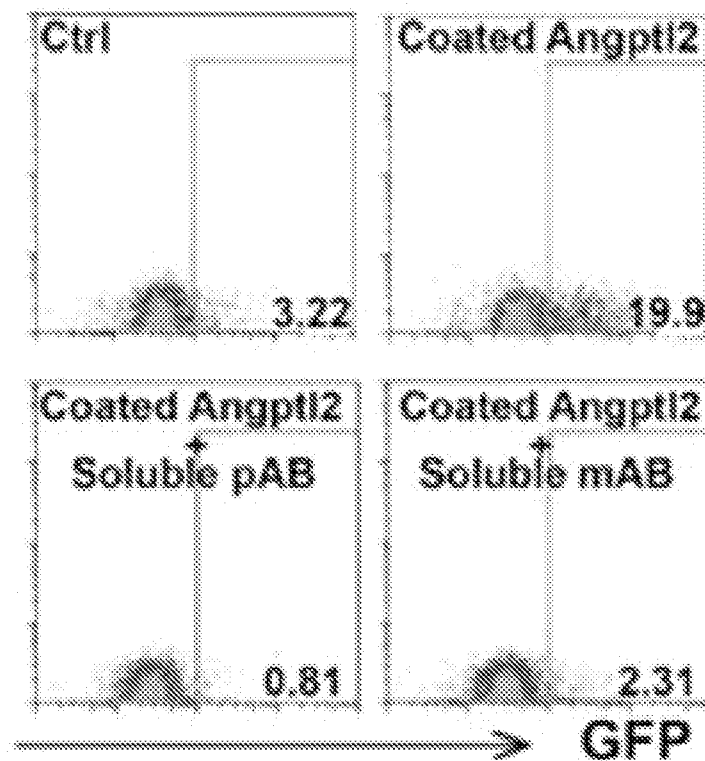


Fig. 5A

14/63

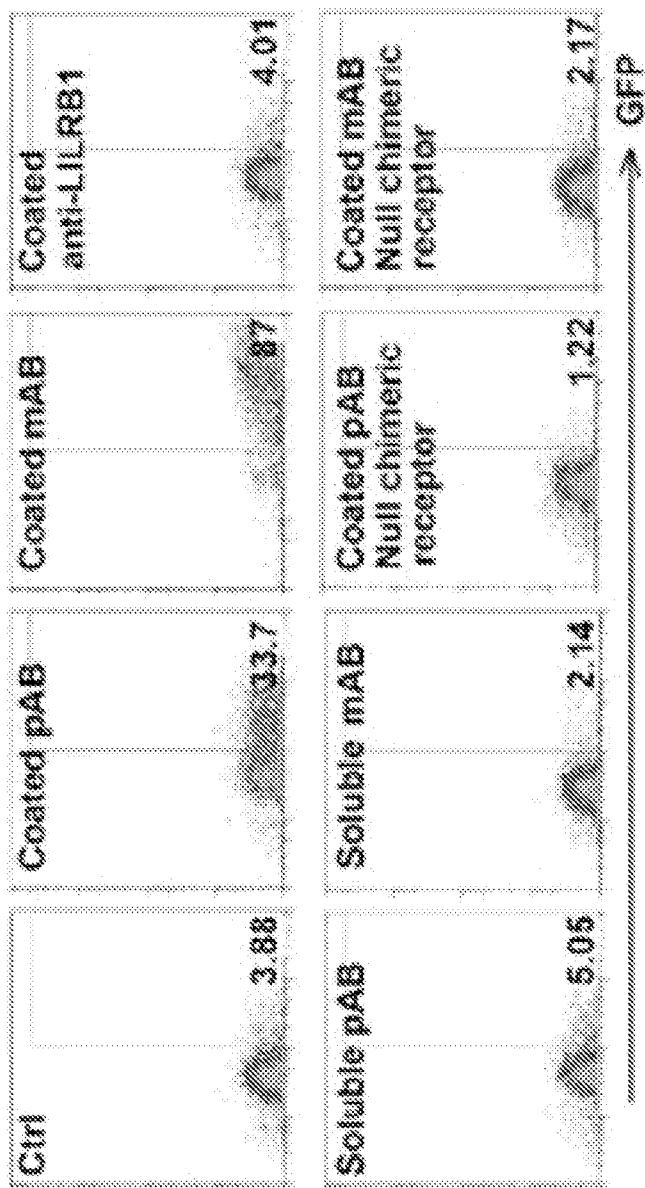


Fig. 5B

15/63

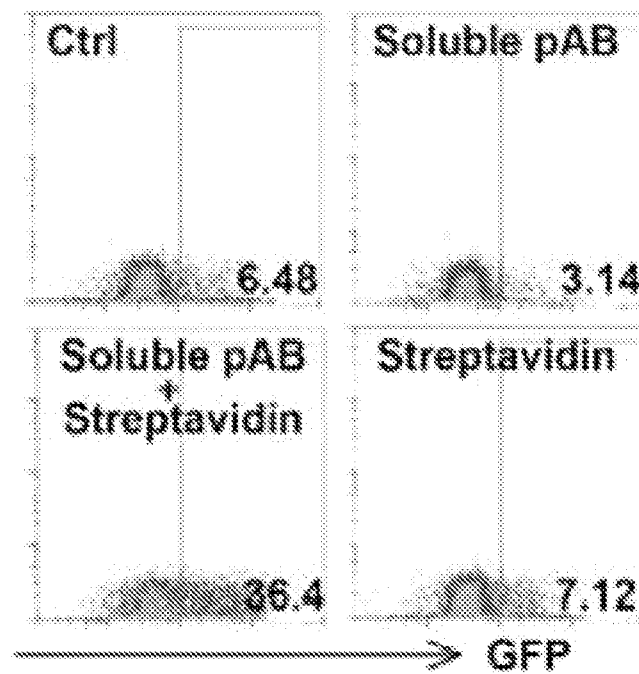


Fig. 5C

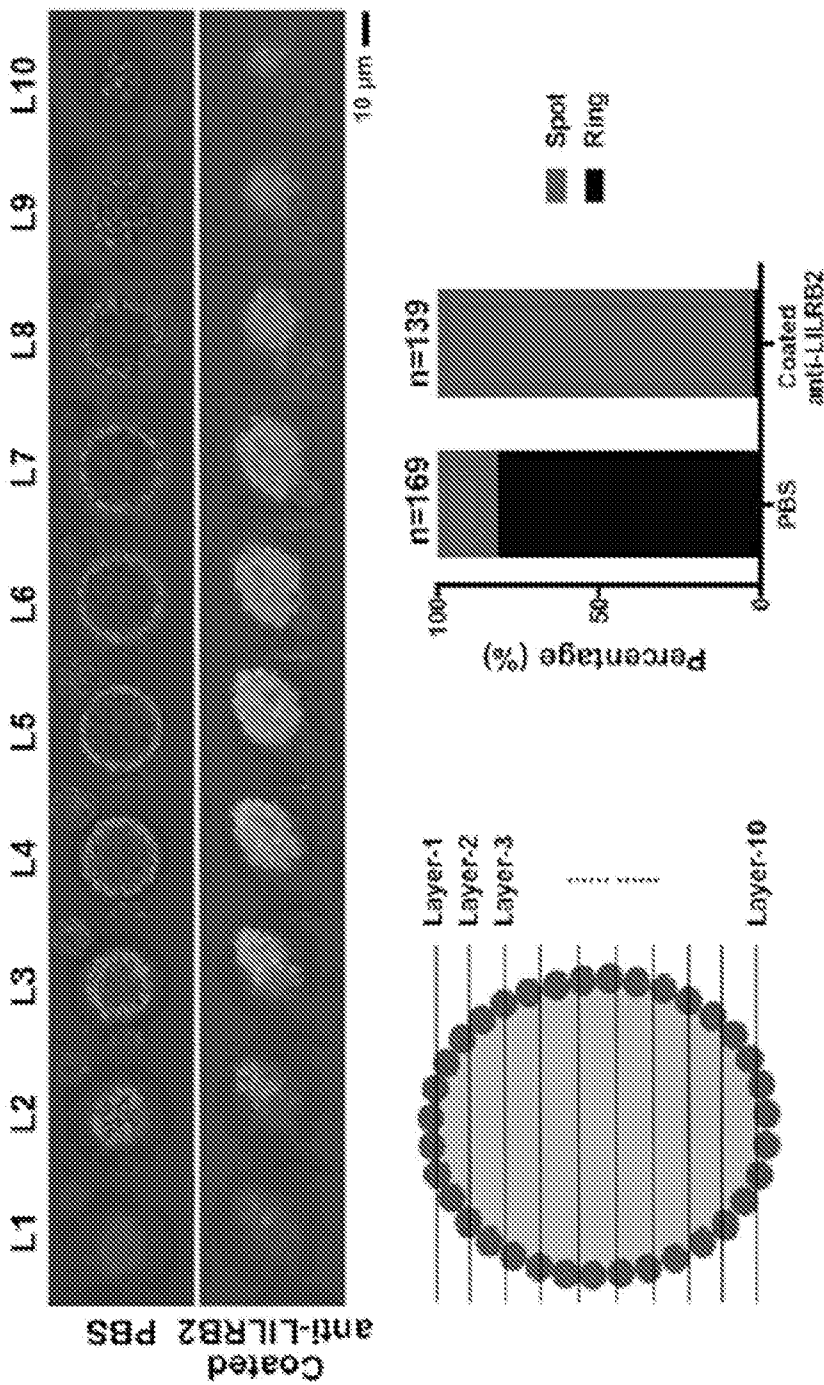


Fig. 5D

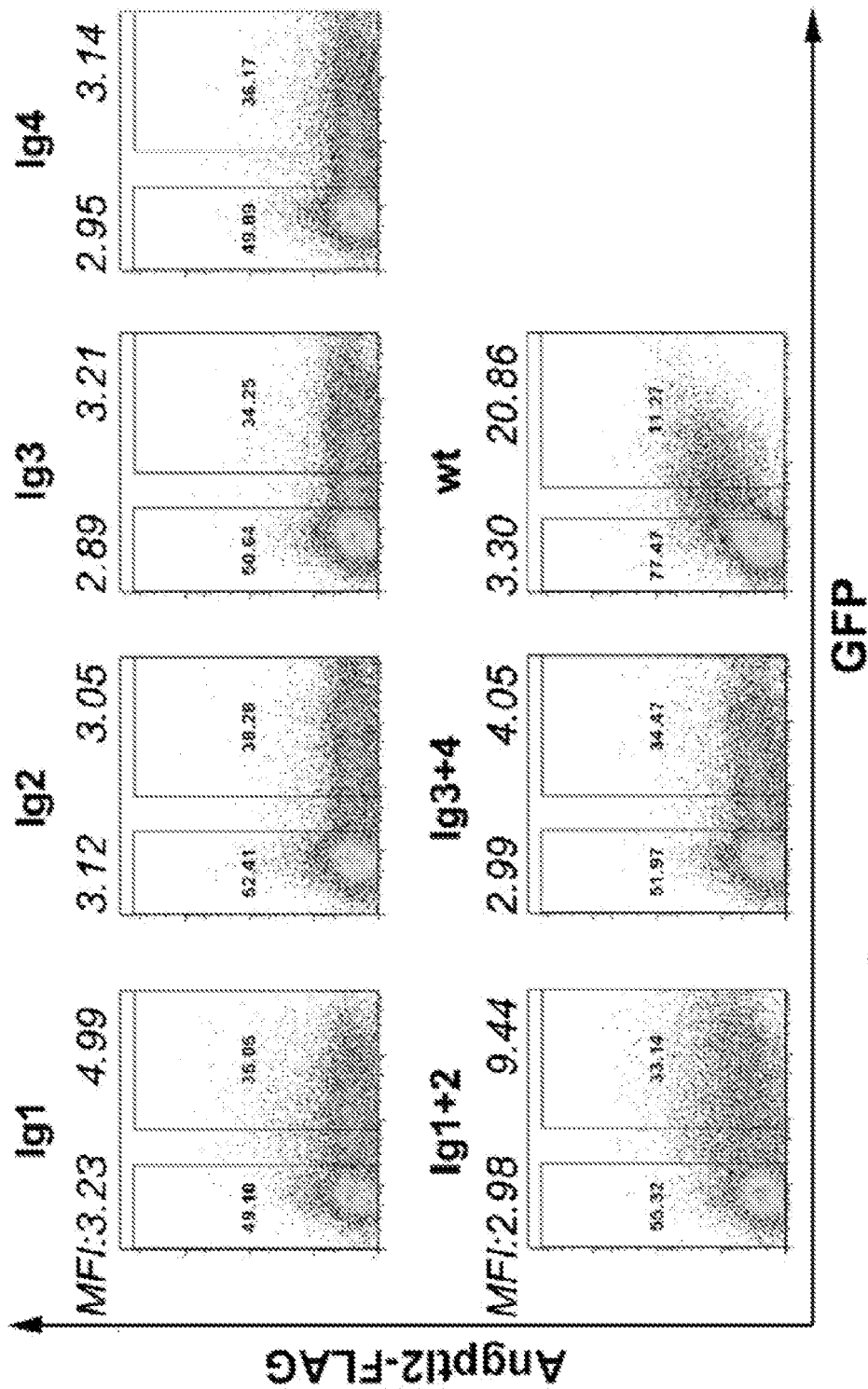


Fig. 6A

18/63

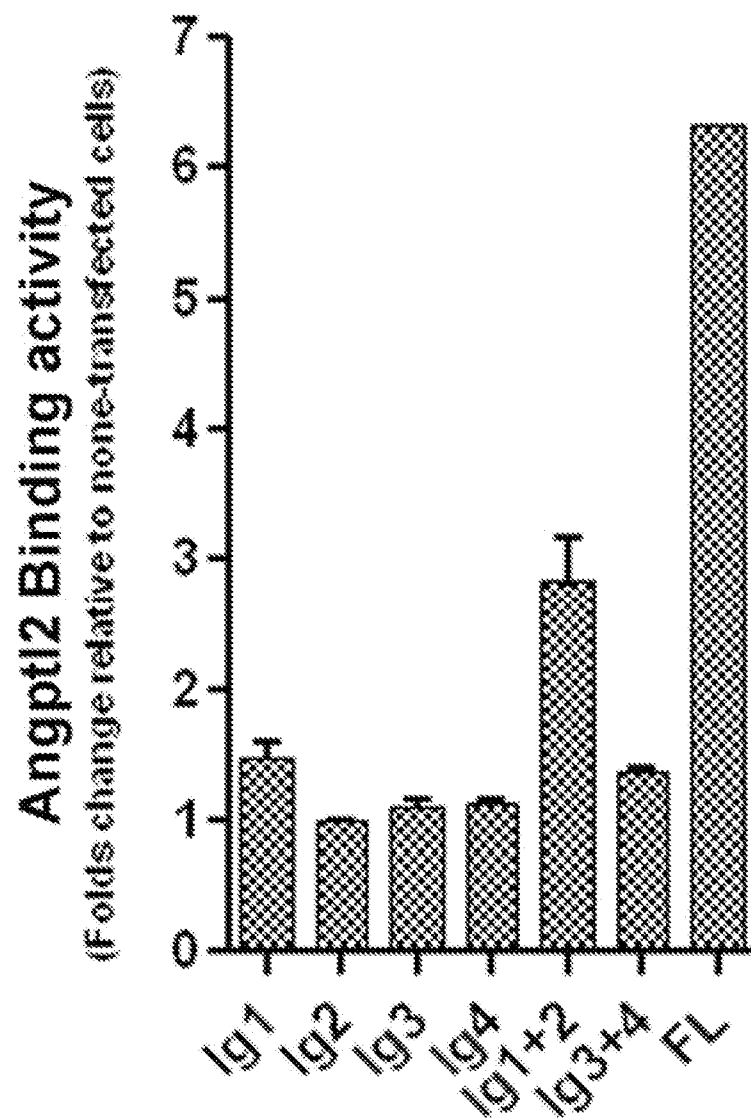


Fig. 6B

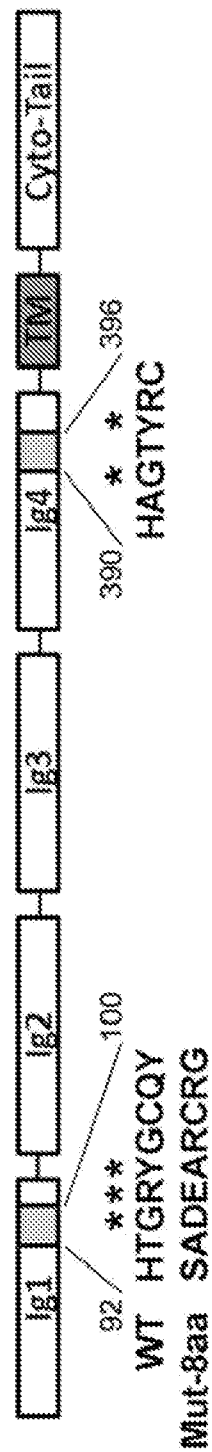


Fig. 6C

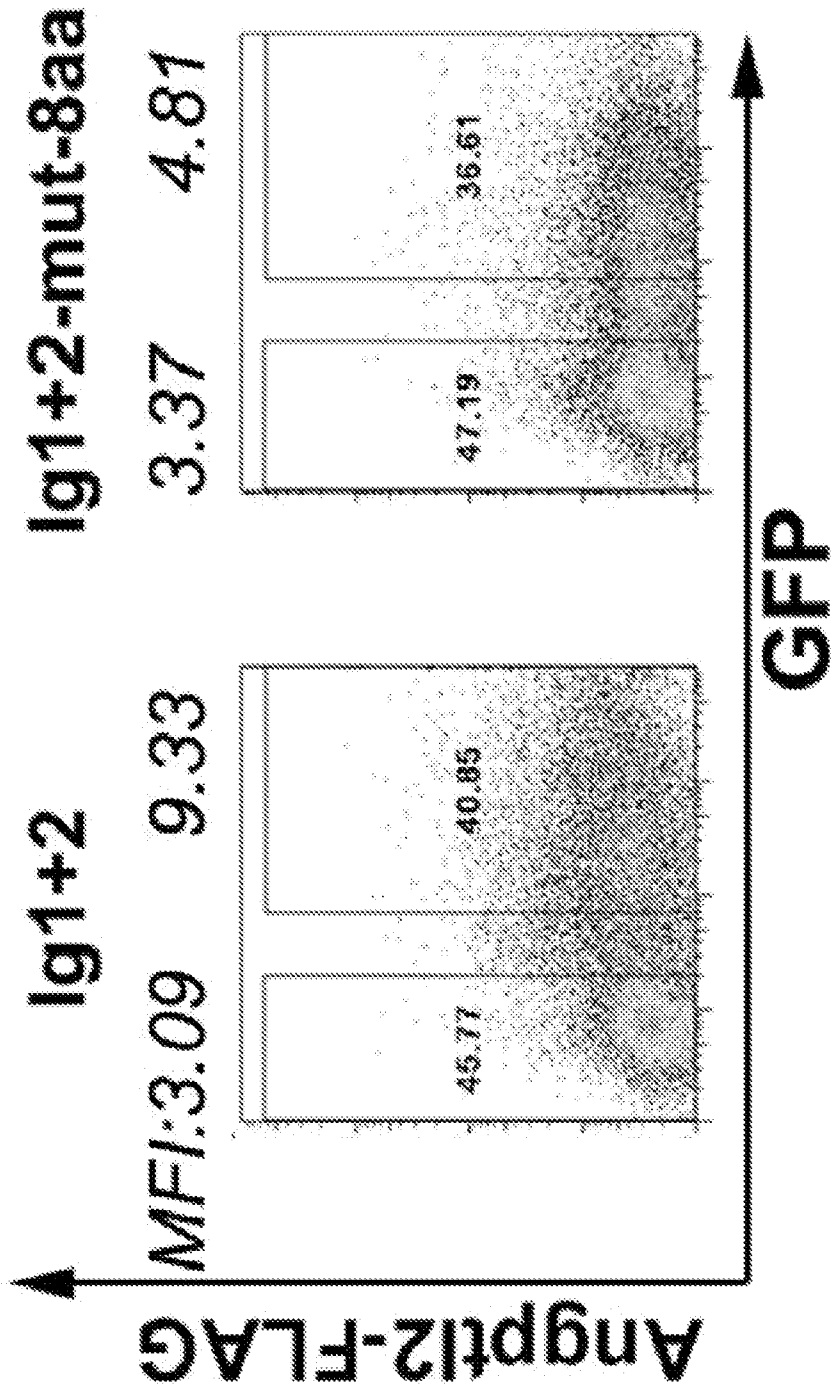


Fig. 6D

21/63

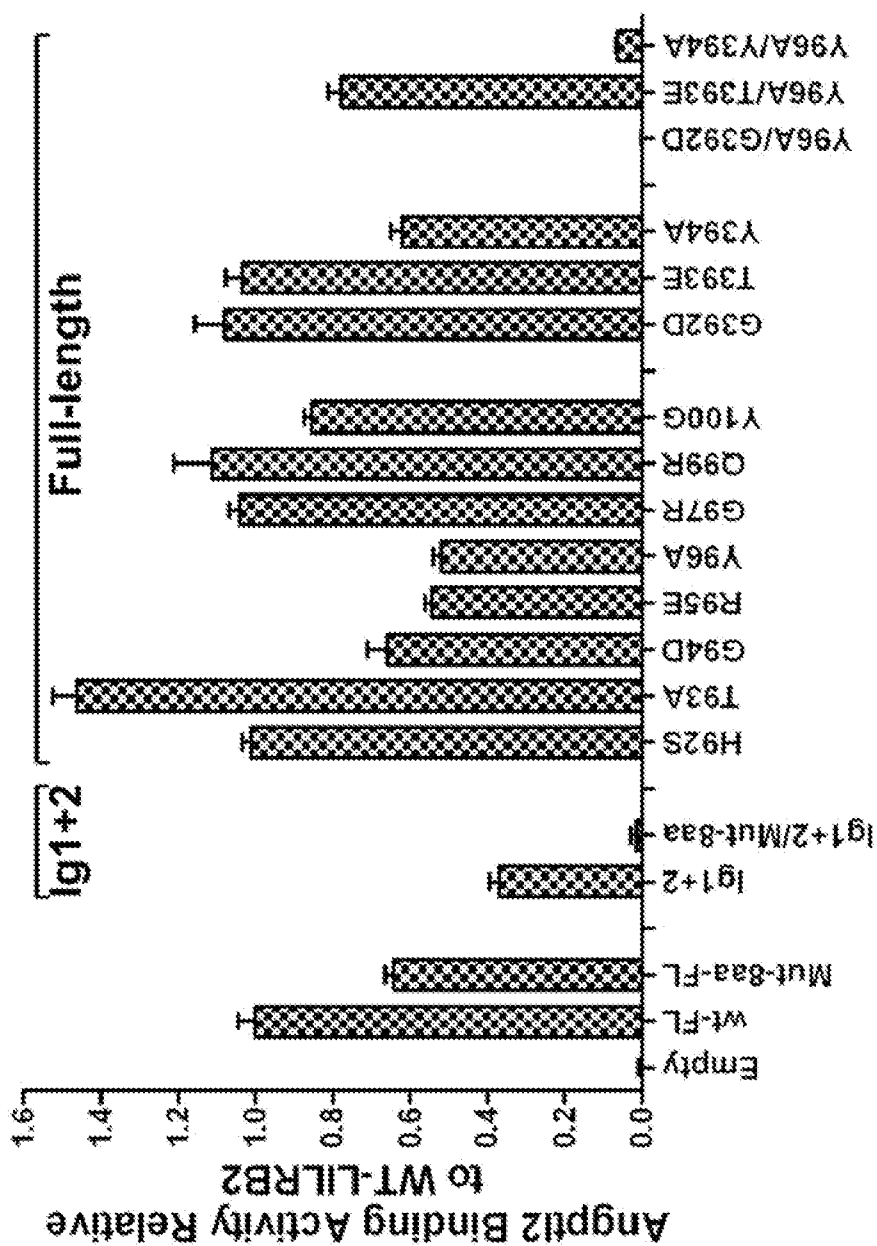


Fig. 6E

22/63

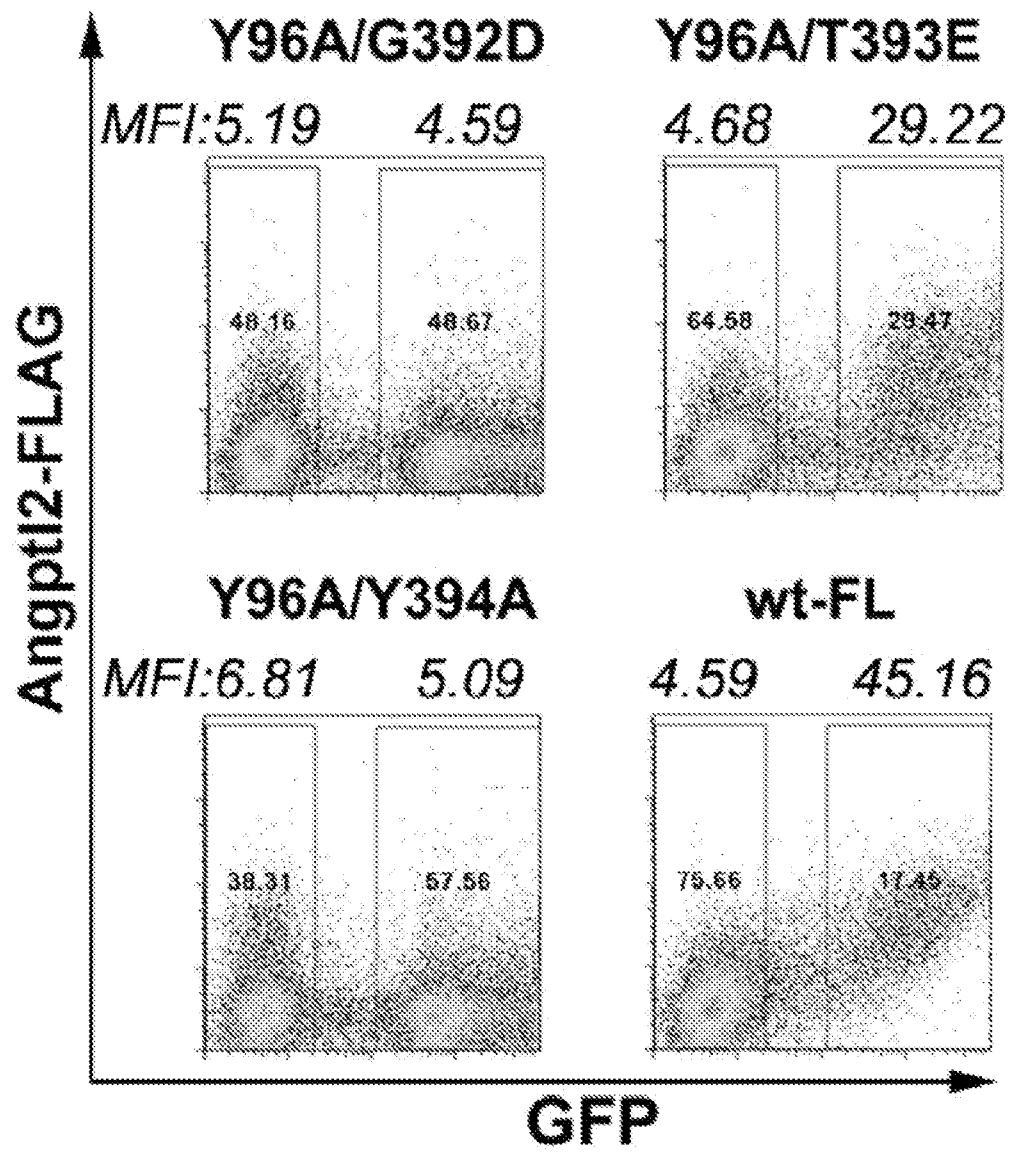


Fig. 6F

23/63

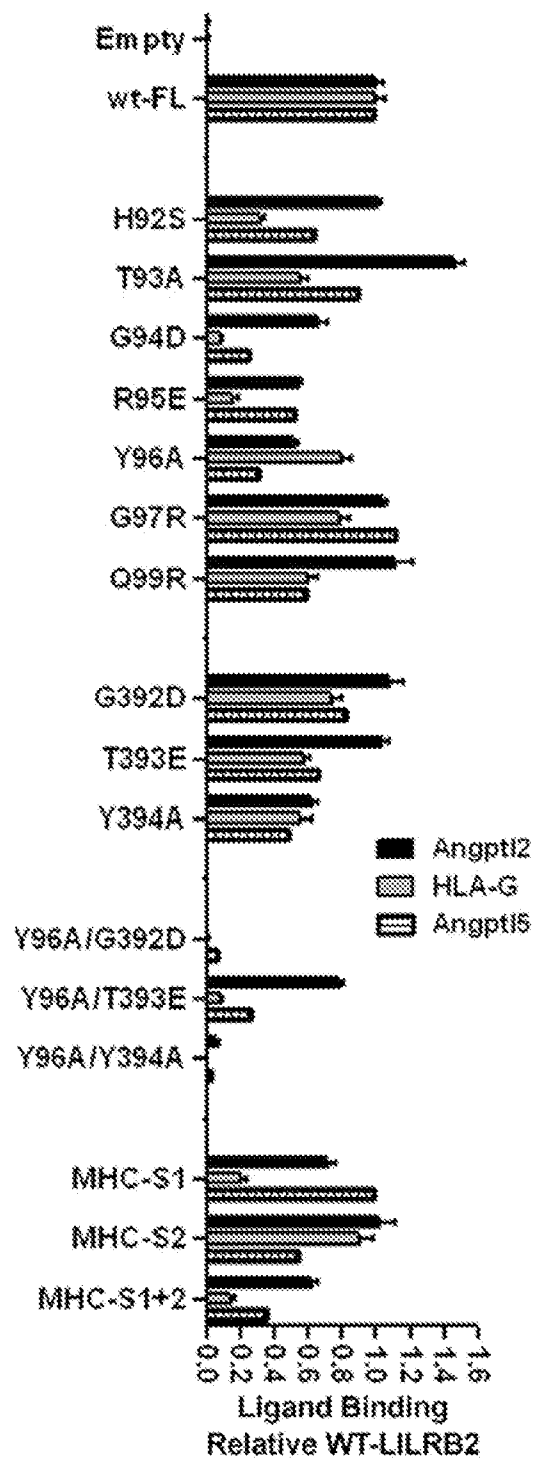


Fig. 6G

24/63

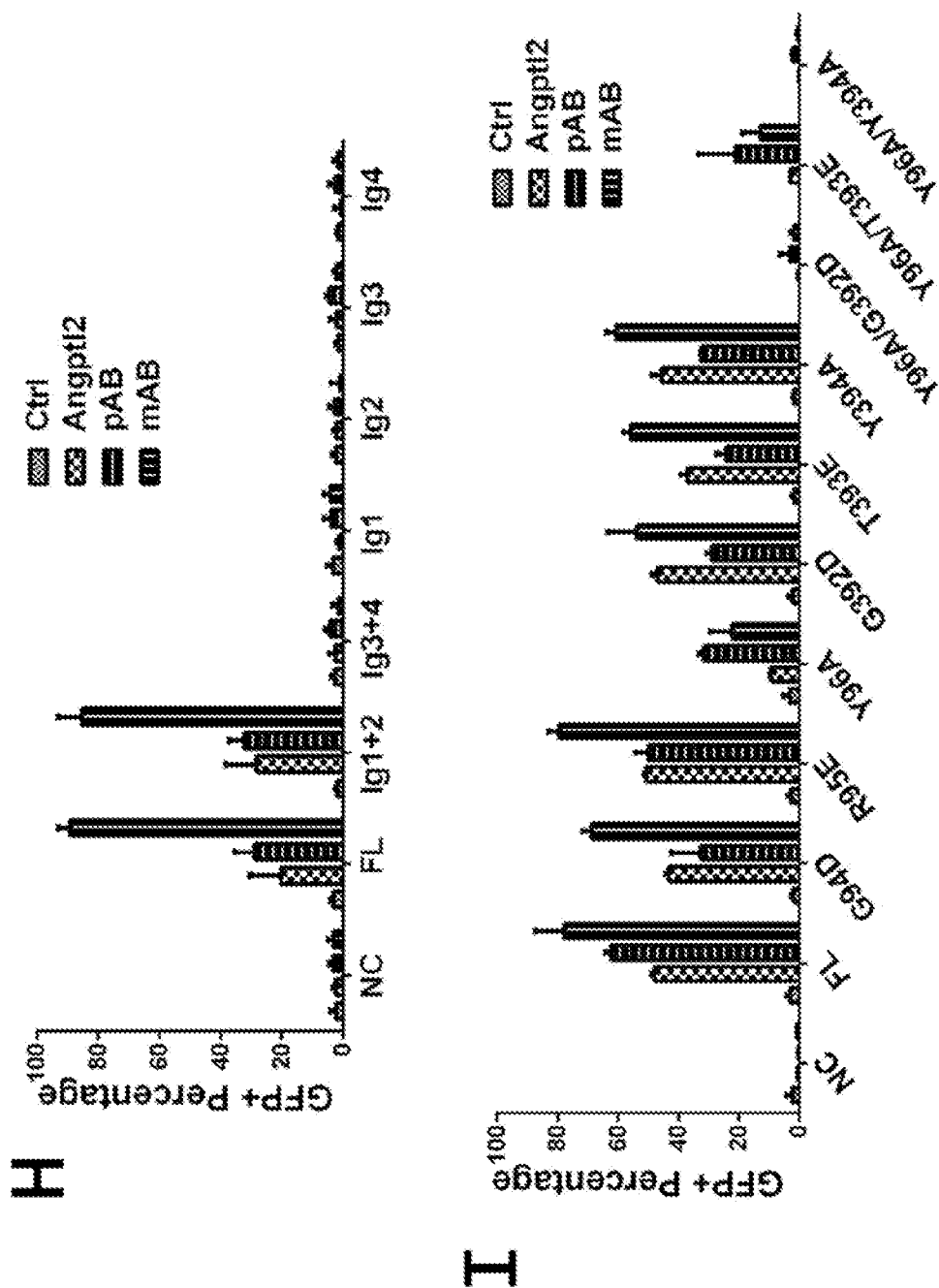


Fig. 6H-I

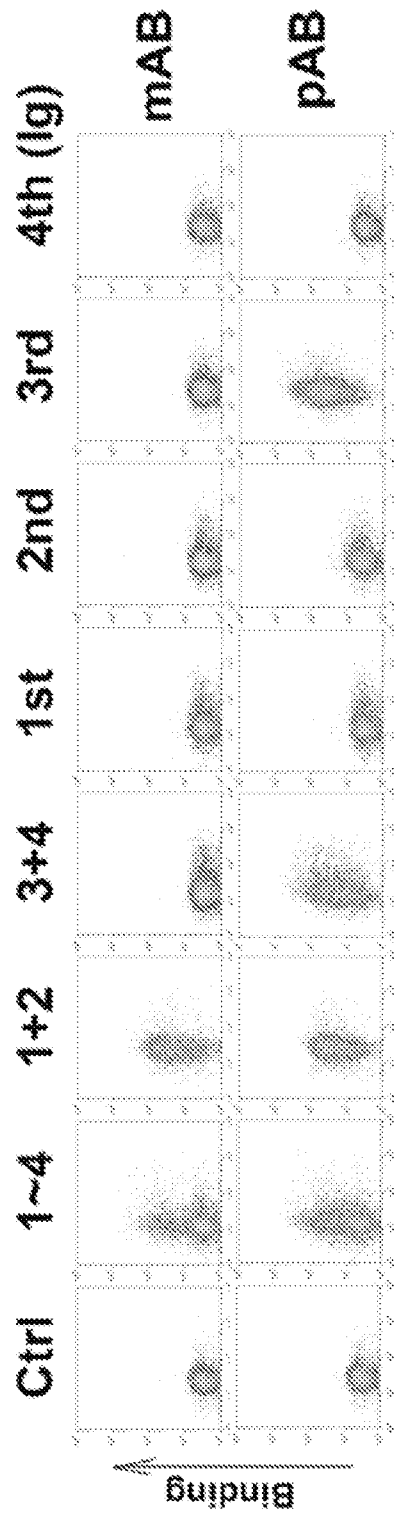


Fig. 7

26/63

MTPIVTVLCLGLSGPRTHVQTSTIPKPTLWAEPSDVITQGGSPVTLSCQGSLEAQEYRLYREKKSASWITRIR
 PELVKNQGQHIPSITWENTGTRYGCCQYYSRARWSELSDPLVLVMTGAYPKPTLSAQPSPVVTSGGRTVLOCE
 SQVAFGGFILCKEGEEHPQCLNSQPHARGSSRAIFSVGPVSPNRRWWSHRCYGYDLNSPYVWSSPSDLELL
 VPGVSRKPSLSVQPGPVVAPGESLTLCVSDVGYDRFVLYKEGERDLRQLPGRQPOAGLSQANFTLGPVSR
 SYGGQYRCYGANNLSECSAPSDPLDILITGQIRGTPFISVQPGPTVASGENVTLLCQSWRQFHTFLLTKAGA
 ADAPLRLSIHEYPKYQAEFPMSPVTSAHAGTYRCYGSUNSDPYLLSHHPSEPLELVSGPSMGSSPPPTGPIST
 PGPEDQPLTPTGSDPQSGLRHGLGVVIGILVAVVLLLLLLLLFLILRHRROGKHWTSTQRKADFQHPAGAVG
 PEPTDRGLQWRSSPAADAQEEENLYAAVKDTQPEDGVEMDTRAAASEAPODVTVACLHSLTLRRKATEPP
 PSQEREPPAEPsiYATLAIH

Fig. 8A

27/63

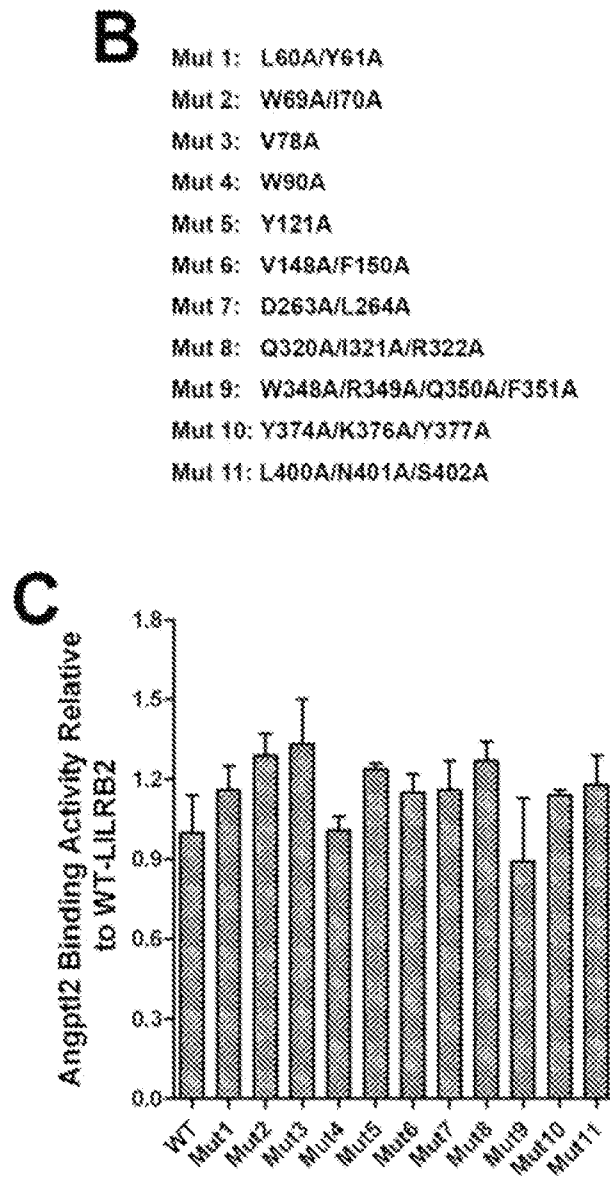


Fig. 8B-C

28/63

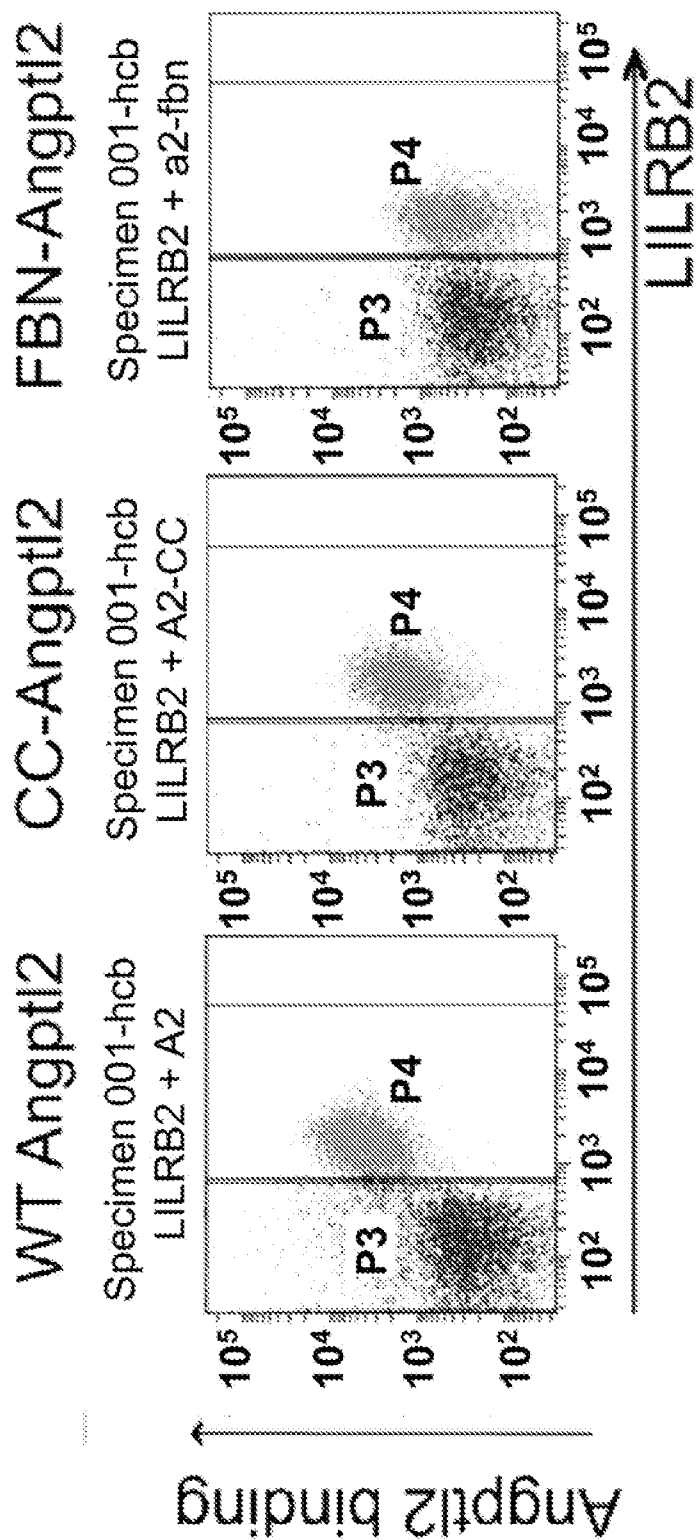


Fig. 9

29/63

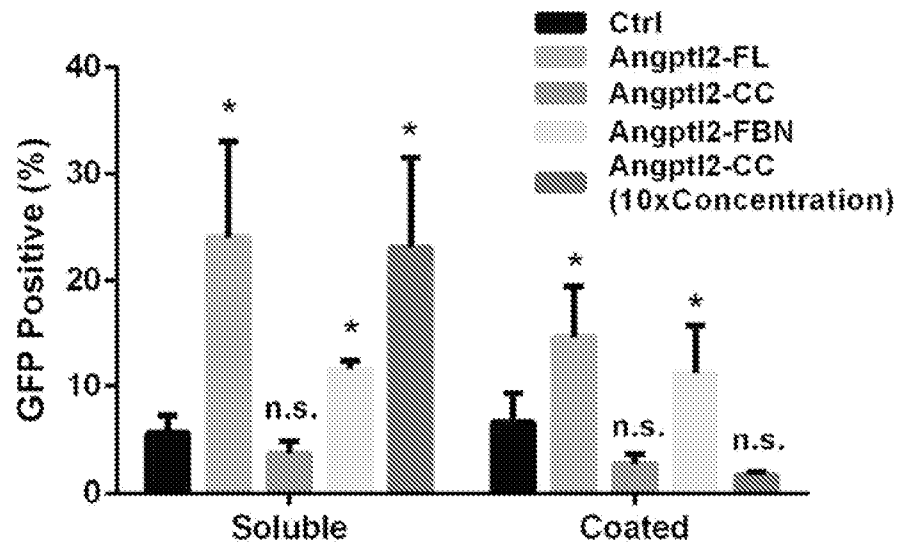


Fig. 10

30/63

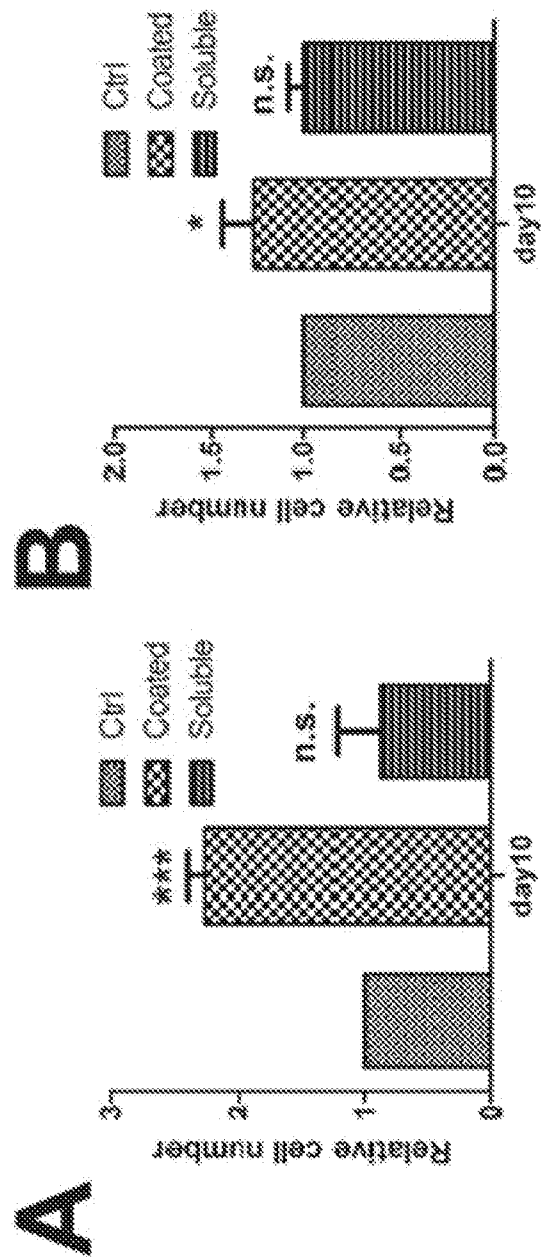


Fig. 11A-B

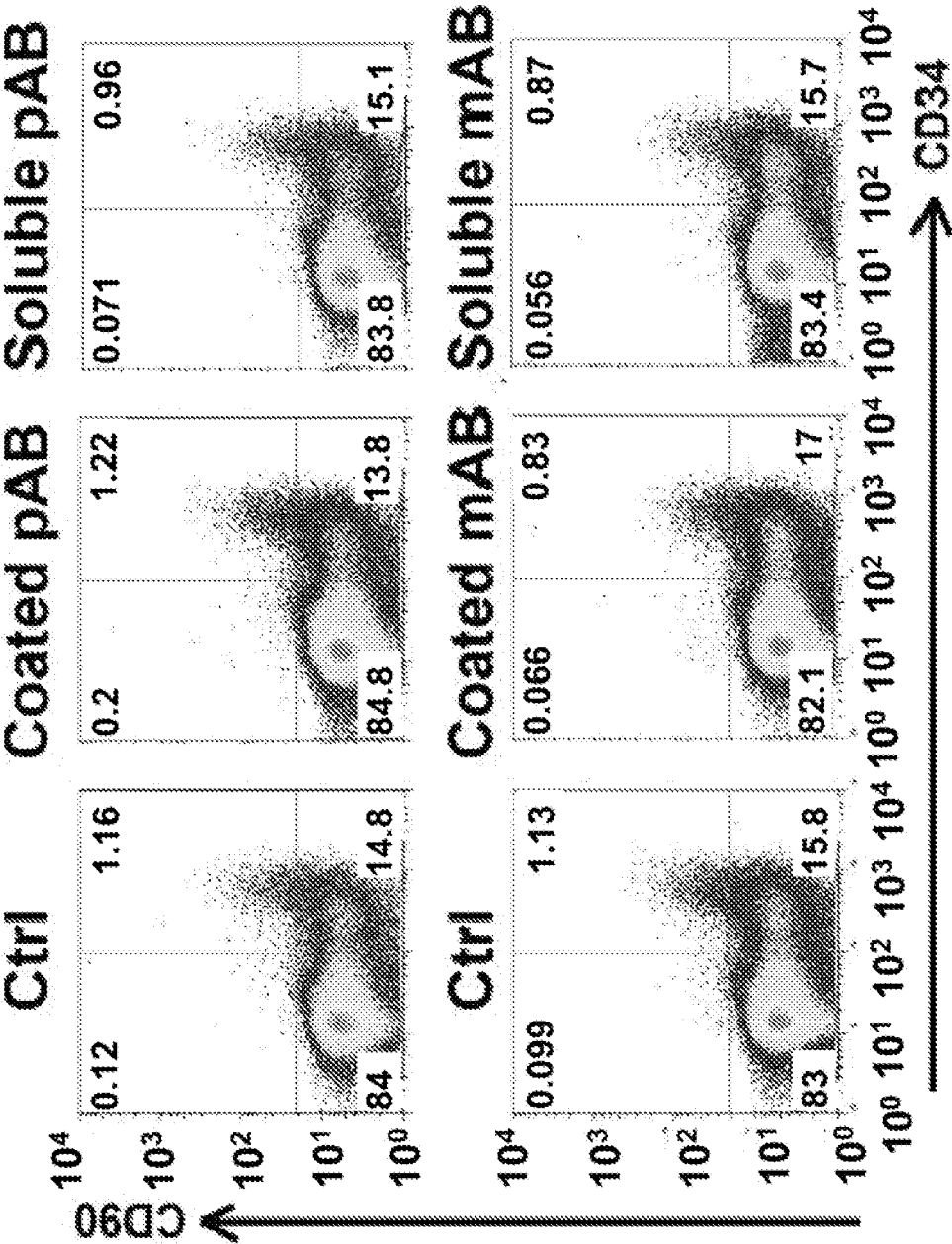


Fig. 11C

32/63

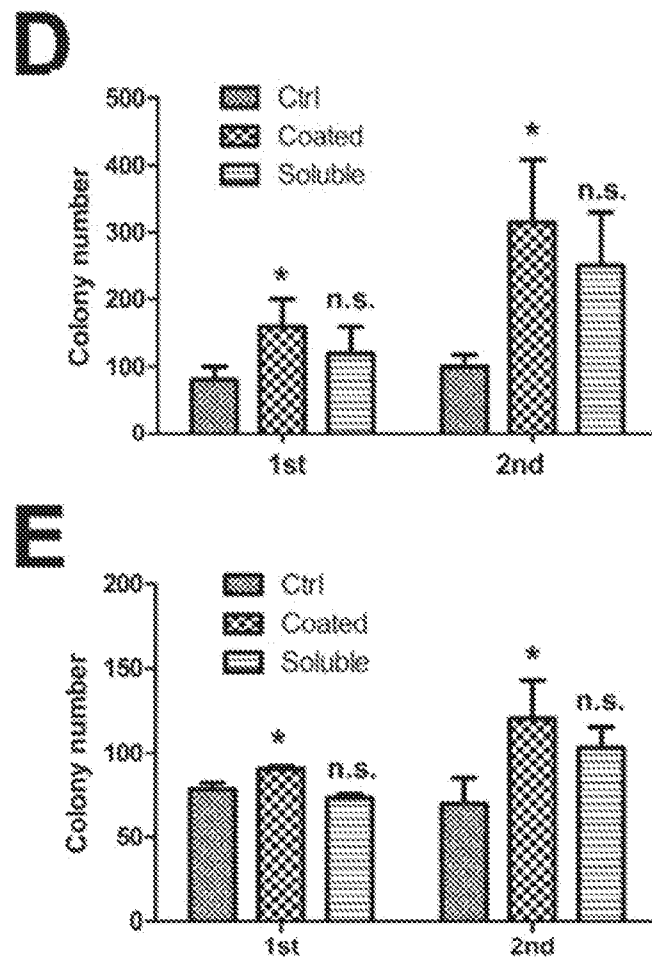


Fig. 11D-E

33/63

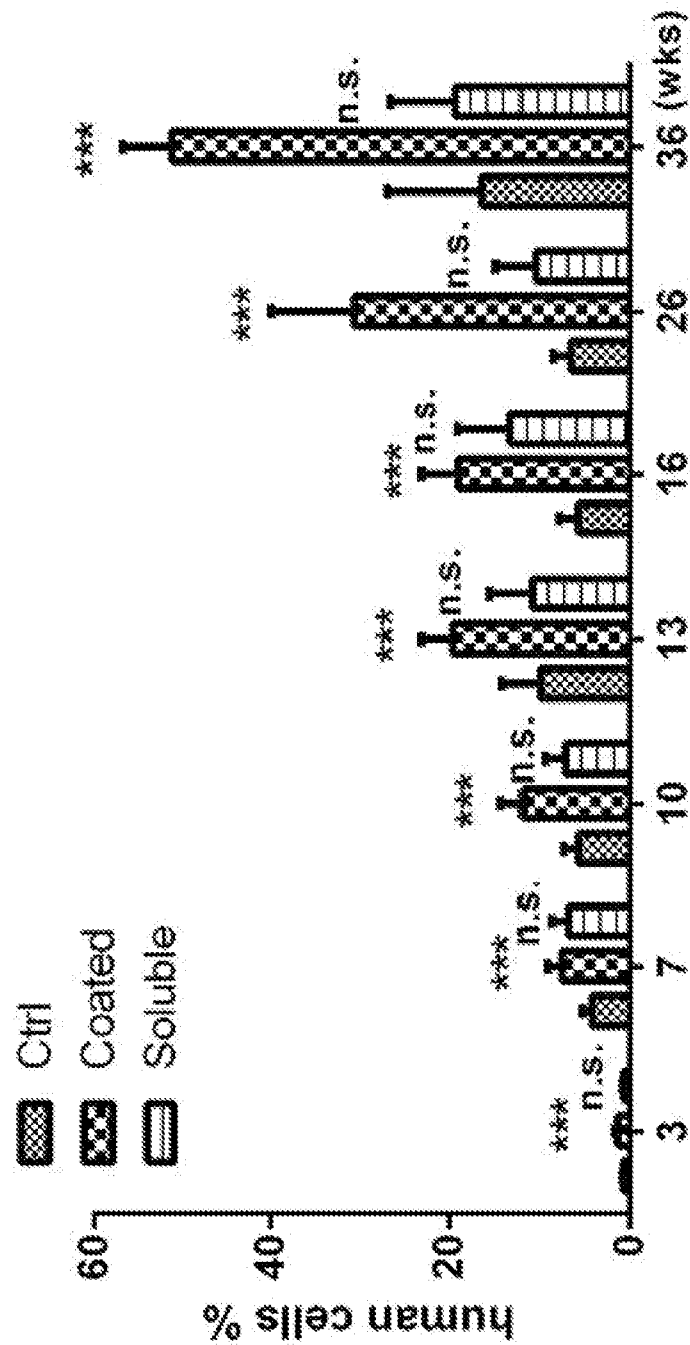


Fig. 12A

34/63

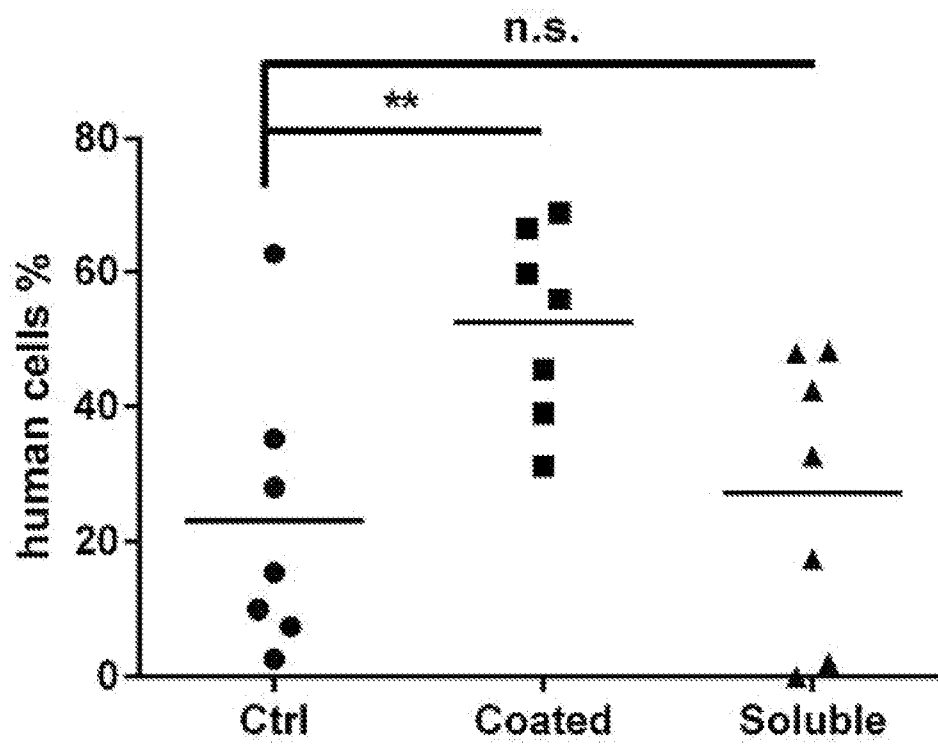


Fig. 12B

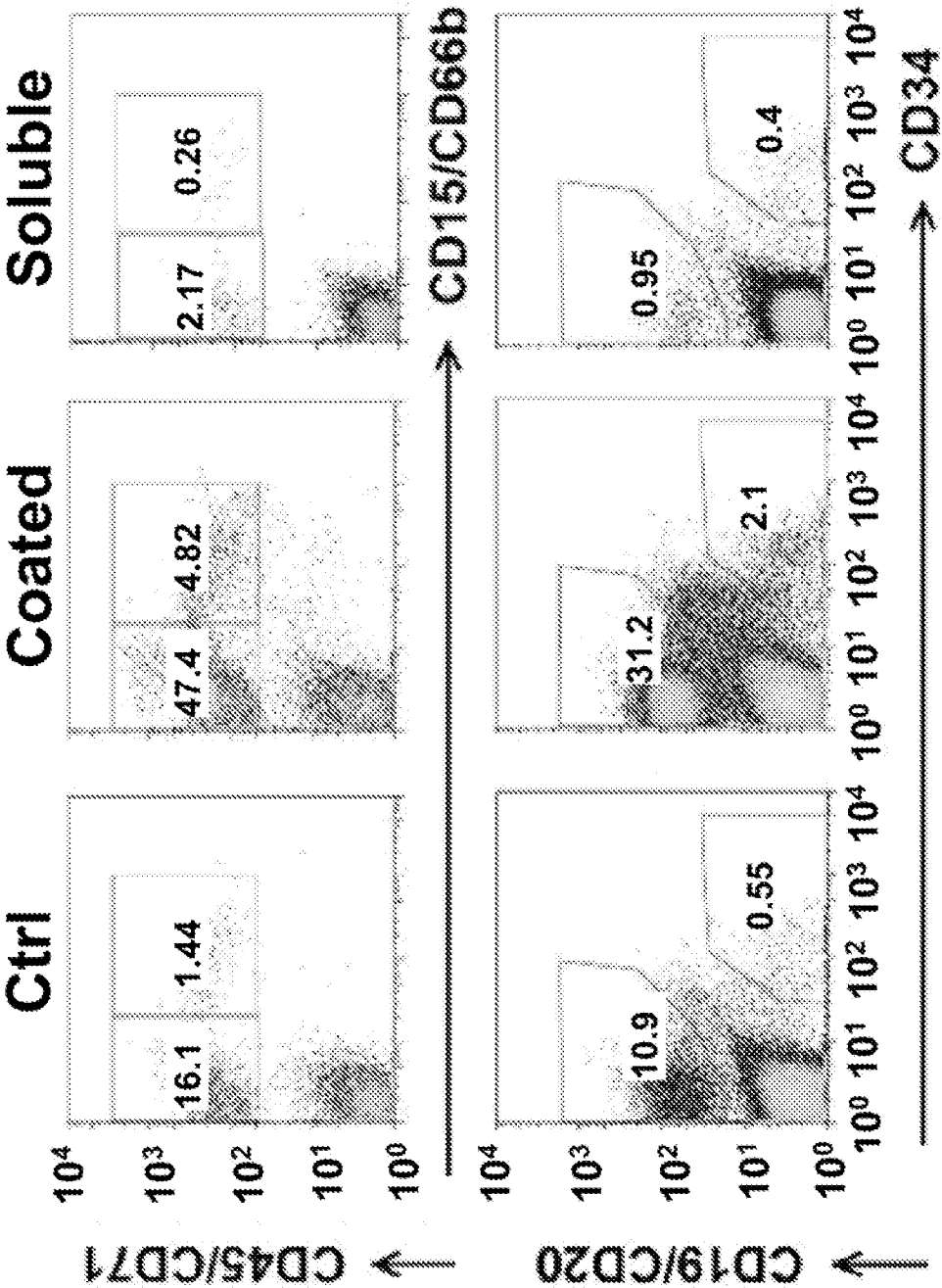


Fig. 12C

36/63

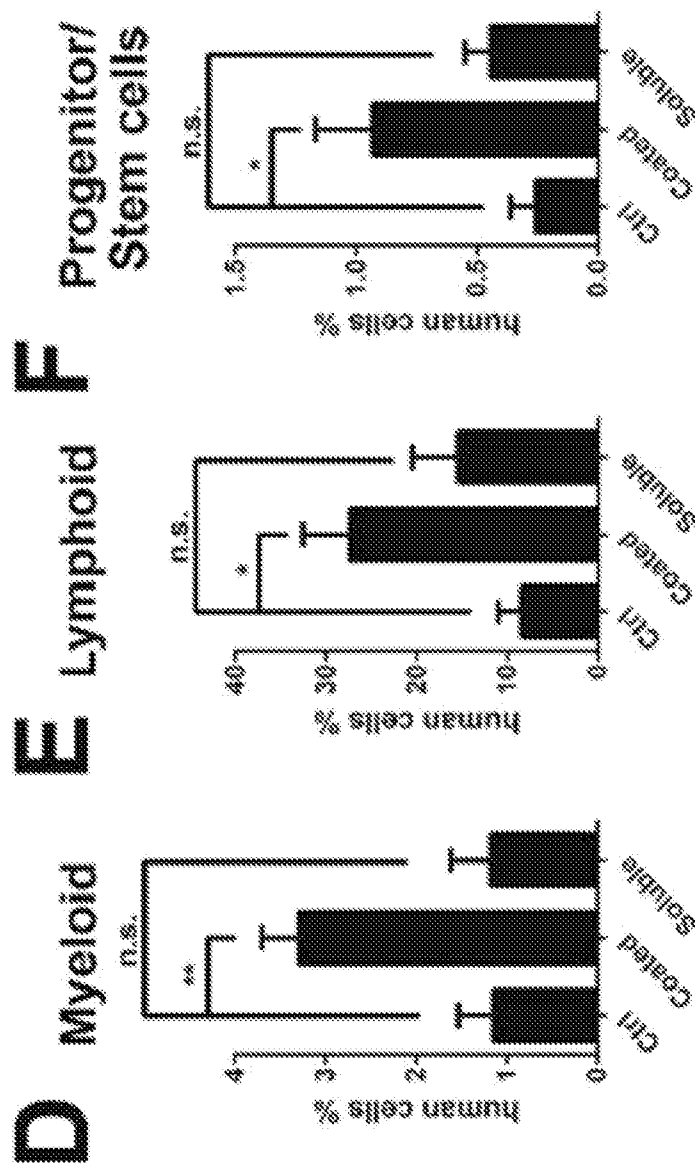


Fig. 12D-F

37/63

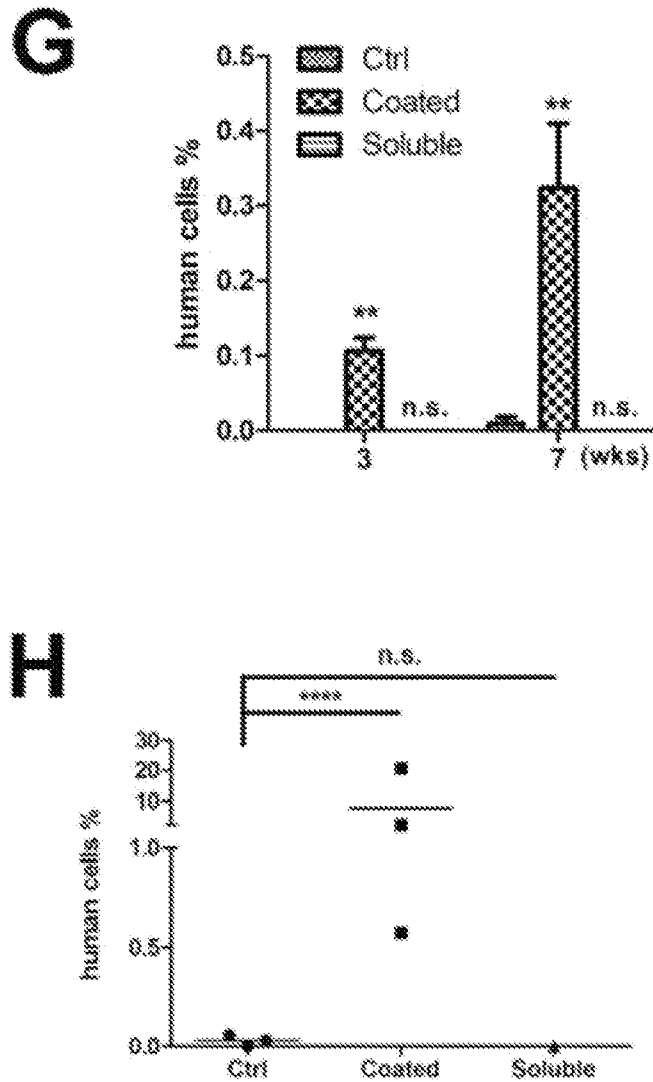


Fig. 12G-H

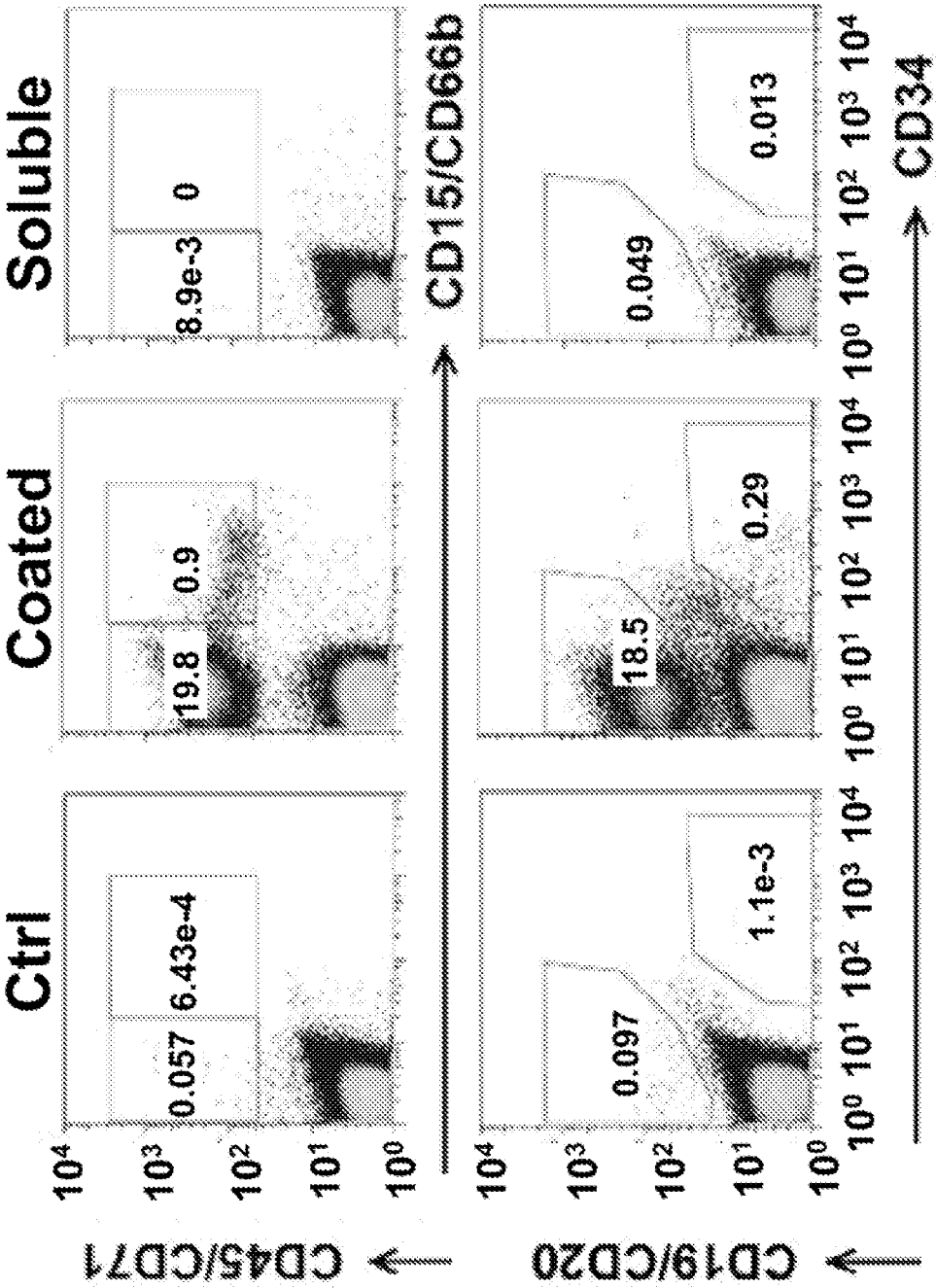


Fig. 12I

39/63

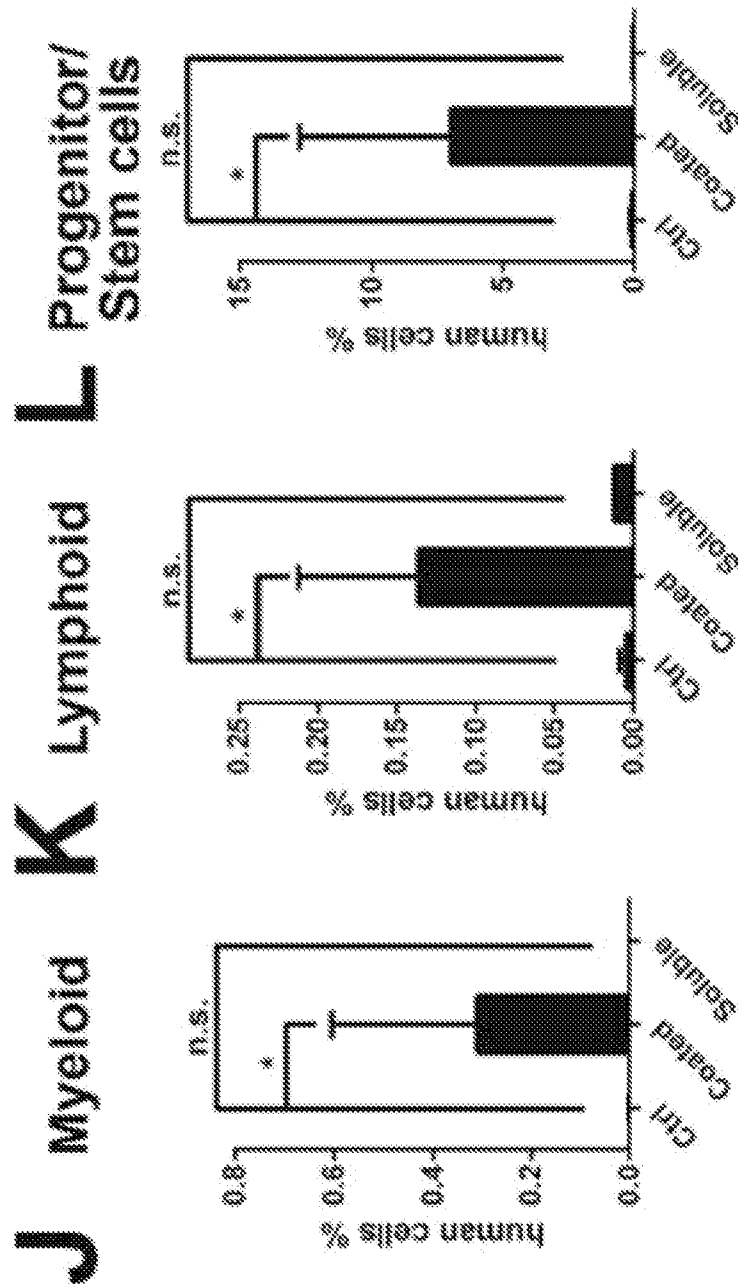


Fig. 12J-L

40/63

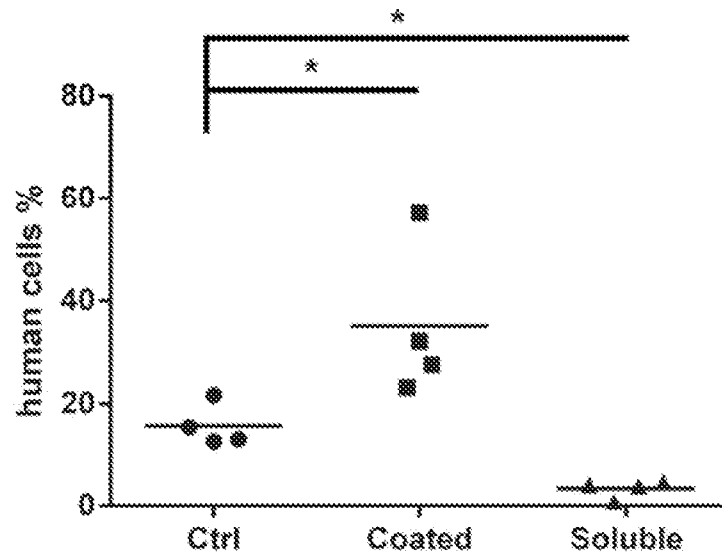
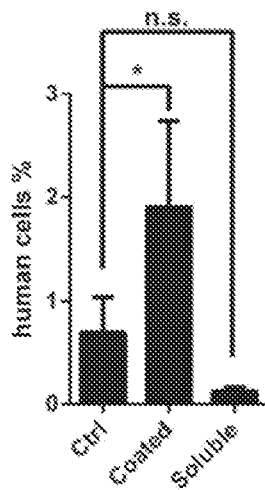
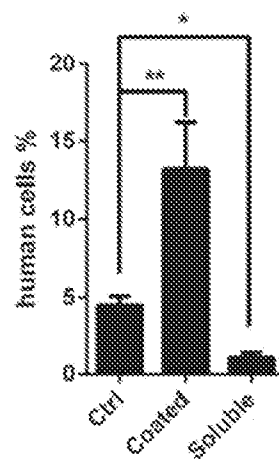
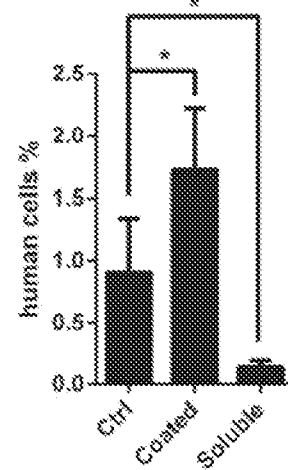
A**B****Myeloid****C****Lymphoid****D****Progenitor/
Stem cells**

Fig. 13A-D

41/63

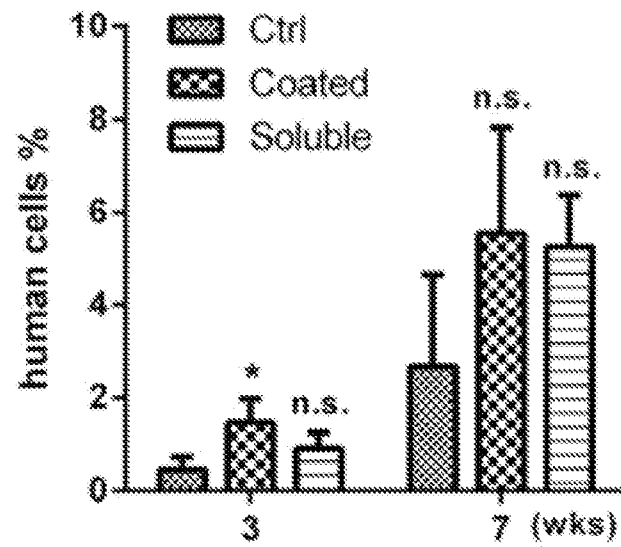
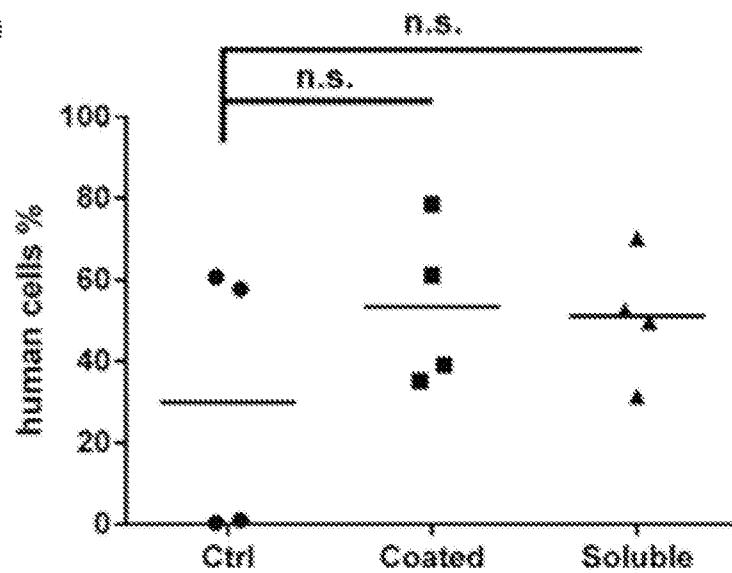
A**B**

Fig. 14A-B

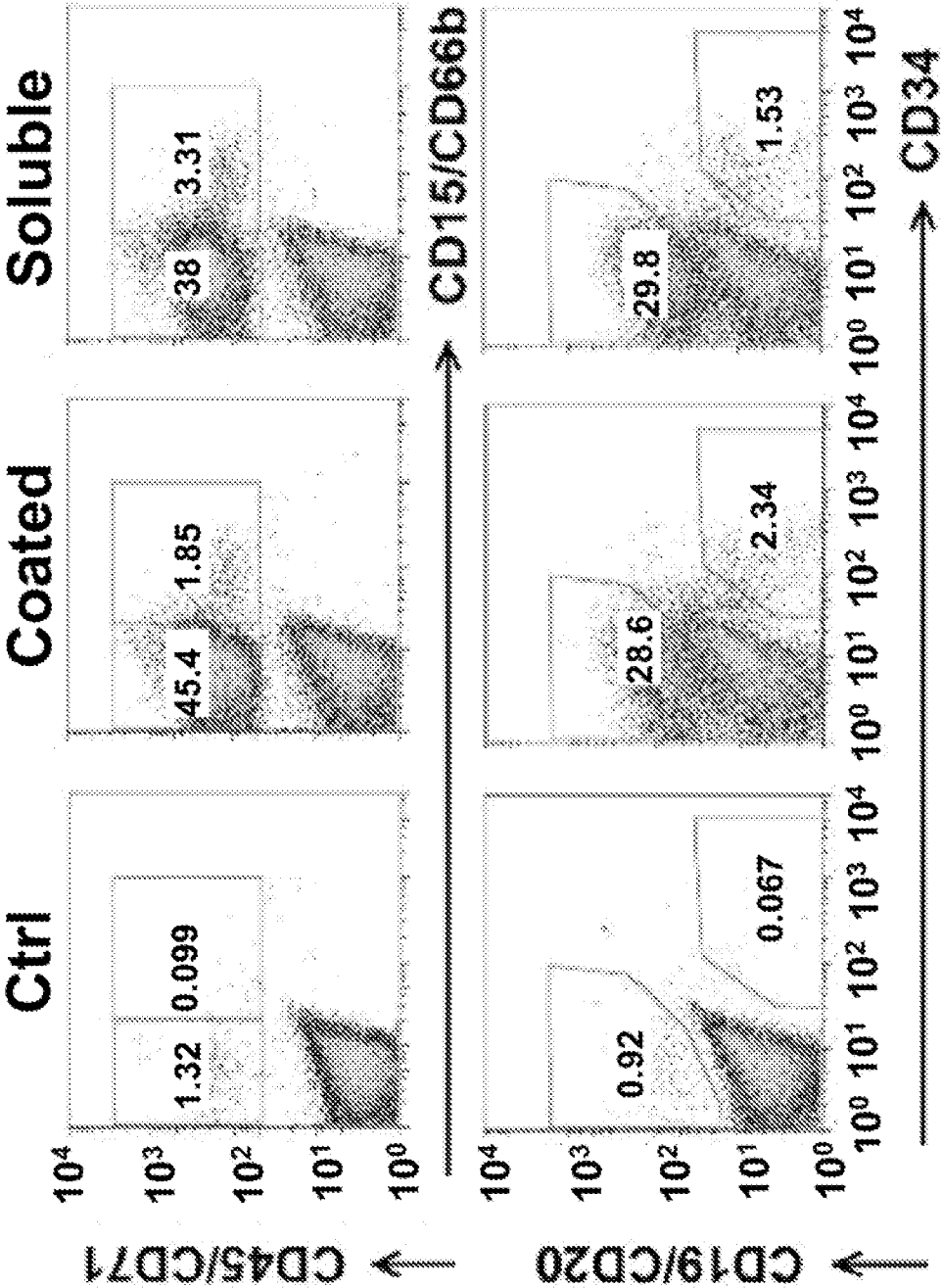


Fig. 14C

43/63

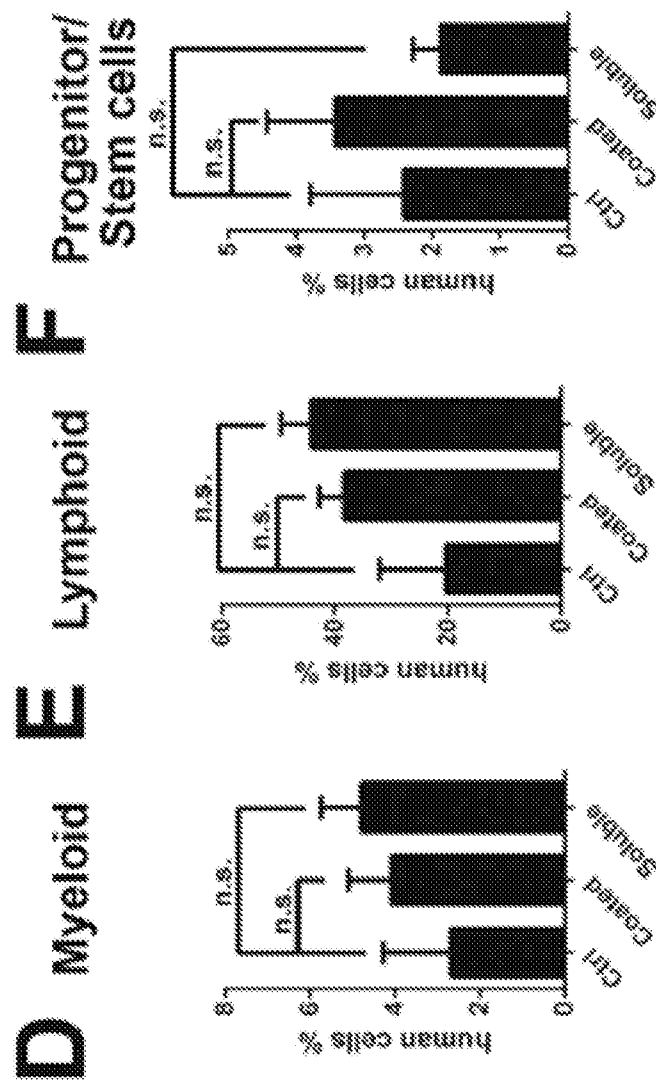


Fig. 14D-F

44/63

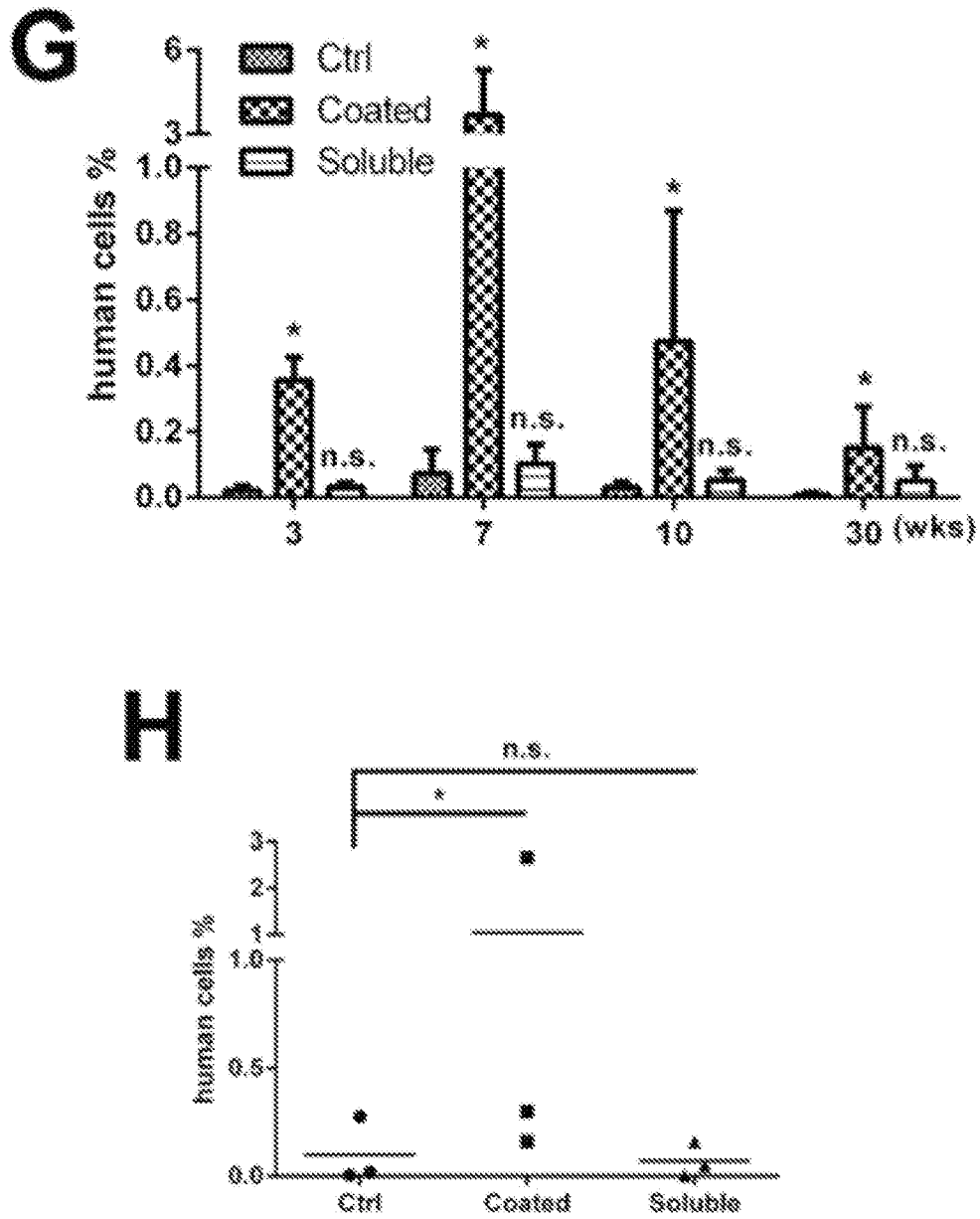


Fig. 14G-H

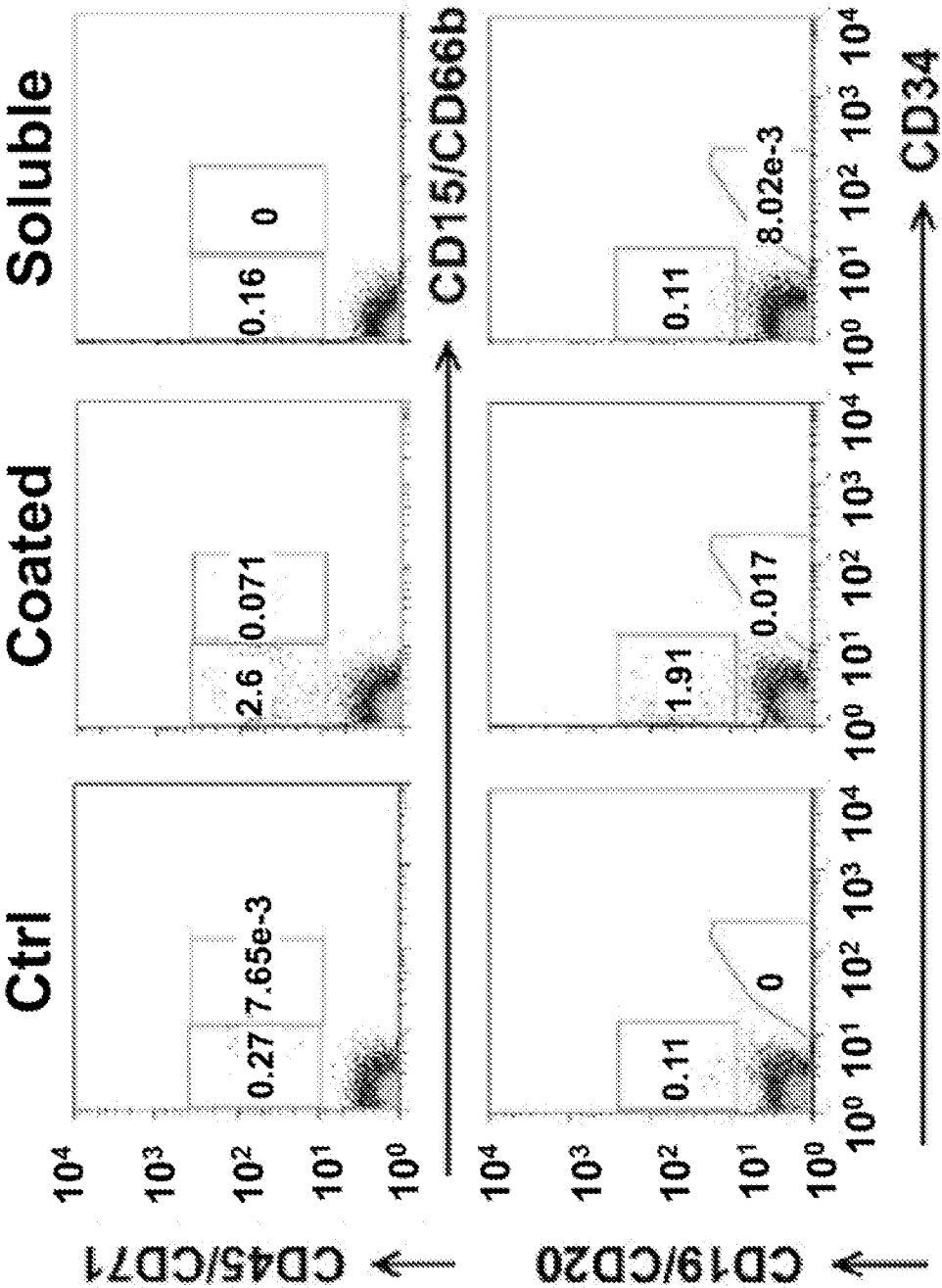


Fig. 14I

46/63

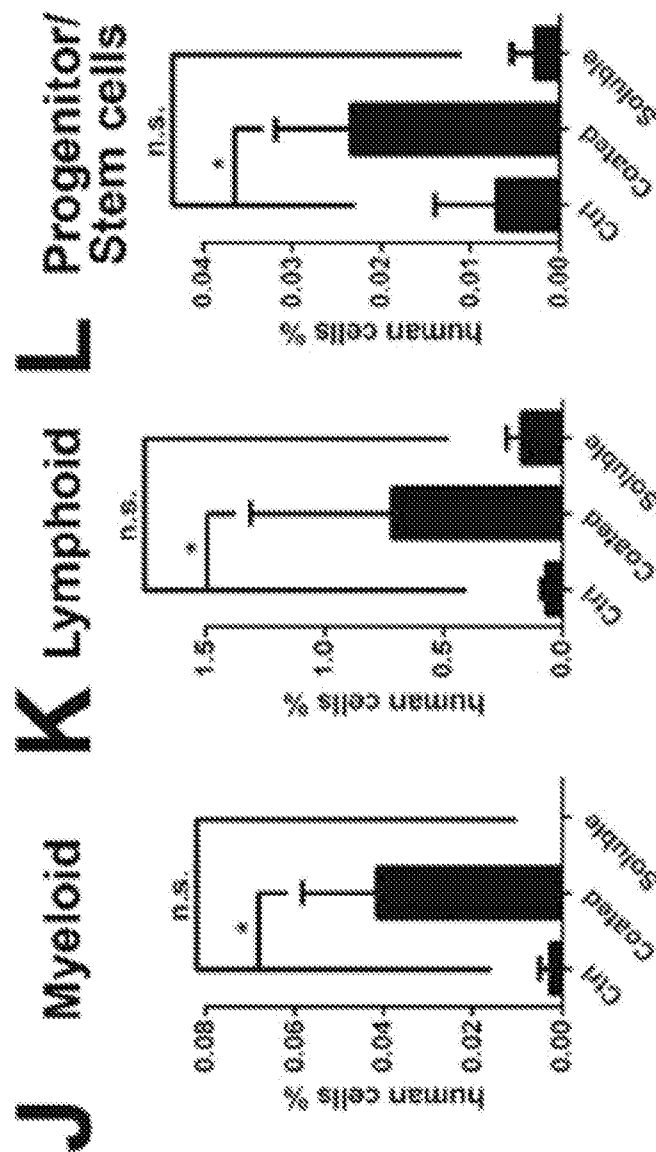


Fig. 14J-L

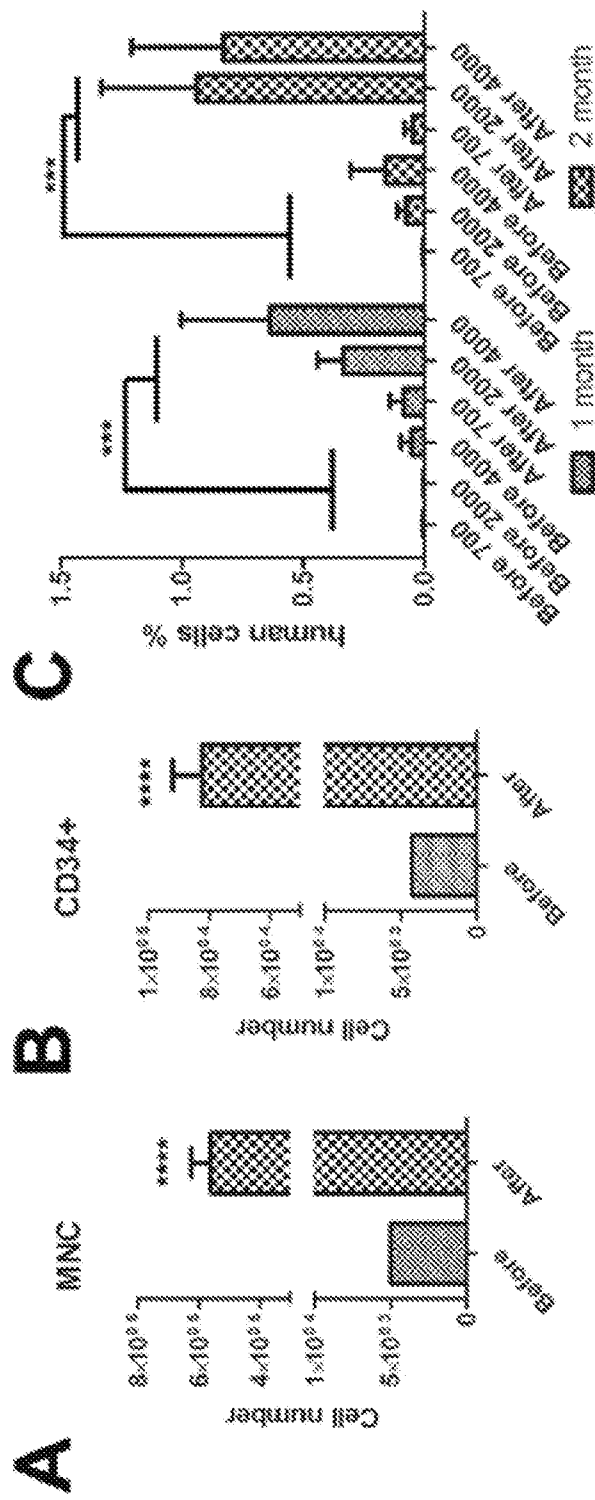


Fig. 15A-C

48/63

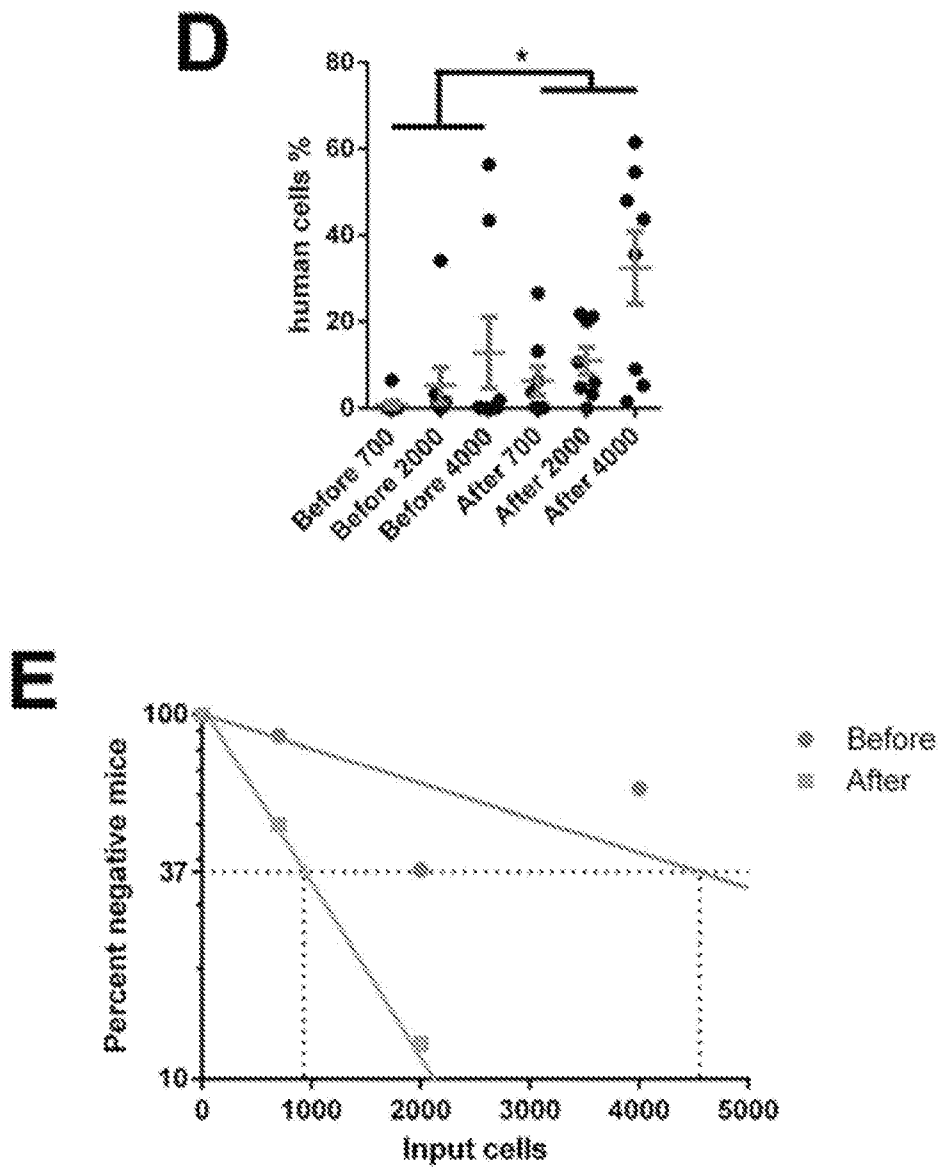


Fig. 15D-E

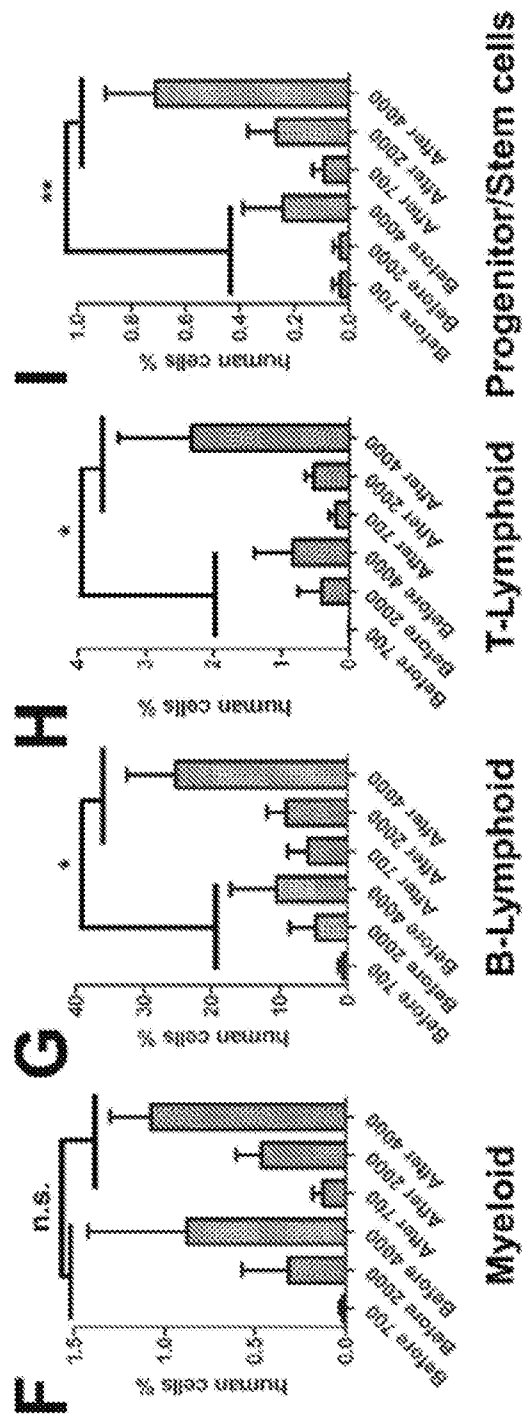


Fig. 15F-I

50/63

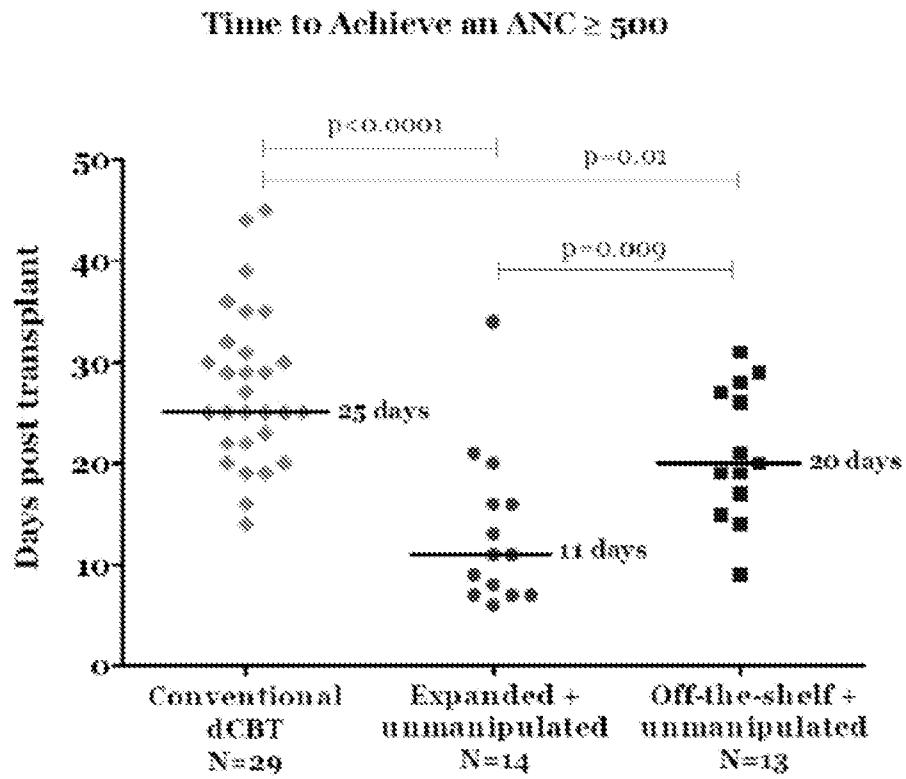


Fig. 16

51/63

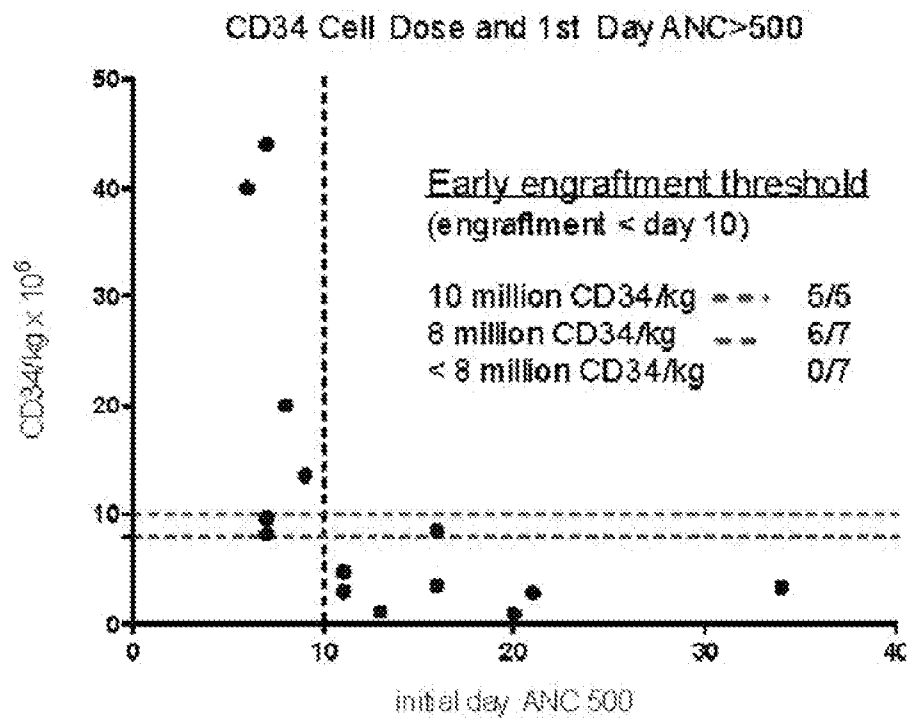


Fig. 17

52/63

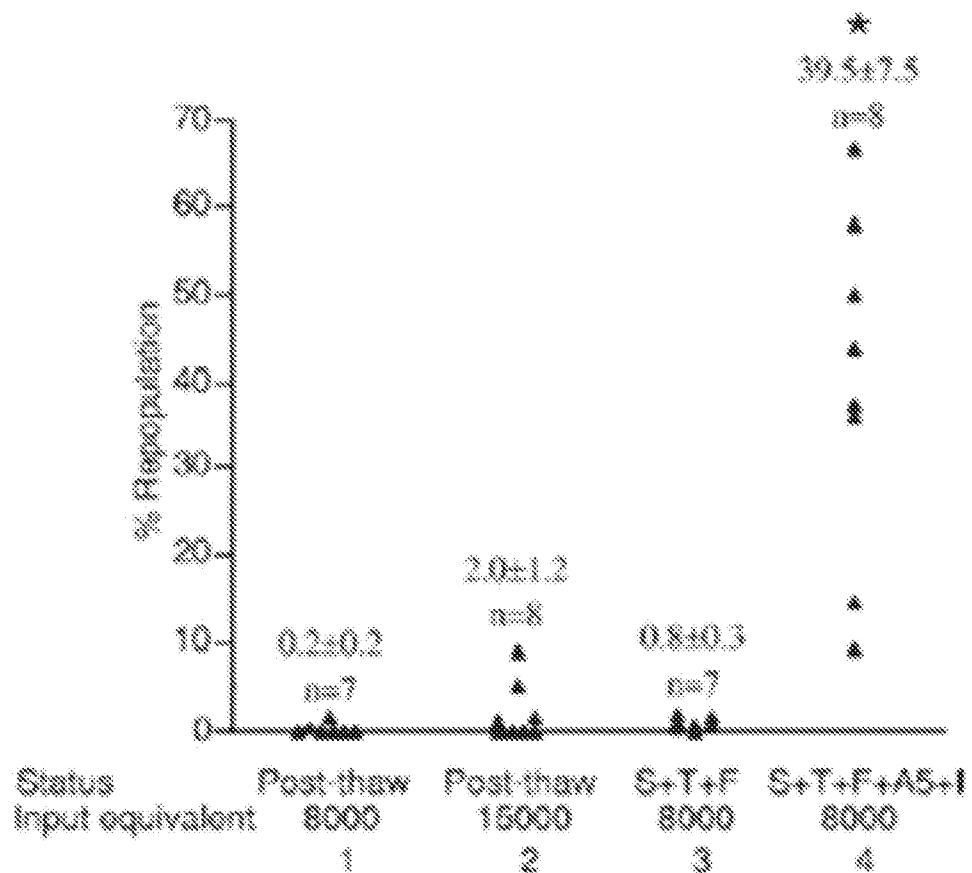


Fig. 18

53/63

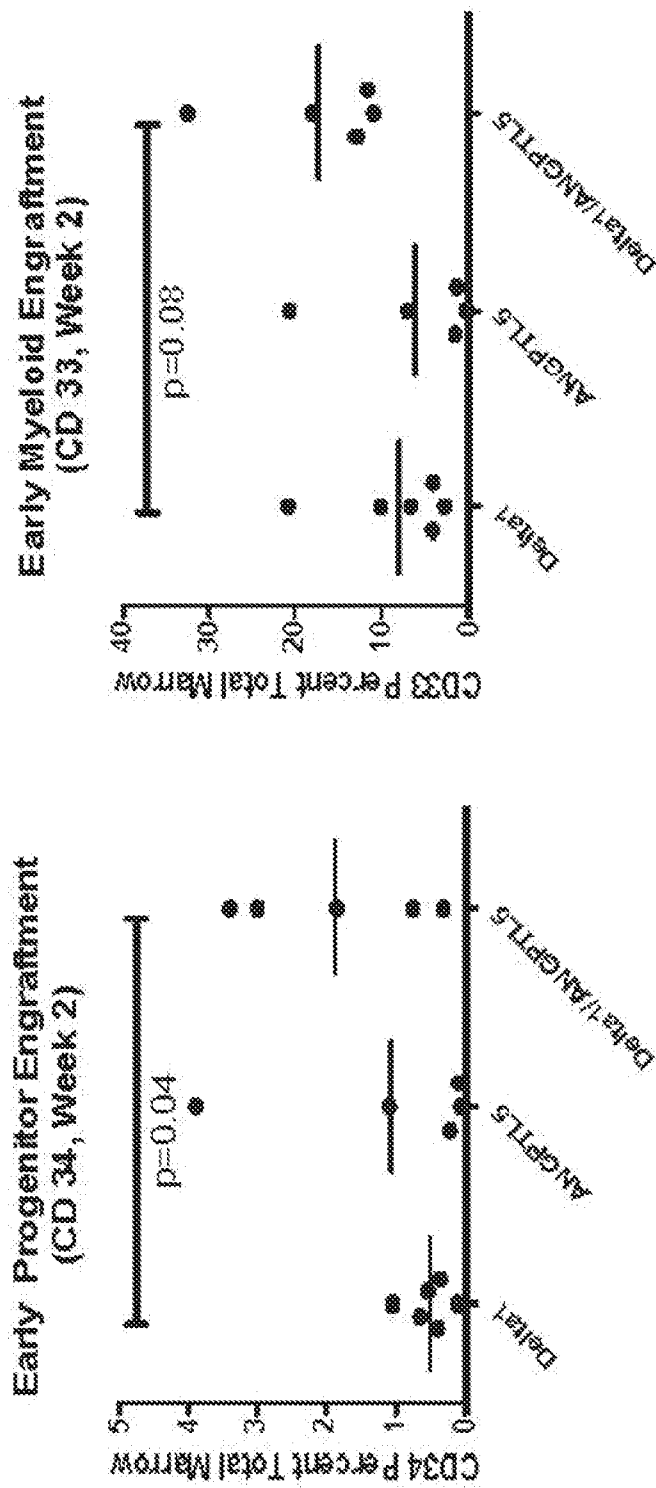


Fig. 19

54/63

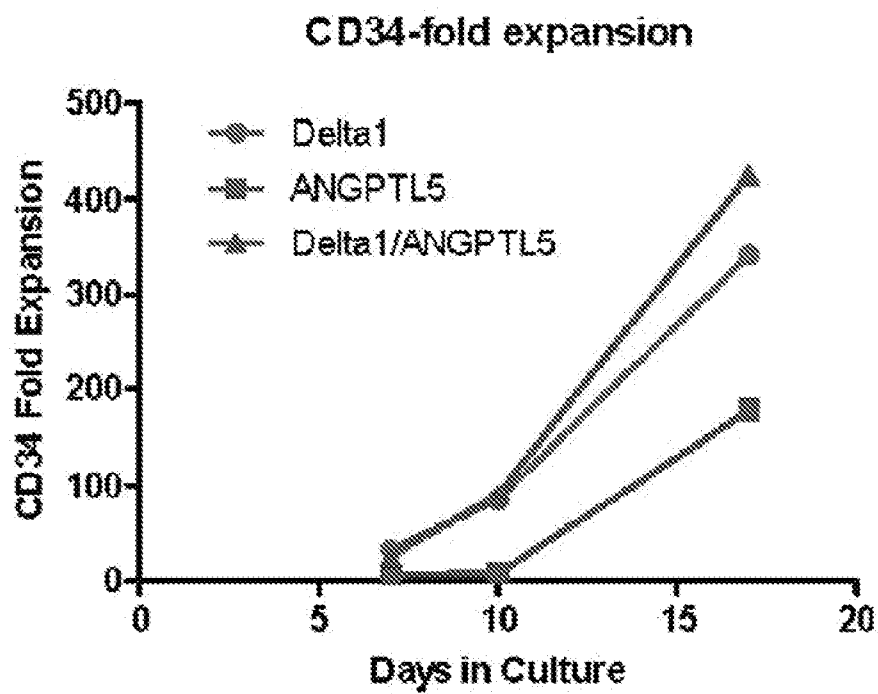


Fig. 20

55/63

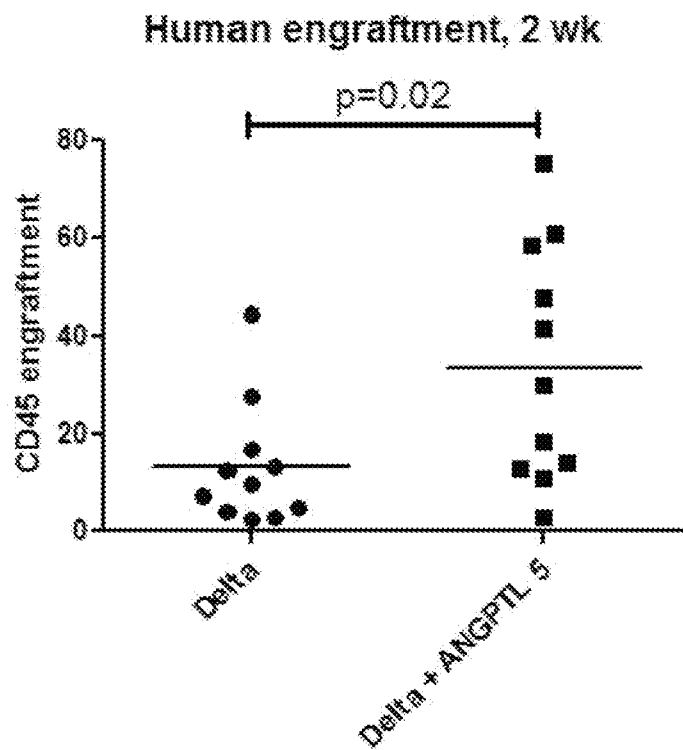


Fig. 21

56/63

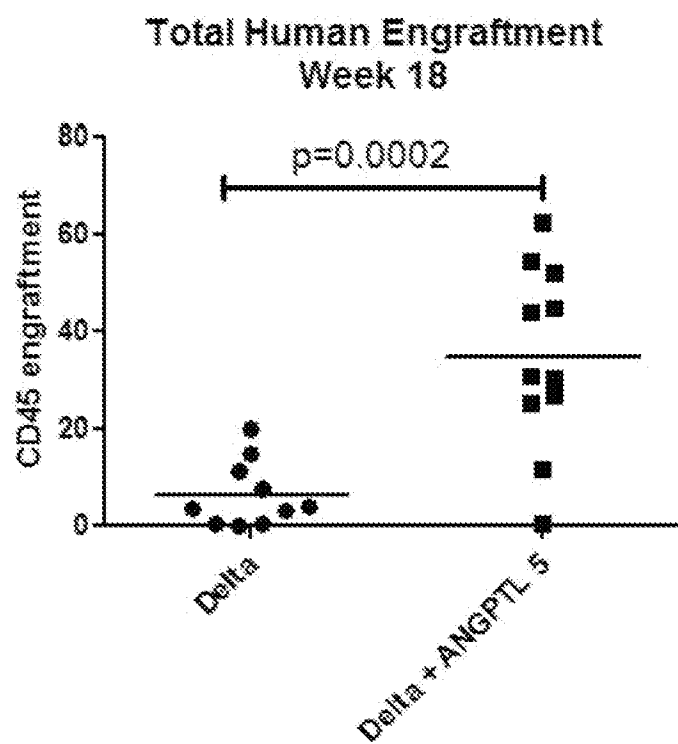


Fig. 22

57/63

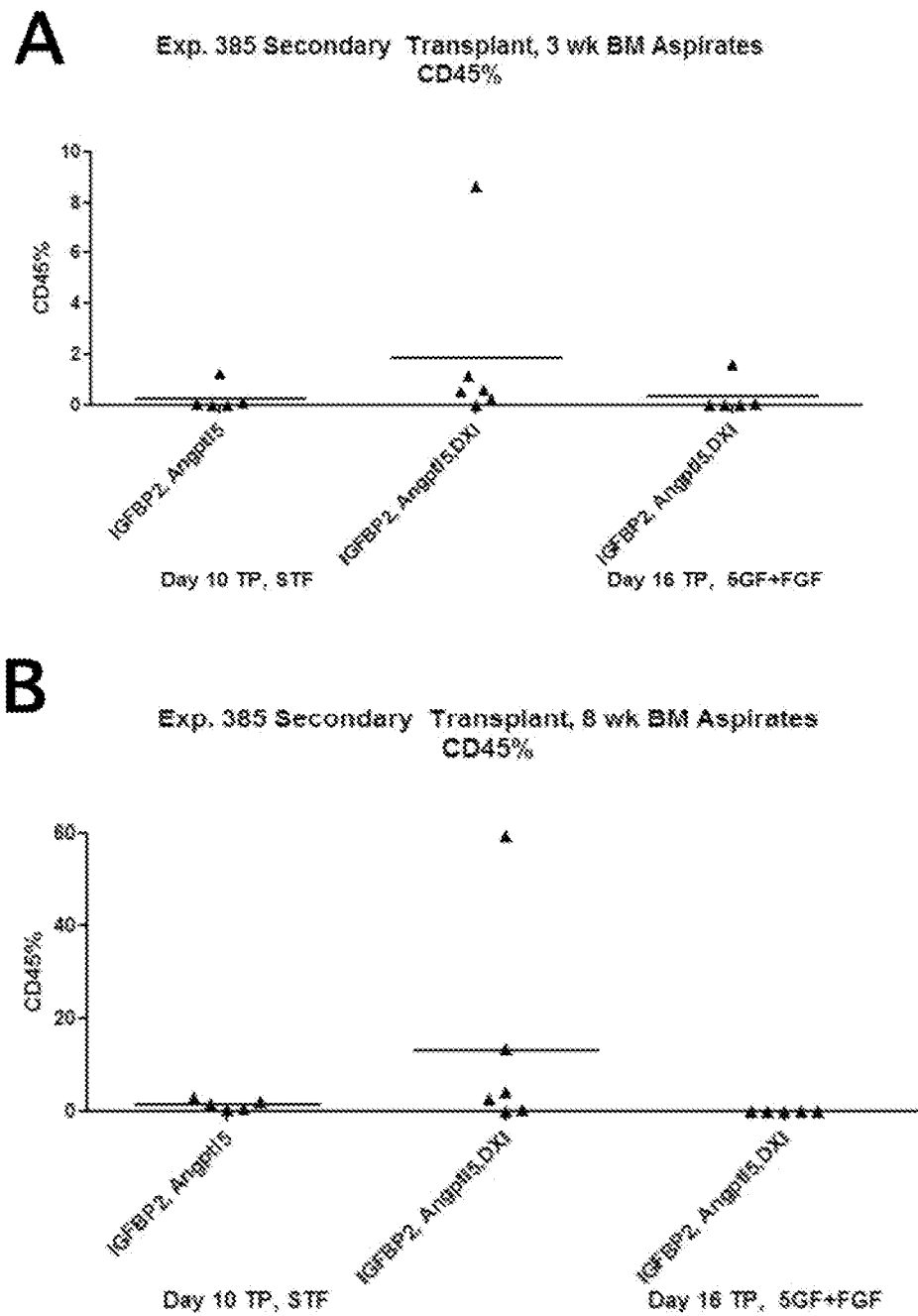


Fig. 23A-B

58/63

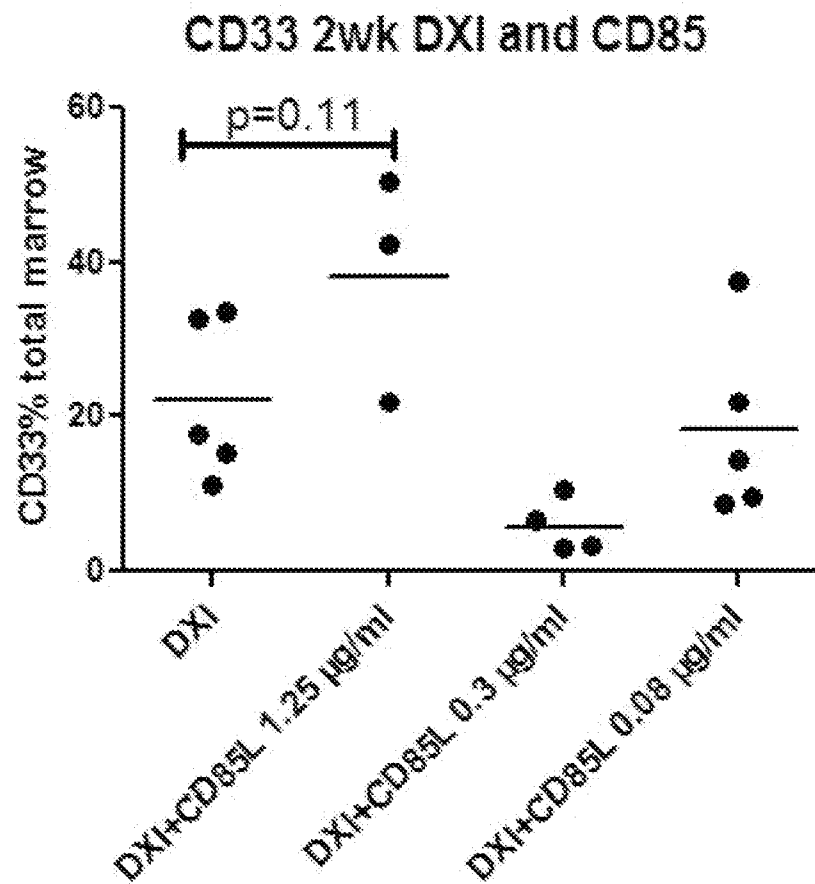


Fig. 24

59/63

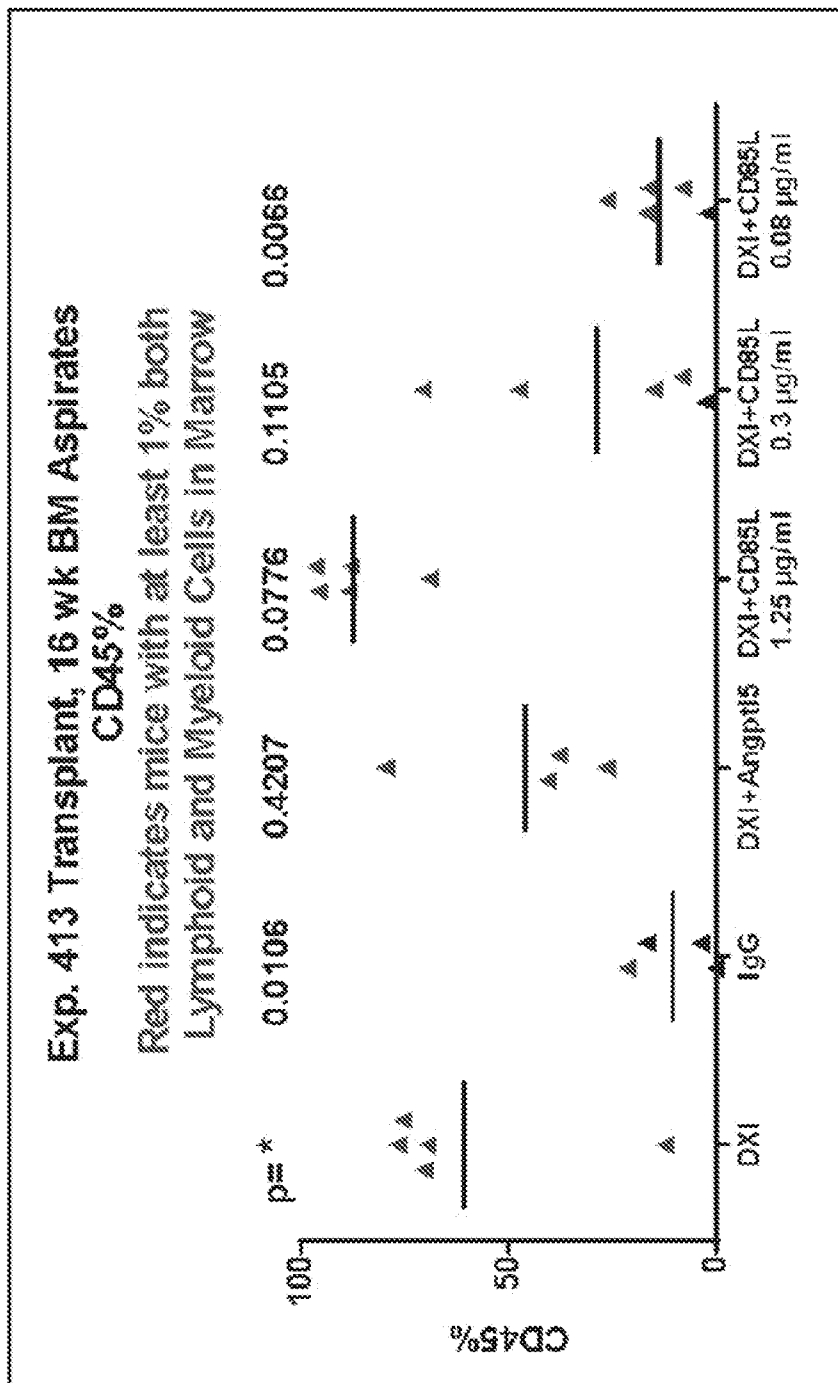


Fig. 25

60/63

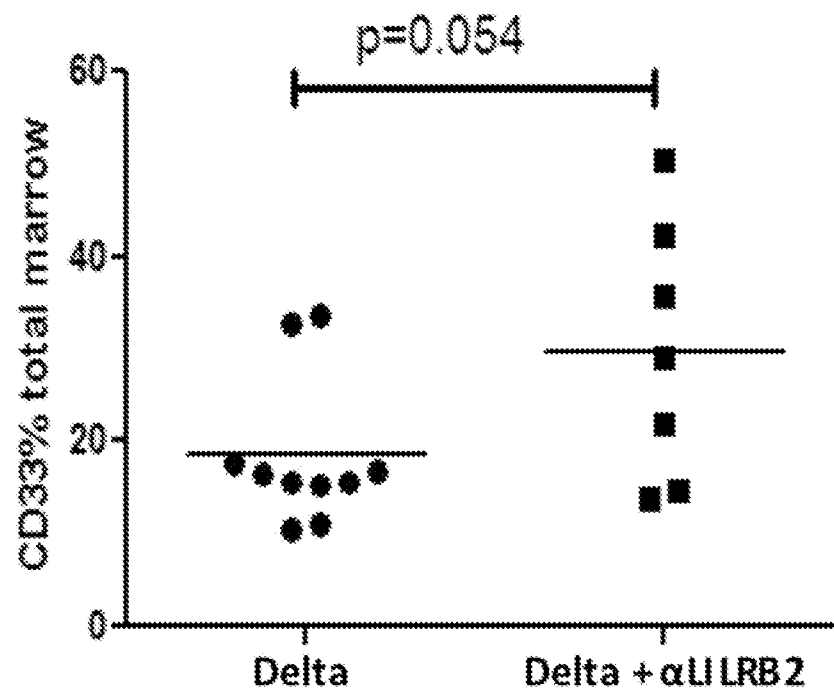


Fig. 26

61/63

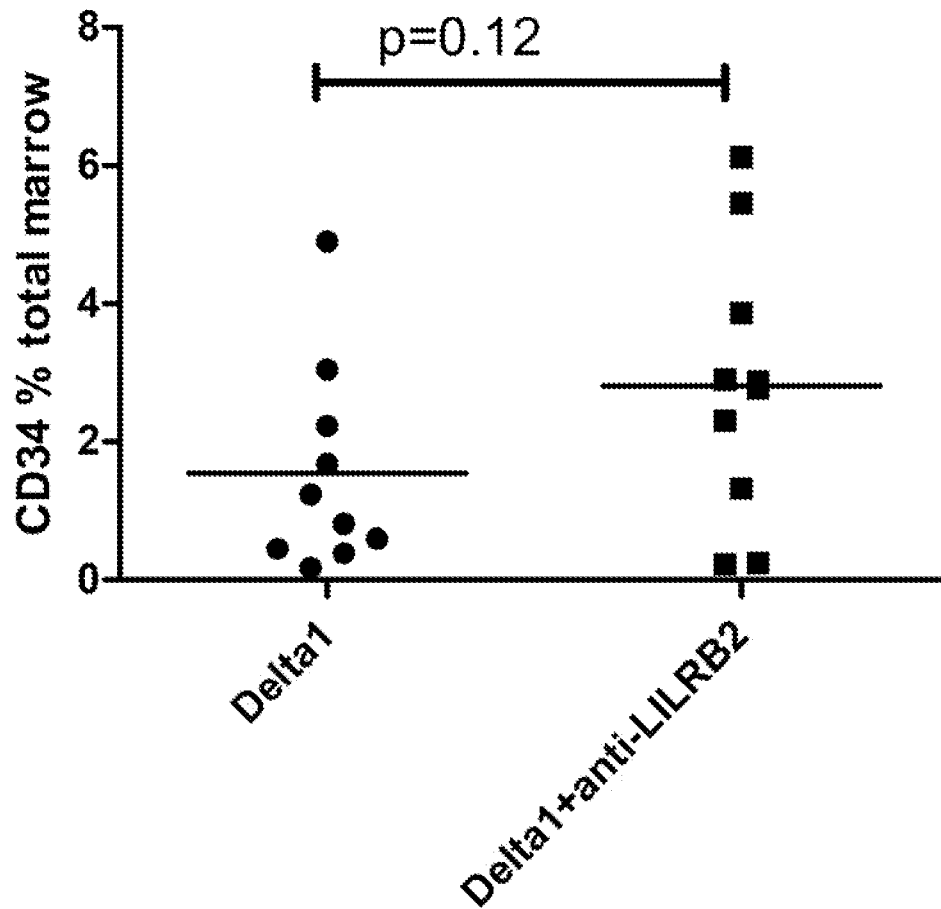


Fig. 27

62/63

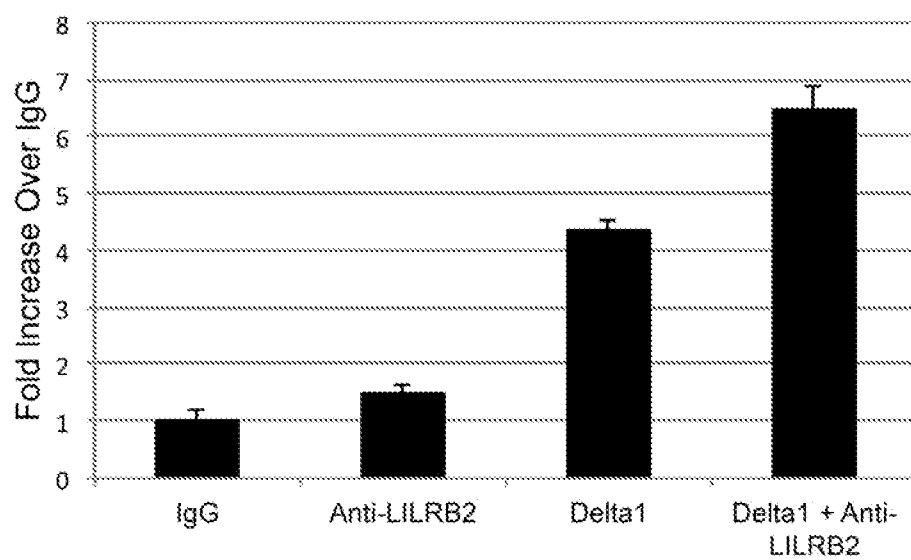


Fig. 28

63/63

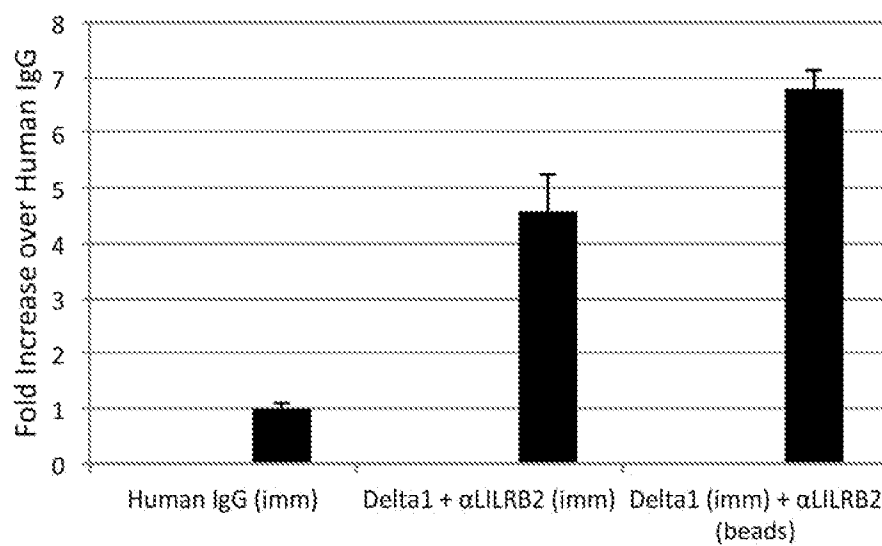


Fig. 29

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/031959

A. CLASSIFICATION OF SUBJECT MATTER INV. C12N5/0789 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) C12N		
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.
Y	WO 2008/137641 A2 (WHITEHEAD BIOMEDICAL INST [US]; ZHANG CHENGCHENG [US]; LODISH HARVEY []) 13 November 2008 (2008-11-13) paragraphs [0014], [0017] - [0021], [0038], [0071]; claims 1-6 -----	1-40
Y	JUNKE ZHENG ET AL: "Inhibitory receptors bind ANGPTLs and support blood stem cells and leukaemia development", NATURE, vol. 485, no. 7400, 30 May 2012 (2012-05-30), pages 656-660, XP055204718, ISSN: 0028-0836, DOI: 10.1038/nature11095 page 659; figures 1-3 ----- -/--	1-40
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "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	Date of mailing of the international search report	
3 August 2015	21/10/2015	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Novak-Giese, Sabine	

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/031959

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	ZHANG CHENG CHENG ET AL: "Angiopoietin-like 5 and IGFBP2 stimulate ex vivo expansion of human cord blood hematopoietic stem cells as assayed by NOD/SCID transplantation", BLOOD, AMERICAN SOCIETY OF HEMATOLOGY, US, vol. 111, no. 7, 1 April 2008 (2008-04-01) , pages 3415-3423, XP002498871, ISSN: 0006-4971, DOI: 10.1182/BLOOD-2007-11-122119 [retrieved on 2008-01-17] page 3416, last paragraph -----	1-40
Y	C C HOFMEISTER ET AL: "Ex vivo expansion of umbilical cord blood stem cells for transplantation: growing knowledge from the hematopoietic niche", BONE MARROW TRANSPLANTATION, vol. 39, no. 1, 1 January 2007 (2007-01-01), pages 11-23, XP055064629, ISSN: 0268-3369, DOI: 10.1038/sj.bmt.1705538 page 5; figure 1 -----	1-40
Y	WO 2013/086436 A1 (HUTCHINSON FRED CANCER RES [US]; NOVARTIS INST FOR FUNCTIONAL GENOMICS) 13 June 2013 (2013-06-13) claims 81-87 -----	1-40
Y	WO 2013/181438 A2 (ICAHN SCHOOL MED MOUNT SINAI [US]; UNIV TEXAS [US]) 5 December 2013 (2013-12-05) claims 1-29 -----	1-40
Y	EP 1 899 457 B1 (WHITEHEAD BIOMEDICAL INST [US]) 5 September 2012 (2012-09-05) paragraphs [0022], [0025], [0057] - [0061], [0151] -----	1-40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/031959

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-40

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-40

A method for expanding hematopoietic stem cells by culturing them with a LILRB2 agonist, which is a antibody to the LILRB2 receptor.

2. claims: 41-68, 205

A method for expanding precursor cells by culturing them with a LILRB2 agonist, which agonist has a molecular weight of at least 225kD.

3. claims: 69-113, 142-186, 206, 208

A method for expanding precursor cells by culturing them with a LILRB2 agonist and a Notch agonist.

4. claims: 114-141, 207

A method for producing precursor cells for hematopoietic transplantation by culturing them with a LILRB2 agonist, which agonist has at least 225kD.

5. claims: 187-204

A chimeric receptor reporter system comprising cells expressing a fusion protein comprising a LILRB2 domain and domains of PILRbeta.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/031959

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008137641	A2	13-11-2008	EP 2155862 A2 24-02-2010
			JP 2010525836 A 29-07-2010
			US 2011117061 A1 19-05-2011
			US 2014308747 A1 16-10-2014
			WO 2008137641 A2 13-11-2008

WO 2013086436	A1	13-06-2013	AU 2012347534 A1 26-06-2014
			CA 2858069 A1 13-06-2013
			EP 2788476 A1 15-10-2014
			US 2014369973 A1 18-12-2014
			WO 2013086436 A1 13-06-2013

WO 2013181438	A2	05-12-2013	US 2015174203 A1 25-06-2015
			WO 2013181438 A2 05-12-2013

EP 1899457	B1	05-09-2012	EP 1899457 A2 19-03-2008
			JP 5139271 B2 06-02-2013
			JP 2008545412 A 18-12-2008
			US 2007020757 A1 25-01-2007
			US 2011196343 A1 11-08-2011
			US 2014017784 A1 16-01-2014
			WO 2006127809 A2 30-11-2006
