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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 September 2016 (29.09.2016)

(10) International Publication Number
WO 2016/154623 A2

(51) International Patent Classification:
A61K 39/395 (2006.01)

(21) International Application Number:
PCT/US2016/024531

(22) International Filing Date:
28 March 2016 (28.03.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/138,825 26 March 2015 (26.03.2015) US

(71) Applicant: **THE UNITED STATES OF AMERICA AS REPRESENTED BY THE SECRETARY OF THE DEPARTMENT OF HEALTH AND HUMAN SERVICES** [US/US]; Office of Technology Transfer, 6011 Executive Blvd., Suite 325, Rockville, Maryland 20852 (US).

(72) Inventors: **PFISTER, Thomas D.**; 300 W. South Street, Frederick, Maryland 21701 (US). **KINDERS, Robert J.**; 298 Maplewood Place, Walkersville, Maryland 21793 (US). **NAVAS, Tony**; 300A Mill Pond Road, Frederick, Maryland 21701 (US).

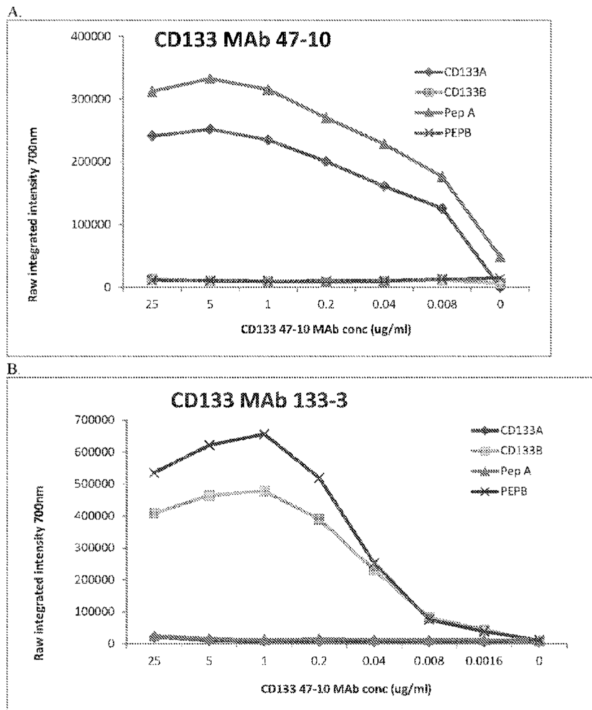
(74) Agents: **POLOVNIKOVA, Elena S.** et al.; Kilpatrick Townsend & Stockton LLP, 1100 Peachtree Street, Suite 2800, 22nd Floor, Atlanta, Georgia 30309 (US).

(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,

[Continued on next page]

(54) Title: ANTI-CD133 MONOCLONAL ANTIBODIES AND RELATED COMPOSITIONS AND METHODS



(57) Abstract: Anti-CD133 monoclonal antibodies having advantageous properties; products, compositions and kits comprising the monoclonal antibodies; methods (processes) of making the monoclonal antibodies and related compositions, as well as methods of using the monoclonal antibodies in analytical, diagnostic and therapeutic applications.

WO 2016/154623 A2

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

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

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

ANTI-CD133 MONOCLONAL ANTIBODIES AND RELATED COMPOSITIONS AND METHODS

PRIOR RELATED APPLICATIONS

[1] The present application claims the benefit of U.S. Provisional Patent Application Serial No. 62,138,825, filed March 26, 2015, the contents of which is incorporated herein by reference in its entirety.

FIELD

[2] The products and processes described in this document relate to the fields of immunology, immunochemistry, immunoassays, screening assays, CD133 studies, cancer studies, cancer diagnostics, cancer therapies, stem cells, cancer stem cells and other related fields.

BACKGROUND

[3] CD133, also known as prominin-1 and several other designations, is a glycoprotein known to be expressed in several types of stem cells, including hematopoietic stem cells, endothelial progenitor cells and neural stem cells. CD133 was found to be present or enriched in cell populations found in several human solid tumors, such as colon carcinoma, melanoma and brain tumors (for example, glioblastoma). Currently, CD133 is considered to be a putative marker for cancer stem cells (CSCs), which are cancer cells possessing stem-cell like characteristics, namely, an ability to differentiate into multiple-cell types, and the ability to give rise to new tumors. CD133 protein was found to localize to membrane protrusions and to be often expressed on adult stem cells. One proposed function for CD133 is maintenance of "stemness" through suppression differentiation.

[4] Anti-CD133 monoclonal antibodies (mAbs) are an important tool in the areas of CD133 studies and detection, as well as in the areas of cancer studies, cancer detection, diagnostics and treatment, and other related fields. Available anti-CD133 monoclonal antibodies suffer from a number of deficiencies. For example, most of the early published work in the field of CD133 studies was carried out with monoclonal antibodies recognizing epitopes of CD133 that may have been glycosylated and became undetectable during cell differentiation. Other known monoclonal antibodies did not recognize certain posttranslationally modified forms of CD133. Some examples of anti-CD133 monoclonal

antibodies recognized only unglycosylated CD133 epitopes, but not their glycosylated form and *vice versa*. In some other examples, anti-CD133 monoclonal antibodies were shown to be useful only in a limited range of biological assays. Accordingly, there is a need for anti-CD133 monoclonal antibodies that recognize a range of CD133 variants and isoforms with high specificity, regardless of the protein's glycosylation state or other posttranslational modifications, and are useful in a variety of applications. There is also a need for methods of producing such antibodies.

SUMMARY

[5] This document describes novel anti-CD133 monoclonal antibodies having advantageous properties, such as high specificity and the ability to bind to both glycosylated and unglycosylated forms of CD133. The new monoclonal antibodies are suitable for a wide range of analytical and diagnostic assays and techniques, are useful in research, analytical and diagnostic applications, and can be employed as therapeutic agents. Also described in this document are products and compositions that include the anti-CD133 monoclonal antibodies, methods (processes) of making and using the improved anti-CD133 monoclonal antibodies, and related compositions and kits. The foregoing antibodies, products, compositions, processes, methods and kids are included among the embodiments of the present invention.

[6] The terms "invention," "the invention," "this invention" and "the present invention," as used in this document, are intended to refer broadly to all of the subject matter of this patent application and the claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below. Covered embodiments of the invention are defined by the claims, not this summary. This summary is a high-level overview of various aspects of the invention and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification, any or all drawings and each claim. Some non-limiting exemplary embodiments of the present invention are summarized below.

[7] Among the exemplary embodiments of the present invention are monoclonal antibodies, such as: an anti-CD133 monoclonal antibody having an antibody binding site

capable of specifically binding an epitope comprising SEQ ID NO:17 or a variant thereof; an anti-CD133 monoclonal antibody having an antibody binding site comprising SEQ ID NO:9 and SEQ ID NO:11 or a variant thereof; an anti-CD133 monoclonal antibody having an antibody binding site comprising a polypeptide encoded by SEQ ID NO:10 and SEQ ID NO:12 or a variant thereof; an anti-CD133 monoclonal antibody having an antibody binding site comprising CDRs contained in SEQ ID NO:9 and SEQ ID NO:11 or a variant thereof. The above antibodies may be capable of specifically binding domain A but not domain B of a CD133 polypeptide, glycosylated or unglycosylated, which, in turn, may contain any one of SEQ ID NOs 1-8 or a variant thereof.

[8] Also included among the exemplary embodiments of the present invention are anti-CD133 monoclonal antibodies having or more of the following features: an anti-CD133 monoclonal antibody capable of specifically binding an epitope comprising SEQ ID NO:18; an anti-CD133 monoclonal antibody having an antibody binding site comprising SEQ ID NO:13 and SEQ ID NO:15 or a variant thereof; an anti-CD133 monoclonal antibody having an antibody binding site comprising a polypeptide encoded by SEQ ID NO:14 and SEQ ID NO:16 or a variant thereof; and an anti-CD133 monoclonal antibody having an antibody binding site comprising CDRs contained in SEQ ID NO:13 and SEQ ID NO:15 or a variant thereof. The above monoclonal antibodies may be capable of specifically binding domain B but not domain A of a CD133 polypeptide, glycosylated or unglycosylated, which may comprise any one of SEQ ID NOs 1-8 or a variant thereof. The above anti-CD133 monoclonal antibodies may be capable of specifically binding an epitope comprising SEQ ID NO:18 or a variant thereof.

[9] An anti-CD133 monoclonal antibody according to the embodiments of the present invention may be a non-human antibody, a human antibody, or a human-like antibody. The anti-CD133 monoclonal antibody may be a reduced immunogenicity antibody, a humanized antibody or a chimeric antibody. The anti-CD133 monoclonal antibody may be or comprise an antibody fragment. The anti-CD133 monoclonal antibody may be recombinantly produced. The anti-CD133 monoclonal antibody may have an amino acid sequence that is different from an amino-acid sequence of a naturally occurring anti-CD133 monoclonal antibody. The anti-CD133 monoclonal antibody may contain a label, a tag, a bioactive substance, a drug, a radioactive moiety or a toxic moiety, any or all of which may be not naturally occurring in a monoclonal antibody molecule. In one example, the anti-CD133 monoclonal antibody may contain a fluorescent label or a fluorescent tag.

[10] The anti-CD133 monoclonal antibody may be employed in a variety of uses and methods, which are included among the embodiments of the present invention. Some examples of such methods are as follows. Among the methods of the present invention is a method of detecting ("detection method") a presence or absence of CD133 polypeptide in a sample, comprising steps of contacting the sample with the monoclonal antibody of any one of an anti-CD133 monoclonal antibody under conditions under which specific binding of the monoclonal antibody and the CD133 polypeptide may occur, and detecting the specific binding of the monoclonal antibody to the CD133 polypeptide, wherein the detected specific binding is indicative of the presence of the CD133 polypeptide in the sample. The method may further comprise determining an amount of CD133 polypeptide present in the sample. The sample may be a cell sample, a tissue sample, an aqueous sample, a solution, a suspension, a blot or an electrophoresis gel. The sample may be a cancerous tissue sample. The specific binding may be detected in an ELISA, a Western Blot assay or in an immunofluorescence assay.

[11] The above detection method can be adapted to a variety of uses or practical applications, which can also be referred to as "methods." One example of such practical application is assessing status of a cancer in a patient, comprising obtaining the sample from the patient and performing the above detection method, wherein the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the status of the cancer in the patient. One more example of the practical application of the detection method is treating a cancer in a patient, comprising performing the above detection method, wherein the presence of CD133 polypeptide detected in the sample or the amount of CD133 polypeptide present in the sample above a predetermined threshold value is indicative of a need to administer a cancer treatment to the patient, and administering the cancer treatment to the patient. The cancer treatment may be a chemotherapy, drug therapy, targeted drug therapy, surgery, radiation therapy, an antibody therapy or a combination thereof. The cancer may be breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma. Another example of a practical application of the detection method is a method of detecting presence, absence or amount of cancer stem cells in the sample, comprising performing the above detection method, wherein the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the cancer stem cells in the

sample. Yet one more example of the practical application of the detection method is detecting presence, absence or amount of circulating tumor cells in the sample, comprising performing the above detection method, wherein the sample is a blood sample and the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the circulating tumor cells in the sample. One more example detection of presence, absence or amount of CD133-positive cells in the sample, comprising performing the above detection method, wherein the sample is a blood sample and the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the CD133-positive cells in the sample.

[12] Also included among the embodiments of the present invention is a method of removing CD133-positive cells from a sample, comprising contacting the sample with the anti-CD133 monoclonal antibody under conditions under which specific binding of the monoclonal antibody and CD133 polypeptide expressed by the CD133-positive cells may occur, thereby allowing complexes the monoclonal antibody and the CD133-positive cells to form, and removing the monoclonal antibody and the CD133-positive cells from the sample. The sample can be a blood sample or a marrow sample. A method of treating or alleviating ("treatment method") a disease or a condition in a subject, comprising administering to the subject a composition containing one or more of the anti-CD133 monoclonal antibodies is also included among the embodiments of the present invention. One example of the disease or the condition thus treated or alleviated is a cancer, such as breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma. In the treatment method, an antibody can be a human-like antibody and the subject can be a human. The antibody can also be not a human-like antibody and the subject may not be not a human. The anti-CD133 monoclonal antibody employed in a treatment method may be a neutralizing antibody.

[13] One more exemplary use of anti-CD133 monoclonal antibodies according to the embodiments of the present invention is a method of assessing or optimizing efficacy of a therapy in a subject with a disease or a condition, comprising determining a value of CD133 in one or more samples obtained from the subject, wherein the determining comprises contacting the one or more samples with the anti-CD133 monoclonal antibody under conditions under which specific binding of the monoclonal antibody and a CD133 polypeptide may occur, and detecting the specific binding of the monoclonal antibody to the

CD133 polypeptide. The detected specific binding is indicative of the value CD133 in the one or more samples. The term "value of CD133" in the one or more samples encompasses presence, absence, or amount of CD133 in the one or more samples. The efficacy of the therapy is determined by comparing the determined value CD133 in the one or more samples to a predetermined threshold value of CD133. The value of CD133 in the one or more samples may be determined one or more times before, during, or after therapy, or any combination thereof. The predetermined threshold value of CD133 may be value based on at least one of the one or more samples. An increase in CD133 value may indicate the therapy is insufficiently effective. Thus, an additional therapy or a change in dosing regimen of the therapy may be indicated to the subject. On the other hand, a decrease in CD133 value may indicate that the therapy is effective. The therapy of the additional therapy may be chemotherapy, drug therapy, targeted drug therapy, surgery, radiation therapy, an antibody therapy or a combination thereof. The sample may be a cell sample, a tissue sample, an aqueous sample, a solution, a suspension, a blot or an electrophoresis gel. For example, the sample may a blood sample or a plasma sample. In the above methods, the specific binding may be detected in an ELISA, a Western Blot assay or in an immunofluorescence assay. The subject may be a cancer subject, meaning the subject who has a cancer. Examples of the subject's cancer are breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma..

[14] Exemplary embodiments of the present invention include a method of producing an anti-CD133 monoclonal antibody, comprising the steps of administering to a subject or a cell an immunogenic composition comprising one or more polypeptide selected from the group consisting of SEQ ID NO:17, SEQ ID NO:18 and variants thereof to generate multiple antibody producing cells, isolating an antibody producing cell from the multiple antibody producing cells; culturing the isolated antibody producing cells under conditions leading to production of anti-CD133 monoclonal antibody, and testing the monoclonal antibody for specific binding to a polypeptide having the amino acid sequence of SEQ ID NO:17 or SEQ ID NO:18. The method of producing may further comprise determining one or more nucleic acid sequences encoding an antibody binding site of the anti-CD133 monoclonal antibody, and using the one or more nucleic acid sequences to produce a recombinant anti-CD133 monoclonal antibody. Expression vectors related to anti-CD133 monoclonal antibodies are also included in the embodiments of the present invention, for example: an

expression vector comprising nucleic acid sequences encoding one or both of SEQ ID NO:9 and SEQ ID NO:11 or variants thereof; an expression vector comprising SEQ ID NO:10 and SEQ ID NO:12 or variants thereof; an expression vector comprising nucleic acid sequences encoding one or more CDRs contained in SEQ ID NO:9, SEQ ID NO:11 or variants thereof; an expression vector comprising nucleic acid sequences encoding one or both of SEQ ID NO:13 and SEQ ID NO:15 or variants thereof; an expression vector comprising nucleic acid sequences encoding one or more CDRs contained in SEQ ID NO:13, SEQ ID NO:15 or variants thereof; an expression vector comprising SEQ ID NO:14 and SEQ ID NO:16 or variants thereof Some other example of the embodiments of the present invention are a cell comprising the above expression vectors, a method of producing an anti-CD133 monoclonal antibody, comprising the steps of introducing the expression vector into a cell and culturing the cell under conditions leading to expression of the anti-CD133 monoclonal antibody, and a method of producing an anti-CD133 monoclonal antibody, comprising a step of culturing the cell under conditions leading to expression of the anti-CD133 monoclonal antibody.

[15] Some other exemplary embodiments of the present invention are as follows. An immunogenic composition comprising one or more polypeptides comprising at least one of SEQ ID NO:17 or a variant thereof or SEQ ID NO:18 or a variant thereof, and a carrier or an adjuvant. A screening agent comprising one or more polypeptides comprising at least one of SEQ ID NO:17 or a variant thereof or SEQ ID NO:18 or a variant thereof, and a carrier, a tag or a label, including a non-naturally occurring tag or label. A method of determining a presence, an absence or an amount of an anti-CD133 monoclonal antibody in a sample, comprising the steps of contacting the sample with the screening reagent and detecting a specific binding of the screening reagent to the anti-CD133 monoclonal antibody in the sample, wherein presence of the detected specific binding is indicative of the presence of the anti-CD133 monoclonal antibody in the sample.

[16] It is to be understood that "variant" or "variants" referred to in the above description of the exemplary embodiment may be a sequence variant of the corresponding amino acid or a nucleic acid sequence having a degree of homology with the corresponding sequence of least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99%. Other objects and advantages of the invention will be apparent from the following detailed description of embodiments of the invention.

BRIEF DESCRIPTION OF THE FIGURES

[17] Figure 1 shows a schematic illustration of tertiary structure of CD133 protein. Reproduced from. Adapted from an illustration published in 2003 catalog of R&D Systems Inc., Minneapolis, MN.

[18] Figure 2 A, B, Figure 2 C, D, E and Figure 2 F, G, H reproduce amino acid sequences of CD133 polypeptides from several species. In Figure 2 A, B - Panel A: CD133 polypeptide, *Homo sapiens*, SEQ ID NO:1 (National Center for Biotechnology Information (NCBI) accession number NP_006008.1); Panel B: Prominin-1 isoform 1, *Gorilla gorilla gorilla*, SEQ ID NO:2 (NCBI reference sequence XP_004038519). In Figure 2 C, D, E - Panel C: Prominin-1 isoform X1, *Pan troglodytes*, SEQ ID NO:3 (NCBI reference sequence XP_003310298); Panel D: Prominin 1.s1 splice variant, *Canis lupus familiaris*, SEQ ID NO:4 (NCBI GenBank reference AIA08974.1); Panel E: Prom1 protein, *Mus musculus*, SEQ ID NO:5 (NCBI accession number AAH28286.1). In Figure 2 F, G, H - Panel F: Prominin-1 isoform 1 precursor, *Rattus norvegicus*, SEQ ID NO:6 (NCBI accession number NP_068519.2); Panel G: Prominin-1 isoform X6, *Homo sapiens*, SEQ ID NO:7 (NCBI reference sequence XP_011512200); Panel H: Prominin-1 isoform X5, *Canis lupus familiaris*, SEQ ID NO:8 (NCBI reference sequence XP_005618614.1).

[19] Figure 3 illustrates of the results of the screening by enzyme-linked immunosorbent assay (ELISA) of blood samples obtained from the rabbits immunized by CD133 immunogens. Panel A shows a colored photograph of an ELISA plate screened by a recombinant CD133 domain A polypeptide. Panel B shows a picture of an ELISA plate screened by a recombinant CD133 domain B polypeptide. The samples in panels A and B are coded as follows: Pre - pre-bleed sample; B1 – bleed 1; B2 – bleed 2. Panel C is a line plot showing detected fluorescence levels (Y axis) observed for different dilutions of the blood samples screened by a recombinant CD133 domain A. Panel D is a line plot showing detected fluorescence levels (Y axis) observed for different dilutions of the blood samples screened by recombinant CD133 domain B polypeptide. The samples are coded as follows: R1-pre – rabbit 1, pre-bleed sample; R1-B1 – rabbit 1, bleed 1; R1-B2 – rabbit 1, bleed 2; R2-pre – rabbit 2, pre-bleed sample; R2-B2 – rabbit 2, bleed 2; R2-B2 – rabbit 2, bleed 2.

[20] Figure 4 shows the line plots illustrating the results of ELISA specificity testing for mAb 47-10 (panel A) and clone 133-3 (panel B) conducted using the plates coated with 100 ng per well of the following antigens: recombinant CD133 Extracellular Domain A

(CD133A) or Domain B (CD133B); BSA-conjugated antigenic peptide A (PepA) or peptide B (Pep B).

[21] Figure 5 shows the amino acid and nucleotide sequences of mAb 47-10. Panel A shows heavy chain sequences: amino acid sequence - SEQ ID NO:9; nucleotide sequence – SEQ ID NO:10. Panel B shows light chain sequences: amino acid sequence - SEQ ID NO:11; nucleotide sequence – SEQ ID NO:12.

[22] Figure 6A and Figure 6B show the amino acid and nucleotide sequences of mAb 133-3. Figure 6A shows heavy chain sequences: amino acid sequence - SEQ ID NO:13; nucleotide sequence – SEQ ID NO:14. Figure 6B shows light chain sequences: amino acid sequence - SEQ ID NO:15; nucleotide sequence – SEQ ID NO:16.

[23] Figure 7 illustrates the structure of the heavy chain complementarity determining regions (CDRs) of mAb 47-10; residues 19-127 of 450. The framework regions are represented with light grey (or no bar), and CDRs are represented by darker grey bars. The framework regions continue beyond the light grey bars, so that the abut each CDR and continue to the end of the sequence. The insertions are highlighted in grey. The arrows mark unusual residues found in less than 1% of the sequences.

[24] Figure 8 illustrates the structure of the light chain of mAb 47-10; residues 23-138 out of 239. The framework regions are represented with light grey bars (or no bar), and CDRs are represented by darker grey bars. The framework regions continue beyond the light grey bars, so that the abut each CDR and continue to the end of the sequence. The insertions are highlighted in grey; the arrows mark unusual residues found in less than 1% of the sequences.

[25] Figure 9 illustrates the structure of the heavy chain of mAb 133-3; residues 19-131 of 454. The CDRs are shown in dark grey, and the framework regions are represented with lighter grey bars (or no bar). The framework regions continue beyond the light grey bars, so that the abut each CDR and continue to the end of the sequence. The insertions are highlighted in grey; the arrows mark unusual residues found in less than 1% of the sequences.

[26] Figure 10 illustrates the structure the light chain of mAb 133-3; residues 23-137 out of 238. The framework regions are represented with light grey bars (or no bar) and CDRs are represented by darker grey bars. The framework regions continue beyond the light grey bars, so that the abut each CDR and continue to the end of the sequence. The insertions are highlighted in grey; the arrows mark unusual residues found in less than 1% of the sequences.

[27] Figure 11 shows the images of Western blots of cell lysates of U87 cells (CD133-negative cells; lane 1 in each blot) and HT-29 cells (CD133-positive cells; lane 2 in each blot). Panels A and B show Western blots stained with different subclones of mAb 47. Panels C and D show Western blots stained with different subclones of mAb 133 clone. The left lane of each blot shows molecular weight (MW) standards. The unlabeled arrows at the right of lane 2 in each panel point at a band for unglycosylated CD133 having a MW of 97 kDa. The arrows labelled "Glyc. CD133" point at an approximate location of a band for glycosylated CD133 having a MW of ~133 kDa.

[28] Figure 12 shows the images of Western blots of the cell lysates of cell lines HT29, A375, SKMEL5, SKMEL28 and U87 (as labeled, left to right, the first left lane in each blot contains MW standards). Panels A (lowered brightness) and B (increased brightness) show Western blots using mAb 47-10. Panels C (lowered brightness) and D (increased brightness) show Western blot using mAb 133-3. The arrows at the left of MW standards point at the band locations for unglycosylated CD133 having MW of 97 kDa. The brackets show approximate location of the band for glycosylated CD133. Western blot conditions were as follows: 4-12% gel; 40 μg protein/lane, except for U87 lane (20 μg/lane); the blots were incubated with 1 μg/ml primary rabbit anti-CD133 monoclonal antibodies for 2 hours at room temperature, with 0.1 μg/ml secondary antibody GAR-IR-800 (Li-Cor) 1 hour at room temperature.

[29] Figure 13 shows the images illustrating the results of immunofluorescence testing of mAb 133-3 with H29 cells (panel A) and U87 cells (panel B). Formalin-fixed, paraffin-embedded (FFPE) samples of the cell pellets were stained for CD133 by mAb at 10μg/ml, followed by anti-rabbit-AF546 antibody (Life Technologies); nuclei were stained with 4',6-diamidino-2-phenylindole (DAPI) fluorescent stain.

[30] Figure 14 shows the images showing the results of immunofluorescence testing of mAb 47-10 with H29 cells (panel A) and A375 cells (panel B). FFPE samples of cell pellets were stained for CD133 by mAb at 10μg/ml, followed by anti-rabbit-AF546 antibody; nuclei were stained with DAPI.

[31] Figure 15 shows the images illustrating the results of immunofluorescence testing of mAbs 133-3 (panel A) and 47-10 (panel B) with A375 xenograft cells. FFPE samples of cell pellets were stained for CD133 by mAb at 10μg/ml, followed by anti-rabbit-AF546 antibody; nuclei were stained with DAPI.

[32] Figure 16 shows the images of Western blots illustrating the results of the comparative testing of mAbs 47-10 and 133-3 and commercially available anti-CD133 mAbs. mAbs 47-10 (panel A), 133-3 (panel B) and commercial mAbs obtained from Miltenyi Biotec (AC133 – panel D; 293C3 – panel E) were used as primary antibodies. Panels C and F show negative control Western blots prepared with rabbit (panel C) and mouse (panel F) secondary antibodies but no primary antibody. The lanes of the Western blots are as follows: MW - molecular weight marker; A - recombinant CD133 extracellular domain A; B - recombinant CD133 extracellular domain B; HT-29 – HT29 cell lysate; U87 – U87 cell lysate.

[33] Figure 17 shows the images, organized as matrix, depicting immunofluorescence staining of FFPE samples of cells representing the cell lines with varying CD133 mRNA expression level (rows, top to bottom: HT29 – high; SW620 – medium; U87 – CD133 negative) with various antibodies (columns, top to bottom: mAb 47-10; mAb 133-3; Miltenyi Biotec AC133 mAb; Miltenyi Biotec W683C1 mAb; Miltenyi Biotec 293C3 mAb).

[34] Figure 18 shows the images depicting the results of the immunofluorescence staining of H596 non-small cell lung cancer xenograft tumor samples from mice expressing known cancer stem cell biomarkers, including CD133. See, for example, Akunuru *et al.* 2012 "Non-small cell lung cancer stem/progenitor cells are enriched in multiple distinct phenotypic subpopulations and exhibit plasticity." *Cell Death and Disease*, 3:1-10; Bertolini *et al.* 2009 "Highly tumorigenic lung cancer CD133+ cells display stem-like features and are spared by cisplatin treatment" *PNAS* 106:16281-16286; Karimi-Busheri *et al.* 2013 "CD24+/CD38- as new prognostic marker for non-small cell lung cancer." *Multidisciplinary Respiratory Medicine* 8:65-74. Panels A and B show representative images of multiplex immunofluorescent epithelial to mesenchymal transition (EMT) and/or cancer stem cell (CSC) biomarker staining of H596 tumors grown in immunocompromised $hHGF^{scid/scid}$ mice (mice homozygous for both the hHGFki and Prkdcscid alleles, also called immunocompromised hHGFki mice, which are available from Jackson Laboratory for Genomic Medicine (USA)). Panels C and D show representative images of multiplex immunofluorescent epithelial to mesenchymal transition and/or cancer stem cell biomarker staining of H596 tumors grown in $hHGF^{ki/ki}$ mice (mice that harbor a "humanized" knock-in mutation (hHGFki) that replaces the mouse hepatocyte growth factor (HGF) coding factor, and the *Prkdc*^{scid} mutation that results in T- and B-cell deficiency; these mice may be useful for studying the HGF/MET pathway in human tumor xenografts and mouse tumor allografts). To obtain the images shown in panels A and C, two adjacent tissue sections from each tumor

were stained with E-Cadherin (clone 36, BD Biosciences) and CD133 (mAb clone 47-10) or E-Cadherin and Slug. To obtain the images shown in panels B and D, known cancer stem cell lung biomarkers such as CD44 and ALDH1 (as labeled) were used. Nanog was another CSC biomarker that was not expressed in these tissues. The merged images show the overlapped layers for all CSC biomarker layers (CD44, Nanog and ALDH1).

[35] Figure 19 shows the images depicting the results of CD133 staining of multi tumor tissue array (TMA) MTU951, Biomax, Inc. Panel A: CD133 Multiple Tumor (MTU951) TMA CD133 (clone 133-3); Panel B: CD133 Multiple Tumor (MTU951) TMA CD133 (mAb 47-10), Panel C: CD133 Multiple Tumor (MTU951) TMA CD133 (293C3). Panel D: CD133 Multiple Tumor (MTU951) TMA CD133 (ACC133). Panel E: Array map: Adr - Adrenal gland, Bla - Bladder, urinary, Bon - Bone, scapula, Bra - Brain, Bre - Breast, Eso - Esophagus, Hea - Head and neck, nasal cavity, Int - Intestine, rectum, Kid - Kidney, Liv - Liver, Lun - Lung, Lym - Lymph node, Ova - Ovary, Pan - Pancreas, Pro - Prostate, Ski - Skin, trunk, Sto - Stomach, Tes - Testis, Thr - Thyroid, Ute - Uterus, endometrium; Color coding employed in the original image and illustrated in the legend was as follows: light blue - benign tumor, white, dark blue - malignant tumor, yellow - metastasis, light green - normal tissue. In the greyscale reproduction, medium grey - benign tumor, white, dark grey - malignant tumor, dark grey - metastasis, light grey - normal tissue.

[36] Figure 20A, Figure 20B and Figure 20C show the specifications of the tumor tissue array MTU951 used in the experiments illustrated in Figure 19, 21A and 21B, Biomax, Inc. 2003-2014.

[37] Figure 21 shows the images depicting the results of CD133 staining of selected tumor cores from multi tumor TMA (MTU951, Biomax) stained with CD133 (mAb 133-3, mAb 47-10, 293C3, or AC133 – as indicated in the figure.

[38] Figure 22 shows the images depicting the results of CD133 staining of selected tumor cores from multi tumor TMA (MTU951, Biomax) stained with CD133 (mAb 133-3, mAb 47-10, 293C3, or AC133 – as indicated in the figure.

[39] Figure 23 shows the images depicting the results of CD133 staining of Melanoma Tumor TMA (ME1004c, Biomax, Inc.). TMA was stained with anti-CD133 Panel A: mAb 133-3. Panel B. mAb 47-10, Panel C. Map: Eso - Esophagus, Int - Intestine, Lym - Lymph node, Ora - Oral cavity, Rec - Rectum, Ski - Skin, Sto - Stomach, Vul – Vulva. Color coding employed in the original image and illustrated in the legent was as follows: light blue - benign tumor, dark blue - malignant tumor, the lightest purple - malignant tumor (stage I),

light purple - malignant tumor (stage IB), medium purple - malignant tumor (stage II), dark purple - malignant tumor (stage III), the darkest purple - malignant tumor (stage IV), yellow – metastasis.

[40] Figure 24A, Figure 24B and Figure 24C show the specifications of the the tumor tissue array ME1004c used in the experiments illustrated in Figure 22, Biomax, Inc. 2003-2014.

[41] Figure 25 shows the images depicting the results of CD133 staining of selected tumor coresof Melanoma Tumor TMA (ME1004c, Biomax) stained with CD133 (mAb 133-3).

[42] Figure 26 shows the images depicting the results of CD133 staining of selected tumor cores of Melanoma Tumor TMA (ME1004c, Biomax) stained with mAbs133-3 and 47-10, as indicated in the figure.

[43] Figure 27 shows colored images depicting the results of peptide blocking of CD133 staining of FFPE HT-29 and SW620 cell pellets stained with mAbs 133-3 and 47-10, as indicated in the figure. Monoclonal antibodies were pre incubated overnight with peptide SEQID NO:17 conjugated to BSA or SEQID NO:18 conjugated to BSA or 1% BSA. The peptides were used at a 20-fold molar excess to mAbs.

[44] Figure 28 shows the scatter graphs illustrating the results of quantitation of CD133+CD44v6+ colocalized cells in the slides prepared from Sum149-PT xenograft tumors inoculated subcutaneously into experimental mice treated with vehicle (water, 0.1 ml/10g body wt), 67.5 mg/kg or 100 mg/kg (42 doses over 21 days) of a FAK inhibitor VS-606 (PO, BID x42), a putative inhibitor of cancer stem cells obtained from Verastem Inc. (Needham, MA). The slides were stained with a multiplex of CD44v6 (clone 2F10, R&D Systems) and mAb 47-10, followed by specific secondary antibodies (Goat anti-Rabbit IgG Alexa546 for CD133 and Goat anti-mouse IgG Alexa 488; both secondary antibodies obtained from Thermo-Fisher (Waltham, MA)). The results of the staining were quantified. Figure 28 shows the scatter graphs illustrating the results of quantitation of CD133+CD44v6+ colocalized cells.

[45] Figure 29 shows the scatter graphs illustrating the results of quantitation of CD133+ cells in the slides prepared from Sum149-PT xenograft tumors inoculated subcutaneously into experimental mice treated with vehicle (water, 0.1 ml/10g body wt), 67.5 mg/kg or 100 mg/kg (42 doses over 21 days) of a FAK inhibitor VS-606 (PO, BID x42). The slides were stained with mAb 47-10, followed by s Goat anti-Rabbit IgG Alexa546

secondary antibody obtained from Thermo-Fischer. The results of the staining were quantified.

DESCRIPTION

[46] Embodiments of the present invention provide novel anti-CD133 monoclonal antibodies having advantageous properties, products, compositions and kits comprising the monoclonal antibodies, methods (processes) of making the monoclonal antibodies and related compositions, as well as methods of using the monoclonal antibodies in analytical, diagnostic and therapeutic applications.

Anti-CD133 Monoclonal antibodies

[47] Embodiments of the present invention include anti-CD133 monoclonal antibodies described in this document, as well as various modifications and variations of these monoclonal antibodies. Anti-CD133 monoclonal antibodies according to some embodiments of the present invention were obtained by carefully selecting potentially immunogenic amino acid sequences from the regions of CD133 extracellular domains that are devoid of glycosylation sites, using the selected sequences to generate immunogenic peptides, using the immunogenic peptides to generate monoclonal antibodies via a hybridoma technology and screening the resulting monoclonal antibodies for specific binding of the polypeptides containing the above immunogenic amino acid sequences. Monoclonal antibodies with the desired binding properties were thus selected. The selected monoclonal antibodies were further tested for specificity as well as for suitability for analytical assays. The antibodies with acceptable specificity and suitability and capable of detecting both glycosylated and unglycosylated forms of CD133 were cloned, sequenced and produced by recombinant technology. The resulting monoclonal antibodies detect both unglycosylated CD133 protein and a range of its glycosylated forms and are suitable for various analytical procedures, including immunofluorescence assays, Western blotting and ELISA. The monoclonal antibodies may be useful in a wide range of analytical, diagnostic and therapeutic applications, in which specific binding of a monoclonal antibody to CD133 polypeptides is desired.

Antibodies

[48] As used herein, the term "antibody" encompasses whole immunoglobulin (i.e., an intact antibody) of any class, including natural, natural-based, modified and non-natural antibodies, as well as their fragments. Natural antibodies are very large, complex polypeptide molecules (molecular weight (MW) of about 150,000, which about 1320 amino acids) with intricate internal structure. Natural antibodies are usually heterotetrameric glycoproteins. A natural antibody molecule contains two identical pairs of polypeptide chains, each pair having one light chain and one heavy chain. Each light chain and heavy chain in turn consists of two regions: a variable ("V") region involved in binding the target antigen, and a constant ("C") region that interacts with other components of the immune system. Depending on the amino acid sequence of the constant domain of their heavy chains, immunoglobulins can be assigned to different classes. There are five major classes of immunoglobulins: IgA, IgD, IgE, IgG and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG-1, IgG-2, IgG-3, and IgG-4; IgA-1 and IgA-2. The prevalence of the isotopes differs among the species. For example, rabbit has only one IgG subclass, while mouse has IgG1, IgG2a, IgG2b, IgG2c, IgG3 subclasses. Most of rabbit research antibodies are of IgG isotope. They possess a number of advantages, in comparison to other antibody types. Some of the advantages are more diverse epitope recognition, improved immune response to small-size epitopes, high specificity and affinity, and greatly improved response to mouse antigens.

[49] The heavy chain constant domains that correspond to the different classes of immunoglobulins are called alpha, delta, epsilon, gamma, and mu, respectively. The term "variable" may be used in reference to antibodies to describe certain portions of their variable regions that differ in sequence among antibodies and are used in the binding and specificity of each particular antibody for its particular antigen. The variability is not usually evenly distributed through the variable domains of antibodies but typically concentrated in the segments called complementarity determining regions (CDRs) or hypervariable regions, both in the light chain and the heavy chain variable domains. The other, more highly conserved portions of the variable domains, are called the framework (FR). Within each light or heavy chain variable region, there are three CDRs averaging 10 amino acids in length. The "Kabat Numbering Scheme" is a scheme for the numbering of amino acid residues in antibodies based upon variable regions. The scheme employs the so-called "Kabat numbers" to denote amino acid residues and is useful when comparing these variable regions between antibodies. The six CDRs in an antibody variable domain (three from the light chain and three from the

heavy chain) fold up together in 3-D space to form the actual antibody binding site which locks onto the target epitope within the antigen.

[50] The term "antibody binding site" and the related terms may be used herein to describe a polypeptide structure capable of specifically binding an "epitope - the region of its antigen to which the antibody binding site binds. As used herein, the terms "specific binding," "selective binding" or related terms refer to a binding reaction in which, under designated conditions, a molecule or a composition containing an antibody binding site binds to its epitope and does not bind in a significant amount to other potential binding partners. The absence of binding in a significant amount is considered to be binding that is less than 1.5 times background (i.e., the level of non-specific binding or slightly above non-specific binding levels). For example, the anti-CD133 monoclonal antibodies of the present invention specifically bind to their respective CD133 epitopes. Antibody binding site may also be described in reference to amino acid sequences of the polypeptides within the binding site, for example, CDR amino acid sequences, or in terms of the nucleic acid sequences encoding the amino acid sequences.

Monoclonal antibodies

[51] The antibodies of the embodiments of the present invention are monoclonal. The terms "monoclonal antibody," "monoclonal antibodies," "mAb," "mAbs" and other related terms may be used in this document to refer to a substantially homogenous population of antibodies or to an antibody obtained from a substantially homogeneous population of antibodies. The antigen binding sites of the individual antibodies comprising the population are comprised of polypeptide regions similar (although not necessarily identical) in sequence. The nature of the monoclonal antibodies is easier understood in comparison to polyclonal antibodies. In laboratory conditions, polyclonal antibodies are typically produced by injecting an animal (such as a rodent, rabbit or goat) with an immunizing agent (which may be referred to as immunogen or antigen), which elicits animal's immune system lymphocytes to produce antibodies to the antigen, and extracting the antibody-containing serum from the animal. The extracted serum contains a population of immunoglobulin molecules produced by different B-cell lineages. This population is typically referred to as "polyclonal antibodies." Polyclonal antibodies react against the same antigen, but may bind to different epitopes within the antigen. Polyclonal antibodies have binding sites with different sequences and structures, as well as varying properties, such as affinity or specificity. In

contrast, a population of monoclonal antibodies binds to the same epitope on an antigen and are understood to have antigen binding sites with similar sequence and structure.

[52] Monoclonal antibodies may be prepared in the laboratory conditions using hybridoma methods. First, as during the production of polyclonal antibodies, a host animal, such as a mouse or a rabbit, may be administered an antigen. After the host animal mounts an immune response to the antigen, spleen cells or lymph node cells are extracted from the animal. If a human is used as a "host animal," peripheral blood lymphocyte ("PBL") cells are typically obtained. Alternatively, the lymphocytes may be immunized *in vitro*. The cells are then fused with an immortalized cell line using a suitable fusing agent, such as polyethylene glycol, to form a hybridoma cell line. Immortalized cell lines are usually transformed mammalian cells, including myeloma cells of rodent, bovine, equine, and human origin. Usually, rat or mouse myeloma cell lines are employed. The hybridoma cells may be cultured in a suitable culture medium that preferably contains one or more substances that inhibit the growth or survival of the unfused, immortalized cells. For example, if the parental cells lack the enzyme hypoxanthine guanine phosphoribosyl transferase (HGPRT or HPRT), the culture medium for the hybridomas typically will include hypoxanthine, aminopterin, and thymidine ("HAT medium"), which substances prevent the growth of HGPRT-deficient cells. For hybridoma, immortalized cell lines are useful that fuse efficiently, support stable high level expression of antibody by the selected antibody-producing cells, and are sensitive to a medium such as HAT medium. One example are immortalized cell lines are murine myeloma cell lines. The culture medium in which the hybridoma cells are cultured can then be assayed for the presence of monoclonal antibodies by various assays, such as immunoprecipitation or *in vitro* binding assays, such as radioimmunoassay (RIA) or enzyme-linked immunoabsorbent assay (ELISA). After the desired hybridoma cells are identified, their clones may be subcloned by limiting dilution or FACS sorting procedures and grown by standard methods. Suitable culture media for this purpose include, for example, Dulbecco's Modified Eagle Medium and RPMI-1640 medium. Alternatively, the hybridoma cells may be grown *in vivo* as ascites in a mammal. The monoclonal antibodies secreted by the subclones may be isolated or purified from the culture medium or ascites fluid by conventional immunoglobulin purification procedures.

[53] Monoclonal antibodies may also be produced by recombinant DNA methods. For example, phage display/yeast display libraries are used for rapid cloning of immunoglobulin segments to create libraries of antibodies, from which antibody binding sites with desired

properties may be selected. In another example, DNA encoding the monoclonal antibodies, such as those generated by hybridoma technology, or parts of the monoclonal antibodies, such as their binding sites, is isolated, synthesized and sequenced using conventional procedures from hybridoma cells. DNA encoding the monoclonal antibodies can be isolated and amplified by polymerase chain reaction (PCR) using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains antibodies. Once isolated, the DNA encoding antibodies or their parts, may be placed into expression vectors, which are then transfected into host cells to synthesize recombinant monoclonal antibodies in the recombinant host cells. Various types of mammalian cell expression systems may be employed, such as, but not limited to, simian COS cells, Chinese hamster ovary (CHO) cells, HEK293 cells, plasmacytoma cells, or myeloma cells, as well as other types of cells that do not otherwise produce immunoglobulin protein. Non-mammalian host cells and/or expression systems can also be employed, one example being insect cells expression systems or avian expression systems. *In vitro* translation/expression systems may also be used to produce monoclonal antibodies according to the embodiments of the present invention. Some of the compositions and methods related to recombinant production of monoclonal antibodies are discussed in more detail below and included within the scope of the embodiments of the present invention.

Fragments, variants, modified and engineered antibodies

[54] Monoclonal antibodies according to the embodiment of the present invention can be derived from naturally occurring monoclonal antibodies or artificially produced ("engineered), for example, by recombinant techniques, and encompass fragments, variants and modification of immunoglobulin molecules. In the broadest sense, the term "monoclonal antibody" is used in this document to denote any product, composition or molecule that contains at least one antibody binding cite. For example, monoclonal antibodies encompass chimeric antibodies and hybrid antibodies, with dual or multiple antigen or epitope specificities, and fragments, such as F(ab')2, Fab', Fab, hybrid fragment, single chain variable fragments (scFv) and "third generation" (3G) fragments. Monoclonal antibodies also encompass fusion proteins, single domain and "miniaturized" antibody molecules.

[55] Fragments can be made by known techniques, for example, they can be recombinantly and/or enzymatically produced, and can be screened for specificity and activity according to known methods, such as radioimmunoassays, ELISA, Western blotting

or immunofluorescence assays and techniques. Digestion of whole antibody molecules can be employed to produce fragments, particularly, Fab fragments. For example, papain digestion of whole antibody molecules typically produces two identical antigen binding fragments, called Fab fragments, each with a single antigen binding site, and a residual Fc fragment. In another example, pepsin treatment yields a fragment, called the $F(ab')_2$ fragment, that has two antigen binding sites. The Fab fragments produced in the antibody digestion also contain the constant domains of the light chain and the first constant domain of the heavy chain. Fab' fragments differ from Fab fragments by the addition of a few residues at the carboxy-terminus of the heavy chain domain, including one or more cysteines from the antibody hinge region. $F(ab')_2$ fragments are bivalent fragments comprising two Fab' fragments, which may linked by a disulfide bridge at the hinge region. Fab'-SH is the designation that may be used Fab' in which the cysteine residue(s) of the constant domains bear a free thiol group. Antibody fragments may be produced as pairs of Fab' fragments with hinge cysteines between them. Other chemical couplings of antibody fragments may also be employed.

[56] Various modifications of monoclonal antibodies may be produced, for example, by recombinant DNA techniques. As used herein, a "recombinant" or "recombinant produced" monoclonal antibody is a product, composition or molecule containing an antibody binding site produced with the help of recombinant DNA techniques. As used herein, the terms "recombinant" or "recombinant produced" encompass antibodies for which the genes have been constructed and/or placed in an unnatural environment, for example for expression, with the help of recombinant DNA techniques. In one example, the DNA encoding a monoclonal antibody may be modified, for example, by joining to the all or part of immunoglobulin coding sequence all or part of the coding sequence for a non-immunoglobulin polypeptide. Such a non-immunoglobulin polypeptide, which is included within the scope of the "monoclonal antibodies" of the present invention, can be substituted for the constant domains of a monoclonal antibody. In another example, a chimeric antibody may be produced. A chimeric antibody, which also included within the scope of the monoclonal antibodies of the present invention, is an antibody in which parts of antibody molecules of different origins are combined. For example, the variable region of a non-human antibody may be combined with the constant region of a human antibody to produce a chimeric antibody. Such chimeric antibodies retain the binding specificity of the non-human antibody, while being about two-thirds human.

[57] One more example of an "engineered" antibody is a humanized antibody, in which the CDRs from a non-human antibody ("donor antibody," which can be, for example, mouse, rat, hamster or other mammalian species) are grafted onto a human antibody ("acceptor antibody"). Humanized antibodies can also be made with less than the complete CDRs from a donor antibody. Thus, a humanized antibody is an antibody having CDRs from a donor antibody and variable region framework and constant regions from a human antibody. The term "framework" or "framework region" in the context of antibody structure generally denotes amino acid sequences interposed between CDRs in a heavy or light variable region of an antibody. Framework includes variable light and variable heavy framework regions. The framework regions serve to hold the CDRs in an appropriate orientation. For example, a humanized antibody may contain a light chain comprising three CDRs (or their portions) from a non-human donor antibody, a variable region framework from a human antibody, a human constant region, and a heavy chain comprising three CDRs (or their portions) from a donor antibody, a variable region framework from a human antibody and a human constant region. Various approaches may be used to retain high binding affinity of humanized antibodies to their antigens. In the first structural element, the framework of the heavy chain variable region of the humanized antibody is chosen to have maximal sequence identity (between 65% and 95%) with the framework of the heavy chain variable region of the donor antibody, by suitably selecting the acceptor antibody from among the many known human antibodies. Sequence identity is determined when antibody sequences being compared are aligned according to the Kabat numbering convention. In the second structural element, in constructing the humanized antibody, selected amino acids in the framework of the human acceptor antibody (outside the CDRs) are replaced with corresponding amino acids from the donor antibody, in accordance with specified rules. Specifically, the amino acids to be replaced in the framework are chosen on the basis of their ability to interact with the CDRs. For example, the replaced amino acids can be adjacent to a CDR in the donor antibody sequence or within 4-6 angstroms of a CDR in the humanized antibody as measured in three-dimensional space.

[58] Embodiments of the present invention encompass "human-like" monoclonal antibodies, meaning monoclonal antibodies in which a substantial portion of the amino acid sequence of one or both chains (for example, about 50% or more) originates from human immunoglobulin genes. Human-like antibodies include, but are not limited to chimeric and humanized and human antibodies. Other types of genetically engineered antibodies that may

be human-like include human antibodies using phage display methods or produced using transgenic animals. Embodiments of the present invention also use "reduced-immunogenicity" antibodies, meaning the heterologous (originating form a species other than the intended recipient) antibodies which, upon administration to a recipient, have reduced immunogenicity. Such antibodies encompass chimeric, humanized and human antibodies as well as antibodies made by replacing specific amino acids in mouse antibodies that may contribute to B- or T-cell epitopes, for example exposed.

[59] Monoclonal antibodies according to the embodiments of the present invention may contain a label. The term "label" encompasses any detectable tag that can be attached directly (for example, a fluorescent molecule integrated into a polypeptide) or indirectly, by way of binding to a primary antibody a secondary antibody with an integrated label or tag. The term "label" or "tag" also encompasses an epitope recognized by another (secondary) antibody or protein that can be conjugated to a label or tag. Detectable label may be an enzymatic label (such as but not limited to horse radish peroxidase (HRP) or alkaline phosphatase (AP)), a radio-opaque substance, a radiolabel, a fluorescent label, a nano-particle label or a magnetic label, a hapten, or a oligonucleotide or polynucleotide label. Detectable label may be a gamma-emitter, beta-emitter, alpha-emitter, gamma-emitter, positron-emitter, X-ray-emitter or fluorescence-emitter. Suitable fluorescent compounds include fluorescein sodium, fluorescein isothiocyanate, phycoerythrin (PE), Allophycocyanin (APC), Alexa Fluor® family of dyes (such as, Alexa Fluor® 350; Alexa Fluor® 405, Alexa Fluor® 488, Alexa Fluor® 532, Alexa Fluor® 546, Alexa Fluor® 555, Alexa Fluor® 568, Alexa Fluor® 594, Alexa Fluor® 647, Alexa Fluor® 680 or Alexa Fluor® 750), Cy® family of dyes (such as Cy®3 or Cy®5), BODIPY® FL, Coumarin, Oregon Green®, Pacific Blue®, Pacific Green®, Pacific Orange®, tetramethylrhodamine (TRITC), Texas Red®, Q-dot® probes (such as Qdot® 525. Qdot® 565. Qdot® 605. Qdot® 655, Qdot® 705, or Qdot® 800), Expressed fluorescent proteins (such as Cyan Fluorescent Protein (CFP), Green Fluorescent Protein (GFP). Or Red Fluorescent Protein (RFP), haptens (such as biotin or DIG). Monoclonal antibodies according to the embodiments of the present invention can also be conjugated or fused to bioactive substances, drugs and radioactive or toxic moieties, such as diphtheria or ricin toxin.

Properties of anti-CD133 monoclonal antibodies

Binding properties

[60] Monoclonal antibodies according to the embodiments of the present invention have one or more of the more structural and/or functional properties described in this document. One of the properties used to describe the monoclonal antibodies according to the embodiments of the present invention is their ability to bind defined polypeptide "antigens." Another property is the structure of the monoclonal antibodies or their parts, for example, amino acid sequence of the one or more polypeptides in an antibody binding site. Nucleotide sequences encoding the amino acid sequence of the monoclonal antibodies or their parts can also be employed.

[61] For example, the monoclonal antibodies according to the embodiments of the present invention can be described in reference to their binding properties - as capable of binding CD133 protein, its fragments and/or variants, including at least some orthologs. The term "CD133 protein," which can also be referred to as prominin-1, PROM1, PROML1 prominin, AC133, CORD12, MCDR2, RP41, STGD4 refers to a five-transmembrane domain glycoprotein encoded by PROM1 gene. The term "CD133 protein" includes orthologs from different species, including, but not limited to, rat, mouse, gorilla, chimpanzee, rhesus monkey, cotton-top tamarin, dog and human. The term also includes various variants and isoforms, such as splice variants and isoforms, postranslationally modified (form example, glycosylated) variants and isoforms, as well as mutants and homologs. CD133 protein may be described by using an amino acid sequence of human CD133 protein (SEQ ID NO:1) and homologous sequences, such as SEQ ID NOs 2-8, or sequences with an extent of homology (as defined further in this document) of at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98% or at least 99%.

[62] As discussed elsewhere in this documents, anti-CD133 monoclonal antibodies of the present invention were obtained by using immunogenic polypeptides having amino acid sequences from the regions of CD133 extracellular domains A and B (SEQ ID NO:17 – domain A immunogenic polypeptide sequence ("polypeptide A"); SEQ ID NO:18 – domain B immunogenic polypeptide ("polypeptide B") sequence and screened for specific binding using polypeptides A and B and recombinantly expressed CD133 domain A and B polypeptides (SEQ ID NO:19 – recombinant domain A polypeptide; SEQ ID NO:20 – recombinant domain B polypeptide). Monoclonal antibodies according to some embodiments of the present invention specifically bind to domain A polypeptides

SEQ ID NOs 17 and 19) but not to domain B polypeptides (SEQ ID NOs 18 and 20), or, alternatively, to domain B but not to domain A polypeptides. Accordingly, monoclonal antibodies specific for domain A polypeptides are capable of specifically binding polypeptides comprising SEQ ID NO:17 and/or 19, or their variants or homologues. Monoclonal antibodies specific for domain B polypeptides are capable of specifically binding polypeptides comprising SEQ ID NO:18 and/or 20, or their variants or homologues. Binding of the monoclonal antibodies according to the embodiments of the present invention to their polypeptides may be described in terms of binding affinity. For example, monoclonal antibodies of the present invention typically have a binding affinity (K_a) for their respective CD133 polypeptides of at least 10^7 M^{-1}, at least 10^8 M^{-1}, at least 10^9 M^{-1}, or at least 10^{10} M^{-1}.

Structural properties - sequences

[63] Monoclonal antibodies according to the embodiments of the present invention can also be described using binding site antibody amino acid sequences or nucleic acids encoding such amino acid sequences. One exemplary embodiment is a monoclonal antibody having an antibody binding site containing SEQ ID NO:9 (or its homologues or variants) in its heavy chain and SEQ ID NO:11 (or its homologues or variants) in its light chain. One more exemplary embodiment is a monoclonal antibody having an antibody binding site containing an amino acid sequence encoded by SEQ ID NO:10 (or its homologues or variants) in its heavy chain and an amino acid sequence encoded by SEQ ID NO:12 (or its homologues or variants) in its light chain. Another exemplary embodiment is a monoclonal antibody having an antibody binding site containing SEQ ID NO:13 (or its homologues or variants) in its heavy chain and SEQ ID NO:15 (or its homologues or variants) in its light chain. Yet another exemplary embodiment is a monoclonal antibody having an antibody binding site containing an amino acid sequence encoded by SEQ ID NO:14 (or its homologues or variants) in its heavy chain and an amino acid sequence encoded by SEQ ID NO:16 (or its homologues or variants) in its light chain. One more exemplary is a monoclonal antibody having an antibody binding site containing one or more amino acid sequences corresponding to H1, H2 and H3 CDRs contained within SEQ ID NO:9 (or its homologues or variants) in its heavy chain and containing one or more amino acid sequences corresponding to L1, L2 and L3 CDRs contained within SEQ ID NO:11 (or its homologues or variants) in its light chain. Yet another exemplary is a monoclonal antibody having an antibody binding site containing one or more amino acid sequences corresponding to H1, H2 and H3 CDRs contained within

SEQ ID NO:13 (or its homologues or variants) in its heavy chain and containing one or more amino acid sequences corresponding to L1, L2 and L3 CDRs contained within SEQ ID NO:15 (or its homologues or variants) in its light chain. Homologues or variants discussed above may refer to variants or homologues of at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98% or at least 99% degree of homology.

Variations and modifications of nucleic acids and polypeptides; sequence homology

[64] Embodiments of the present invention encompass homologues, variants, isoforms, fragments, mutants, modified forms and other variations of the polypeptides and nucleic acid sequences described in this document. The term "homologous," "homologues" and other related terms used in this document in reference to various amino acid and nucleic acid sequences, are intended to describe a degree of sequence similarity among protein sequences or among and nucleic acid sequences, calculated according to an accepted procedure.. Homologous sequences may be at least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% 99% or 100% homologous. As used herein, "percent homology" of two amino acid sequences or of two nucleic acid sequences is determined using the algorithm of Karlin and Altschul, which is incorporated into the NBLAST and XBLAST programs, available for public use through the website of the National Institutes of Health (U.S.A.). To obtain gapped alignments for comparison purposes, Gapped BLAST is utilized. When utilizing BLAST and Gapped BLAST programs, the default parameters of the respective programs (e.g., XBLAST and NBLAST) are used. "Percent homology" may be used in this document to describe fragments, variants or isoforms of amino acids and nucleic acid sequences, but other ways of describing fragments, variants or isoforms may be employed alternatively to or in conjunction with homology.

[65] Fragments of a polypeptide can include any portion of a polypeptide of at least 3, 5, 8, 10, 15, 20, 25, 30, 35, 40, 45 amino acids. It is to be appreciated, for example, that some epitopes can contain only three amino acids. Furthermore, since epitopes (antigens) to which the monoclonal antibodies bind can involve residues that are not adjacent in in peptide sequence, but are next to each other in three-dimensional structure, it is possible to achieve a special configuration of an epitope using smaller fragments of a polypeptide sequence included discontinuously within a longer sequence.

[66] Variants may result from sequence variations, such as amino acid substitutions, deletions, and insertions, as well as post-translational modifications. Variations in post-translational modifications can include variations in the type or amount of carbohydrate moieties of the protein core or any fragment or derivative thereof. Variations in amino acid sequence may arise naturally as allelic variations (such as due to genetic polymorphism) or may be produced by human intervention (such as by mutagenesis of cloned DNA sequences), the examples being induced point, deletion, insertion and substitution mutants. Variations in a nucleic acid sequence may result in changes in the amino acid sequence, provide silent mutations, modify a restriction site, or provide other specific mutations.

[67] The term "mutation" or "mutated sequence," when used in reference to nucleotide or amino acid or nucleotide sequence can be used interchangeably with the terms "variant," "allelic variant," "variance," or "polymorphism." Amino acid sequence modifications include substitutions, insertions or deletions. Insertions include amino and/or carboxyl terminal fusions as well as intrasequence insertions of single or multiple amino acid residues. Insertions ordinarily will be smaller insertions than those of amino or carboxyl terminal fusions, for example, on the order of one to four residues. Deletions are characterized by the removal of one or more amino acid residues from the protein sequence. Amino acid substitutions are typically of single residues but may include multiple substitutions at different positions; insertions usually will be on the order of about from 1 to 10 amino acid residues but can be more; and deletions will range about from 1 to 30 residues, but can be more. Amino acid substitutions may be characterized as "conservative," meaning substitution for an amino acid with similar properties. Some examples of conservative substitutions are shown in Table 1, below. Conservative amino acid substitutions in monoclonal antibodies may have substantially no effect on antigen binding or other immunoglobulin functions. See, for example, Harlow & Lane, "Antibodies, A Laboratory Manual, Cold Spring Harbor Publications," New York (1988). A variant or an isoform can contain one or more of substitutions (including, for example, conservative amino acid substitutions, such as 1-5, 1-10, 1-20, 1-50 or more conservative amino acid substitutions), deletions, insertions.

[68] An isoform or a variant can also be a result of post-translational modifications, derivatizations or lack thereof. For example, variants may arise as a result of differences in glycosylation, such as N- and O-glycosylation. Glutaminyl and asparaginyl residues are frequently post-translationally deamidated to the corresponding glutamyl and asparyl

residues. Alternatively, these residues may be deamidated under mildly acidic conditions. Other post-translational modifications include hydroxylation of proline and lysine, phosphorylation of hydroxyl groups of seryl or threonyl residues, methylation of the o-amino groups of lysine, arginine, and histidine side chains (acetylation of the N-terminal amine and, in some instances, amidation of the C-terminal carboxyl. Modifications can also include modifications in glycosylation.

Table 1. Conservative amino acid substitutions

Original residue	Exemplary Residue Substitutions
Ala	Ser
Arg	Lys
Asn	Gln
Asp	Glu
Cys	Ser
Gln	Asn
Glu	Asp
Gly	Pro
His	Gln
Ile	Leu; Val
Leu	Ile; Val
Lys	Arg; Gln
Met	Leu; Ile
Phe	Met; Leu; Tyr
Ser	Thr
Thr	Ser
Trp	Tyr
Tyr	Trp; Phe
Val	Ile; Leu

Methods of making anti-CD133 monoclonal antibodies and related compositions; molecules, products and kits

[69] Methods of making monoclonal antibodies are included within the scope of the embodiments of the present invention. Monoclonal antibodies can be produced by processes comprising a step of administering an immunogenic composition containing at least one of immunogenic polypeptides (described elsewhere in this document) to subjects, cells or tissues, to induce antibody production in the subjects, cells or tissues. Administration of the immunogenic composition induces production of antibodies in the subjects, cells or tissues.

Thus, antibody-producing subjects, cells or tissues are provided. Methods of making antibodies according to the embodiments of the present invention can include one or more steps typically employed in hybridoma technology, such as isolating antibody-producing cells from the subject, using the antibody-producing cells to generate a hybridoma cell culture and isolating an individual antibody-producing cell from the hybridoma cell culture. Antibody-producing cells may be expanded in culture and used to generate monoclonal antibodies.

[70] Anti-CD133 antibody production processes according to the embodiments of the present invention may include one or more screening steps, methods or processes. Such screening steps, methods and processes are included within the scope of the present invention. "Screening," which may also be referred to as "analysis," "characterization," "testing" or by other related terms The binding properties of thus generated monoclonal antibodies may be characterized or tested during the screening, which may involve the steps of contacting monoclonal antibodies with a screening composition comprising the at least one of immunogenic polypeptides under conditions of an assay intended to detect binding of the antibody to the one or more immunogenic polypeptides. The assay, which can be referred to as "screening assay," may be, but is not limited to, an immunoprecipitation assay, a Western blot, an ELISA, a flow cytometry assay, an immunofluorescence assay (IFA), an immunohistochemistry (IHC) assay, a cytospin assay, a fluorescence resonance energy transfer (FRET) assay, or a reverse phase array. More than one screening assay may be employed. A plurality of monoclonal antibodies may be obtained and tested by the above processes. Based on the results of the screening monoclonal antibodies with desired binding properties, such as binding strength, specificity or both, may be selected for further processes and uses. Desired binding properties may be binding strength and/or specificity of binding of an antibody to a screening compositions. For example, a screening may reveal that an antibody exceeds a certain predetermined threshold value characterizing binding strength or specificity, or that the antibody's characteristics are superior in comparison to other screened antibodies, which case the antibody may be selected for further processes and uses. Screening may also involve conducting various assays, such as immunofluorescence assays, flow cytometry and the like, that employ antibody-based reagents, using monoclonal antibodies of the present invention.

[71] The methods, processes and steps of producing monoclonal antibodies according to the embodiments of the present invention may include recombinant techniques. The nucleic acid sequences (for example, cDNA sequences and genomic DNA sequences)

encoding antibody binding site or amino acid sequences of the selected monoclonal antibodies may be determined. Recombinantly produced monoclonal antibodies containing the antibody binding sites may be generated based on these sequences using appropriate vectors and expression systems, which are described in more detail elsewhere in this document. The methods, processes and steps of producing monoclonal antibodies according to the embodiments of the present invention may include various steps related to analysis and generation of nucleic acid and amino acid sequences and molecules, such as nucleic acid and polypeptide sequencing, amplification (for example, by polymerase chain reaction (PCR)), restriction, nucleic acid and polypeptide synthesis, mass spectroscopy, HPLC, and various other procedures. The methods, processes and steps of producing monoclonal antibodies according to the embodiments of the present invention may include isolation and purification steps, such as dialysis, precipitation, microfiltration, ultrafiltration, protein A or G affinity chromatography, size exclusion chromatography, anion exchange chromatography, hydroxylapatite (hydroxyapatite) chromatography, hydrophobic interactions chromatography, cation exchange chromatography, other forms of affinity chromatograph, gel electrophoresis, HPLC and other techniques and procedures. Compositions, methods and kits related to the antibody production and processes (such compositions, methods and kits for recombinant antibody production, are included within the scopes of the embodiments of the present invention).

Vectors and cells

[72] Anti-CD133 monoclonal antibodies and other polypeptides described in this documents can be produced with the aid of recombinant technologies. Accordingly, the embodiments of the present invention include expression vectors comprising one or more nucleic acids encoding one or more of the polypeptides described in this documents. In the expression vectors, the encoding nucleic acid is typically operably linked to one or more regulatory sequences. Such useful regulatory sequences include, for example, the early or late promoters, such as promoter sequences of SV40, CMV, vaccinia, polyoma or adenovirus, the lac system, the trp system, the TAC system, the TRC system, the LTR system, the major operator and promoter regions of phage lambda, the control regions of fd coat protein, the promoter for 3-phosphoglycerate kinase or other glycolytic enzymes, the promoters of acid phosphatase (for example, Pho5), the AOX 1 promoter of methylotrophic yeast, the

promoters of the yeast a-mating factors, and other sequences known to control the expression of genes of prokaryotic or eukaryotic cells or their viruses.

[73] An expression vector according to the embodiments of the present invention can be designed to produce anti-CD133 monoclonal antibodies or immunogenic polypeptides described in this document. An expression vector can be suitable for expression in eukaryotic cells or prokaryotic cells and thus include DNA molecules which are capable of integration into a prokaryotic or eukaryotic chromosome and subsequent expression. The inserted genes in viral and retroviral vectors usually contain promoters and/or enhancers to help control the expression of the desired gene product. A promoter is generally a sequence or sequences of DNA that function when in a relatively fixed location in regard to the transcription start site. A promoter contains core elements required for basic interaction of RNA polymerase and transcription factors, and may contain upstream elements and response elements. Specific regulatory elements can be cloned and used to construct expression vectors that are selectively expressed in specific cell types. For example, the glial fibrillary acetic protein (GFAP) promoter has been used to selectively express genes in cells of glial origin. Expression vectors used in eukaryotic host cells (e.g., yeast, fungi, insect, plant, animal, human or nucleated cells) may also contain sequences necessary for the termination of transcription which may affect mRNA expression. These regions are transcribed as polyadenylated segments in the untranslated portion of the mRNA encoding tissue factor protein. The 3' untranslated regions also include transcription termination sites. It is preferred that the transcription unit also contain a polyadenylation region. One benefit of this region is that it increases the likelihood that the transcribed unit will be processed and transported like mRNA. The identification and use of polyadenylation signals in expression constructs is well established. It is preferred that homologous polyadenylation signals be used in the transgene constructs. In certain transcription units, the polyadenylation region is derived from the SV40 early polyadenylation signal and consists of about 400 bases. It is also preferred that the transcribed units contain other standard sequences alone or in combination with the above sequences improve expression from, or stability of, the construct. Some examples of the vectors are PUC vectors, pcDNA3 vectors, pEE series vectors, pGL3 vectors or pEGFP vectors. pFUSE-CLIg and pFUSE-CHIg plasmid vectors can be employed, which are designed to change a monoclonal antibody from one isotype to another, thus permitting the generation of a variety of antibodies with the same antigen affinity.

[74] The vectors according to the embodiments of the present invention include viral vectors that transport the nucleic acids encoding monoclonal antibodies and polypeptides described in this document into cells without degradation and include a promoter yielding expression of the nucleic acids in the cells into which it is delivered. Viral vectors are derived from viruses, including retroviruses, such as Adenovirus, Adeno-associated virus, Herpes virus, Vaccinia virus, Polio virus, AIDS virus, neuronal trophic virus, Sindbis virus and other RNA viruses. Also preferred are any viral families that share the properties of these viruses that make them suitable for use as vectors. Retroviruses include Murine Maloney Leukemia virus, MMLV, and retroviruses that express the desirable properties of MMLV as a vector. Some other examples of viral vectors are simian virus 40 (SV40) and baculovirus vectors. Typically, viral vectors contain, nonstructural early genes, structural late genes, an RNA polymerase III transcript, inverted terminal repeats necessary for replication and encapsidation, and promoters to control the transcription and replication of the viral genome. When engineered as vectors, viruses typically have one or more of the early genes removed and a gene or gene/promoter cassette is inserted into the viral genome in place of the removed viral DNA. The necessary functions of the removed early genes are typically supplied by cell lines that have been engineered to express the gene products of the early genes in trans.

[75] Cells including the expression vectors are also included among the embodiments of the present invention. The resulting cells can thus produce anti-CD133 monoclonal antibodies or immunogenic polypeptides described in this document. A cell can be either a eukaryotic or prokaryotic cell, such as strains of *E. coli, Pseudomonas, Bacillus or Streptomyces*, fungi such as yeasts (*Saccharomyces*, and methylotrophic yeast such as *Pichia, Candida, Hansenula,* and *Torulopsis*); animal cells, such as CHO, R1. 1, B-W and LM cells, African Green Monkey kidney cells (for example, COS 1, COS 7, BSC1, BSC40, and BMT10), insect cells (for example, Sf9), human cells (such as human embryonic kidney cells, for instance, HEK293) and plant cells in cell or tissue culture.

[76] When the host is a eukaryote, such methods of transfection of DNA as calcium phosphate coprecipitates, conventional mechanical procedures such as microinjection, electroporation, insertion of a plasmid encased in liposomes, or virus vectors may be used. Eukaryotic cells can also be co-transformed with polynucleotide sequences encoding the antibody, labeled antibody, or antigen binding fragment thereof, and a second foreign DNA molecule encoding a selectable phenotype, such as the herpes simplex thymidine kinase gene. Another method is to use a eukaryotic viral vector, such as simian virus 40 (SV40) or bovine

papilloma virus, to transiently infect or transform eukaryotic cells and express the protein. Expression systems, such as plasmids and vectors, can be employed to produce proteins in cells, including higher eukaryotic cells, such as the COS, CHO, HeLa and myeloma cell lines.

Exemplary process of making recombinant monoclonal antibodies

[77] In an illustrative example, anti-CD133 monoclonal antibodies according to the embodiments of the present invention, including chimeric and humanized monoclonal antibodies, are recombinantly produced. In one example illustrating the process of using the above-described vectors and cells, a nucleic acid sequence encoding an anti-CD133 monoclonal antibody is introduced into a plasmid or other vector, which is then used to transform living cells. For instance, genes encoding light and heavy chain V regions are synthesized from overlapping oligonucleotides and inserted together with available C regions into expression vectors that provide the necessary regulatory regions, such as promoters, enhancers, poly A sites and other sequences. Expression vectors may be employed, in which a cDNA containing the entire anti-CD133 monoclonal antibody coding sequence, a fragment of the anti-CD133 monoclonal antibody coding sequence, amino acid variations of the anti-CD133 coding sequence, or fusion proteins of the aforementioned, is inserted in the correct orientation in an expression plasmid. In some cases. it may be desirable to express the coding sequence under the control of an inducible or tissue-specific promoter. The expression vectors may then be transfected using various methods, such as lipofection or electroporation, into cells of an appropriate mammalian cell line, thus generating cells expressing the monoclonal antibodies. The cells expressing the antibodies may be selected by appropriate antibiotic selection or other methods and cultured. Larger amounts of antibody may be produced by growing the cells in commercially available bioreactors. Once produced by the antibody-producing cells, anti-CD133 monoclonal antibodies may be purified according to standard procedures, such as dialysis, filtration and chromatography. A step of lysing the cells to isolate the anti-CD133 monoclonal antibody can be included. Thus, a method of making an anti-CD133 monoclonal antibody may contain one or more steps of culturing a cell comprising a vector under conditions permitting expression of the anti-CD133 monoclonal antibody, harvesting the cells and/or harvesting the medium from the cultured cells, and isolating the anti-CD133 monoclonal antibody from the cells and/or the culture medium. Compositions, methods and kits related to the antibody production and processes

(such compositions, methods and kits for recombinant antibody production, are included within the scopes of the embodiments of the present invention.

Immunogenic polypeptides

[78] Among the embodiments of the present invention are immunogenic polypeptides of CD133 that were employed in the production of the monoclonal antibodies according to the embodiments of the present invention, as well their variants and modifications that preserve their immunogenic properties. One example of such an embodiment is an isolated or recombinantly produced polypeptide of SEQ ID NO:17 or 18 or a homologous sequence. Another example is a polypeptide having SEQ ID NO:17 or 18, or a homologous sequence and also containing additional residues (for example, a lysine residue may be added at the C terminus). One more example is a polypeptide having SEQ ID NO:17 or 18, or a homologous sequence, conjugated to a label or a heterologous polypeptide. Nucleic acid sequences encoding the above polypeptides are also envisioned and included among the embodiments of the present invention.

[79] Molecules, compositions, products, kits including the above immunogenic polypeptides, as well as methods of making and using the above polypeptides, for example, for producing, testing or screening antibodies, inducing immune response in the subjects, cells or tissues are also included within the scope of the present invention. For instance, compositions or molecules containing above polypeptides or nucleic acids may be employed in the methods of producing monoclonal antibodies described in this document as probes in the screening assays. In another example, the compositions or molecules containing above polypeptides or nucleic acids may be administered to subjects, cells or tissues to induce immune response, including production of antibodies.

Methods of using monoclonal antibodies

[80] The processes of using anti-CD133 monoclonal antibodies are included among the embodiments of the present invention. Anti-CD133 monoclonal antibodies can be used in diagnostic, preparative, analytical, prognostic or laboratory methods or assays, as well as in therapeutic methods. For example, the monoclonal antibodies may be used to measure the presence, absence or level of CD133 in samples, such as cells, tissues or organisms, which may be referred to as "subjects." As used throughout the document, the term "subject" and related terms refer to an organism. Subject may be a mammal such as a primate, including a

human. The term "subject" can include domesticated animals, such as cats, dogs, etc., livestock (e.g., cattle, horses, pigs, sheep, goats, etc.), and laboratory animals (e.g., mouse, rabbit, rat, guinea pig, etc.). The term "subject" as used may refer to a subject, such as but not limited to a human person, having a cancer, including a solid tumor cancer or a blood cancer. It is to be understood, that a subject having a cancer can be a patient with a known cancer, meaning the cancer that was detected prior to the performance of the embodiments of the methods of the present invention, or a subject with a previously undetected cancer.

Detection methods

[81] The methods according to the embodiments of the present invention involve binding of the antibody to its epitope. Thus, the processes of using anti-CD133 monoclonal antibodies according to some of the methods described in this document include a step of contacting the anti-CD133 monoclonal antibody (meaning one or more monoclonal antibody) with a sample under conditions that permit binding of the monoclonal antibody with its CD133 epitope. The conditions under which the binding of anti-CD133 monoclonal antibody to its epitope occurs depend on the context of the specific method. The terms "sample" or "samples" is not intended to be limiting and refers to any product, composition, cell, tissue or organism that may contain epitopes of the anti-CD133 monoclonal antibodies described in this document. For example, "sample" may be any cell or tissue sample or extract originating from cells, tissues or subjects, and include samples of human or animal cells or tissues as well as cells of non-human or non-animal origin, including bacterial samples. A sample can be directly obtained from a human or animal organism, or propagated or cultured. Samples can be subject to various treatment, storage or processing procedures before being analyzed according to the methods described in the document. Generally, the terms "sample" or "samples" are not intended to be limited by their source, origin, manner of procurement, treatment, processing, storage or analysis, or any modification. Samples include, but are not limited to samples of human cells and tissues, such as blood samples including circulating stem cells (cSC), cerebrospinal fluid samples, synovial tissue samples, synovial fluid samples, brain tissue samples, blood vessel samples, or tumor samples including circulating tumor cells (CTCs) and circulating cancer stem cells (cCSCs). Blood samples include both blood serum and blood plasma samples. Samples encompass samples of healthy or pathological cells, tissues or structures. Samples can contain or be predominantly composed of cells or tissues, or can be prepared from cells or tissues. Some examples of the samples

are solutions, suspensions, supernatants, precipitates (cell precipitates), pellets, cell extracts (for examples, cell lysates), cell extracts, blood or plasma samples, tissue sections and/or including needle biopsies, microscopy slides, including fixed tissues (ex. formalin-fixed, paraffin-embedded (FFPE)) or frozen tissue sections, flow cytometry samples and fixed cell samples. Samples, such as cells and small tissues may be mixed in a slurry of an inert support with or without use of optimal cutting temperature (OCT) or other compounds before freezing, electrophoresis gels and blots (such as those used in Western blotting).

[82] The methods according to the embodiments of the present invention may include a step of detecting the binding of an anti-CD133 monoclonal antibody to its epitope. The detection may be accomplished by detecting epitope-antibody complexes using various types of labels. For example, for various assays, the monoclonal antibodies may be labeled with fluorescent molecules, metals, spin-labeled molecules, nano-particles, enzymes or radioisotopes. The labels are sometimes referred to as "reporter molecules." Anti-CD133 monoclonal antibodies may be directly labeled, meaning that the labels can be directly attached (conjugated to the antibodies) or indirectly (non-covalently) labeled, meaning that antibody-binding molecules containing the labels may be employed. For example, labeled secondary antibodies or their fragments capable of binding anti-CD133 monoclonal antibodies may be used. Some examples of antibody labels and procedures used in labeling are described, for example, in "Guide to Antibody Labeling and Detection," Innova Biosciences (2010), Cambridge (UK), Buchwalow & Bocker "Immunohistochemistry: Basics and Methods" Springer-Verlag Berlin Heidelberg (2010) (see, for example, Chapter 2 "Antibody Labeling and the Choice of a Label," pages, 9-17). Detection of the labels, which includes qualitative and quantitative detection, is accomplished by various methods, depending on the label, the method in which it is used, and the result desired.

[83] For example, in some of the embodiments of the methods described in this documents, the binding of anti-CD133 monoclonal antibodies to their epitopes in cell and tissue samples may be visually detected, such as in the slides examined or imaged under the microscope, by using either a direct (covalently attached) fluorescent label or fluorescently labeled secondary antibodies. In another example, fluorescence emitted by labeled anti-CD133 monoclonal antibodies or by the secondary antibodies is quantitatively detected by registering light emitted by the sample at a particular wavelength. One or more monoclonal antibodies may be employed. In some exemplary methods, two monoclonal antibodies binding to different CD133 epitopes (i.e., not competing for binding) may be simultaneously

employed, for example, in a "sandwich" assays, such as ELISA. Anti-CD133 monoclonal antibodies according to the embodiments of the present invention and may be provided in the form of kits with all the necessary reagents to perform the assay for CD133 presence, absence or level.

[84] Monoclonal anti-CD133 antibodies according to the embodiments of the present invention detect a range of CD133 variants and isoforms, including unglycosylated and a range of glycosylated variants, and are useful for various analytical procedures and protocols, including pharmacodynamic immunoassays, immunofluorescence assays, Western blotting, ELISA, flow cytometry and immunoprecipitation. The methods described in this document can involve detecting the total level of all CD133 variants or isoforms, or the level of some of them. A method can contain a step of detecting a level of CD133 in a sample and comparing it to a control level. Control levels can be used to establish a threshold value. This threshold value can be determined empirically by comparing positive controls (for examples, samples with a certain level of CD133 present) and negative controls (samples without CD133).

[85] Such procedures and protocols employing anti-CD133 monoclonal antibodies may be useful in a wide range of analytical, diagnostic and therapeutic applications, for example, in research and laboratory applications in which detection of CD133 is desirable, or in methods of assessing various conditions, such as cancer, in subjects. Since the presence of CD133 may be indicative of cancer stem cells, monoclonal anti-CD133 antibodies according to the embodiments of the present invention may be used in the methods of detecting and monitoring cancer stem cells (cancer cells that can self-renew and drive tumorogenesis) in samples or in subjects.

[86] The terms "assess," "assessment" "detect," "detecting," "indicate," "indicative" and similar terms are used in this document to broadly refer to a process or discovering or determining the presence or an absence, as well as a degree, quantity, or level, or probability of occurrence of something. For example, the term "assessing" when used in reference to a disease or a condition can denote discovery or determination one or more of presence of a disease or a condition, absence of a disease or a condition, progression, level or severity of a disease or a condition, as well as a probability of present or future exacerbation of symptoms, or of efficacy of a treatments. The terms "assess," "assessment," "assessing" and the related terms may be used in reference to cancer, status of cancer or status of a subject with cancer, and in some other contexts. These terms can denote, but are not limited to, inferring the presence or the absence of cancer stem cells in cancerous tumors based on the detected

presence or absence of CD133 in the tumors. The terms "assess," "assessment," "assessing" and the related terms may also encompass, depending on the context, recommending or performing any additional diagnostic procedures related to evaluating cancer, evaluating potential effectiveness of the treatments for cancer, as well as recommending or performing such treatments, monitoring the cancer, or any other steps or processes related to treatment or diagnosis of a cancer. For example, evaluating prognosis of a cancer in a subject, or evaluating prognosis of a cancer subject fall within the scope of the terms "assess," "assessment," "assessing" and the related terms. These terms also encompass recommending or not recommending and performing or not performing treatment or diagnostic procedures based on the results of detection of cancer-associated mutations in the subject's tumors.

Diagnostic and Therapeutic Methods

[87] Anti-CD133 monoclonal antibodies described in this document may be used in diagnostic as well as in therapeutic methods, or methods related to treating diseases or conditions. Some of these methods may be referred to as "screening" and/or "profiling" methods and may be employed in the fields of diagnostics, therapy, personalized medicine and other related fields. The term "condition" when used in reference to the embodiments of the present invention is used broadly to denote a biological state or process, which can be normal or abnormal or pathological. The term "condition" can be used to refer to a medical or a clinical condition, meaning broadly a process occurring in a body or an organism and distinguished by certain symptoms and signs. The term "condition" can be used to refer to a disease or pathology, meaning broadly an abnormal disease or condition affecting a body or an organism. Some examples of conditions related to the methods of using anti-CD133 monoclonal antibodies described in this document are cancers, such as breast cancer, colorectal cancer, gliblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia, retinoblastoma. Some other examples of conditions related to the methods of using anti-CD133 monoclonal antibodies described in this document are Stargardt disease, an inherited form of juvenile macular degeneration Retinitis pigmentosa 41, and cone-rod dystrophy 12.

[88] The term "cancer" as used herein includes solid tumor cancers and blood cancers. The term "solid tumor cancer" denotes the cancers that are characterized by the formation of cancerous tumors, or cohesive masses of abnormally proliferating cells, in tissues and organs.

It is to be understood that some tumors formed by the solid tumor cancers can be cysts, meaning fluid-filled sacks of tissue. The term "solid tumor cancer" is used herein to distinguish tumor-forming cancers from the so-called blood cancers or hematological malignancies that are formed from hematopoietic (blood-forming) cells and affect blood, bone marrow, and lymph nodes. Examples of solid tumor cancers are carcinomas, or cancers derived from epithelial cells, sarcomas, or cancers arising from connective tissue, germ cell tumors, such as seminomas and dysgerminomas, blastomas, or cancers that derive from precursor cells or embryonic tissue. Some non-limiting examples of solid tumor cancers are lung cancer, breast cancer, colorectal cancer, prostate cancer, thyroid cancer, brain cancer, such as glioblastoma, and bladder cancer. Examples of hematological malignancies are lymphomas, leukemias, myelomas, myelodysplastic syndromes and myeloproliferative diseases.

[89] Circulating tumor cells (CTCs) are included within the scope of the term "cancer." See, for example, "CD133 expression in circulating tumor cells from breast cancer patients: Potential role in resistance to chemotherapy." *Int. J. Cancer*. 2013, 33:2398-407; "Circulating and disseminated tumor cells in the management of breast cancer." *Am. J. Clin. Pathol.* 2009, 132:237-245; "Circulating tumor cells: a useful predictor of treatment efficacy in metastatic breast cancer." *J. Clin. Oncol.* 2009; 27:5153-5159; "Characterization of metastatic breast cancer patients with non-detectable circulating tumor cells." *Int. J. Cancer* 2011, 129:417-423; and "Epithelial-mesenchymal transition and stem cell markers in patients with HER2-positive metastatic breast cancer." *Mol. Cancer. Ther.* 2012; 11:2526-34

[90] Anti-CD133 monoclonal antibodies described in this document may be used in methods of determining efficacy of a therapy, such as a cancer therapy in a subject based on a change or changes in CD133 expression levels. Such methods can be described as pharmacodynamic methods, or methods of evaluating efficacy of a treatment or therapy. An exemplary method comprises obtaining a first blood sample from a subject with cancer prior to treatment with a first cancer therapy, determining a value of CD133 expression in the first blood sample (i.e., as a baseline measurement), obtaining a second blood sample from a subject with cancer after at least one treatment with the first cancer therapy, determining a second CD133 value in the second blood sample (i.e., as a means of assessing the treatment effect), and comparing the first value to the second value. An increase in CD133 value may indicated that the cancer therapy is insufficiently effective and that a second cancer therapy or an increase in dosing regimen (increased dosage or frequency using the current treatment

agent) for the subject should be selected. A second cancer therapy can also include administration of multiple chemotherapeutics in combination, surgery, and/or radiation therapy. Proper dosages and treatment methods, or change in treatment regimens can be determined by accepted methods.

[91] Anti-CD133 monoclonal antibodies described in this document may be used in various other methods, that can be characterized, depending on the context, as screening, diagnostic, therapeutic or treatment methods. For example, anti-CD133 monoclonal antibodies of the present invention may be employed in methods of detecting presence, absence or amount of cancer stem cells in the sample, where the presence, absence or amount of CD133 polypeptide detected in the sample with the help of anti-CD133 monoclonal antibodies is indicative of the presence, absence or amount of the cancer stem cells in the sample. In another example, anti-CD133 monoclonal antibodies of the present invention may be used in methods of detecting presence, absence or amount of circulating tumor cells (CTCs) in the sample, such as a blood sample, where and the presence, absence or amount of CD133 polypeptide detected in the sample with the help of anti-CD133 monoclonal antibodies indicative of the presence, absence or amount of the circulating tumor cells in the sample. In one more example, anti-CD133 monoclonal antibodies of the present invention may be useful for detecting presence, absence or amount of CD133-positive cells in the sample, such as a blood sample, where the presence, absence or amount of CD133 polypeptide detected in the sample with the help of anti-CD133 monoclonal antibodies is indicative of the presence, absence or amount of the CD133-positive cells in the sample.

[92] In yet one more example, anti-CD133 monoclonal antibodies of the present invention are used as reagents for removing CD133-positive cells from a sample. When a monoclonal antibody is contacted with the samples under conditions under which specific binding of the monoclonal antibody and CD133 polypeptide expressed by the CD133-positive cells may occur, complexes the monoclonal antibody and the CD133-positive cells for and can be removed from the sample. The removal may be accomplished by a variety of procedures, one of examples being blood plasma filtration. Blood can be removed from the patient, pumped through a filter device containing bound CD133 mABs that capture the CD133 expressing cells, and, after capturing, the blood is returned to the patient. This method may be useful in preparatory or treatment methods, when it is desirable to reduce the number of the CD133-positive cells a sample of blood or a marrow sample obtained from a subject. Such procedures may be useful in the context of transplantation or transfusion, or in the

context of cancer treatment methods. Some other methods of treatment, in which the monoclonal antibodies of the present invention may be usefully employed, are discussed below.

Treatment Methods and Compositions

[93] Methods of treating cancer in a subject that comprise administering a treatment or therapy in the subject based on the detection of CD133 levels using anti-CD133 monoclonal antibodies described in this document are also included among the embodiments of the present invention. The term "therapy" is used herein synonymously with the term "treatment," and may include surgical treatments. The term "cancer therapy" as used herein encompasses various types of cancer therapy or treatment, including surgery, radiotherapy, chemotherapy, and targeted drug therapy. A therapy may include one or more types of therapy. For example, a therapy may include a combination of chemotherapy and targeted drug therapy. The terms "therapy" and "treatment" can be used in conjunction with the terms "cycle" or "period." A therapy or treatment can be administered one or more times over a certain period of time, followed by a period during which no treatment or therapy is administered. A therapy cycle can last for days or weeks (in one example, four weeks). One or more cycles of therapy or treatment can be administered. For example, one, two, three, four, five, six, seven, eight, nine, ten or more than ten cycles of therapy or treatment can be administered. The therapy may be the same or varied during different cycles. For example, the types and/or the doses of therapy may be varied from cycle to cycle. During a therapy cycle, the therapies may be administered on a single day, several consecutive days, or continuously as an outpatient or as an inpatient. A therapy may last minutes, hours, or days, depending on the specific protocol. Therapy cycle may repeat weekly, bi-weekly, or monthly. A therapy cycle can include one or more therapy sessions. For example, a therapy cycle can be defined in monthly intervals, with two bi-weekly chemotherapy sessions classified as one cycle. One or more therapy cycles can be referred collectively as a "course" of therapy.

Compositions

[94] Anti-CD133 monoclonal antibodies may be included in compositions employed in the treatment or alleviation of various conditions, such as cancer. Such conditions may be referred to as pharmaceutical compositions, therapeutic compositions, formulations,

medicaments or by other terms. In one example, monoclonal antibodies according employed in such compositions may be neutralizing antibodies. A monoclonal antibody that binds CD133 is said to neutralize CD133, or be neutralizing, if the binding partially or completely inhibits one or more biological activities of CD133. For example, a neutralizing anti-CD133 monoclonal antibody at a concentration of 0.01, 0.1, 0.5, 1, 2, 5, 10, 20 or 50 μg/ml may inhibit a biological function of CD133 by about at least 50%, 75%, 90% or 95% 99% or essentially completely. The compositions containing neutralizing anti-CD133 antibodies may be administered to the subjects. That is, the antibodies can be used in the manufacture of a medicament for treatment or alleviation of a condition or disease. The compositions may contain the anti-CD133 monoclonal antibodies in a physiologically acceptable carrier, optionally with excipients or stabilizers, in the form of lyophilized or aqueous solutions. Acceptable carriers, excipients or stabilizers are nontoxic to recipients at the dosages and concentrations employed, and include buffers such as phosphate, citrate, or acetate at a pH typically of 5.0 to 8.0, most often 6.0 to 7.0; salts such as sodium chloride, potassium chloride, etc. to make isotonic; antioxidants, preservatives, low molecular weight polypeptides, proteins, hydrophilic polymers such as polysorbate 80, amino acids, carbohydrates, chelating agents, sugars, and other standard ingredients.

Administration

[95] Methods of treating a subject with a disease or a conditions using compositions containing anti-CD133 monoclonal antibodies described in this document are also including among the embodiments of the present invention. The composition can be administered to a patient by any suitable route, especially parentally by intravenous infusion or bolus injection, intramuscularly or subcutaneously. Intravenous infusion can be given over as little as 15 minutes, but more often for 30 minutes, or over 1, 2 or even 3 hours. The composition can also be injected directly into the site of disease (for example, a tumor), or encapsulated into carrying agents such as liposomes. The dose given will be sufficient to alleviate the condition being treated ("therapeutically effective dose") and may be 0.1 to 5 mg/kg body weight, for example 1, 2, 3 or 4 mg/kg, but may be as high as 10 mg/kg or even 15 or 20 mg/kg. A fixed unit dose may also be given, for example, 50, 100, 200, 500 or 1000 mg, or the dose may be based on the patient's surface area, e.g., 100 mg/m^2. Between 1 and 8 doses, (e.g., 1, 2, 3, 4, 5, 6, 7 or 8) may be administered over a therapy cycle, but 10, 20 or more doses may be given. The monoclonal antibody can be administered daily, biweekly, weekly,

every other week, monthly or at some other interval, depending, e.g. on the half-life of the monoclonal antibody, for 1 week, 2 weeks, 4 weeks, 8 weeks, 36 months or longer. Repeated courses of treatment are also possible, as is chronic administration. A regime of a dosage and intervals of administration that alleviates or at least partially arrests the symptoms of the disease (biochemical, histologic and/or clinical), including its complications and intermediate pathological phenotypes in development of the disease is referred to as a therapeutically effective regime.

Prophylactic Methods

[96] The pharmaceutical compositions containing anti-CD133 monoclonal antibodies can also be used in prophylaxis of a patient at risk of cancer. Such patients include those having genetic susceptibility to cancer, patients who have undergone exposure to carcinogenic agents, such as radiation or toxins, and patients who have undergone previous treatment for cancer and are at risk of recurrence. A prophylactic dosage is an amount sufficient to eliminate or reduce the risk, lessen the severity, or delay the outset of the disease, including biochemical, histologic and/or clinical symptoms of the disease, its complications and intermediate pathological phenotypes presenting during development of the disease. Administration of a pharmaceutical composition in an amount and at intervals effective to effect one or more of the above is referred to as a prophylactically effective regime.

[97] The following examples will serve to further illustrate the present invention without, at the same time, however, constituting any limitation thereof. On the contrary, it is to be clearly understood that resort may be had to various embodiments, modifications and equivalents thereof which, after reading the description herein, may suggest themselves to those skilled in the art without departing from the spirit of the invention.

EXAMPLE 1

Development of monoclonal antibodies

Antigen

[98] Tertiary structure of CD133 protein is schematically illustrated in Figure 1. For immunization, CD133 immunogenic polypeptides were prepared using amino acid sequences corresponding to CD133 sequences selected from extracellular domains A and B of CD133 protein. The amino acid sequences for the immunogenic polypeptides were selected based on

their predicted antigenicity, which was calculated with the software using the method described in Kolaskar and Tongaonkar, "A semi-empirical method for prediction of antigenic determinants on protein antigens" *FEBS Lett*. 1990 276(1-2):172-4. Surface exposure of the amino acid residues was taken into account, and CD133 glycosylation sites known to be located at amino acids 220, 274, 395, 414, 548, 580, 729 and 730 were expressly avoided. In reference to CD133 amino acid sequence NCBI accession number NP_006008.1 (SEQ ID NO:1, shown in Figure 2), the two amino acid sequences employed in the immunogenic polypeptides corresponded to amino acids 295-329 and 615-643 of CD133 amino acid sequence. The N-terminal lysine residue of Peptide A (SEQ ID NO:17) was used for conjugation, whereas a lysine residue was added as a c-terminal residue of petide B (SEQ ID NO:18) for conjugation, as shown in Table 2.

Table 2. CD133 immunogenic polypeptides

Polypeptide		SEQ ID	Amino acids in CD133 sequence	CD133 domain
A	KTSLRSSLNDPLCLVHPSSETCNSI RLSLSQLNSN	SEQ ID NO:17	295-329	A
B	RKNLQDFAACGIDRMNYDSYLAQTG KSPAK	SEQ ID NO:18	295-329	B

Immunization

[99] For immunization, recombinant polypeptides I and II were expressed in *Escherichia coli,* purified, and conjugated to Keyhole limpet hemocyanin (KLH) using standard protocols. An equimolar mixture of both conjugated polypeptides was used to prepare an immunogen according to the procedure discussed below. Two three-month old New Zealand white rabbits were immunized using a protocol of five injections and two test bleeds per rabbit. At the time of each injection, aliquots of peptide mixture were thawed and combined with Complete Freund's Adjuvant (CFA) (for the first injection) or with incomplete Freund's Adjuvant for the subsequent injections. The injection route was subcutaneous. Immunization and bleed details are summarized in Table 3.

Table 3. Immunization and bleed schedule.

Date	Procedure	immunization or bleed #	Amount of polypeptide injected (mg) or blood obtained (ml)
6/19/2012	Bleed	0	5 ml
6/20/2012	Injection	1	0.5 mg
7/11/2012	Injection	2	0.25 mg
7/25/2012	Injection	3	0.25 mg
8/8/2012	Injection	4	0.25 mg
8/20/2012	Bleed	1	5 ml
8/22/2012	Injection	5	0.25 mg
9/3/2012	Bleed	2	5 ml

Blood screening

[100] During the primary screening of the blood samples, colorimetric ELISA against BSA-conjugated immunogenic peptides A and B (see Table 2) and was performed as follows. ELISA plates (96 well, Grenier or Nunc) were coated with 50 ng/well of peptide-BSA conjugate in bicarbonate buffer, pH 9.6, incubated at 4°C overnight, then blocked with 1% BSA in Tris buffered saline (TBS) . Diluted (1:250 -1:256,000) rabbit anti-sera (50 µl/well) were added and incubated at room temperature. Plates were washed with Tris buffered saline (TBS) with 0.05% Tween (TBST). Anti-rabbit secondary antibody conjugated to alkaline phosphatase (PIERCE; cat# 31340; 1:2,500 dilution, prepared in 1% BSA-TBS) was used for detection with p-nitrophenyl phosphate (PNPP) substrate. Optical density (O.D.) of the plate wells at 405 nm was measured with a plate reader. The results are summarized in Table 4 and illustrated in Figure 3, panels A and B.

[101] Secondary screening of the blood samples was conducted with using BSA-conjugated immunogenic CD133 polypeptides A and B as well as recombinant polypeptides of CD133 domain A (amino acids 180-400 plus 21 amino acid tag; SEQ ID NO:19, shown below) and domain B (amino acids 515-745 plus 24 amino acid tag; SEQ ID NO:20, shown below) produced in *E. coli*. The secondary screening was conducted as follows. Flat bottom, black, high binding 360 µL plates with clear bottom (VWR) were coated with 100 ng/well of peptide-BSA conjugate in bicarbonate buffer, pH 9.6 (Sigma), incubated at 4°C overnight and blocked with ODYSSEY® blocking buffer (LiCor). Diluted (1:250 -1:1,000,000) rabbit anti-sera (100 µl/well) were added to the plates, which were then incubated at 24°C for 1-2 hours,

and washed with phosphate-buffered saline (PBS) with 0.05% Tween-20 (PBS-T). Anti-rabbit secondary antibody conjugated to IR680 fluorescent dye (LiCor) was used for detection. Plates were read at 700 nm wavelength with a Licor ODYSSEY® scanner. Images were quantified using Licor ODYSSEY® application software v. 3.0. The results of the secondary screening are illustrated in Figure 3, panels C and D.

Table 4. Primary screening data (O.D. measured at 405 nm)

Screening Antigen	**A-BSA**		**B-BSA**		Control antigen and antibody
Rabbit 1					
Dilution	Bleed #				
	B1	B2	B1	B2	
1:250	1.10	1.73	1.85	1.74	1.10
1:1,000	1.19	1.63	1.79	1.63	1.13
1:4,000	1.32	1.47	1.76	1.79	0.76
1:16,000	1.08	1.23	1.34	1.11	0.60
1:64,000	0.70	0.60	0.84	0.70	0.35
1:256,000	0.31	0.32	0.41	0.34	0.20
0 (background no bleed/primary antibody)	0.09	0.09	0.08	0.09	0.12
Pre-Bleed (1:60,000)	0.13	0.08	0.09	0.08	0.31
Rabbit 2					
Dilution	Bleed #				
	B1	B2	B1	B2	
1:250	1.41	1.31	1.34	1.25	1.38
1:1,000	1.51	1.49	1.34	1.42	1.49
1:4,000	1.43	1.34	1.59	1.32	1.18
1:16,000	1.08	1.08	1.18	1.08	0.79
1:64,000	0.62	0.58	0.80	0.72	0.45
1:256,000	0.29	0.29	0.39	0.34	0.19
0 (background no bleed/primary antibody)	0.12	0.09	0.08	0.09	0.10
Pre-Bleed (1:60,000)	0.08	0.08	0.08	0.08	0.07

Recombinant CD133 domain A polypeptides (SEQ ID NO:19)

MHHHHHHSSGVDLGTENLYFQSNANHQVRTRIKRSRKLADSNFKDLRTLLNETPEQIKYILA
QYNTTKDKAFTDLNSINSVLGGGILDRLRPNIIPVLDEIKSMATAIKETKEALENMNSTLKS
LHQQSTQLSSSLTSVKTSLRSSLNDPLCLVHPSSETCNSIRLSLSQLNSNPELRQLPPVDAE
LDNVNNVLRTDLDGLVQQGYQSLNDIPDRVQRQTTTVVAGIKRVLNSIGSDIDNVTQRL

Recombinant CD133 domain B polypeptides (SEQ ID NO:20)

MHHHHHHSSGVDLGTENLYFQSNAICEPYTSKELFRVLDTPYLLNEDWEYYLSGKLFNKSKM
KLTFEQVYSDCKKNRGTYGTLHLQNSFNISEHLNINEHTGSISSELESLKVNLNIFLLGAAG
RKNLQDFAACGIDRMNYDSYLAQTGKSPAGVNLLSFAYDLEAKANSLPPGNLRNSLKRDAQT
IKTIHQQRVLPIEQSLSTLYQSVKILQRTGNGLLERVTRILASLDFAQNFITNNTSSVIIEE
TKKYGRT

Fusion

[102] Rabbit 1 was selected for splenectomy and fusion due to higher antibody titers observed in the blood samples. A final boost of immunogen composition (peptides A+B) was administered to Rabbit 1 intravenously, and splenectomy was performed. Splenocytes were isolated from the spleen tissue. Four hundred million lymphocyte spleen cells were fused with 200 million fusion partner cells and plated on 40 96-well plates. The plates were kept in tissue culture incubators under standard conditions. Fusion data is shown in Table 5.

Table 5. Fusion data for the spleen tissue sample from rabbit 1.

Harvest Date	Tissue Type	Weight (g)	Size (cm)	Cell Viability (%)	Total Cells (M)	Notes
10/09/2012	spleen	3.89	7	85	2500	40X fusion

Hybridoma screening

[103] Cell growth of the hybridoma culture was monitored for 2-3 weeks after fusion. Hybridoma supernatants were screened by standard colorimetric ELISA against BSA-conjugated immunogenic peptides A and B, as described earlier for primary screening. The hybridoma screening process consisted of an initially screen on 40 plates, using bleed 2 of Rabbit 1 at 1:100 dilution as a positive control. Clones with O.D. greater than 0.5 were

considered putatively positive and were further expanded to a 24-well plate. Confirmatory screen was performed, and six clones were confirmed positive against the same BSA-Conjugated peptides as those used for bleed screening. Additional screening was performed by the same ELISA assay according to the secondary screening procedure described above. Western blotting was performed on the clones selected for subcloning.

Subcloning and subclone screening

[104] Subcloning was performed using limited cell dilution method using standard protocols. Positive subclones were selected for screening and screened by ELISA and Western blot. As a result of the screening, mAb subclones 47-10 (domain A specific) and 133-3 (domain B specific) were selected for production of the purified mAbs.

Cloning of cDNA

[105] The cDNA of mAb subclones termed "47-10" and "133-3" was cloned to generate recombinant antibodies. The cDNAs of IgG heavy and light chains were amplified by polymerase chain reaction (PCR) and cloned into a mammalian expression vector. The recombinant monoclonal antibody was then transiently expressed using a HEK293 cell system. The expressed recombinant antibodies were then tested by ELISA against CD133 immunogenic polypeptides A and B and recombinant domain A and B polypeptides. Figure 4 illustrates the results of ELISA testing of mAbs 47-10 (panel A) and 133-3 (panel B). The testing confirmed the specificity of the mAbs. The cDNA was sequenced. Figures 5-10 illustrate the amino acid sequences of mAbs 47-10 and 133-3.

Purification of recombinant antibodies

[106] Recombinant antibodies were produced In a HEK293 cell system in serum-free medium and purified by protein A. Briefly, protein A gel (GE Life Science) was pre-washed with dH_2O until $OD_{280}<0.05$ was achieved, then re-equilibrated extensively with 1xPBS. The protein A gel was then incubated with rotation overnight at 4°C with antibody-containing supernatant and binding buffer, pH 8.0 (Pierce), at volume ratio 1:1. After the incubation, a chromatography column was packed with the protein A gel, and the flow-through collected. The protein A gel was washed with 1xPBS until $OD_{280} < 0.05$ was achieved. The recombinant antibodies were eluted off the gel with 10 ml of elution buffer, pH 2.8 (Pierce). The eluate was collected in 1 ml fractions into the glass tubes containing 100 µl 1M Tris-HCl

neutralizing buffer, pH8.0. Absorbance at 280 nm of each eluted fraction was measured. The fractions with positive OD_{280} were pooled and dialyzed against 1xPBS (with at least 2 exchanges) overnight at 4°C. The antibodies were then concentrated to desired concentration using ultra centrifugal filter units (Amicon, Millipore).

EXAMPLE 2

Specificity of monoclonal antibodies and use in immunoassays

Specificity testing via ELISA

[107] The specificity of the monoclonal antibodies was demonstrated by direct ELISA with the antigenic peptides A and B conjugated to BSA or the recombinant CD133 extracellular domain peptides described in Example I. As illustrated by Figure 4, based on ELISA results, mAbs 47-10 and 133-3 bound to the polypeptides corresponding to CD133 extracellular domains, A and B, respectively, and no cross-reaction with the other CD133 extracellular domain was observed.

Specificity testing via Western blotting

[108] The specificity of mAbs 47-10 and 133-3 was demonstrated by employing them as primary antibodies for detection of CD133 in Western blots of lysates from the cells expressing CD133. As illustrated in Figures 11 and 12, mAbs 47-10 and 133-3 both detected the bands at about 97 and approximately 120-133 kDa, which is consistent with the predicted MWs for unglycosylated and glycosylated forms of CD133, respectively.

Specificity testing via immunofluorescence assay

[109] MAbs 47-10 and 133-3 were tested in a slide-based immunofluorescent assay (IFA). Formalin fixed paraffin embedded (FFPE) pellets were generated using cells known to express CD133 (cell lines HT29, HCT-116, SKMEL28, or SW620), as well as the cells negative for CD133 expression (U87 or A375). The cells were grown *in vitro* and harvested by scraping, transferred into sterile 50 ml conical centrifuge tubes with media containing 10% serum and pelleted at 1000×g for 5 minutes. Cell growth medium was replaced with fresh serum-containing medium and centrifuged again at 1000×g for five minutes. All but approximately 1 ml of the medium was removed from the tubes, and the pellet was re-suspended by flicking the tubes. Suspended cells were transferred using a 2 ml pipette into a clean 1.5 ml conical Eppendorf tube. The cells were the pelleted for 30 seconds at 8,000 rpm

in an Eppendorf microcentrifuge. Most of the supernatant was discarded, leaving approximately 100-200 µl in each tube. The cell pellet was loosened by gently flicking the tubes and thrombin stock (8 µl of 1 unit/µl solution in water, Sigma) was added. The cells were mixed briefly by gently flicking the tubes, then held on ice for 2-5 minutes. Fibrinogen stock (5 µl of 10 mg/ml aqueous solution) was added, and the tubes were incubated for 2-5 minutes at room temperature. The clotted cells were pelleted by a brief centrifuge for 20 seconds at 10K. The supernatant was discarded, and 1.0 ml of room temperature 10% neutral buffered formalin (Sigma) was added. The cells were then fixed at room temperature for 8-16 hours. Following fixation, the cells were centrifuged 30 seconds at 8,000 rpm in an Eppendorf micro centrifuge. The supernatant (fixative) was removed, and 1 ml of 70% ethanol in nuclease-free water was added. Paraffin processing was performed within 3 days. The slides were generated and stained with mAbs 47-10 and 133-3 as primary antibodies. Image capture of FFPE tissue sections was carried out using a Nikon 90i Microscope with an A1 confocal head with a 20X objective. As illustrated in Figures 13-15, mAbs 47-10 and 133-3 specifically detected CD133 expression in IFA.

[110] Detection of CD133 in the A375 xenograft material in spite of the fact that Western blots and IFA of A375 cells grown in vitro were negative for CD133 is consistent with previous studies, which found that A375 melanoma cells, despite harboring a comparable number of CD133+ cells in xenografts, are negative for CD133 *in vitro*. Similar induction of CD133+ subsets from CD133 cells in vivo have been observed by others, suggesting that tumor "stemness" is a dynamic process and progenitor marker-negative cells may evolve into CSCs through proper environment cues or accumulating genetic alterations, the so-called stochastic model of CSC hypothesis. See Lai et *al.* 2012 "$CD133^{+}$ Melanoma Subpopulations Contribute to Perivascular Niche Morphogenesis and Tumorigenicity through Vasculogenic Mimicry" *Cancer Res.* 72:5111-5118. Thus, others have observed similar findings of A375 cell lines being negative for CD133, with CD133 is detected in the resulting tumor when these cell are injected into a mouse, possibly due to stimulation from the tumor micorenviromment/stroma inducing the stem cell phenotype.

EXAMPLE 3

Use of mAbs 47-10 and 133-3 to detect expression of CD133 in non-small cell lung cancer xenograft tumors

[111] *In vivo* studies were performed in a non-small cell lung cancer xenograft model. mAbs 47-10 and 133-3 were used to detect expression of CD133 protein in non-small cell lung cancer xenograft tumors. Figure 18 illustrates the results of the immunofluorescence staining of the samples of H596 non-small cell lung cancer xenograft tumors in mice expressing known cancer stem cell biomarkers, including CD133. Staining for EMT and/or CSC biomarkers staining of H596 tumors grown in immunocompromised $hHGF^{scid/scid}$ mice and $hHGF^{ki/ki}$ mice was performed. Immunofluorescence images suggested that CD133 was expressed in a majority of cells in H596 tumors grown in $hHGF^{scid/scid}$ mice, but CD133 expression diminished on tumor cells that has undergone EMT transition in $hHGF^{ki/ki}$ microenvironment, as evidenced by the increased Slug staining in invading cells. Diminished CD133 expression was observed in apparently invasive H596 tumor cells that has upregulated Slug expression. Other known CSC lung biomarkers, such as CD44 and ALDH1, were found to be co-expressed with CD133 in the H596 tumor cells in tumors grown in $hHGF^{scid/scid}$. The expression of these markers appeared to be down regulated in tumors derived from or $hHGF^{ki/ki}$ mice, suggesting that these markers also became down regulated in cells undergoing EMT in $hHGF^{ki/ki}$ microenvironment, similarly to CD133.

EXAMPLE 4

Use of monoclonal antibodies 47-10 and 133-3 to for PD applications of detect changes in expression of CD133 as a stem cell marker in xenograft tumors

[112] *In vivo* PD studies are performed in a triple negative breast cancer (TNBC) xenograft model SUM149PT. Clone 47-10 and 133-3 are demonstrated to work in a slide based IFA on Formalin fixed paraffin embedded (FFPE) tumor xenograft tissues. The triple negative breast cancer (TNBC) xenograft model SUM149PT is treated with the antimicrotubule agent paclitaxel to enrich for CSC populations in tumors, followed by drug combination with either a TGFβ inhibitor (LY-215729) or FAK inhibitor (VS-6063) to show inhibition of CSC populations and tumor growth in these tumors. CD133 is used as a marker to monitor CSC tumor growth and inhibition in these models. Paclitaxel treated group shows increased CD133 staining consistent with enriched levels for CSC populations, as compared to the vehicle treated group, which was administered only the medium for delivery of the

drugs ("vehicle"), such as water, saline, buffer, or other medium. Subsequent treatment or co treatment with TGFβ inhibitor (LY-215729) or FAK inhibitor (VS-6063) shows decreased CD133 levels, as compared to paclitaxel-treated group. Paclitaxel-treated group shows decreased tumor growth consistent with published data for paclitaxel treatment in this model.

EXAMPLE 5

Comparison of mAbs 47-10 and 133-3 with commercially available antibodies by Western blotting and immunofluorescence assay.

[113] MAbs 47-10 and 133-3 were compared with each other and anti-CD133 commercially available antibodies, including those available from Miltenyi Biotech. Comparison of mAbs 47-10 and 133-3 with commercially available antibodies was conducted by Western blotting and IFA.

Comparison by Westen blotting

[114] The comparison was conducted on identical replicate Western blots of crude cell lysates. . Figure 16 illustrates the comparison of Western blots using mAbs 47-10 (panel A), 133-3 (panel B) and commercial mAbs obtained from Miltenyi Biotec (AC133 – panel D; 293C3 – panel E) as the primary antibodies. The samples were loaded at 50 μg/well on 4-12% Tris Bis 1.5 mm gels, and the electrophoresis was run in MOPS running at 150V. The proteins were transferred to nitrocellulose membranes for 2 hours at 4°C. The blots were blocked with Odyssey blocking buffer (Licor) and incubated with primary antibodies overnight at 4°C at 1 μg/ml. Either goat anti-rabbit-IR800 at 0.1 μg/ml (for clones 47-10 and 133-3) or goat anti-mouse-IR-800 at 0.1 μg/ml (for Miltenyi Biotec mAbs) were used as secondary antibodies. mAbs 47-10 and 133-3 detect CD133 specific bands with good specificity while Miltenyi monoclonal antibodies do not detect CD133 with good specificity. The results showed that mAbs 47-10 and/or 133-3 were specific for CD133, and that they were far more effective than the commercially available antibodies tested. For example, mAbs 47-10 and/or 133-3 detected CD133 in the cell lysate by Western blotting and they were therefore considered suitable for certain immunoassay applications, such as certain pharmacodynamic assays or other techniques. In contrast commercially available CD133 antibodies resulted in very weak detection and are therefore judged to be unsuitable for certain immunoassay applications, such as certain pharmacodynamic assays or other techniques.

Comparison by IFA on cell pellets.

[115] Figure 17 illustrates the comparison of mAbs 47-10 and 133-3 and commercial mAbs obtained from Miltenyi Biotec conducted by immunofluorescence staining of FFPE samples of cells representing the cell lines with varying CD133 mRNA expression levels. Antigen retrieval was performed using citrate buffer, pH 6.0, for 20 minutes and 10% normal goat serum (NGS) for blocking non-specific staining. Immunofluorescence staining was performed in a Bond-max Autostainer (Leica Microsystems) using 10 μg/ml of the above-listed CD133 antibodies as primary antibodies and either goat anti-rabbit-AF546 (for mAbs 47-10 and 133-3) or goat anti-mouse-AF546 (for Miltenyi Biotec mAbs) as secondary antibodies. DAPI was used as nuclear counterstain. Slides were imaged on a fluorescence microscope (Nikon 90i Andor Camera, NIS Elements Software). The testing showed higher sensitivity of mAbs 47-10 and 133-3, in comparison to commercially available antibodies.

Comparison by IFA on human tissue tumor micro arrays

[116] MAbs 47-10 and 133-3 were successfully used in several IFA assay applications. Based on the testing results (illustrated by the figures discussed below), mAbs 47-10 and 133-3 appeared to be at least equivalent to commercially available antibodies in some cases and and showed more intense staining in other cases. Figure 19 illustrates the comparison of mAbs 47-10 and 133-3 and commercial mAbs obtained from Miltenyi Biotec conducted by immunofluorescence staining of FFPE samples of a multitumor array consisting of a broad range of tumor types with varying CD133 levels (the specifications are shown in Figures 20A, 20B and 20C. Figure 21 illustrates the comparison of select cores, at higher magnification than the previous figure, of mAbs 47-10 and 133-3 and commercial mAbs obtained from Miltenyi Biotec conducted by immunofluorescence staining of FFPE samples from selected cores of a multitumor array consisting of a broad range of tumor types with varying CD133.

EXAMPLE 6

Use of mAbs 47-10 and 133-3 for cancer diagnostics

[117] The testing was conducted to evaluate suitability of mAbs 47-10 and 133-3 for cancer diagnostics. The testing results, illustrated by the figures discussed below, indicated that mAbs 47-10 and 133-3 were suitable for cancer diagnostics. Figures 19, 21 and 22 illustrate the ability of mAbs 47-10 and 133-3 to stain a broad range of tumor types in an

FFPE multitumor array MTU951 (Biomax, Inc.), which is described in Figures 20A, 20B and 20C. Selected results from Figure 19 are shown at higher magnification in Figures 21 and 22.

[118] Figure 23 illustrates the ability of mAbs 47-10 and 133-3 to stain melanoma tumor types in an FFPE melanoma tumor array ME1004c (Biomax, Inc.) in an immunofluorescence assay. The array is described in Figures 24A, 24B and 24C. Selected results are shown at higher magnification in Figures 25 and 26. Figure 25 illustrates the ability of mAbs 133-3 to differentially stain benign or malignant metastatic Melanoma tumors in an FFPE tumor array in an immunofluorescence assay.

EXAMPLE 7

Antibody specificity

[119] Antibody binding is specific was demonstrated by peptide blocking experiments of FFPE HT-29 and SW620 cell pellets stained with mAbs 133-3 and 47-10. The results are shown in Figure 27. The peptide corresponding to domain A (SEQ ID NO:17, conjugated to BSA) specifically blocked mAb 47-10 but not mAb 133-3, while the peptide corresponding to domain B (SEQ ID NO:18, conjugated to BSA) blocked binding of mAb 133-3 but not mAb 47-10. BSA was used as a negative control and did not block the binding.

EXAMPLE 8

Use of mAbs 47-10 and 133-3 in pre-clinical studies *in vitro* and *in vivo*

In vitro studies

[120] HT-29 cell lines expressing CD133 are treated with mAbs 47-10 or 133-3 (or their fragments or variants) resulting in cell kill, whereas U87 cells (negative for CD133) do not show significant changes in growth. Cells are washed twice with PBS, trypsinized and counted on a Cellometer (Nexcelom), using trypan blue to exclude dead cells.

In vivo studies in mice

[121] *In vivo* studies are conducted using mice engrafted with HT-29 or U87 tumors and treated with mAbs 47-10 or 133-3 (or their fragments or variants). Tumor cells are inoculated subcutaneously into female nude ($NC^{r/nu}$) mice, which are obtained from the Animal Production Area (National Cancer Institute-Frederick) in an AAALAC-accredited facility with an approved animal protocol. Treatment commences once tumors reach a weight of approximately 200 mg. Tumor weights are calculated as weight in mg = (length ×

width^2)/2. Optimal dosing and administration schedule are determined from maximum tolerated dose (MTD) and efficacy studies. NCI-Frederick is accredited by Association for the Assessment and Accreditation of Laboratory Animal Care International and follows the Public Health Service Policy for the Care and Use of Laboratory Animals. Animal care is provided in accordance with the accepted procedures. Mice engrafted with human patient derived tumors (PDx) expressing CD133 are also treated with mAbs 47-10 or 133-3 (or their fragments or variants), resulting in tumor stasis or regression.

EXAMPLE 9

Use of humanized mAbs 47-10 and 133-3 in clinical studies

[122] Humanized mAbs 47-10 and 133-3 are used as therapeutic agents during a clinical study human patients. Screening for patients with high CD133 tumor levels is used for patient selection. All patients are enrolled in approved protocols and give informed consent. Clinical responses are observed in patients treated with humanized mAbs 47-10 and 133-3. Optimal dose is determined from dose escalation phase. Tumor stasis or regression is observed in some of the patients.

EXAMPLE 10

Use of humanized mAb 47-10 for cancer detection *in vivo*

[123] *In vivo* studies of mAb 47-10 for cancer detection were conducted using mice engrafted with Sum149-PT, a basal-like triple negative breast cancer tumor. Tumor cells were inoculated subcutaneously into nude mice obtained from the Biological Testing Branch, National Cancer Institute. Tumor weights were calculated as weight in mg = (length × width^2)/2. Optimal dosing and administration schedule were determined from maximum tolerated dose (MTD) and efficacy studies. Animal care was provided in accordance with the accepted procedures. The mice were treated with vehicle (water, 0.1 ml/10g body wt), 67.5 mg/kg or 100 mg/kg (42 doses over 21 days) of a FAK inhibitor VS-606 (PO, BID x42), a putative inhibitor of cancer stem cells obtained from Verastem Inc. (Needham, MA). The tumors were collected at Day 4 after the last treatment dose. The tumors were fixed in 10% neutral buffered formalin and sectioned. The slides were prepared and stained with CD44v6 (clone 2F10, R&D Systems) and mAb 47-10 or mAb 47-10 only, followed by specific secondary antibodies, Goat anti-Rabbit IgG Alexa546 (for CD133) and Goat anti-mouse IgG Alexa 488; both antibodies from Thermo-Fisher. Stained sections were scanned by Aperio

digital scanner, Leica Biosystems, Buffalo Grove, IL, and quantified by Definiens (Carlsbad, CA) tissue analysis software. Figure 28 shows the scatter graphs illustrating the results of quantitation of CD133+CD44v6+ colocalized cells. Figure 29 shows the scatter graphs illustrating the results of quantitation of CD133+ cell alone. Both graphs show significant decreases in CD133+ CSCs in FAK-inhibitor treated xenograft tumors.

[124] All patents and non-patent publications and other information cited above are incorporated herein by reference in their entirety. Various embodiments of the invention have been described in fulfillment of the various objectives of the invention. It should be recognized that these embodiments are merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those of skill in the art without departing from the spirit and scope of the invention as defined in the following claims.

CLAIMS

1. An anti-CD133 monoclonal antibody having an antibody binding site capable of specifically binding an epitope comprising SEQ ID NO:17 or a variant thereof.

2. An anti-CD133 monoclonal antibody having an antibody binding site comprising SEQ ID NO:9 and SEQ ID NO:11 or a variant thereof.

3. An anti-CD133 monoclonal antibody having an antibody binding site comprising polypeptides encoded by SEQ ID NO:10 and SEQ ID NO:12 or a variant thereof.

4. An anti-CD133 monoclonal antibody having an antibody binding site comprising CDRs contained in SEQ ID NO:9 and SEQ ID NO:11 a variant thereof.

5. The monoclonal antibody of any one of Claim 1-4, wherein the monoclonal antibody is capable of specifically binding domain A but not domain B of a CD133 polypeptide, wherein the CD133 polypeptide is glycosylated or unglycosylated.

6. The monoclonal antibody of Claim 5, wherein the CD133 polypeptide comprises any one of SEQ ID NOs 1-8 or a variant thereof.

7. An anti-CD133 monoclonal antibody capable of specifically binding an epitope comprising SEQ ID NO:18 or a variant thereof.

8. An anti-CD133 monoclonal antibody having an antibody binding site comprising SEQ ID NO:13 and SEQ ID NO:15 a variant thereof.

9. An anti-CD133 monoclonal antibody having an antibody binding site comprising a polypeptides encoded by SEQ ID NO:14 and SEQ ID NO:16 or a variant thereof.

10. An anti-CD133 monoclonal antibody having an antibody binding site comprising CDRs contained in SEQ ID NO:13 and SEQ ID NO:15 or a variant thereof.

11. The monoclonal antibody of any one of Claim 7-10, wherein the monoclonal antibody is capable of specifically binding domain B of but not domain A of a CD133 polypeptide, wherein the CD133 polypeptide is glycosylated or unglycosylated.

12. The monoclonal antibody of any one of Claim 11, wherein the CD133 polypeptide comprises any one of SEQ ID NOs 1-8 or a variant thereof.

13. The anti-CD133 monoclonal antibody of any one of Claims 1-12, wherein the monoclonal antibody is a non-human antibody, a human antibody or a human-like antibody.

14. The anti-CD133 monoclonal antibody of any one of Claims 1-13, wherein the monoclonal antibody is a reduced immunogenicity antibody, a humanized antibody or a chimeric antibody.

15. The anti-CD133 monoclonal antibody of any one of Claims 1-14, wherein the monoclonal antibody is or comprises an antibody fragment.

16. The anti-CD133 monoclonal antibody of any one of Claims 1-15, wherein the monoclonal antibody is recombinantly produced.

17. The anti-CD133 monoclonal antibody of any one of Claims 1-16, wherein the monoclonal antibody has an amino acid sequence that is different from an amino-acid sequence of a naturally occurring anti-CD133 monoclonal antibody.

18. The anti-CD133 monoclonal antibody of any one of Claims 1-17, wherein the antibody contains a label, a tag, a bioactive substance, a drug, a radioactive moiety or a toxic moiety.

19. The anti-CD133 monoclonal antibody of Claim 18, wherein the label, the tag, the bioactive substance, the drug, the radioactive moiety or the toxic moiety is not naturally occurring in a monoclonal antibody molecule.

20. The anti-CD133 monoclonal antibody of Claim 18 or 19, wherein the antibody contains fluorescent label or a fluorescent tag.

21. A method of detecting a presence or absence of CD133 polypeptide in a sample, comprising:

contacting the sample with the monoclonal antibody of any one of Claims 1-20 under conditions under which specific binding of the monoclonal antibody and the CD133 polypeptide may occur; and,

detecting the specific binding of the monoclonal antibody to the CD133 polypeptide,

wherein the detected specific binding is indicative of the presence of the CD133 polypeptide in the sample.

22. The method of Claim 21, further comprising determining an amount of CD133 polypeptide present in the sample.

23. The method of Claim 21 or 22, wherein the sample is a cell sample, a tissue sample, an aqueous sample, a solution, a suspension, a blot or an electrophoresis gel.

24. The method of any one of Claims 21-23, wherein the specific binding is detected in an ELISA, a Western Blot assay or in an immunofluorescence assay.

25. The method of any one of Claims 21-24, wherein the sample is a sample of a cancerous tissue.

26. A method of assessing status of a cancer in a patient, comprising obtaining the sample from the patient and performing the method of any one of Claims 21-25, wherein the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the status of the cancer in the patient.

27. A method of treating a cancer in a patient, comprising:

performing the method of Claim 26, wherein the presence of CD133 polypeptide detected in the sample or the amount of CD133 polypeptide present in the sample above a predetermined threshold value is indicative of a need to administer a cancer treatment to the patient; and,

administering the cancer treatment to the patient.

28. The method of Claim 27, wherein the cancer treatment is a monoclonal antibody therapy.

29. The method of Claim 28, wherein the cancer is breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma.

30. A method of detecting presence, absence or amount of cancer stem cells in the sample, comprising performing the method of any one of Claims 21-25, wherein the

presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the cancer stem cells in the sample.

31. A method of detecting presence, absence or amount of circulating tumor cells in the sample, comprising performing the method of any one of Claims 21-25, wherein the sample is a blood sample and the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the circulating tumor cells in the sample.

32 A method of detecting presence, absence or amount of CD133-positive cells in the sample, comprising performing the method of any one of Claims 21-25, wherein the sample is a blood sample and the presence, absence or amount of CD133 polypeptide detected in the sample is indicative of the presence, absence or amount of the CD133-positive cells in the sample.

33. A method of removing CD133-positive cells from a sample, comprising:

contacting the sample with the monoclonal antibody of any one of Claims 1-20 under conditions under which specific binding of the monoclonal antibody and CD133 polypeptide expressed by the CD133-positive cells may occur, thereby allowing complexes the monoclonal antibody and the CD133-positive cells to form; and,

removing the monoclonal antibody and the CD133-positive cells from the sample.

34. The method of Claims 33, wherein the sample is a blood sample or a marrow sample.

35. A method of treating or alleviating a disease or a condition in a subject, comprising administering to the subject a composition comprising one or more of the anti-CD133 monoclonal antibodies of any one of Claims 1-20.

36. The method of Claim 35, wherein the disease or the condition is a cancer.

37. The method of Claim 35 or 36, wherein the cancer is breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma.

38. The method of any one of Claims 35-37, wherein the antibody is a human-like antibody and the subject is a human.

39. The method of any one of Claims 35-37, wherein the antibody is not a human-like antibody and the subject is not a human.

40. The method of any one of Claims 35-39, wherein the anti-CD133 monoclonal antibody is a neutralizing antibody.

41. An immunogenic composition comprising one or more polypeptides comprising at least one of SEQ ID NO:17 or a variant thereof or SEQ ID NO:18 or a variant thereof, and a carrier or an adjuvant.

42. A screening agent comprising one or more polypeptides comprising at least one of SEQ ID NO:17 or a variant thereof or SEQ ID NO:18 or a variant thereof, and a carrier, a tag or a label.

43. The screening agent of Claim 42, wherein the tag or the label is a non-naturally occurring tag or label.

44. A method of determining a presence, an absence or an amount of an anti-CD133 monoclonal antibody in a sample, comprising:

contacting the sample with the screening reagent of Claim 42 or 43; and,

detecting a specific binding of the screening reagent to the anti-CD133 monoclonal antibody in the sample, wherein presence of the detected specific binding is indicative of the presence of the anti-CD133 monoclonal antibody in the sample.

45. A method of assessing or optimizing efficacy of a therapy for a disease or a conditin in a subject having the disease or the condition, comprising:

determining a value of CD133 in one or more samples obtained from the subject,

wherein the determining comprises:

contacting the one or more samples with the monoclonal antibody of any one of Claims 1-20 under conditions under which specific binding of the monoclonal antibody and a CD133 polypeptide may occur; and,

detecting the specific binding of the monoclonal antibody to the CD133 polypeptide,

wherein the detected specific binding is indicative of the value CD133 in the one or more samples and wherein the value of CD133 in the one or more samples is presence, absence, or amount of CD133 in the one or more samples; and,

determining efficacy of the therapy by comparing the determined value CD133 in the one or more samples to a predetermined threshold value of CD133.

46. The method of Claim 45, wherein the determining comprises determining the value of CD133 in the one or more samples one or more times before, during, or after therapy, or any combination thereof.

47. The method of Claim 45 or 46, wherein the predetermined threshold value of CD133 is a value based on at least one of the one or more samples.

48. The method of any one of Claims 45-47, wherein an increase in CD133 value indicates that the therapy is insufficiently effective.

49. The method of Claim 48, wherein an additional therapy or a change in dosing regimen of the therapy is indicated to the subject.

50. The method of any one of Claims 45-47, wherein a decrease in CD133 value indicates that the therapy is effective.

51. The method of any one of Claims 45-50, wherein the therapy or the additional therapy is chemotherapy, drug therapy, targeted drug therapy, surgery, radiation therapy, an antibody therapy or a combination thereof.

52. The method of any one of Claims 45-51, wherein the sample is a cell sample, a tissue sample, an aqueous sample, a solution, a suspension, a blot or an electrophoresis gel.

53. The method of any one of Claims 45-51, wherein the sample is a blood sample or a plasma sample.

54. The method of any one of Claims 45-53, wherein the specific binding is detected in an ELISA, a Western Blot assay or in an immunofluorescence assay.

55. The method of any one of Claims 45-54 wherein the subject has a cancer.

56. The method of Claim 55, wherein the cancer is breast cancer, colorectal cancer, glioblastoma, melanoma, lung cancer, ovarian cancer, gastric cancer, acute leukemia, acute lymphoblastic leukemia (AML), prostate cancer, liver cancer, kidney cancer sarcomas, brain cancers, leukemia or retinoblastoma..

57. The method or the monoclonal antibody of any one of Claims 1-56, wherein the variant of any one of SEQ ID NOs 1-18 is a variant having a degree of homology with a corresponding sequence of least 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99%.

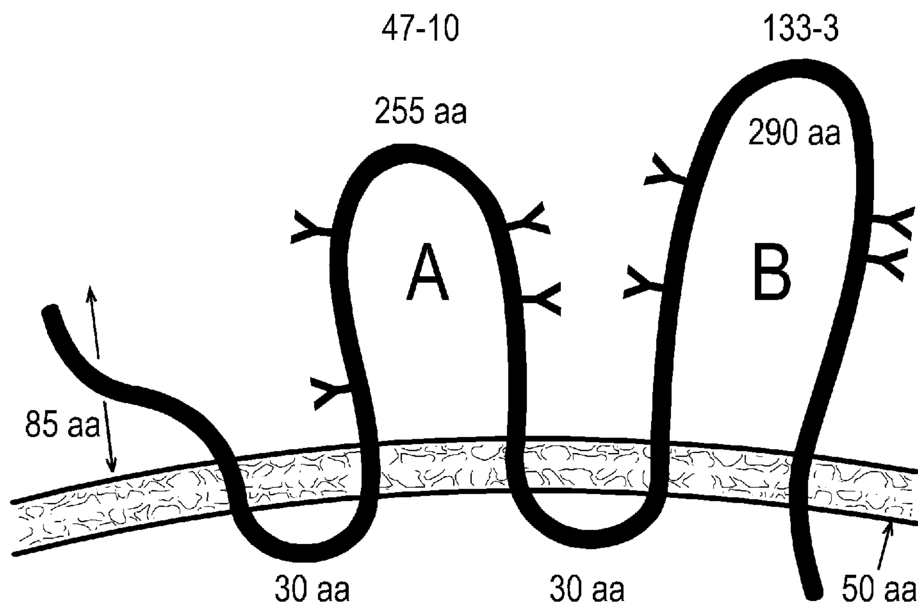


FIGURE 1

FIGURE 2 A,B.

A. SEQ ID NO:1

aa

```
1     MALVLGSLLL LGLCGNSFSG GQPSSTDAPK AWNYELPATN YETQDSHKAG PIGILFELVH
61    IFLYVVQPRD FPEDTLRKFL QKAYESKIDY DKPETVILGL KIVYYEAGII LCCVLGLLFI
121   ILMPLVGYFF CMCRCCNKCG GEMHQRQKEN GPFLRKCFAI SLLVICIIIS IGIFYGFVAN
181   HQVRTRIKRS RKLADSNFKD LRTLLNETPE QIKYILAQYN TTKDKAFTDL NSINSVLGGG
241   ILDRLRPNII PVLDEIKSMA TAIKETKEAL ENMNSTLKSL HQQSTQLSSS LTSVKTSLRS
301   SLNDPLCLVH PSSETCNSIR LSLSQLNSNP ELRQLPPVDA ELDNVNNVLR TDLDGLVQQG
361   YQSLNDIPDR VQRQTTTVVA GIKRVLNSIG SDIDNVTQRL PIQDILSAFS VYVNNTESYI
421   HRNLPTLEEY DSYWWLGGLV ICSLLTLIVI FYYLGLLCGV CGYDRHATPT TRGCVSNTGG
481   VFLMVGVGLS FLFCWILMII VVLTFVFGAN VEKLICEPYT SKELFRVLDT PYLLNEDWEY
541   YLSGKLFNKS KMKLTFEQVY SDCKKNRGTY GTLHLQNSFN ISEHLNINEH TGSISSELES
601   LKVNLNIFLL GAAGRKNLQD FAACGIDRMN YDSYLAQTGK SPAGVNLLSF AYDLEAKANS
661   LPPGNLRNSL KRDAQTIKTI HQQRVLPIEQ SLSTLYQSVK ILQRTGNGLL ERVTRILASL
721   DFAQNFITNN TSSVIIEETK KYGRTIIGYF EHYLQWIEFS ISEKVASCKP VATALDTAVD
781   VFLCSYIIDP LNLFWFGIGK ATVFLLPALI FAVKLAKYYR RMDSEDVYDD VETIPMKNME
841   NGNNGYHKDH VYGIHNPVMT SPSQH
```

B. SEQ ID NO:2

```
MALVLGSLLLLGLCGNSFSGGQPSSTDAPKAWNYELPATKYETQDSHKAGPIGILFELVHIFLYVVQPRD
FPEDTLRKVIQKAYESKIDYDKIVYYEAGIILCCVLGLLFIILMPLVGYFFCMCRCCNKCGGEMHQRQKE
NGPFLRKCFAISLLVICIIISIGIFYGFVANHQVRTRIKRSRKLADSNFKDLRTLLNETPEQIKYILAQY
NTTKDKAFTDLNSISSVLGGGILDRLRPNIIPVLDEIKSMATAIKETKEALENMNSTLKSLHQQSTQLSS
SLTSVKTSLRSSLNDPLCLVRPSSETCNSIRLSLSQLNSNPELRQLPPVDAELDNVNNVLRTDLDGLVQQ
GYQSLNDIPDRVQRQTTTVVAGIKRVLNSIGSDIDNVTQRLPIQDILSEFSVYVNNTESYIHRNLPTLEE
YDSYWWLGGLVICSLLTLIVIFYYLGLLCGVCGYDRHATPTTRGCVSNTGGIFLMVGVGLSFLFCWILMI
IVVLTFVFGANVEKLICEPYTSKELFRVLDTPYLLNEDWEYYLSGKLFNKSKMKLTFEQVYSDCKKNRGT
YGTLHLQNSFNISERLNINEHTGSISSELESLKVNLNIFLLGAAGRKNLQDFAACGIDRMNYDSYLAQTG
KSPAGVNLLSFAYDLEAKANSLPPGNLRNSLKRDAQTIKTIHQQRVLPIEQSLSTLYQSVKILQRTGNGL
LERVTRILASLDFAQNFITNNTSSVIIEETKKYGRTIIGYFEHYLQWIEFSISEKVASCKPVATALDTAV
DVFLCSYIIDPLNLFWFGIGKATVFLLPALIFAVKLAKYYRRMDSEDVYDDVETIPMKNMENGNNGYHKD
HVYGIHNPVMTSPSQH
```

FIGURE 2 C, D, E.

C. SEQ ID NO:3

MALVLGSLLLLGLCGNSFSGGQPSSTDAPKAWNYELPATNYETQDSHKAGPIGILFELVHIFLYVVQPRD
FPEDTLRKVIQKAYESKIDYDKPETVILGLKIVYYEAGIILCCVLGLLFIILMPLVGYFFCMCRCCNKCG
GEMHQRQKENGPFLRKCFAISLLVICIIISIGIFYGFVANHQVRTRIKRSRKLADSNFKDLRTLLNETPE
QIKYILAQYNTTKDKAFTDLNSINSVLGGGILDRLRPNIIPVLDEIKSMATAIKETKEALENMNSTLKSL
HQQSTQLSSSLTSVKTSLRSSLNDPLCLVRPSSEICNSIRLSLSQLNSNPELRQLPPVDAELDNVNNVLR
TDLDGLVQQGYQSLNDIPDRVQRQTTTVVAGIKRVLNSIGSDIDNVTQRLPIQDILSEFSVYVNNTESYI
HRNLPTLEEYDSYWWLGGLVICSLLTLIVIFYYLGLLCGVCGYDRHATPTTRGCVSNTGGVFLMVGVGLS
FLFCWILMIIVVLTFVFGANVEKLICEPYTSKELFQVLDTPYLLNEDWEYYLSGKLFNKSKMKLTFEQVY
SDCKKNRGTYGTLHLQNSFNISERLNINEHTGSISSELESLKVNLNIFLLGAAGRKNLQDFAACGIDRMN
YDSYLAQTGKSPAGVNLLSFAYDLEAKANSLPPGNLRNSLKRDAQTIKTIHQQRVLPIEQSLSTLYQSVK
ILQRTGNGLLERVTRILASLDFAQNFITNNTSSVIIEETKKYGRTIIGYFEHYLQWIEFSISEKVASCKP
VATALDTAVDVFLCSYIIDPLNLFWFGIGKATVFLLPALIFAVKLAKYYRRMDSEDVYDDVETIPMKNME
NGNNGYHKDHVYGIHNPVMTSPSQH

D. SEQ ID NO:4

MALLLGFLLLLELCWDTSALGPLSSTKGSDGLEFELPATNYETKDSNQAGPISVLFQIVQVFLQVVQPHP
FPEDILRKILQKKFDFSTDYDKIIYYEIGIIICAVLGLLFVILMPLVGFCLGLCRCCNKCGGEMHQRQKK
NGAFLRKYFTVSLLVICIFISVGIIYGFVANHHLRTRIEKTRKLAESNLKDLRTLLIGTPAQINYVLSQY
ASTKEKAFSDLDNIKSLLGGGIHDQLRPKVIPVLDDIKAMAEAIKETREALLNVNNTLKELKMSTAQLNT
SLSDVKRNLEQSLNDPMCSVPPVATTCNNIRMSLGQLDDNTNLGQLPSLDKQIDNINNVLQTDLSSLVQK
GYKSFNDIPEMVQNQTTDIVSDVKRTLNSLGSDIENMSEQIPIQDKLSDFIGYINDTETYIHRNLPTLEE
YDSYRWLGGLIVCCLLTLIVVFYYLGLMCGTFGYDRHATPTRRGCVSNTGGIFLMVGVGISFLFCWILMT
IVVLTFVIGGNMEKLVCEPYQNRKLFQILDTPYLLNENWKYYLSGMVLNKPDINLTFEQVYSDCKENKGI
YSTLKLENTYNISEHLNIQEHARNLSNDFKNMNVNIDNIVLLDAAGRKNLMDFSSSGVDTIDYNVYLAEM
GKTPTKVNLLSFADDLDTKANNLPQGSLKQSLKNNVQNLKTIHHGQVMPLEQSMSTINQSIKELQHKSSG
LRVKVANILSSLDSAQDFLQTRISSVIVKESSKYGNMIIGYFEHYLQWVKISITEQIAACKPVATALDSA
VDVFLCSYIIDPMNLFWFGIGKATIFLLPAIIFAVKLAKYYRRMDSEDVYDDMENGNIGFHRHHSTQTV

E. SEQ ID NO:5

MALVFSALLLLGLCGKISSEGQPAFHNTPGAMNYELPTTKYETQDTFNAGIVGPLYKMVHIFLNVVQPND
FPLDLIKKLIQNKNFDISVDSKEPEIIVLALKIALYEIGVLICAILGLLFIILMPLVGCFFCMCRCCNKC
GGEMHQRQKQNAPCRRKCLGLSLLVICLLMSLGIIYGFVANQQTRTRIKGTQKLAKSNFRDFQTLLTETP
KQIDYVVEQYTNTKNKAFSDLDGIGSVLGGRIKDQLKPKVTPVLEEIKAMATAIKQTKDALQNMSSSLKS
LQDAATQLNTNLSSVRNSIENSLSSSDCTSDPASKICDSIRPSLSSLGSSLNSSQLPSVDRELNTVTEVD
KTDLESLVKRGYTTIDEIPNTIQNQTVDVIKDVKNTLDSISSNIKDMSQSIPIEDMLLQVSHYLNNSNRY
LNQELPKLEEYDSYWWLGGLIVCFLLTLIVTFFFLGLLCGVFGYDKHATPTRRGCVSNTGGIFLMAGVGF
GFLFCWILMILVVLTFVVGANVEKLLCEPYENKKLLQVLDTPYLLKEQWQFYLSGMLFNNPDINMTFEQV
YRDCKRGRGIYAAFQLENVVNVSDHFNIDQISENINTELENLNVNIDSIELLDNTGRKSLEDFAHSGIDT
IDYSTYLKETEKSPTEVNLLTFASTLEAKANQLPEGKLKQAFLLDVQNIRAIHQHLLPPVQQSLKFVRVR
NTLRQSVWTLQQTSNKLPEKVKKILASLDSVQHFLTNNVSLIVIGETKKFGKTILGYFEHYLHWVFYAIT
EKMTSCKPMATAMDSAVNGILCGYVADPLNLFWFGIGKATVLLLPAVIIAIKLAKYYRRMDSEDVYDDPS
RY

FIGURE 2 F, G, H

F. SEQ ID NO:6

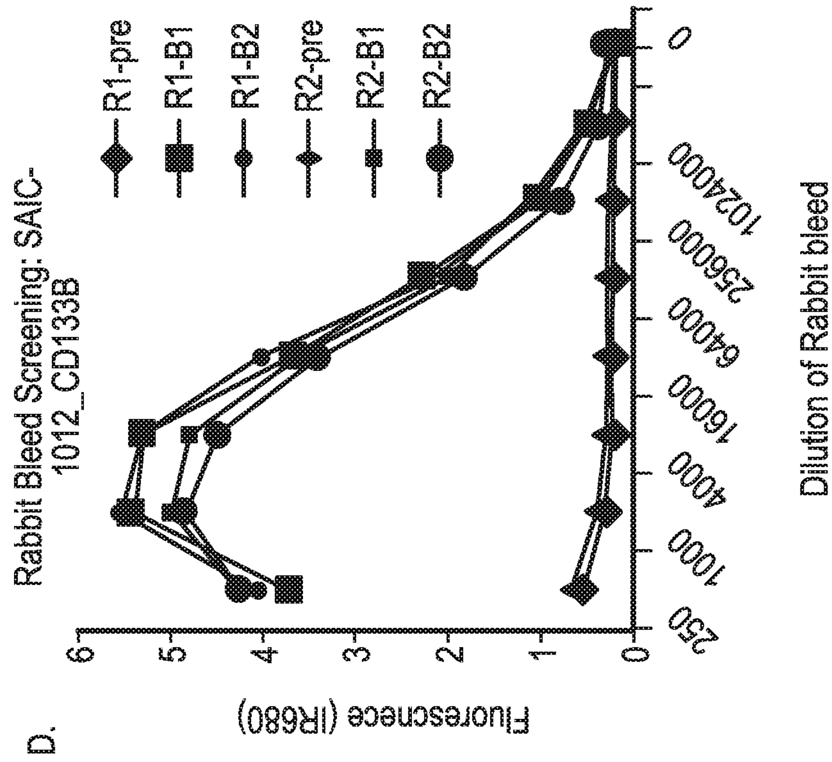
MALVFSVLLLLGLCGKMASGGQPAFDNTPGALNYELPTTEYETQDTFNAGIIDPLYQMVHIFLNVVQPND
FPQDLVKKLIQKRFDISVDTKEVAIYEIGVLICVILGLLFIFLMPLVGFFFCMCRCCNKCGGEMHQRQKQ
NESCRRKCLAISLLLICLLMSLGIAFGFVANQQTRTRIQRTQKLAESNYRDLRALLTEAPKQIDYILGQY
NTTKNKAFSDLDSIDSVLGGRIKGQLKPKVTPVLEEIKAMATAIRQTKDALQNMSSSLKSLRDASTQLST
NLTSVRNSIENSLNSNDCASDPASKICDSLRPQLSNLGSNHNGSQLPSVDRELNTVNDVDRTDLESLVKR
GYMSIDEIPNMIQNQTGDVIKDVKKTLDSVSSKVKNMSQSIPVEEVLLQFSHYLNDSNRYIHESLPRVEE
YDSYWWLGGLIVCFLLTLIVTFFYLGLLCGVFGYDKRATPTRRGCVSNTGGIFLMAGVGFSFLFCWILMI
LVVLTFVVGANVEKLLCEPYENKKLLQVLDTPYLLNDQWQFYLSGILLKNPDINMTFEQVYRDCKRGRGV
YATFQLENVFNITENFNIERLSEDIVKELEKLNVNIDSIELLDKTGRKSLEDFAQSGIDRINYSMYLQEA
EKPPTKVDLLTFASFLETEANQLPDGNLKQAFLMDAQNIRAIHQQHVPPVQQSLNSLKQSVWALKQTSSK
LPEEVKKVLASLDSAQHFLTSNLSSIVIGETKKFGRTIIGYFEHYLQWVLYAITEKMTSCKPMITAMDSA
VNGILCSYVADPLNLFWFGIGKATMLLLPAVIIAIKLAKYYRRMDSEDVYDDVETVPMKNLENGSNGYHK
DHLYGVHNPVMTSPSRY

G. SEQ ID NO:7

MALVLGSLLLLGLCGNSFSGGQPSSTDAPKAWNYELPATNYETQDSHKAGPIGILFELVHIFLYVVQPRD
FPEDTLRKFLQKAYESKIDYDKPETVILGLKIVYYEAGIILCCVLGLLFIILMPLVGYFFCMCRCCNKCG
GEMHQRQKENGPFLRKCFAISLLVICIIISIGIFYGFVANHQVRTRIKRSRKLADSNFKDLRTLLNETPE
QIKYILAQYNTTKDKAFTDLNSINSVLGGGILDRLRPNIIPVLDEIKSMATAIKETKEALENMNSTLKSL
HQQSTQLSSSLTSVKTSLRSSLNDPLCLVHPSSETCNSIRLSLSQLNSNPELRQLPPVDAELDNVNNVLR
TDLDGLVQQGYQSLNDIPDRVQRQTTTVVAGIKRVLNSIGSDIDNVTQRLPIQDILSAFSVYVNNTESYI
HRNLPTLEEYDSYWWLGGLVICSLLTLIVIFYYLGLLCGVCGYDRHATPTTRGCVSNTGGVFLMVGVGLS
FLFCWILMIIVVLTFVFGANVEKLICEPYTSKELFRVLDTPYLLNEDWEYYLSGKLFNKSKMKLTFEQVY
SDCKKNRGTYGTLHLQNSFNISEHLNINEHTGSISSELESLKVNLNIFLLGAAGRKNLQDFAACGIDRMN
YDSYLAQTGKSPAGVNLLSFAYDLEAKANSLPPGNLRNSLKRDAQTIKTIHQQRVLPIEQSLSTLYQSVK
ILQRTGNGLLERVTRILASLDFAQNFITNNTSSVIIEETKKYGRTIIGYFEHYLQWIEFSISEKVASCKP
VATALDTAVDVFLCSYIIDPLNLFWFGIGKATVFLLPALIFAVKLAKYYRRMDSEDVYDDSSWVTSVQVN
FFFLVLIFLYLF

H. SEQ ID NO:8

MALLLGFLLLLELCWDTSALGPLSSTKGSDGLEFELPATNYETKDSNQAGPISVLFQIVQVFLQVVQPHP
FPEDILRKILQKKFDFSTDYDKPENVVLTLKIIYYEIGIIICAVLGLLFVILMPLVGFCFGLCRCCNKCG
GEMHQRQKKNGAFLRKYFTVSLLVICIFISVGIIYGFVANHHLRTRIEKTRKLAESNLKDLRTLLIGTPA
QINYVLSQYASTKEKAFSDLDNIKSLLGGGIHDQLRPKVIPVLDDIKAMAEAIKETREALLNVNNTLKEL
KMSTAQLNTSLSDVKRNLEQSLNDPMCSVPPVATTCNNIRMSLGQLDDNTNLGQLPSLDKQIDNINNVLQ
TDLSSLVQKGYKSFNDIPEMVQNQTTDIVSALPYVKRTLNSLGSDIENMSEQIPIQDKLSDFIGYINDTE
TYIHRNLPTLEEYDSYRWLGGLIVCCLLTLIVVFYYLGLMCGTFGYDRHATPTRRGCVSNTGGIFLMVGV
GISFLFCWILMTIVVLTFVIGGNMEKLVCEPYQNRKLFQILDTPYLLNENWKYYLSGMVLDKPDINLTFE
QVYSDCKENKGIYSTLKLENTYNISEHLNIQEHARNLSNDFKNMNVNIDNIVLLDAAGRKNLMDFSSSGV
DTIDYNVYLAEMGKTPTKVNLLSFADDLDTKANNLPQGSLKQSLKNNAQNLKTIHHGQVMPLEQSMKYGK
ARSTINQSIKELQHKSSGLRVKVANILSSLDSAQDFLQTRISSVIVKESSKYGNMIIGYFEHYLQWVKIS
ITEQIAACKPVATALDSAVDVFLCSYIIDPMNLFWFGIGKATIFLLPAIIFAVKLAKYYRRMDSEDVYDD
SSVLGTWHFTL



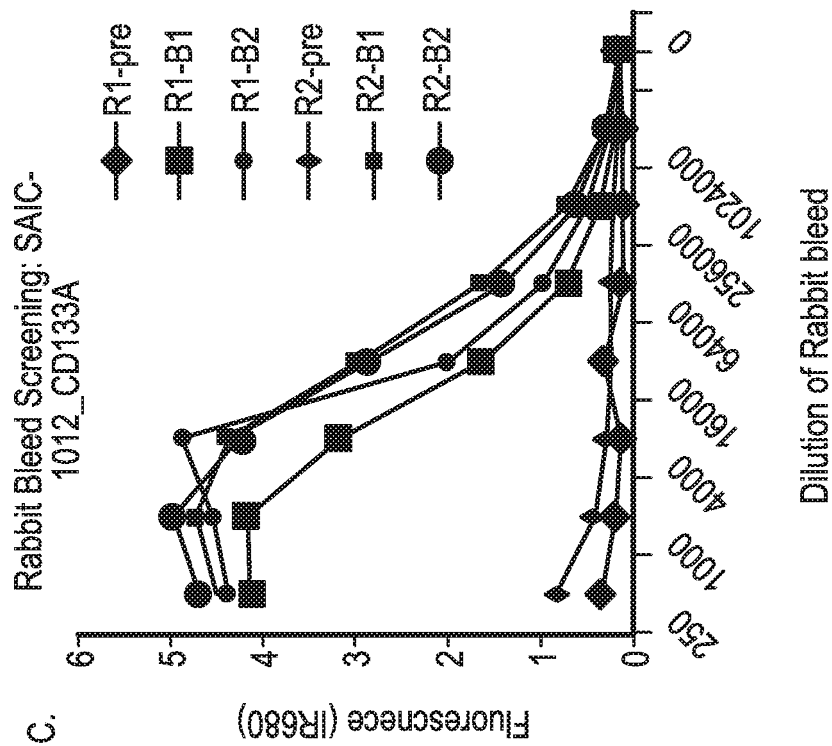
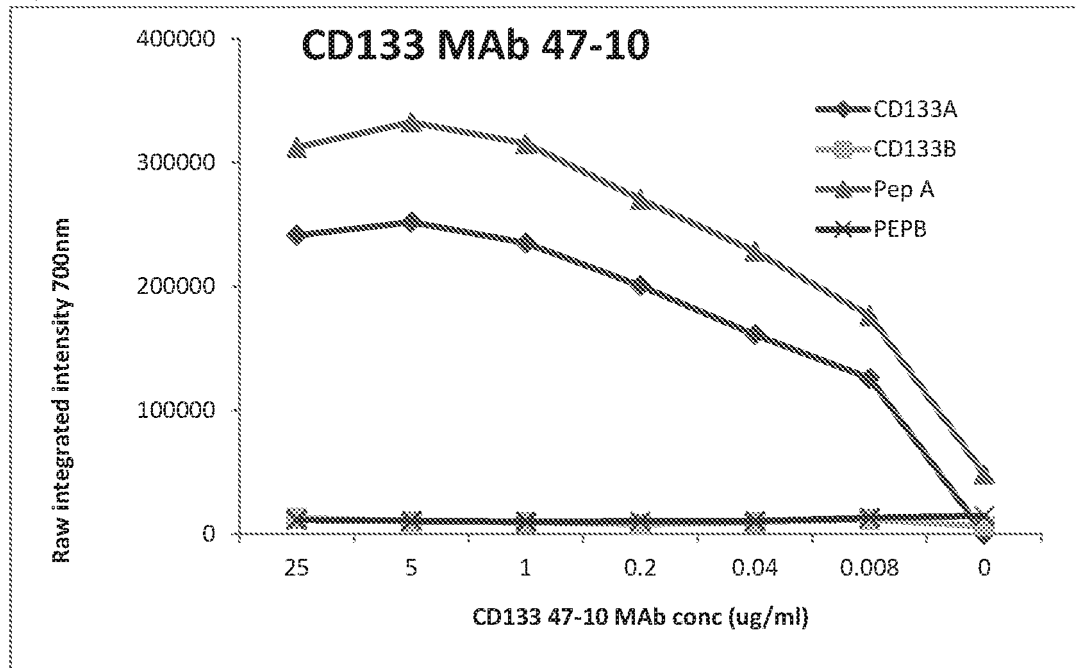


FIGURE 3

FIGURE 4.

A.



B.

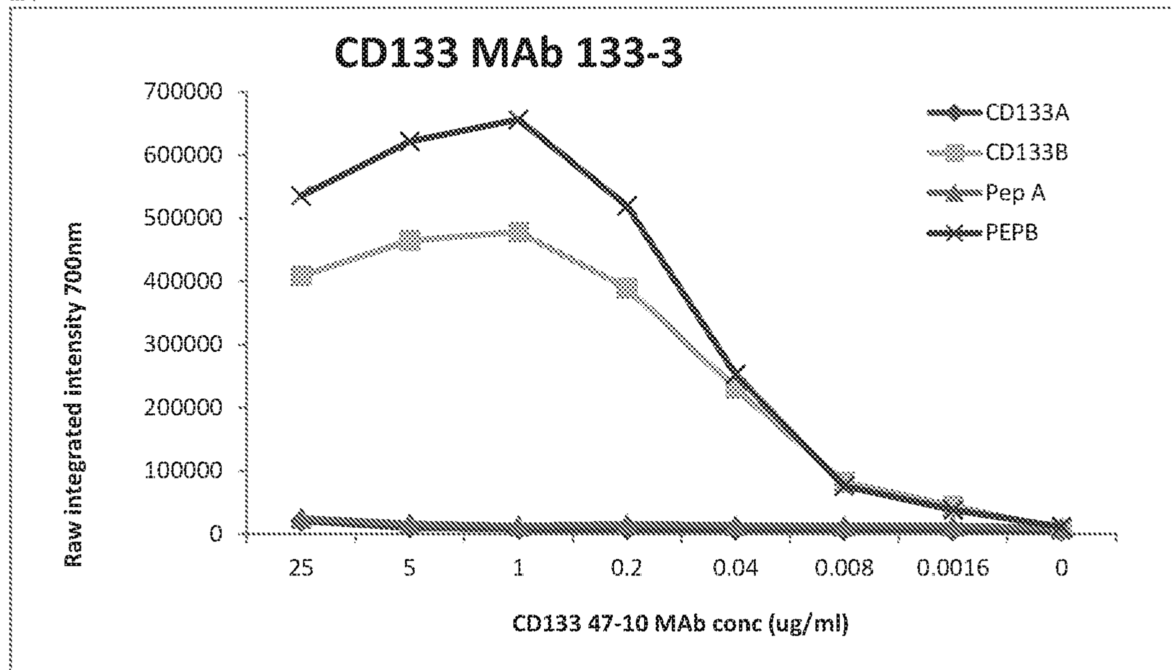


FIGURE 5

A. Heavy Chain

SEQ ID NO:9

M E T G L R W L L L V A V L K G V Q C Q S V E E S G G R L V T P
G T P L T L T C T V S G I D L N N Y N M Q W V R Q A P G K G L E
W I G A T F G S D S I Y Y A T W A K G R F T I S K T S T T V D L
K M T S L T T E D T A T Y F C A R G G L W G P G T L V T V S S G
Q P K A P S V F P L A P C C G D T P S S T V T L G C L V K G Y L
P E P V T V T W N S G T L T N G V R T F P S V R Q S S G L Y S L
S S V V S V T S S S Q P V T C N V A H P A T N T K V D K T V A P
S T C S K P T C P P P E L L G G P S V F I F P P K P K D T L M I
S R T P E V T C V V V D V S Q D D P E V Q F T W Y I N N E Q V R
T A R P P L R E Q Q F N S T I R V V S T L P I A H Q D W L R G K
E F K C K V H N K A L P A P I E K T I S K A R G Q P L E P K V Y
T M G P P R E E L S S R S V S L T C M I N G F Y P S D I S V E W
E K N G K A E D N Y K T T P A V L D S D G S Y F L Y S K L S V P
T S E W Q R G D V F T C S V M H E A L H N H Y T Q K S I S R S P
G K

SEQ ID NO:10

ATGGAGACTGGGCTGCGCTGGCTTCTCCTGGTCGCTGTGCTCAAAGGTGTCCAGTGTCAGTCGG
TGGAGGAGTCCGGGGGTCGCCTGGTCACGCCTGGGACACCCCTGACACTCACCTGCACCGTCTC
TGGAATCGACCTCAATAACTATAACATGCAATGGGTCCGCCAGGCTCCAGGGAAGGGGCTGGAA
TGGATCGGGGCCACTTTTGGTAGTGATAGTATATACTACGCGACCTGGGCGAAAGGCCGATTCA
CCATCTCCAAAACCTCGACCACGGTGGATCTGAAAATGACCAGTCTGACAACCGAGGACACGGC
CACCTATTTCTGTGCCAGAGGTGGTCTCTGGGGCCCAGGCACCCTGGTCACCGTCTCCTCAGGG
CAACCTAAGGCTCCATCAGTCTTCCCACTGGCCCCCTGCTGCGGGGACACACCCAGCTCCACGG
TGACCCTGGGCTGCCTGGTCAAAGGGTACCTCCCGGAGCCAGTGACCGTGACCTGGAACTCGGG
CACCCTCACCAATGGGGTACGCACCTTCCCGTCCGTCCGGCAGTCCTCAGGCCTCTACTCGCTG
AGCAGCGTGGTGAGCGTGACCTCAAGCAGCCAGCCCGTCACCTGCAACGTGGCCCACCCAGCCA
CCAACACCAAAGTGGACAAGACCGTTGCGCCCTCGACATGCAGCAAGCCCACGTGCCCACCCCC
TGAACTCCTGGGGGGACCGTCTGTCTTCATCTTCCCCCCAAAACCCAAGGACACCCTCATGATC
TCACGCACCCCCGAGGTCACATGCGTGGTGGTGGACGTGAGCCAGGATGACCCCGAGGTGCAGT
TCACATGGTACATAAACAACGAGCAGGTGCGCACCGCCCGGCCGCCGCTACGGGAGCAGCAGTT
CAACAGCACGATCCGCGTGGTCAGCACCCTCCCCATCGCGCACCAGGACTGGCTGAGGGGCAAG
GAGTTCAAGTGCAAAGTCCACAACAAGGCACTCCCGGCCCCCATCGAGAAAACCATCTCCAAAG
CCAGAGGGCAGCCCCTGGAGCCGAAGGTCTACACCATGGGCCCTCCCCGGGAGGAGCTGAGCAG
CAGGTCGGTCAGCCTGACCTGCATGATCAACGGCTTCTACCCTTCCGACATCTCGGTGGAGTGG
GAGAAGAACGGGAAGGCAGAGGACAACTACAAGACCACGCCGGCCGTGCTGGACAGCGACGGCT
CCTACTTCCTCTACAGCAAGCTCTCAGTGCCCACGAGTGAGTGGCAGCGGGGCGACGTCTTCAC
CTGCTCCGTGATGCACGAGGCCTTGCACAACCACTACACGCAGAAGTCCATCTCCCGCTCTC

B. Light Chain

SEQ ID NO:11

M D T R A P T Q L L G L L L L W L P G V T F A Q V L T Q T A S P
V S A A V G A T V T I N C Q S S Q S V Y N N N Y L A W F Q Q K P
G Q P P K L L I Y R A S T L A S G V S S R F K G S G S G T Q F A
L T I S G V Q C D D A G T Y Y C Q G E F S C D S A D C A A F G G
G T E V V V K G D P V A P T V L I F P P A A D Q V A T G T V T I
V C V A N K Y F P D V T V T W E V D G T T Q T T G I E N S K T P
Q N S A D C T Y N L S S T L T L T S T Q Y N S H K E Y T C K V T
Q G T T S V V Q S F N R G D C

SEQ ID NO:12

ATGGACACGAGGGCCCCCACTCAGCTGCTGGGGCTCCTGCTGCTCTGGCTCCCAGGTGTCACAT
TTGCCCAAGTGCTGACCCAGACTGCATCGCCCGTGTCTGCAGCTGTGGGCGCCACCGTCACCAT
CAACTGCCAGTCCAGTCAGAGTGTTTATAATAACAACTACTTAGCCTGGTTTCAGCAGAAACCA
GGGCAGCCTCCCAAGCTCCTGATCTACAGGGCATCCACTCTGGCTTCTGGGGTCTCATCGCGGT
TCAAAGGCAGTGGATCTGGGACACAGTTCGCTCTCACCATCAGCGGCGTGCAGTGTGACGATGC
TGGCACTTACTATTGTCAAGGCGAATTTAGTTGTGATAGTGCTGATTGTGCTGCTTTCGGCGGA
GGGACCGAGGTGGTGGTCAAAGGTGATCCAGTTGCACCTACTGTCCTCATCTTCCCACCAGCTG
CTGATCAGGTGGCAACTGGAACAGTCACCATCGTGTGTGTGGCGAATAAATACTTTCCCGATGT
CACCGTCACCTGGGAGGTGGATGGCACCACCCAAACAACTGGCATCGAGAACAGTAAAACACCG
CAGAATTCTGCAGATTGTACCTACAACCTCAGCAGCACTCTGACACTGACCAGCACACAGTACA
ACAGCCACAAAGAGTACACCTGCAAGGTGACCCAGGGCACGACCTCAGTCGTCCAGAGCTTCAA
TAGGGGTGACTGT

FIGURE 6A.

Heavy Chain

SEQ ID NO:13

M E T G L R W L L L V A V L K G V Q C Q S V E E S G G R L V T P
G T P L T L T C T V S G F S L S R Y A M S W V R Q A P G K G L D
W I G Y I D I G G G A Y Y A S W A K G R F T I S E T S T T V Y L
K V N S P T T E D T A T Y F C A R G V A N S D I W G P G T L V T
V S S G Q P K A P S V F P L A P C C G D T P S S T V T L G C L V
K G Y L P E P V T V T W N S G T L T N G V R T F P S V R Q S S G
L Y S L S S V V S V T S S S Q P V T C N V A H P A T N T K V D K
T V A P S T C S K P T C P P P E L L G G P S V F I F P P K P K D
T L M I S R T P E V T C V V V D V S Q D D P E V Q F T W Y I N N
E Q V R T A R P P L R E Q Q F N S T I R V V S T L P I A H Q D W
L R G K E F K C K V H N K A L P A P I E K T I S K A R G Q P L E
P K V Y T M G P P R E E L S S R S V S L T C M I N G F Y P S D I
S V E W E K N G K A E D N Y K T T P A V L D S D G S Y F L Y S K
L S V P T S E W Q R G D V F T C S V M H E A L H N H Y T Q K S I
S R S P G K

SEQ ID NO:14

ATGGAGACTGGGCTGCGCTGGCTTCTCCTGGTCGCTGTGCTCAAAGGTGTCCAGTGTCAGTCGG
TGGAGGAGTCCGGGGGTCGCCTGGTCACGCCTGGGACACCCCTGACACTCACCTGCACAGTCTC
TGGATTCTCCCTCAGTAGGTATGCAATGAGCTGGGTCCGCCAGGCTCCAGGGAAGGGACTGGAC
TGGATCGGGTATATTGATATTGGTGGTGGCGCATACTACGCGAGCTGGGCGAAAGGTCGATTCA
CCATCTCCGAGACCTCGACCACGGTGTACCTGAAAGTCAACAGTCCGACAACCGAGGACACGGC
CACCTATTTCTGTGCCAGAGGTGTTGCTAATAGTGACATCTGGGGCCCAGGCACCCTGGTCACC
GTCTCCTCAGGGCAACCTAAGGCTCCATCAGTCTTCCCACTGGCCCCCTGCTGCGGGGACACAC
CCAGCTCCACGGTGACCCTGGGCTGCCTGGTCAAAGGGTACCTCCCGGAGCCAGTGACCGTGAC
CTGGAACTCGGGCACCCTCACCAATGGGGTACGCACCTTCCCGTCCGTCCGGCAGTCCTCAGGC
CTCTACTCGCTGAGCAGCGTGGTGAGCGTGACCTCAAGCAGCCAGCCCGTCACCTGCAACGTGG
CCCACCCAGCCACCAACACCAAAGTGGACAAGACCGTTGCGCCCTCGACATGCAGCAAGCCCAC
GTGCCCACCCCCTGAACTCCTGGGGGGACCGTCTGTCTTCATCTTCCCCCCAAAACCCAAGGAC
ACCCTCATGATCTCACGCACCCCCGAGGTCACATGCGTGGTGGTGGACGTGAGCCAGGATGACC
CCGAGGTGCAGTTCACATGGTACATAAACAACGAGCAGGTGCGCACCGCCCGGCCGCCGCTACG
GGAGCAGCAGTTCAACAGCACGATCCGCGTGGTCAGCACCCTCCCCATCGCGCACCAGGACTGG
CTGAGGGGCAAGGAGTTCAAGTGCAAAGTCCACAACAAGGCACTCCCGGCCCCCATCGAGAAAA
CCATCTCCAAAGCCAGAGGGCAGCCCCTGGAGCCGAAGGTCTACACCATGGGCCCTCCCCGGGA
GGAGCTGAGCAGCAGGTCGGTCAGCCTGACCTGCATGATCAACGGCTTCTACCCTTCCGACATC
TCGGTGGAGTGGGAGAAGAACGGGAAGGCAGAGGACAACTACAAGACCACGCCGGCCGTGCTGG
ACAGCGACGGCTCCTACTTCCTCTACAGCAAGCTCTCAGTGCCCACGAGTGAGTGGCAGCGGGG
CGACGTCTTCACCTGCTCCGTGATGCACGAGGCCTTGCACAACCACTACACGCAGAAGTCCATC
TCCCGCTCTCCGGGTAAA

Figure 6B.

Light Chain

SEQ ID NO:15

M D T R A P T Q L L G L L L L W L P G A R C A L V M T Q T P S P
V S A A V G G T V T I N C Q S S Q S V F N N K W L S W Y Q Q K P
G Q P P K L L I Y F V S T L A S G V P S R F K G S G S G T Q F T
L T I S G V Q C D D A A T Y Y C Q G S D Y S S G W Y S P F G G G
T E V V V E G D P V A P T V L I F P P A A D Q V A T G T V T I V
C V A N K Y F P D V T V T W E V D G T T Q T T G I E N S K T P Q
N S A D C T Y N L S S T L T L T S T Q Y N S H K E Y T C K V T Q
G T T S V V Q S F N R G D C

SEQ ID NO:16

ATGGACACGAGGGCCCCCACTCAGCTGCTGGGGCTCCTGCTGCTCTGGCTCCCAGGTGCCAGAT
GTGCCCTTGTGATGACCCAGACTCCATCCCCCGTGTCTGCAGCTGTGGGAGGCACAGTCACCAT
CAATTGCCAGTCCAGTCAGAGTGTTTTTAATAATAAATGGTTATCCTGGTATCAGCAGAAACCA
GGGCAGCCTCCCAAGCTCCTGATCTATTTTGTATCCACTCTGGCATCTGGGGTCCCATCGCGGT
TCAAAGGCAGTGGATCTGGGACACAGTTCACTCTCACCATCAGCGGCGTGCAGTGTGACGATGC
TGCCACTTACTACTGTCAAGGCAGTGATTATAGTAGTGGTTGGTATAGTCCTTTCGGCGGAGGG
ACCGAGGTGGTGGTCGAAGGTGATCCAGTTGCACCTACTGTCCTCATCTTCCCACCAGCTGCTG
ATCAGGTGGCAACTGGAACAGTCACCATCGTGTGTGTGGCGAATAAATACTTTCCCGATGTCAC
CGTCACCTGGGAGGTGGATGGCACCACCCAAACAACTGGCATCGAGAACAGTAAAACACCGCAG
AATTCTGCAGATTGTACCTACAACCTCAGCAGCACTCTGACACTGACCAGCACACAGTACAACA
GCCACAAAGAGTACACCTGCAAGGTGACCCAGGGCACGACCTCAGTCGTCCAGAGCTTCAATAG
GGGTGACTGT

Query protein sequence	C	Q	S	V	E	E	S	G	G	R	L	V	T	P	G	T	P	L	T	L
Kabat numbering	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20

REGIONS: CHOTHIA HFR1
ABM HFR1
KABAT HFR1
CONTACT HFR1

T	C	T	V	S	G	I	D	L	N	N	Y	N	M	Q	W	V	R	Q	A	P	G	K
H21	H22	H23	H24	H25	H26	H27	H28	H29	H30	H31	H32	H33	H34	H35	H36	H37	H38	H39	H40	H41	H42	H43

CDR-H1 HFR2
CDR-H1 HFR2
CDR-H1 HFR2
CDR-H1 HFR2

G	L	E	W	I	G	A	T	F	G	S	D	S	I	Y	Y	A	T	W	A	K	G	R
H44	H45	H46	H47	H48	H49	H50	H51	H52	H53	H54	H55	H56	H57	H58	H59	H60	H61	H62	H63	H64	H65	H66

CDR-H2 HFR3
CDR-H2 HFR3
CDR-H2 HFR3
CDR-H2 HFR3

F	T	I	S	K	T	S	T	T	V	D	L	K	M	T	S	L	T	T	E	D	T	A
H67	H68	H69	H70	H71	H72	H73	H74	H75	H76	H77	H78	H79	H80	H81	H82	H82A	H83	H84	H85	H86	H87	H88

T	Y	F	C	A	R	G	G	L	W	G	P	G	T	L	V	T	V	S	S
H89	H90	H91	H92	H93	H94	H95	H101	H102	H103	H104	H105	H106	H107	H108	H109	H110	H111	H112	H113

CDR-H3 HFR4
CDR-H3 HFR4
CDR-H3 HFR4
CDR-H3 HFR4

FIGURE 7

Query protein sequence	A	Q	V	L	T	Q	T	A	S	P	V	S	A	A	V	G	A	T	V	T
Kabat numbering	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20
REGIONS: CHOTHIA	LFR1																			
ABM	LFR1																			
KABAT	LFR1																			
CONTACT	LFR1																			

I	N	C	Q	S	S	Q	S	V	Y	N	N	N	Y	L	A	W	F	Q	Q	K	P	G
L21	L22	L23	L24	L25	L26	L27	L27A	L27B	L28	L29	L30	L31	L32	L33	L34	L35	L36	L37	L38	L39	L40	L41
			CDR-L1													LFR2						
			CDR-L1													LFR2						
			CDR-L1													LFR2						
									CDR-L1									LFR2				

Q	P	P	K	L	L	I	Y	R	A	S	T	L	A	S	G	V	S	S	R	F	K	G
L42	L43	L44	L45	L46	L47	L48	L49	L50	L51	L52	L53	L54	L55	L56	L57	L58	L59	L60	L61	L62	L63	L64
								CDR-L2							LFR3							
								CDR-L2							LFR3							
								CDR-L2							LFR3							
				CDR-L2										LFR3								

S	G	S	G	T	Q	F	A	L	T	I	S	G	V	Q	C	D	D	A	G	T	Y	Y
L65	L66	L67	L68	L69	L70	L71	L72	L73	L74	L75	L76	L77	L78	L79	L80	L81	L82	L83	L84	L85	L86	L87

C	Q	G	E	F	S	C	D	S	A	D	C	A	A	F	G	G	G	T	E	V	V	V
L88	L89	L90	L91	L92	L93	L94	L95	L95A	L95B	L95C	L95D	L96	L97	L98	L99	L100	L101	L102	L103	L104	L105	L106
	CDR-L3													LFR4								
	CDR-L3													LFR4								
	CDR-L3													LFR4								
	CDR-L3												LFR4									

K	G	D	P
L107	L108	L109	L110

FIGURE 8

Query protein sequence	C	Q	S	V	E	E	S	G	G	R	L	V	T	P	G	T	P	L	T	L
Kabat numbering	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20

REGIONS: CHOTHIA HFR1
ABM HFR1
KABAT HFR1
CONTACT HFR1

T	C	T	V	S	G	F	S	L	S	R	Y	A	M	S	W	V	R	Q	A	P	G	K
H21	H22	H23	H24	H25	H26	H27	H28	H29	H30	H31	H32	H33	H34	H35	H36	H37	H38	H39	H40	H41	H42	H43

CDR-H1 HFR2
CDR-H1 HFR2
CDR-H1 HFR2
CDR-H1 HFR2

G	L	D	W	I	G	Y	I	D	I	G	G	G	A	Y	Y	A	S	W	A	K	G	R
H44	H45	H46	H47	H48	H49	H50	H51	H52	H53	H54	H55	H56	H57	H58	H59	H60	H61	H62	H63	H64	H65	H66

CDR-H2 HFR3
CDR-H2 HFR3
CDR-H2 HFR3
CDR-H2 HFR3

F	T	I	S	E	T	S	T	T	V	Y	L	K	V	N	S	P	T	T	E	D	T	A
H67	H68	H69	H70	H71	H72	H73	H74	H75	H76	H77	H78	H79	H80	H81	H82	H82A	H83	H84	H85	H86	H87	H88

T	Y	F	C	A	R	G	V	A	N	S	D	I	W	G	P	G	T	L	V	T	V	S
H89	H90	H91	H92	H93	H94	H95	H96	H97	H98	H99	H101	H102	H103	H104	H105	H106	H107	H108	H109	H110	H111	H112

CDR-H3 HFR4
CDR-H3 HFR4
CDR-H3 HFR4
CDR-H3 HFR4

S
H113

FIGURE 9

Query protein sequence	A	L	V	M	T	Q	T	P	S	P	V	S	A	A	V	G	G	T	V	T
Kabat numbering	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20

REGIONS: CHOTHIA — LFR1
ABM — LFR1
KABAT — LFR1
CONTACT — LFR1

I	N	C	Q	S	S	Q	S	V	F	N	N	K	W	L	S	W	Y	Q	Q	K	P	G
L21	L22	L23	L24	L25	L26	L27	L27A	L27B	L28	L29	L30	L31	L32	L33	L34	L35	L36	L37	L38	L39	L40	L41

CDR-L1 — LFR2
CDR-L1 — LFR2
CDR-L1 — LFR2
CDR-L1 — LFR2

Q	P	P	K	L	L	I	Y	F	V	S	T	L	A	S	G	V	P	S	R	F	K	G
L42	L43	L44	L45	L46	L47	L48	L49	L50	L51	L52	L53	L54	L55	L56	L57	L58	L59	L60	L61	L62	L63	L64

CDR-L2 — LFR3
CDR-L2 — LFR3
CDR-L2 — LFR3
CDR-L2 — LFR3

S	G	S	G	T	Q	F	T	L	T	I	S	G	V	Q	C	D	D	A	A	T	Y	Y
L65	L66	L67	L68	L69	L70	L71	L72	L73	L74	L75	L76	L77	L78	L79	L80	L81	L82	L83	L84	L85	L86	L87

C	Q	G	S	D	Y	S	S	G	W	Y	S	P	F	G	G	G	T	E	V	V	V	E
L88	L89	L90	L91	L92	L93	L94	L95	L95A	L95B	L95C	L96	L97	L98	L99	L100	L101	L102	L103	L104	L105	L106	L107

CDR-L3 — LFR4
CDR-L3 — LFR4
CDR-L3 — LFR4
CDR-L3 — LFR4

G	D	P
L108	L109	L110

FIGURE 10

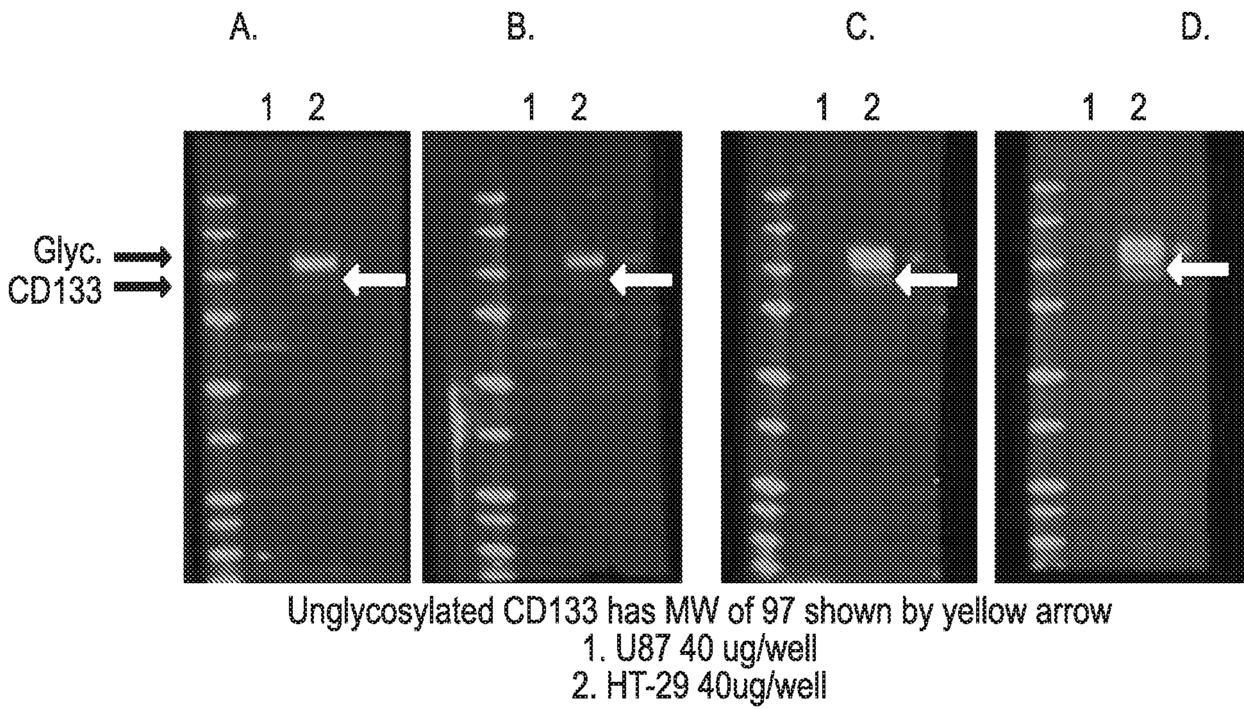


FIGURE 11

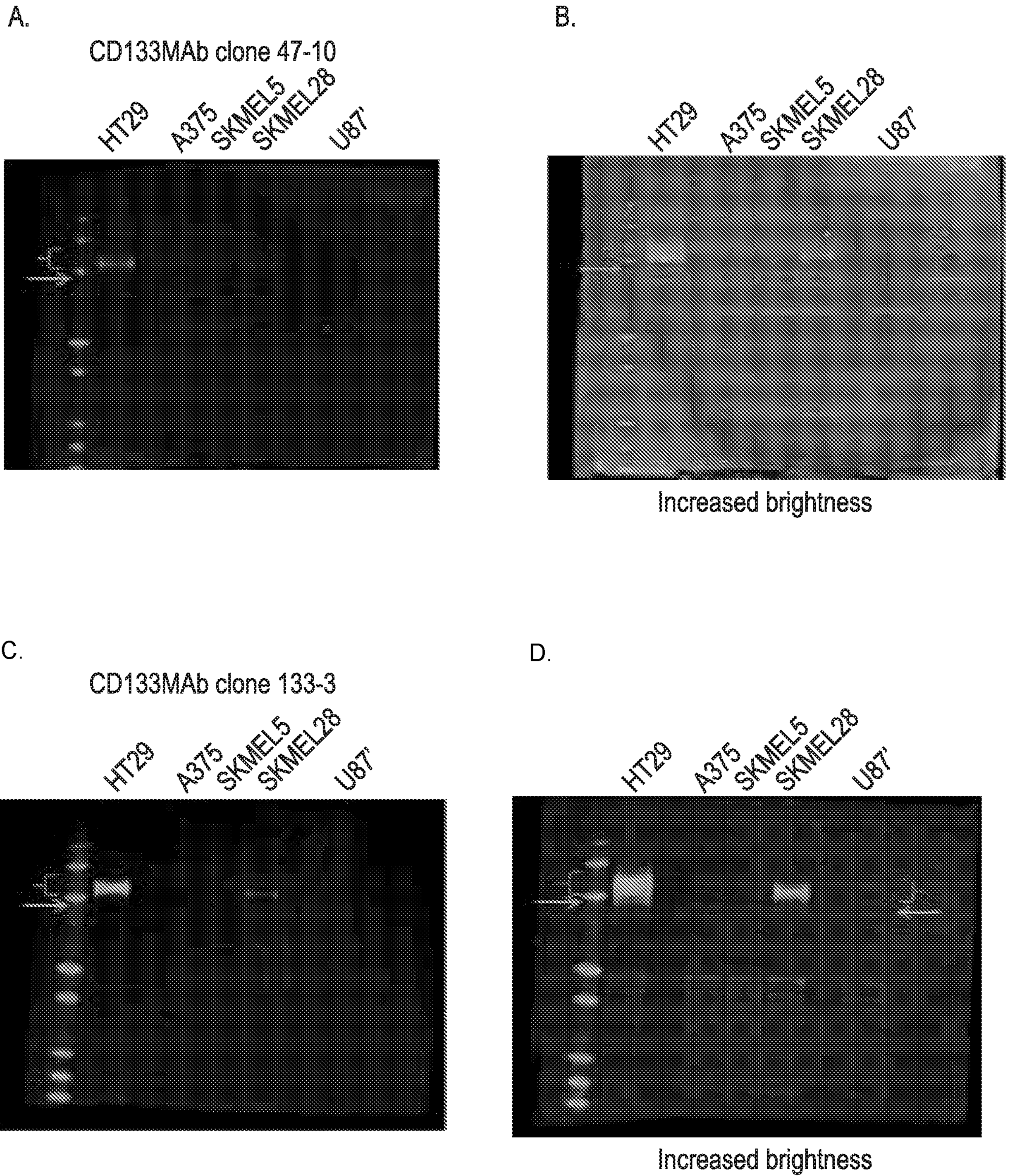
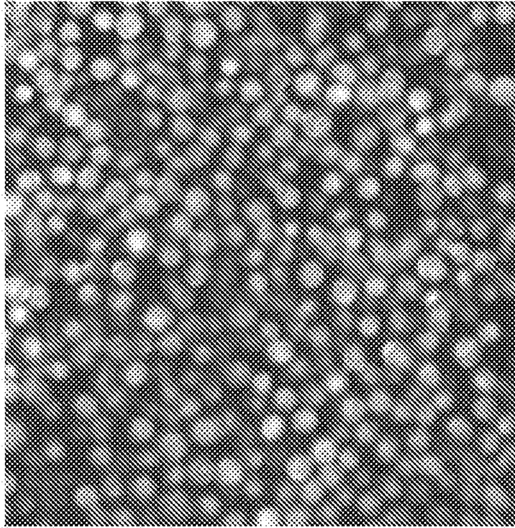


FIGURE 12

FIGURE 13.

A.



B.

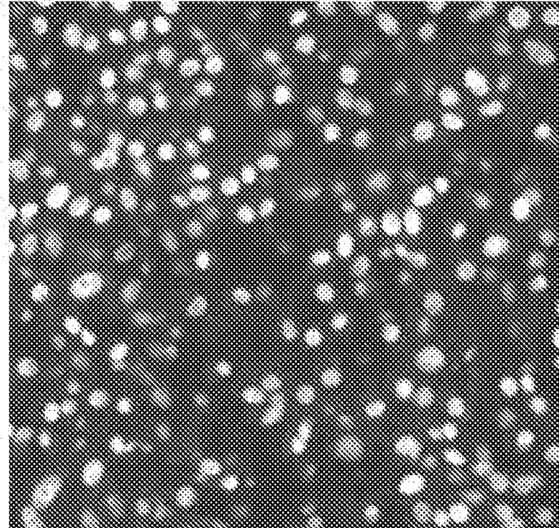
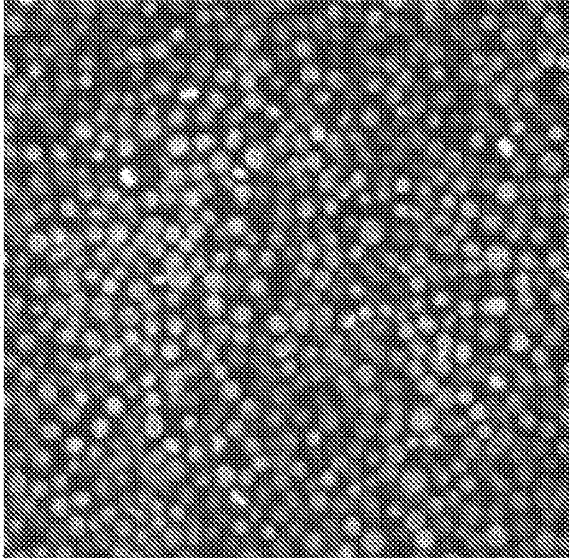


FIGURE 14.

A.



B.

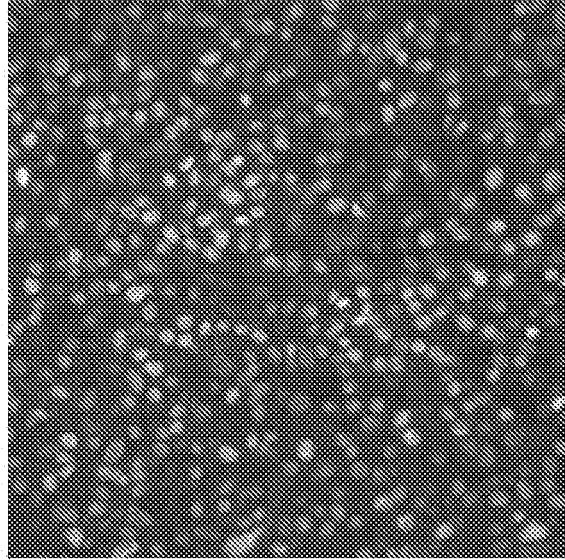
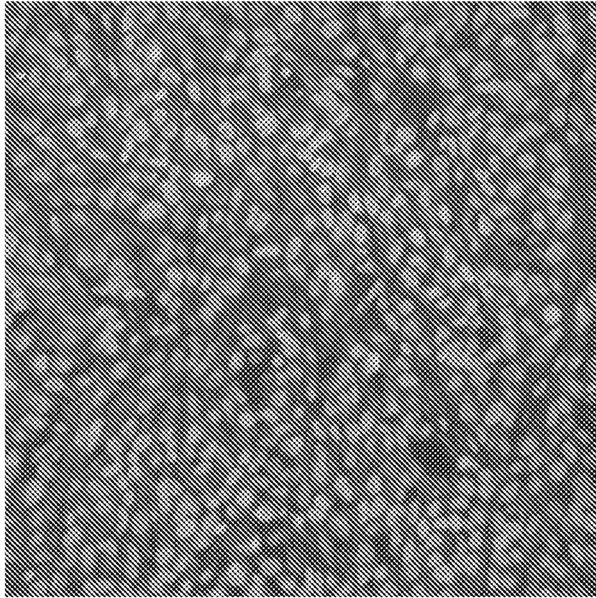
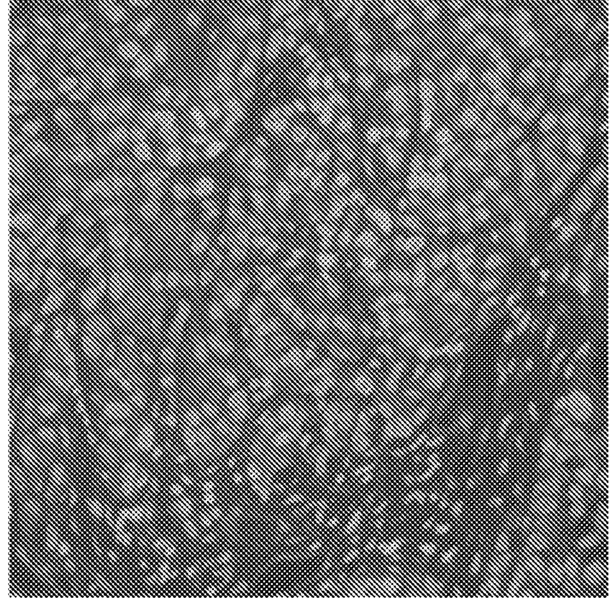


FIGURE 15.

A.



B.



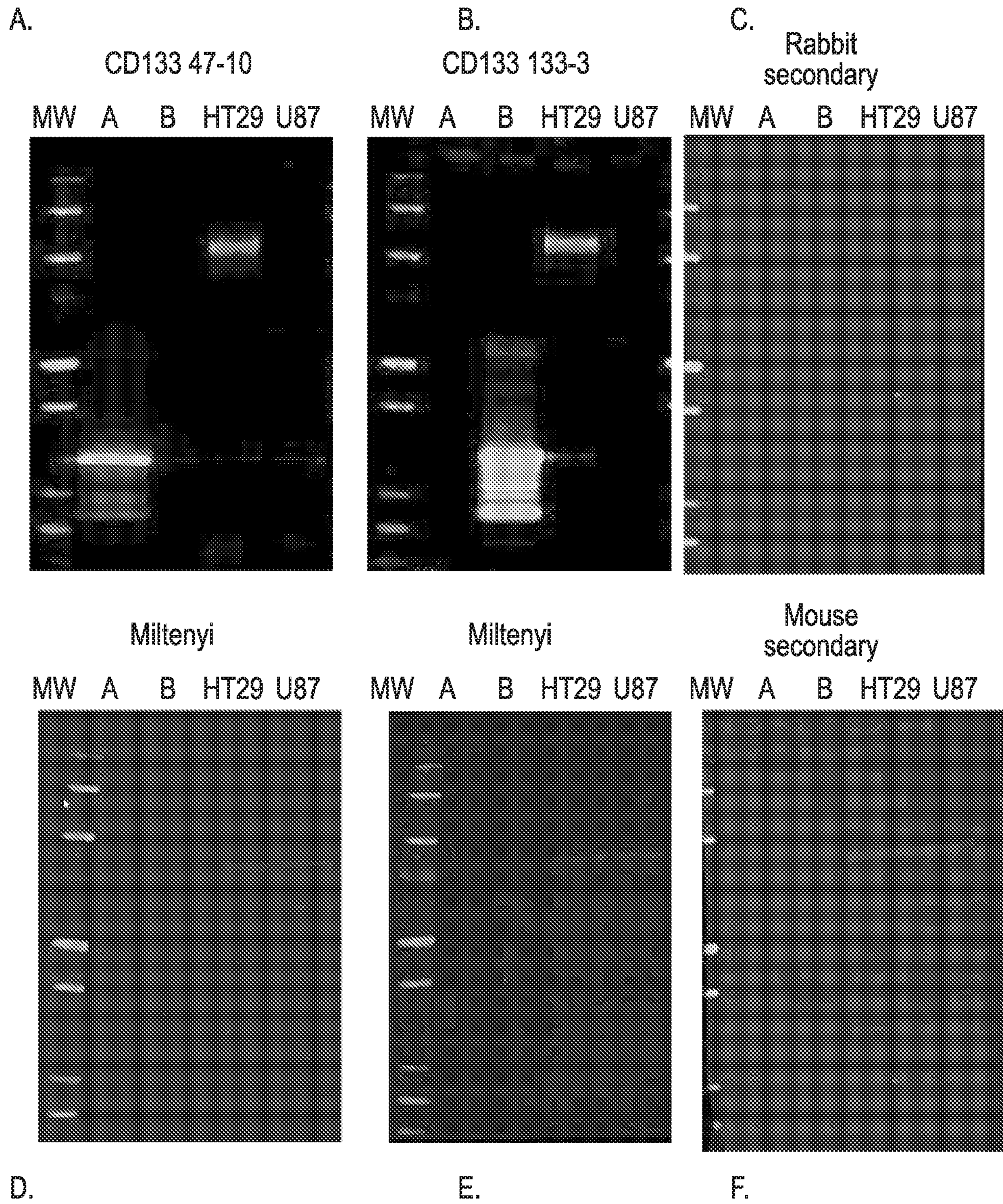


FIGURE 16

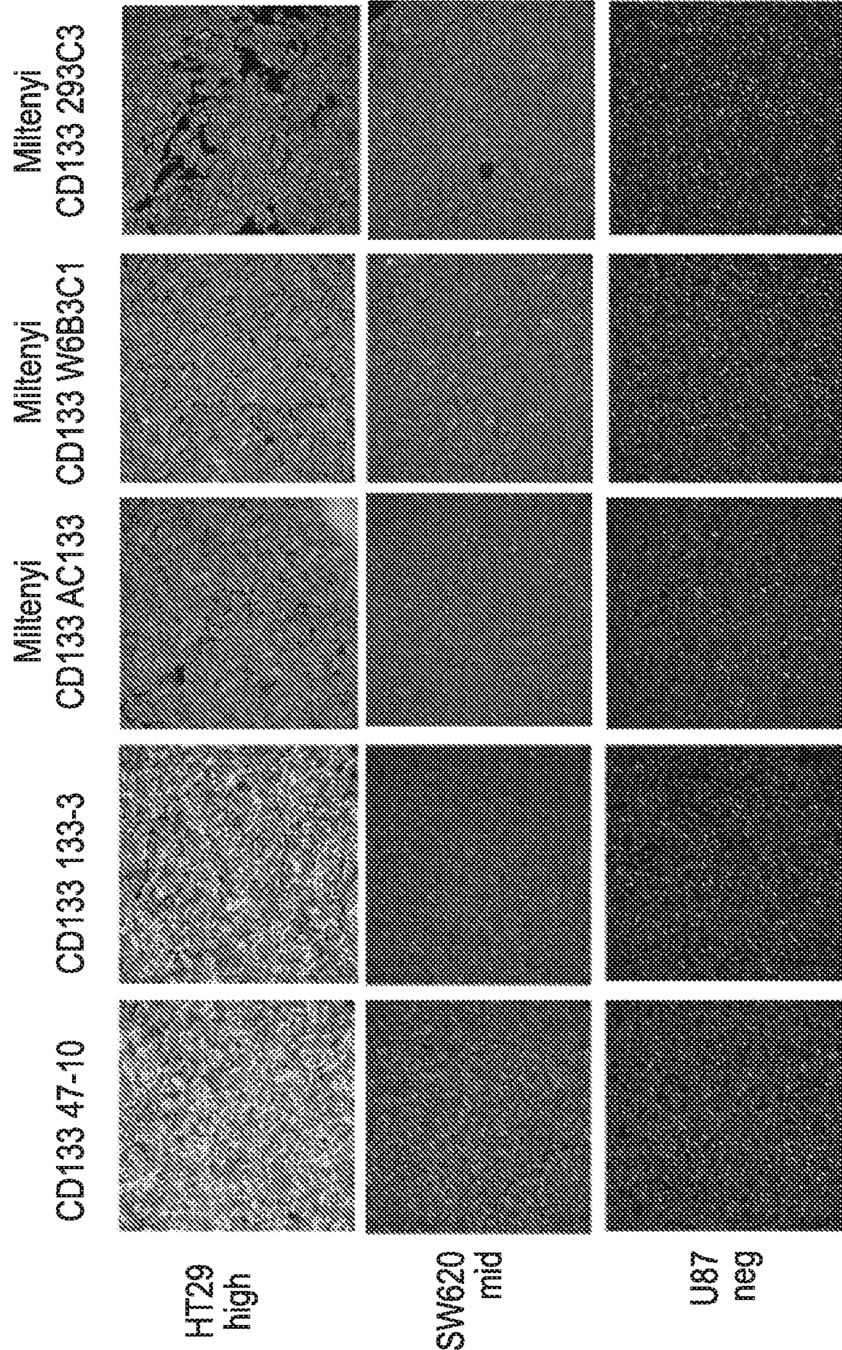


FIGURE 17

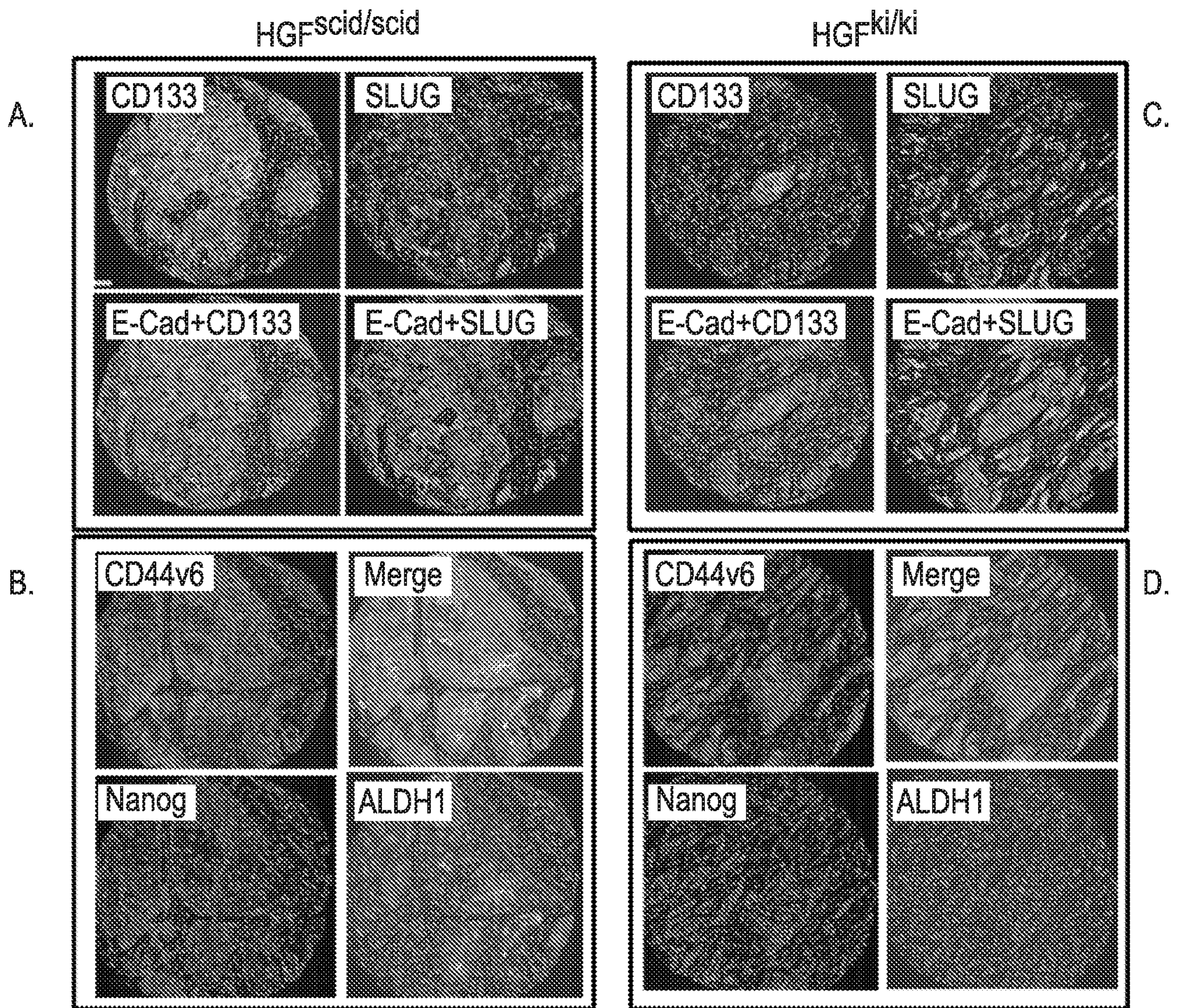
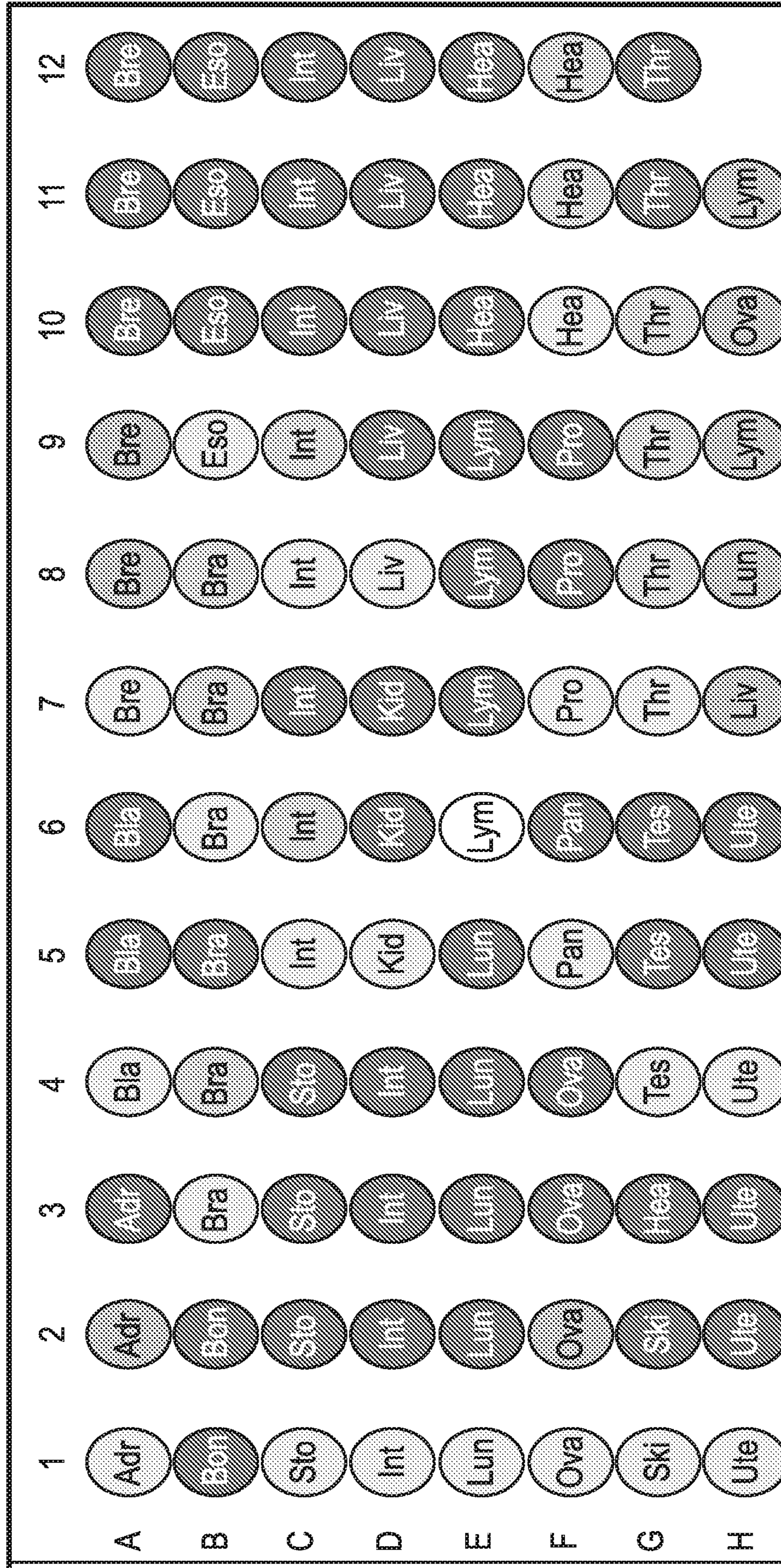


FIGURE 18

E.



Legend: Adr-Arenal gland, **Bla** - Bladder, urinary, **Bon** - Bone, scapula, **Bra** - Brain, **Bre** - Breast, **Eso** - Esophagus, **Hea** - Head and neck, nasal cavity, **Int** - Intestine, rectum, **Kid** - Kidney, **Liv** - Liver, **Lun** - Lung, **Lym** - Lymph node, **Ova** - Ovary, **Pan** - Pancreas, **Pro** - Prostate, **Ski** - Skin, trunk, **Sto** - Stomach, **Tes** - Testis, **Thr** - Thyroid, **Ute** - Uterus, endometrium

- Benign tumor, - , - Malignant tumor, - Mestasis, - Normal tissue

FIGURE 19

FIGURE 20A.

position	sex	age	organ	pathology	grade	tnm	type
A1	F	37	Adrenal gland	Normal, hyperplasia			Normal
A2	M	61	Adrenal gland	Adenoma, cortical			Benign
A3	M	28	Adrenal gland	Adrenocortical carcinoma		T2N0M0	Malignant
A4	M	53	Bladder, urinary	Normal			Normal
A5	F	53	Bladder, urinary	Transitional cell carcinoma	I~II	T1N0M0	Malignant
A6	F	65	Bladder, urinary	Transitional cell carcinoma	I~II	T1N0M0	Malignant
A7	F	30	Breast	Normal			Normal
A8	F	40	Breast	Fibroadenoma			Benign
A9	F	39	Breast	Fibroadenoma			Benign
A10	F	58	Breast	Invasive ductal carcinoma	II	T2N1M0	Malignant
A11	F	53	Breast	Invasive ductal carcinoma	II	T2N0M0	Malignant
A12	F	42	Breast	Invasive ductal carcinoma	II	T4N1M0	Malignant
B1	M	17	Bone, tibia	Osteosarcoma			Malignant
B2	M	44	Bone, scapula	Chondrosarcoma			Malignant
B3	M	49	Brain, cerebellum	Normal*			Normal
B4	F	65	Brain, cerebellum	Meningioma, fibroblastic			Benign
B5	M	55	Brain, cerebellum	Malignant meningioma			Malignant
B6	M	58	Brain	Normal*			Normal
B7	F	26	Brain	Meningioma, fibroblastic			Benign
B8	M	47	Brain	Astrocytoma	II		Benign
B9	M	53	Esophagus	Normal			Normal
B10	F	68	Esophagus	Squamous cell carcinoma	I	T2N0M0	Malignant
B11	M	54	Esophagus	Squamous cell carcinoma	II	T3N1M0	Malignant
B12	F	61	Esophagus	Squamous cell carcinoma	III	T2N1M0	Malignant
C1	M	59	Stomach	Normal			Normal
C2	M	52	Stomach	Adenocarcinoma	I	T2N0M0	Malignant
C3	M	66	Stomach	Adenocarcinoma	II	T3N0M0	Malignant
C4	M	47	Stomach	Adenocarcinoma	III	T3N2M0	Malignant
C5	F	40	Intestine, small intestine	Normal			Normal
C6	F	18	Intestine, small intestine	Adenoma			Benign
C7	F	57	Intestine, small intestine	Adenocarcinoma	II	T2N0M0	Malignant
C8	F	27	Intestine, colon	Normal			Normal
C9	M	57	Intestine, colon	Adenoma			Benign
C10	M	56	Intestine, colon	Adenocarcinoma	I	T3N0M0	Malignant
C11	M	89	Intestine, colon	Adenocarcinoma	II	T2N0M0	Malignant
C12	F	43	Intestine, colon	Adenocarcinoma	III	T3N0M0	Malignant
D1	M	61	Intestine, rectum	Normal			Normal
D2	M	40	Intestine, rectum	Adenocarcinoma	I	T3N0M0	Malignant

FIGURE 20B.

D3	M	38	Intestine, rectum	Adenocarcinoma	II	T3N1M0	Malignant
D4	M	50	Intestine, rectum	Adenocarcinoma	III	T3N1M0	Malignant
D5	F	51	Kidney	Normal cortex			Normal
D6	M	40	Kidney	Clear cell carcinoma		T1N0M0	Malignant
D7	F	79	Kidney	Clear cell carcinoma		T1N0M0	Malignant
D8	M	43	Liver	Normal			Normal
D9	M	26	Liver	Hepatocellular carcinoma	I	T2N0M0	Malignant
D10	M	40	Liver	Hepatocellular carcinoma	II	T2N0M0	Malignant
D11	M	53	Liver	Hepatocellular carcinoma	I	T2N0M0	Malignant
D12	M	41	Liver	Hepatocellular carcinoma	III	T2N0M0	Malignant
E1	M	58	Lung	Normal			Normal
E2	M	59	Lung	Squamous cell carcinoma	II	T2N2M0	Malignant
E3	M	62	Lung	Squamous cell carcinoma	II~III	T2N0M0	Malignant
E4	M	72	Lung	Adenocarcinoma	III	T2N2M0	Malignant
E5	M	19	Lung	Small cell carcinoma		T3N0M0	Malignant
E6	F	39	Lymph node	Reactive			Inflammatory
E7	M	50	Lymph node, neck	Lymphoma, Hodgkin lymphoma			Malignant
E8	M	42	Lymph node, axillary	Lymphoma, non-Hodgkin B-cell lymphoma			Malignant
E9	M	51	Lymph node, neck	Lymphoma, anaplastic large cell lymphoma			Malignant
E10	F	48	Head and neck, oral cavity, hard palate	Adenocarcinoma	III~IV		Malignant
E11	M	56	Head and neck, oral cavity, tongue	Squamous cell carcinoma	II	T2N0M0	Malignant
E12	F	48	Head and neck, nasopharynx	Nasopharyngeal carcinoma, NPC	III	T2N0M0	Malignant
F1	F	45	Ovary	Normal			Normal
F2	F	55	Ovary	Granulosa cell tumor			Benign
F3	F	45	Ovary	Adenocarcinoma	III	T2N0M0	Malignant
F4	F	49	Ovary	Endometrioid adenocarcinoma	III	T1N0M0	Malignant
F5	M	35	Pancreas	Normal			Normal
F6	F	49	Pancreas	Adenocarcinoma	II	T3N1M1	Malignant
F7	M	65	Prostate	Normal, hyperplasia			Normal
F8	M	60	Prostate	Adenocarcinoma	II	T2N0M0	Malignant
F9	M	47	Prostate	Adenocarcinoma	III	T3N0M0	Malignant
F10	M	38	Head and neck, salivary gland	Normal			Normal
F11	F	28	Head and neck, salivary gland, parotid	Pleomorphic adenoma			Benign
F12	F	38	Head and neck, salivary gland	Adenoid cystic carcinoma	I~II	T1N0M0	Malignant
G1	M	50	Skin	Normal			Normal

FIGURE 20C.

G2	M	67	Skin, trunk	Squamous cell carcinoma	II	T2N0M0	Malignant
G3	M	53	Head and neck, nasal cavity	Melanoma			Malignant
G4	M	77	Testis	Normal			Normal
G5	M	30	Testis	Seminoma			Malignant
G6	M	28	Testis	Seminoma			Malignant
G7	F	62	Thyroid	Normal			Normal
G8	F	47	Thyroid	Adenoma			Benign
G9	F	27	Thyroid	Adenoma			Benign
G10	F	66	Thyroid	Adenoma			Benign
G11	M	16	Thyroid	Follicular carcinoma		T3N1M0	Malignant
G12	M	34	Thyroid	Follicular papillary adenocarcinoma		T2N1M0	Malignant
H1	F	41	Uterus, cervix	Normal			Normal
H2	F	63	Uterus, cervix	Squamous cell carcinoma	III	T1N0M0	Malignant
H3	F	57	Uterus, cervix	Squamous cell carcinoma	III	T1N1M0	Malignant
H4	F	50	Uterus, endometrium	Normal			Normal
H5	F	48	Uterus, endometrium	Adenocarcinoma	I~II	T2N0M0	Malignant
H6	F	53	Uterus, endometrium	Adenocarcinoma	II~III	T1N1M0	Malignant
H7	M	60	Liver	Metastatic colon adenocarcinoma			Metastasis
H8	M	69	Lung	Metastatic cancers, from gastrointestional site?			Metastasis
H9	F	34	Lymph node	Metastatic breast invasive ductal carcinoma			Metastasis
H10	F	40	Ovary	Metastatic colon signet ring cell carcinoma			Metastasis
H11	M	51	Lymph node	Metastatic esophagus squamous cell carcinoma			Metastasis

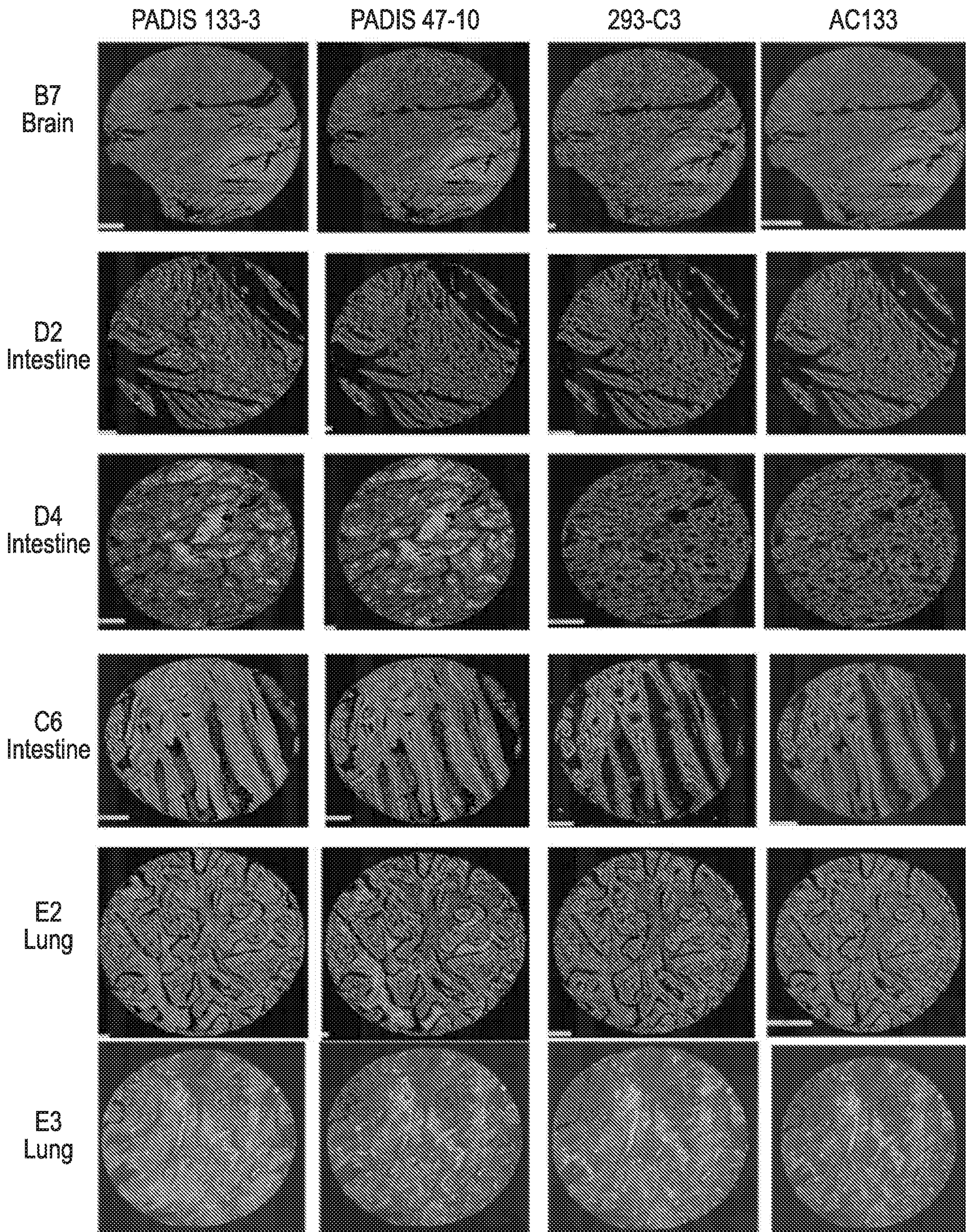


FIGURE 21

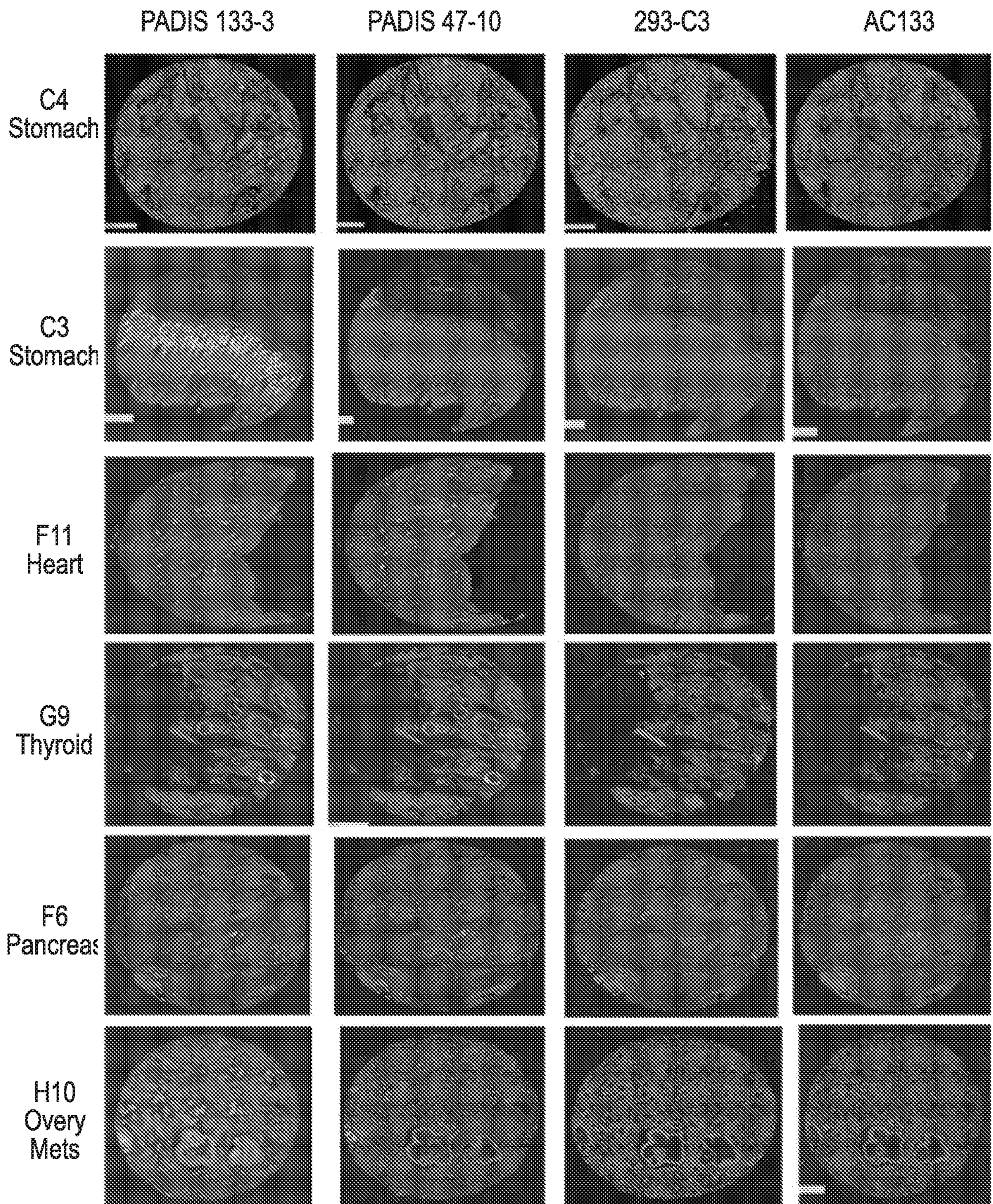


FIGURE 22

C.

	1	2	3	4	5	6	7	8	9	10	
A	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	
B	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	
C	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	
D	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Vul	Vul	
E	Vul	Vul	Vul	Vul	Rec	Rec	Rec	Rec	Rec	Rec	
F	Rec	Rec	Rec	Rec	Rec	Sto	Sto	Eso	Eso	Int	
G	Int	Ora	Lym	Lym	Lym	Lym	Lym	Lym	Lym	Lym	
H	Lym	Lym	Lym	Lym	Lym	Lym	Lym	Lym	Lym	Lym	
I	Lym	Lym	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	
J	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Ski	Adr

Legend: Eso - Esophagus, Int - Intestine, Lym - Lymph node, Ora - Oral cavity, Rec - Rectum, Ski - Skin, Sto - Stomach, Vul - Vulva
○ - Benign tumor, ○ - Malignant tumor, ○ - Malignant tumor (stage I), ○ - Malignant tumor (stage IB), ○ - Malignant tumor (stage II), ○ - Malignant tumor (stage III), ○ - Malignant tumor (stage IV), ○ - Metastasis

FIGURE 23

FIGURE 24A.

position	sex	age	organ	pathology	stage	tnm	type
A1	M	71	Skin	Malignant melanoma of right rump	II	T4N0M0	Malignant
A2	M	60	Skin	Malignant melanoma of right rump	III	T4N1M0	Malignant
A3	M	72	Skin	Malignant melanoma of left sole	IB	T2aN0M0	Malignant
A4	M	61	Skin	Malignant melanoma of left armpit	IV	T4bN0M1	Malignant
A5	M	55	Skin	Malignant melanoma of left sole	II	T4N0M0	Malignant
A6	M	51	Skin	Malignant melanoma of back	II	T4N0M0	Malignant
A7	M	25	Skin	Malignant melanoma of left sole	I	T2N0M0	Malignant
A8	F	46	Skin	Malignant melanoma of thigh	II	T4N0M0	Malignant
A9	F	32	Skin	Malignant melanoma of right lumbar part (fibrofatty tissue)	II	T4N0M0	Malignant
A10	M	80	Skin	Malignant melanoma of right sole	II	T4N0M0	Malignant
B1	F	42	Skin	Malignant melanoma of right thigh	II	T4N0M0	Malignant
B2	M	50	Skin	Malignant melanoma of left shoulder (fibrous tissue and blood vessel)	II	T4N0M0	Malignant
B3	M	41	Skin	Malignant melanoma of left leg	II	T3N0M0	Malignant
B4	M	37	Skin	Malignant melanoma of right upper arm	II	T4N0M0	Malignant
B5	M	61	Skin	Malignant melanoma of right groin	III	T4N2M0	Malignant
B6	M	52	Skin	Malignant melanoma of left abdominal wall	II	T4N0M0	Malignant
B7	F	59	Skin	Malignant melanoma of right rump	I	T1N0M0	Malignant
B8	M	79	Skin	Malignant melanoma of left face	I	T1N0M0	Malignant
B9	M	40	Skin	Malignant melanoma of right chest wall	II	T4N0M0	Malignant
B10	F	59	Skin	Malignant melanoma with necrosis of anus	II	T4N0M0	Malignant
C1	M	42	Skin	Malignant melanoma of left heel	IV	T3N2M1	Malignant
C2	M	41	Skin	Malignant melanoma of left forearm	II	T4N0M0	Malignant
C3	M	49	Skin	Malignant melanoma of left arm	II	T4N0M0	Malignant
C4	M	71	Skin	Malignant melanoma of right groin	II	T4N0M0	Malignant
C5	F	83	Skin	Malignant melanoma of right little finger	I	T2N0M0	Malignant
C6	M	51	Skin	Malignant melanoma of left upper arm	III	T4N1M0	Malignant
C7	F	41	Skin	Malignant melanoma of scalp	II	T4N0M0	Malignant
C8	M	51	Skin	Malignant melanoma of left armpit	II	T4N0M0	Malignant
C9	M	56	Skin	Malignant melanoma of abdominal wall	II	T4N0M0	Malignant
C10	M	66	Skin	Malignant melanoma of right thigh	II	T4N0M0	Malignant
D1	M	65	Skin	Malignant melanoma of scalp	II	T4N0M0	Malignant
D2	M	45	Skin	Malignant melanoma of crissum	II	T4N0M0	Malignant
D3	M	31	Skin	Malignant melanoma of scalp	II	T4N0M0	Malignant
D4	F	72	Skin	Malignant melanoma of right cheek	II	T4N0M0	Malignant
D5	F	46	Skin	Malignant melanoma of right thumb	II	T4N0M0	Malignant
D6	F	47	Skin	Malignant melanoma of left upper arm	II	T4N0M0	Malignant
D7	M	49	Skin	Malignant melanoma of left foot	III	T4N1M0	Malignant

FIGURE 24B.

D8	F	45	Skin	Malignant melanoma of left thigh	I	T2N0M0	Malignant
D9	F	72	Vulva	Malignant melanoma	I	-	Malignant
D10	F	57	Vulva	Malignant melanoma	I	-	Malignant
E1	F	38	Vulva	Malignant melanoma	I	-	Malignant
E2	F	44	Vulva	Malignant melanoma	I	-	Malignant
E3	F	62	Vulva	Malignant melanoma	I	-	Malignant
E4	F	45	Vulva	Malignant melanoma	I	-	Malignant
E5	F	38	Rectum	Malignant melanoma	I	-	Malignant
E6	F	44	Rectum	Malignant melanoma	I	-	Malignant
E7	M	64	Rectum	Malignant melanoma	II	-	Malignant
E8	F	52	Rectum	Malignant melanoma	I	-	Malignant
E9	F	84	Rectum	Malignant melanoma of crissum	I	-	Malignant
E10	F	67	Rectum	Malignant melanoma	I	-	Malignant
F1	M	66	Rectum	Malignant melanoma	I	-	Malignant
F2	F	66	Rectum	Malignant melanoma	I	-	Malignant
F3	M	75	Rectum	Malignant melanoma	II	-	Malignant
F4	F	54	Rectum	Malignant melanoma of anal tube	II	-	Malignant
F5	F	72	Rectum	Malignant melanoma	I	-	Malignant
F6	M	55	Stomach	Malignant melanoma	I	-	Malignant
F7	M	55	Stomach	Malignant melanoma	I	-	Malignant
F8	M	50	Esophagus	Malignant melanoma	II	-	Malignant
F9	M	64	Esophagus	Malignant melanoma	I	-	Malignant
F10	M	71	Intestine	Malignant melanoma	I	-	Malignant
G1	M	73	Intestine	Malignant melanoma	I	-	Malignant
G2	F	70	Oral cavity	Malignant melanoma of left parotid gland	I	-	Malignant
G3	F	63	Lymph node	Metastatic malignant melanoma from right heel	-	-	Metastasis
G4	M	58	Lymph node	Metastatic malignant melanoma from left groin	-	-	Metastasis
G5	F	55	Lymph node	Metastatic malignant melanoma from left groin	-	-	Metastasis
G6	M	44	Lymph node	Malignant malignant melanoma from right armpit	-	-	Metastasis
G7	M	72	Lymph node	Metastatic malignant melanoma from right groin	-	-	Metastasis
G8	F	47	Lymph node	Metastatic malignant melanoma from left thump	-	-	Metastasis
G9	M	63	Lymph node	Metastatic malignant melanoma from left Lower gum	-	-	Metastasis
G10	F	40	Lymph node	Metastatic malignant melanoma from right groin	-	-	Metastasis
H1	M	70	Lymph node	Malignant malignant melanoma from right armpit	-	-	Metastasis
H2	M	56	Lymph node	Metastatic malignant melanoma from left ear	-	-	Metastasis

FIGURE 24C.

H3	M	68	Lymph node	Metastatic malignant melanoma from left groin	-	-	Metastasis
H4	F	72	Lymph node	Metastatic malignant melanoma from left groin	-	-	Metastasis
H5	F	41	Lymph node	Metastatic malignant melanoma from right groin	-	-	Metastasis
H6	F	61	Lymph node	Metastatic malignant melanoma from groin	-	-	Metastasis
H7	F	38	Lymph node	Metastatic malignant melanoma from right leg	-	-	Metastasis
H8	F	43	Lymph node	Metastatic malignant melanoma from thigh	-	-	Metastasis
H9	M	73	Lymph node	Metastatic malignant melanoma from right groin	-	-	Metastasis
H10	F	56	Lymph node	Malignan tmalignant melanoma from left sole	-	-	Metastasis
I1	F	49	Lymph node	Metastatic malignant melanoma from neck	-	-	Metastasis
I2	F	41	Lymph node	Metastatic malignant melanoma from right groin (fibrous tissue and blood vessel)	-	-	Metastasis
I3	M	38	Skin	Compound nevus of right face	-	-	Benign
I4	F	29	Skin	Compound nevus of left shoulder	-	-	Benign
I5	F	30	Skin	Intradermal nevus of left rump	-	-	Benign
I6	F	10	Skin	Junctional nevus of right foot	-	-	Benign
I7	F	23	Skin	Compound nevus of right lumbar part	-	-	Benign
I8	M	25	Skin	Compound nevus of left leg	-	-	Benign
I9	F	2	Skin	Junctional nevus of neck	-	-	Benign
I10	M	6 mon.	Skin	Intradermal nevus of face	-	-	Benign
J1	M	20	Skin	Compound nevus of left shoulder	-	-	Benign
J2	F	2	Skin	Intradermal nevus of right leg	-	-	Benign
J3	M	50	Skin	Compound nevus of upper arm	-	-	Benign
J4	M	42	Skin	Intradermal nevus of face	-	-	Benign
J5	M	55	Skin	Compound nevus of back	-	-	Benign
J6	M	73	Skin	Compound nevus of left heel	-	-	Benign
J7	M	39	Skin	Intradermal nevuss of head	-	-	Benign
J8	M	11	Skin	Intradermal nevuss of left thigh	-	-	Benign
J9	F	34	Skin	Sebaceous nevus of head (skin tissue)	-	-	Benign
J10	M	18	Skin	Sebaceous nevus of left frontal region (skin tissue)	-	-	Benign

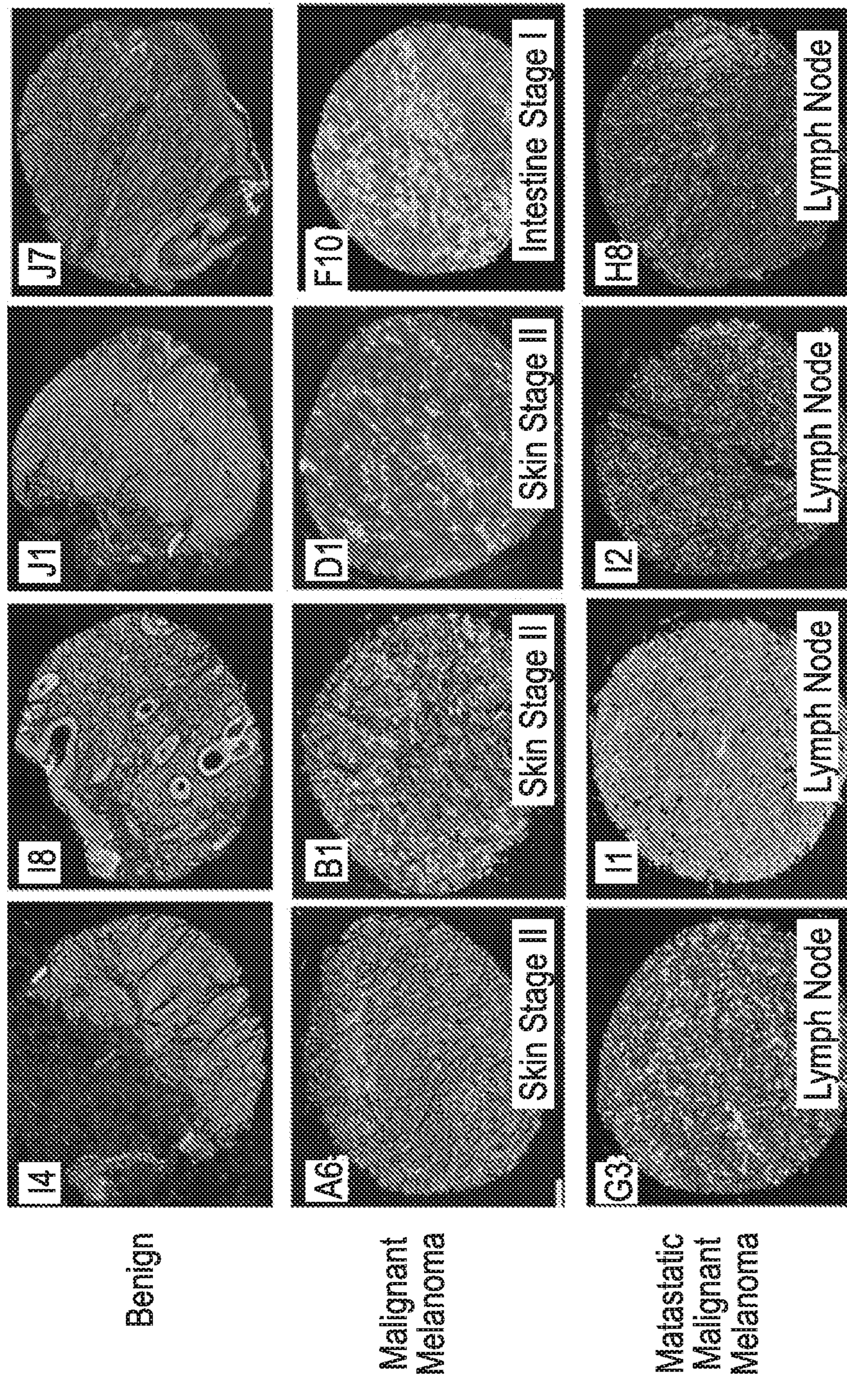
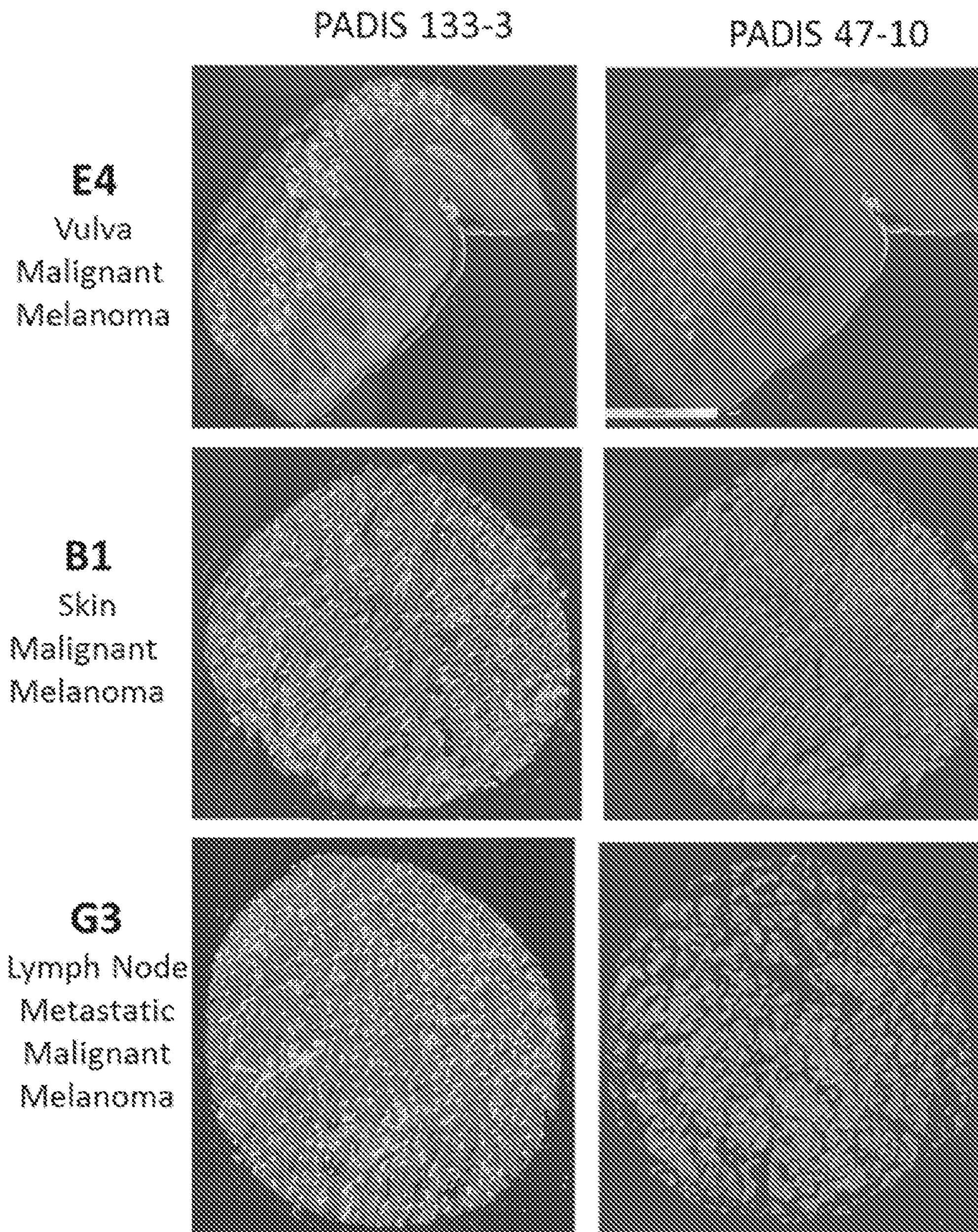


FIGURE 25

FIGURE 26.



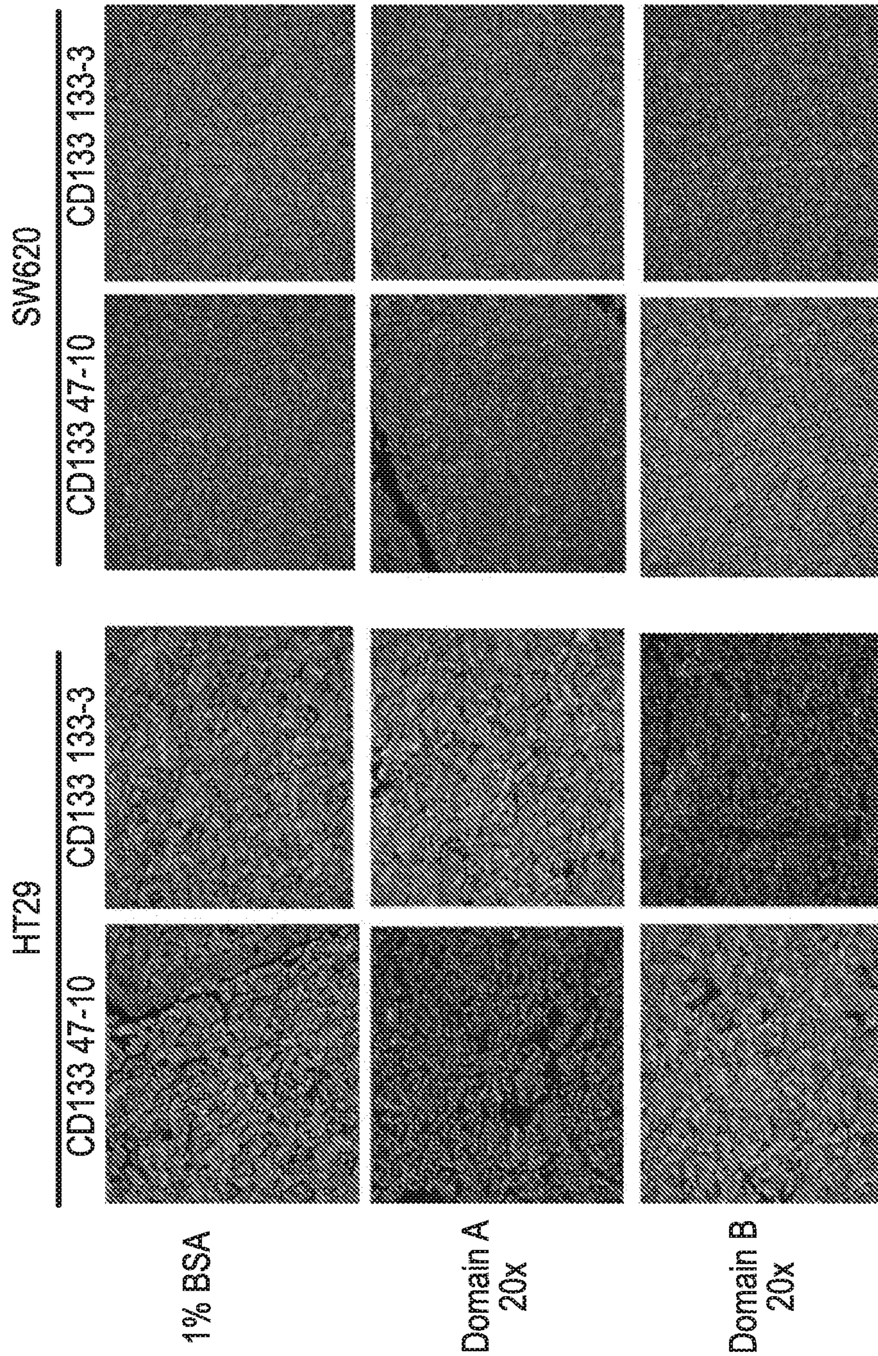


FIGURE 27

FIGURE 28.

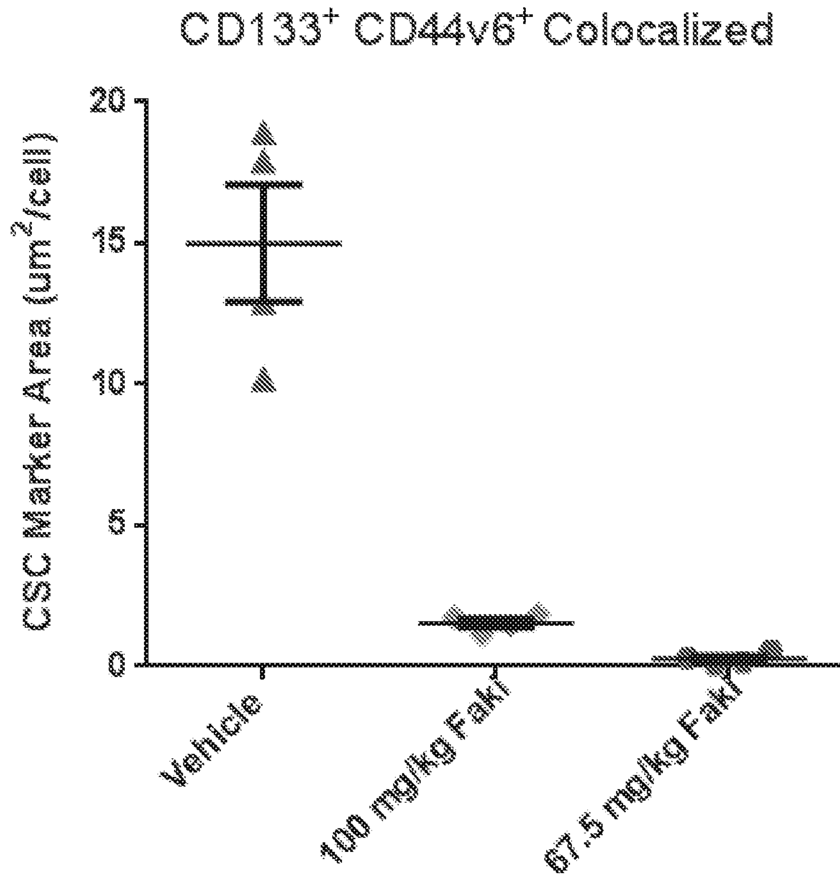


FIGURE 29.