

ANTI-HUMAN VSIG4 ANTIBODIES AND USES THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is a PCT application which claims priority to and the benefit of U.S. Provisional Patent Application No. 62/738,255, filed on September 28, 2018, and U.S. Provisional Patent Application No. 62/776,523, filed on December 7, 2018. The disclosures of the foregoing applications are incorporated herein by reference in their entirety.

10 FIELD OF THE INVENTION

The present disclosure relates to antibodies and antigen-binding fragments that binds to V-Set And Immunoglobulin Domain Containing 4 (VSIG4).

15 BACKGROUND

Cancer remains one of the leading causes of death in the world. Recent statistics report that 13% of the world population dies from cancer. According to estimates from the International Agency for Research on Cancer (IARC), in 2012 there were 14.1 million new cancer cases and 8.2
20 million cancer deaths worldwide. By 2030, the global burden is expected to grow to 21.7 million new cancer cases and 13 million cancer deaths due to population growth and aging and exposure to risk factors such as smoking, unhealthy diet and physical inactivity. Further, pain and medical expenses for cancer treatment cause reduced quality of life for both cancer patients and their families. It is apparent that, above all, cancer is a disease for which it is necessary to urgently
25 find improved treatment methods.

Macrophages are multifunctional antigen presenting cells that play a central role for our immune system and is relevant to cancer biology. In the context of cancer, tumor-associated macrophages (TAMs) infiltrate malignant tumor tissues and are known to be relevant for cancer biology, and influence of tumor progression. TAMs can be described as falling into two categories: M1 and
30 M2. M1 macrophages are seen to have a pro-inflammatory and cytotoxic (anti-tumoral) function, while M2 macrophages are anti-inflammatory (pro-tumoral) and promote wound healing.

Consistent with these functions, the TAMs, especially macrophages with the M2 phenotype, is closely associated with worse clinical prognosis in many kinds of malignant tumors. Infiltrating TAMs themselves or polarization pathway of TAMs are considered as new therapeutic targets for the therapy of malignant tumors.

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SUMMARY

The present disclosure relates, at least in part, to antibodies and fragments thereof that binds to VSIG4 (V-Set And Immunoglobulin Domain Containing 4; also referred to as CRIg or Z39Ig),
10 and methods of using such antibodies and antigen-binding fragments for treating cancer, inducing cytokine and/or chemokine secretion in macrophages, and conversion of M2 macrophages to M1 macrophages.

In one aspect, the present invention relates to an isolated humanized antibody or antigen-binding
15 fragment includes: (a) a heavy chain CDR1 comprising the amino acid sequence of SEQ ID NO: 17, a heavy chain CDR2 comprising the amino acid sequence of SEQ ID NO: 18, a heavy chain CDR3 sequence comprising the amino acid sequence of SEQ ID NO: 19; and (b) a light chain CDR1 comprising the amino acid sequence of SEQ ID NO: 20, a light chain CDR2 comprising the amino acid sequence of SEQ ID NO: 21, and a light chain CDR3 comprising the amino acid
20 sequence of SEQ ID NO: 22 or SEQ ID NO: 23.

In some embodiments, the antibody or antigen-binding fragment described herein may include any one of: (a) a heavy chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16; (b) a light chain variable domain comprising an
25 amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12; or (c) a heavy chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16, and a light chain variable domain comprising an amino acid
30 sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12.

In some embodiments, the antibody or antigen-binding fragment described herein may include any one of, a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16, a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12, or a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16, and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12. In some embodiments, the antibody or antigen-binding fragment described herein may include a light chain CDR3 comprising the amino acid sequence of SEQ ID NO: 23.

In some embodiments, the antibody or antigen-binding fragment described herein may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4. In some embodiments, the antibody or antigen-binding fragment described herein may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 8. In some embodiments, the antibody or antigen-binding fragment may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 10. In some embodiments, the antibody or antigen-binding fragment may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 12. In some embodiments, the antibody or antigen-binding fragment described herein may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 14 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 10. In some embodiments, the antibody or antigen-binding fragment described herein may include a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 16 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 12.

In some embodiments, the antibody or antigen-binding fragment described herein has a binding affinity (K_D) for a human V-Set And Immunoglobulin Domain Containing 4 (VSIG4) molecule of 1×10^{-7} to 1×10^{-9} . In some embodiments, the antibody or antigen-binding fragment described herein has a binding affinity (K_D) for a VSIG4 molecule of about 7.156×10^{-8} to about 7.636×10^{-9} . In some embodiments, the antibody or antigen-binding fragment described herein has a

binding affinity (K_D) for a VSIG4 molecule of about 7.156×10^{-8} , about 7.636×10^{-9} , about 7.952×10^{-9} , about 8.226×10^{-9} , or about 8.688×10^{-9} .

In another aspect, the present invention relates to a nucleic acid molecule encoding any one of the antibody or antigen-binding fragments described herein.

- 5 In another aspect, the present invention relates to a recombinant vector including any one of the nucleic acid molecules described herein. In some embodiments, the recombinant vector described herein contains the nucleic acid molecule described herein that is operatively linked to a promoter. In some embodiments, the recombinant vector includes two separate vectors, each comprising the nucleic acid sequence corresponding to the heavy chain and the light chain of the antibody or antigen-binding fragment provided herein.

- 10 In another aspect, the present invention provides a host cell including the nucleic acid molecule or the recombinant vector described herein. In some embodiments, the host cell is a mammalian cell, a yeast cell, or a bacterial cell. In some embodiments, the host cell is a cell selected from the group consisting of *E.coli*, *P.pastoris*, Sf9, COS, HEK293, Expi293, CHO-S, CHO-DG44, CHO-K1, and a mammalian lymphocyte. In some embodiments, the host cell is the Expi293 cell.

- 15 In another aspect, the present invention relates to a pharmaceutical composition including: any one of the antibody or antigen-binding fragments described herein, any one of the nucleic acid molecules described herein, any one of the recombinant vectors described herein, or any one of the host cells described herein; and a pharmaceutically acceptable carrier.

- 20 By way of further example, in another aspect, the present invention relates to a method of treating a subject in need thereof, the method comprising the steps of: (a) administering to the subject a composition that comprises or delivers any one of the antibody or antigen-binding fragments described herein, any one of the nucleic acid molecules described herein, any one of the recombinant vectors described herein, or any one of the host cells described herein, thereby
- 25 treating a disease or a condition. In some embodiments, the subject has, or is at risk for developing, cancer. In some embodiments, the cancer is selected from a bladder cancer, breast cancer, cervical cancer, colon cancer, endometrial cancer, esophageal cancer, fallopian tube cancer, gall bladder cancer, gastrointestinal cancer, head and neck cancer, hematological cancer, laryngeal cancer, liver cancer, lung cancer, lymphoma, melanoma, mesothelioma, ovarian
- 30 cancer, primary peritoneal cancer, salivary gland cancer, sarcoma, stomach cancer, thyroid cancer, pancreatic cancer, renal cell carcinoma, glioblastoma, and prostate cancer.

In some embodiments, the subject has been administered or will be administered one or more additional anticancer therapies selected from ionizing radiation, a chemotherapeutic agent, an antibody agent, and a cell-based therapy, such that the subject receives treatment with both. For example, in some embodiments, the one or more additional anticancer therapies can include an
5 immune checkpoint inhibitor, IL-12, GM-CSF, an anti-CD4 agent, cisplatin, fluorouracil, doxorubicin, irinotecan, paclitaxel, indoleamine 2,3 -di oxygenase- 1 (IDO1) inhibitor, or cyclophosphamide.

In yet another aspect, the present invention also relates to a method of increasing secretion of cytokines or chemokines in M2 macrophages, the method including contacting the M2
10 macrophages with any one of the antibody or antigen-binding fragments described herein.

In yet another aspect, the present invention relates to a method of inducing CD8⁺ T cell proliferation, the method including: (a) contacting an M2 macrophage with any one of the antibody or antigen-binding fragments described herein; and (b) co-incubating the M2 macrophage with CD8⁺ T cells.

15 In yet another aspect, the present invention also relates to a method of converting an M2 macrophage into an M1 macrophage, the method including contacting the M2 macrophage with any one of the antibody or antigen-binding fragments described herein.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning
20 as commonly understood by one of ordinary skill in the art to which this invention belongs.

Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification,
25 including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Other features and advantages of the invention will be apparent from the following detailed description, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic diagram illustrating mechanism of how administration of anti-VSIG4 antibody to macrophages result in conversion of M2 macrophages to M1 macrophages, which
5 results in proliferation of CD8⁺ T cells and subsequent suppression of cancer.

FIGURE 2A shows sequence alignment of VSIG4 with various human B7 family of proteins.

FIGURE 2B is a phylogenic tree showing evolutionary relationship between VSIG4 and various
10 human B7 family of proteins.

FIGURES 3A and 3B show correlation of VSIG4 mRNA expression with various genes in tumor tissue.

15 FIGURE 4A is a HPLC plot showing protein profile of EU103.2 antibody.

FIGURE 4B is a surface plasmon resonance data showing binding of EU103.2 antibody to VSIG4.

20 FIGURE 5 shows light microscope images of M1 and M2 macrophages (top left and top right, respectively), and FACS analysis data showing expression of VSIG4 in M1 and M2 macrophages.

FIGURE 6 is a set of graphs showing induction of proinflammatory cytokines and chemokines in
25 M1 and M2 macrophages by EU103.2.

FIGURE 7 is a set of FACS data showing decreased expression of CD163 in M2 macrophages treated with EU103.2.

FIGURE 8 is a set of FACS data (first six columns) and quantification of these data (last column) showing induction of CD8⁺ T cell proliferation when CD8⁺ T cells were co-cultured with M2 macrophages treated with EU103.2.

- 5 FIGURE 9 is a set of FACS data showing VSIG4 expression in macrophages isolated from abdominal fluid from ovarian cancer patients.

FIGURE 10 is a set of FACS data showing induction of CD8⁺ T cell proliferation when co-cultured with EU103.2-treated macrophages isolated from ovarian cancer patients.

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FIGURE 11 is a graph showing induction of CD8⁺ T cell proliferation when co-cultured with anti- EU103.2-treated macrophages isolated from ovarian cancer patients.

- 15 FIGURE 12 is a set of microscope images of M1 and M2 macrophages showing morphological differences after conversion of M2 macrophages into M1 macrophages by EU103.2 antibody.

FIGURE 13 is a set of FACS data showing blocking interaction between CD8⁺ cells and VSIG4 enhances proliferation of CD8⁺ T cells.

- 20 FIGURES 14A and 14B are set of graphs showing enhanced CD8⁺ cell proliferation by blocking the suppression by THP-1 cells.

FIGURES 15A-15C are sets of graphs showing the anti-tumor activities of anti-VSIG4 antibody in three different mouse tumor models.

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FIGURE 16 is a set of graphs showing the anti-tumor activities of anti-VSIG4 antibody in a VSIG4 knockout mouse model.

- 30 FIGURE 17A is a set of FACS data showing activation status of T cells and MDSCs in TDLNs in the absence of VSIG4 signaling.

FIGURE 17B is a set of graphs showing activation status of T cells and MDSCs in TDLNs in the absence of VSIG4 signaling.

5 FIGURE 17C is a set of graphs showing activation status of T cells and MDSCs in TDLNs in the absence of VSIG4 signaling.

FIGURE 17D is a set of graphs showing activation status of T cells and MDSCs in TDLNs in the absence of VSIG4 signaling.

10 FIGURE 18A is a graph showing suppression of tumor growth in the absence of VSIG4 signaling.

FIGURE 18B is a set of histological slides showing suppression of tumor growth in the absence of VSIG4 signaling.

15 FIGURE 19 is a graph showing anti-tumor activities of anti-VSIG4 antibody in humanized mouse model.

FIGURE 20 is a schematic diagram illustrating mechanism of how administration of EU103.2
20 antibody to macrophages results in conversion of M2 macrophages to M1 macrophages, which results in proliferation of CD8⁺ T cells.

FIGURES 21A and 21B are schematic diagrams showing expression vectors used to clone and express humanized anti-VSIG4 antibodies.

25 FIGURE 22 is a HPLC plot showing protein profile of A1 antibody (EU103_T01.01).

FIGURE 23 is a HPLC plot showing protein profile of A2 antibody (EU103_T01.02).

30 FIGURE 24 is a HPLC plot showing protein profile of A1.3 antibody (EU103_T01.01S).

FIGURE 25 is a HPLC plot showing protein profile of A2.3 antibody (EU103_T01.02S).

FIGURE 26A is a set of FACS data showing decreased expression of CD163 in M2 macrophages treated with A1 or A2 antibodies.

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FIGURE 26B is a graph showing decreased expression of CD163 in M2 macrophages treated with A1 or A2 antibodies.

FIGURE 27 is a set of graphs showing decrease of M2 type cytokines and chemokines in M2 cells treated with A1 or A2 antibodies.

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FIGURE 28 is a set of FACS data showing decreased expression of CD163 and an increased expression of CD86 in M2 macrophages treated with A1 or A2 antibodies.

FIGURE 29 is a set of graphs showing increased expression of M1 type cytokine/chemokines in M2 macrophages treated with A1 or A2 antibodies.

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FIGURE 30 is a graph showing data from a chemotaxis assay measuring the chemotactic ability of macrophages after the M2 to M1 macrophage conversion by A2 antibodies.

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FIGURES 31A-31C show the anti-tumor effect of A1 and A2 antibodies in a humanized mouse model.

FIGURES 32A-32C show macrophage conversion with A2 antibodies *in vivo*.

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FIGURES 33A and 33B show macrophage conversion with A2 antibodies *in vivo* by analyzing the effect of M2 conversion to M1 macrophages on tumor growth.

FIGURES 34A-34E show the anti-tumor effect of A2 antibodies in a humanized mouse model.

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FIGURES 35A-35D show the anti-tumor effect of A2 and A2.3 antibodies in a humanized mouse model.

5 FIGURES 36A and 36B are set of data from a co-culture assay showing co-cultures of A1, A1.3, A2, and A2.3 antibodies and M2 macrophages showed increase of CD8⁺ T cell proliferation.

FIGURE 37 is a graph showing data from a co-culture assay showing co-cultures of A2 and A2.3 antibodies with M2 macrophages showed increase of CD8⁺ T cell proliferation.

10 FIGURES 38A and 38B are set of graphs showing the use of hVSIG4 expressing HeLa-hVSIG4 cells to observe CD8⁺ T cell proliferation by A2 or A2.3 antibodies.

FIGURE 39 is a graph showing the use of human phosphor-kinase array to observe the signal pathway of the macrophage conversion by A2 antibodies.

15 FIGURE 40 shows sequence alignment of heavy chains and light chains of humanized EU103.3, A1, A2, A1.3, and A2.3 antibodies.

FIGURE 41 shows generation and characterization of VSIG4 K/O Mice.

20 FIGURE 42 is data from gene array analysis showing change in gene expression after conversion of M2 macrophages to M1 macrophages by A2 antibodies.

DETAILED DESCRIPTION

25 The present invention is based, at least in part, on the discovery that inhibition of VSIG4 interaction with CD8⁺ T cells using certain anti-VSIG4 antibodies result in proliferation of CD8⁺ T cells, which can lead to suppression of cancer.

30 As used herein, the term “about”, when used herein in reference to a value, refers to a value that is similar, in context to the referenced value. In general, those skilled in the art, familiar with the context, will appreciate the relevant degree of variance encompassed by “about” in that context.

For example, in some embodiments, the term “about” may encompass a range of values that within 25%, 20%, 19%, 18%, 17%, 16%, 15%, 14%, 13%, 12%, 11%, 10%, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, or less of the referred value.

5 As used herein, the term “administration” typically refers to the administration of a composition to a subject or system to achieve delivery of an agent that is, or is included in, the composition. Those of ordinary skill in the art will be aware of a variety of routes that may, in appropriate circumstances, be utilized for administration to a subject, for example a human. For example, in some embodiments, administration may be ocular, oral, parenteral, topical, etc. In some
10 particular embodiments, administration may be bronchial (e.g., by bronchial instillation), buccal, dermal (which may be or comprise, for example, one or more of topical to the dermis, intradermal, interdermal, transdermal, etc), enteral, intra-arterial, intradermal, intragastric, intramedullary, intramuscular, intranasal, intraperitoneal, intrathecal, intravenous, intraventricular, within a specific organ (e.g. intrahepatic), mucosal, nasal, oral, rectal,
15 subcutaneous, sublingual, topical, tracheal (e.g., by intratracheal instillation), vaginal, vitreal, etc. In some embodiments, administration may involve only a single dose. In some embodiments, administration may involve application of a fixed number of doses. In some embodiments, administration may involve dosing that is intermittent (e.g., a plurality of doses separated in time) and/or periodic (e.g., individual doses separated by a common period of time) dosing. In
20 some embodiments, administration may involve continuous dosing (e.g., perfusion) for at least a selected period of time.

As used herein, the term “affinity” typically refers to a measure of the tightness with a particular ligand binds to its partner. Affinities can be measured in different ways. In some embodiments,
25 affinity is measured by a quantitative assay. In some such embodiments, binding partner concentration may be fixed to be in excess of ligand concentration so as to mimic physiological conditions. Alternatively or additionally, in some embodiments, binding partner concentration and/or ligand concentration may be varied. In some such embodiments, affinity may be compared to a reference under comparable conditions (e.g., concentrations).

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As used herein, the term “affinity maturation” refers to a process in which an antibody is evolved from a reference antibody (also referred to herein as a template or parent antibody), typically by mutation of one or more amino acid residues, to have increased activity for a target antigen than a corresponding form of the reference antibody has for the same target antigen. Hence, the evolved antibody is optimized compared to the reference or template antibody. As used herein, the term “affinity matured antibody” typically refers to an antibody that has an increased activity for a target antigen relative to a reference antibody. In some embodiments, the affinity matured antibody exhibits increased binding to the target antigen compared to the reference or parent antibody. Typically, the affinity matured antibody binds to the same epitope as the reference antibody.

As used herein, the term “antibody” refers to a polypeptide that includes canonical immunoglobulin sequence elements sufficient to confer specific binding to a particular target antigen. As is known in the art, intact antibodies as produced in nature are approximately 150 kD tetrameric agents comprised of two identical heavy chain polypeptides (about 50 kD each) and two identical light chain polypeptides (about 25 kD each) that associate with each other into what is commonly referred to as a “Y-shaped” structure. Each heavy chain is comprised of at least four domains (each about 110 amino acids long)—an amino-terminal variable (VH) domain (located at the tips of the Y structure), followed by three constant domains: CH1, CH2, and the carboxy-terminal CH3 (located at the base of the Y’s stem). A short region, known as the “switch”, connects the heavy chain variable and constant regions. The “hinge” connects CH2 and CH3 domains to the rest of the antibody. Two disulfide bonds in this hinge region connect the two heavy chain polypeptides to one another in an intact antibody. Each light chain is comprised of two domains—an amino-terminal variable (VL) domain, followed by a carboxy-terminal constant (CL) domain, separated from one another by another “switch”. Intact antibody tetramers are comprised of two heavy chain-light chain dimers in which the heavy and light chains are linked to one another by a single disulfide bond; two other disulfide bonds connect the heavy chain hinge regions to one another, so that the dimers are connected to one another and the tetramer is formed. Naturally-produced antibodies are also glycosylated, typically on the CH2 domain. Each domain in a natural antibody has a structure characterized by an “immunoglobulin fold” formed from two beta sheets (e.g., 3-, 4-, or 5-stranded sheets) packed against each other in

a compressed antiparallel beta barrel. Each variable domain contains three hypervariable loops known as “complement determining regions” (CDR1, CDR2, and CDR3) and four somewhat invariant “framework” regions (FR1, FR2, FR3, and FR4). When natural antibodies fold, the FR regions form the beta sheets that provide the structural framework for the domains, and the CDR

5 loop regions from both the heavy and light chains are brought together in three-dimensional space so that they create a single hypervariable antigen binding site located at the tip of the Y structure. The Fc region of naturally-occurring antibodies binds to elements of the complement system, and also to receptors on effector cells, including for example effector cells that mediate cytotoxicity. As is known in the art, affinity and/or other binding attributes of Fc regions for Fc

10 receptors can be modulated through glycosylation or other modification. In some embodiments, antibodies produced and/or utilized in accordance with the present invention include glycosylated Fc domains, including Fc domains with modified or engineered such glycosylation. For purposes of the present invention, in certain embodiments, any polypeptide or complex of polypeptides that includes sufficient immunoglobulin domain sequences as found in natural

15 antibodies can be referred to and/or used as an “antibody”, whether such polypeptide is naturally produced (e.g., generated by an organism reacting to an antigen), or produced by recombinant engineering, chemical synthesis, or other artificial system or methodology. In some embodiments, an antibody is polyclonal; in some embodiments, an antibody is monoclonal. In some embodiments, an antibody has constant region sequences that are characteristic of mouse,

20 rabbit, primate, or human antibodies. In some embodiments, antibody sequence elements are humanized, primatized, chimeric, etc, as is known in the art. Moreover, the term “antibody” as used herein, can refer in appropriate embodiments (unless otherwise stated or clear from context) to any of the art-known or developed constructs or formats for utilizing antibody structural and functional features in alternative presentation. For example, embodiments, an antibody utilized in

25 accordance with the present invention is in a format selected from, but not limited to, intact IgA, IgG, IgE or IgM antibodies; bi- or multi-specific antibodies (e.g., Zybodies®, etc); antibody fragments such as Fab fragments, Fab' fragments, F(ab')₂ fragments, Fd' fragments, Fd fragments, and isolated CDRs or sets thereof; single chain Fvs; polypeptide-Fc fusions; single domain antibodies (e.g., shark single domain antibodies such as IgNAR or fragments thereof);

30 cameloid antibodies; masked antibodies (e.g., Probodies®); Small Modular ImmunoPharmaceuticals (“SMIPs™”); single chain or Tandem diabodies (TandAb®);

humabodies, VHHs; Anticalins®; Nanobodies® minibodies; BiTE®s; ankyrin repeat proteins or DARPINs®; Avimers®; DARTs; TCR-like antibodies; Adnectins®; Affilins®; Trans-bodies®; Affibodies®; TrimerX®; MicroProteins; Fynomers®, Centyrins®, and KALBITOR®s. In some embodiments, an antibody may lack a covalent modification (e.g., attachment of a glycan) that it would have if produced naturally. In some embodiments, an antibody may contain a covalent modification (e.g., attachment of a glycan, a payload [e.g., a detectable moiety, a therapeutic moiety, a catalytic moiety, etc], or other pendant group [e.g., poly-ethylene glycol, etc].

As used herein, an “antibody fragment” refers to a portion of an antibody or antibody agent as described herein, and typically refers to a portion that includes an antigen-binding portion or variable region thereof. An antibody fragment may be produced by any means. For example, in some embodiments, an antibody fragment may be enzymatically or chemically produced by fragmentation of an intact antibody or antibody agent. Alternatively, in some embodiments, an antibody fragment may be recombinantly produced (i.e., by expression of an engineered nucleic acid sequence. In some embodiments, an antibody fragment may be wholly or partially synthetically produced. In some embodiments, an antibody fragment (particularly an antigen-binding antibody fragment) may have a length of at least about 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190 amino acids or more, in some embodiments at least about 200 amino acids.

As used herein, the term “binding” typically refers to a non-covalent association between or among two or more entities. “Direct” binding involves physical contact between entities or moieties; indirect binding involves physical interaction by way of physical contact with one or more intermediate entities. Binding between two or more entities can typically be assessed in any of a variety of contexts—including where interacting entities or moieties are studied in isolation or in the context of more complex systems (e.g., while covalently or otherwise associated with a carrier entity and/or in a biological system or cell).

As used herein, the terms “cancer”, “malignancy”, “neoplasm”, “tumor”, and “carcinoma” typically refer to cells that exhibit relatively abnormal, uncontrolled, and/or autonomous growth, so that they exhibit an aberrant growth phenotype characterized by a significant loss of control of

cell proliferation. In some embodiments, a tumor may be or comprise cells that are precancerous (e.g., benign), malignant, pre-metastatic, metastatic, and/or non-metastatic. The present disclosure specifically identifies certain cancers to which its teachings may be particularly relevant. In some embodiments, a relevant cancer may be characterized by a solid tumor. In
5 some embodiments, a relevant cancer may be characterized by a hematologic tumor. In general, examples of different types of cancers known in the art include, for example, hematopoietic cancers including leukemias, lymphomas (Hodgkin's and non-Hodgkin's), myelomas and myeloproliferative disorders; sarcomas, melanomas, adenomas, carcinomas of solid tissue, squamous cell carcinomas of the mouth, throat, larynx, and lung, liver cancer, genitourinary
10 cancers such as prostate, cervical, bladder, uterine, and endometrial cancer and renal cell carcinomas, bone cancer, pancreatic cancer, skin cancer, cutaneous or intraocular melanoma, cancer of the endocrine system, cancer of the thyroid gland, cancer of the parathyroid gland, head and neck cancers, breast cancer, gastro-intestinal cancers and nervous system cancers, benign lesions such as papillomas, and the like.

15 As used herein, the term “CDR” refers to a complementarity determining region within an antibody variable region. There are three CDRs in each of the variable regions of the heavy chain and the light chain, which are designated CDR1, CDR2 and CDR3, for each of the variable regions. A “set of CDRs” or “CDR set” refers to a group of three or six CDRs that occur in either
20 a single variable region capable of binding the antigen or the CDRs of cognate heavy and light chain variable regions capable of binding the antigen. Certain systems have been established in the art for defining CDR boundaries (e.g., Kabat, Chothia, etc.); those skilled in the art appreciate the differences between and among these systems and are capable of understanding CDR boundaries to the extent required to understand and to practice the claimed invention.

25 As used herein, the term “chemotherapeutic agent” has its art-understood meaning referring to one or more pro-apoptotic, cytostatic and/or cytotoxic agents, for example specifically including agents utilized and/or recommended for use in treating one or more diseases, disorders or conditions associated with undesirable cell proliferation. In many embodiments,
30 chemotherapeutic agents are useful in the treatment of cancer. In some embodiments, a chemotherapeutic agent may be or comprise one or more alkylating agents, one or more

anthracyclines, one or more cytoskeletal disruptors (e.g. microtubule targeting agents such as taxanes, maytansine and analogs thereof, of), one or more epothilones, one or more histone deacetylase inhibitors HDACs), one or more topoisomerase inhibitors (e.g., inhibitors of topoisomerase I and/or topoisomerase II), one or more kinase inhibitors, one or more nucleotide
5 analogs or nucleotide precursor analogs, one or more peptide antibiotics, one or more platinum-based agents, one or more retinoids, one or more vinca alkaloids, and/or one or more analogs of one or more of the following (i.e., that share a relevant anti-proliferative activity). In some particular embodiments, a chemotherapeutic agent may be or comprise one or more of Actinomycin, All-trans retinoic acid, an Auiristatin, Azacitidine, Azathioprine, Bleomycin,
10 Bortezomib, Carboplatin, Capecitabine, Cisplatin, Chlorambucil, Cyclophosphamide, Curcumin, Cytarabine, Daunorubicin, Docetaxel, Doxifluridine, Doxorubicin, Epirubicin, Epothilone, Etoposide, Fluorouracil, Gemcitabine, Hydroxyurea, Idarubicin, Imatinib, Irinotecan, Maytansine and/or analogs thereof (e.g. DM1) Mechlorethamine, Mercaptopurine, Methotrexate, Mitoxantrone, a Maytansinoid, Oxaliplatin, Paclitaxel, Pemetrexed, Teniposide, Tioguanine,
15 Topotecan, Valrubicin, Vinblastine, Vincristine, Vindesine, Vinorelbine, and combinations thereof. In some embodiments, a chemotherapeutic agent may be utilized in the context of an antibody-drug conjugate. In some embodiments, a chemotherapeutic agent is one found in an antibody-drug conjugate selected from the group consisting of: hLL1-doxorubicin, hRS7-SN-38, hMN-14-SN-38, hLL2-SN-38, hA20-SN-38, hPAM4-SN-38, hLL1-SN-38, hRS7-Pro-2-P-Dox,
20 hMN-14-Pro-2-P-Dox, hLL2-Pro-2-P-Dox, hA20-Pro-2-P-Dox, hPAM4-Pro-2-P-Dox, hLL1-Pro-2-P-Dox, P4/D10-doxorubicin, gemtuzumab ozogamicin, brentuximab vedotin, trastuzumab emtansine, inotuzumab ozogamicin, glembatumomab vedotin, SAR3419, SAR566658, BIIBO15, BT062, SGN-75, SGN-CD19A, AMG-172, AMG-595, BAY-94-9343, ASG-5ME, ASG-22ME, ASG-16M8F, MDX-1203, MLN-0264, anti-PSMA ADC, RG-7450, RG-7458, RG-
25 7593, RG-7596, RG-7598, RG-7599, RG-7600, RG-7636, ABT-414, IMGN-853, IMGN-529, vorsetuzumab mafodotin, and lorvotuzumab mertansine.

As used herein, the term “combination therapy” refers to those situations in which a subject is simultaneously exposed to two or more therapeutic regimens (e.g., two or more therapeutic
30 agents). In some embodiments, the two or more therapeutic regimens may be administered simultaneously. In some embodiments, the two or more therapeutic regimens may be

administered sequentially (e.g., a first regimen administered prior to administration of any doses of a second regimen). In some embodiments, the two or more therapeutic regimens are administered in overlapping dosing regimens. In some embodiments, administration of combination therapy may involve administration of one or more therapeutic agents or modalities to a subject receiving the other agent(s) or modality.

As used herein, the term “framework” or “framework region” refers to the sequences of a variable region minus the CDRs. Because a CDR sequence can be determined by different systems, likewise a framework sequence is subject to correspondingly different interpretations. The six CDRs divide the framework regions on the heavy and light chains into four sub-regions (FR1, FR2, FR3 and FR4) on each chain, in which CDR1 is positioned between FR1 and FR2, CDR2 between FR2 and FR3, and CDR3 between FR3 and FR4. Without specifying the particular sub-regions as FR1, FR2, FR3 or FR4, a framework region, as referred by others, represents the combined FRs within the variable region of a single, naturally occurring immunoglobulin chain. As used herein, a FR represents one of the four sub-regions, FR1, for example, represents the first framework region closest to the amino terminal end of the variable region and 5' with respect to CDR1, and FRs represents two or more of the sub-regions constituting a framework region.

As used herein, the term “humanized” is commonly used to refer to antibodies (or antibody components) whose amino acid sequence includes V_H and V_L region sequences from a reference antibody raised in a non-human species (e.g., a mouse), but also includes modifications in those sequences relative to the reference antibody intended to render them more “human-like”, i.e., more similar to human germline variable sequences. In some embodiments, a “humanized” antibody (or antibody component) is one that immunospecifically binds to an antigen of interest and that has a framework (FR) region having substantially the amino acid sequence as that of a human antibody, and a complementary determining region (CDR) having substantially the amino acid sequence as that of a non-human antibody. A humanized antibody comprises substantially all of at least one, and typically two, variable domains (Fab, Fab', F(ab')₂, FabC, Fv) in which all or substantially all of the CDR regions correspond to those of a non-human immunoglobulin (i.e., donor immunoglobulin) and all or substantially all of the framework regions are those of a

human immunoglobulin consensus sequence. In some embodiments, a humanized antibody also comprises at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin constant region. In some embodiments, a humanized antibody contains both the light chain as well as at least the variable domain of a heavy chain. The antibody also may
5 include a C_H1, hinge, C_H2, C_H3, and, optionally, a C_H4 region of a heavy chain constant region.

As used herein, the term “*in vitro*” refers to events that occur in an artificial environment, e.g., in a test tube or reaction vessel, in cell culture, etc., rather than within a multi-cellular organism. As used herein, the term “*in vivo*” refers to events that occur within a multi-cellular organism,
10 such as a human and a non-human animal. In the context of cell-based systems, the term may be used to refer to events that occur within a living cell (as opposed to, for example, *in vitro* systems).

As used herein, the term “isolated” refers to a substance and/or entity that has been (1) separated
15 from at least some of the components with which it was associated when initially produced (whether in nature and/or in an experimental setting), and/or (2) designed, produced, prepared, and/or manufactured by the hand of man. Isolated substances and/or entities may be separated from about 10%, about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about
20 97%, about 98%, about 99%, or more than about 99% of the other components with which they were initially associated. In some embodiments, isolated agents are about 80%, about 85%, about 90%, about 91%, about 92%, about 93%, about 94%, about 95%, about 96%, about 97%, about 98%, about 99%, or more than about 99% pure. As used herein, a substance is “pure” if it is substantially free of other components. In some embodiments, as will be understood by those
25 skilled in the art, a substance may still be considered “isolated” or even “pure”, after having been combined with certain other components such as, for example, one or more carriers or excipients (e.g., buffer, solvent, water, etc.); in such embodiments, percent isolation or purity of the substance is calculated without including such carriers or excipients. To give but one example, in some embodiments, a biological polymer such as a polypeptide or polynucleotide that occurs in
30 nature is considered to be “isolated” when, a) by virtue of its origin or source of derivation is not associated with some or all of the components that accompany it in its native state in nature; b) it

is substantially free of other polypeptides or nucleic acids of the same species from the species that produces it in nature; c) is expressed by or is otherwise in association with components from a cell or other expression system that is not of the species that produces it in nature. Thus, for instance, in some embodiments, a polypeptide that is chemically synthesized or is synthesized in a cellular system different from that which produces it in nature is considered to be an “isolated” polypeptide. Alternatively or additionally, in some embodiments, a polypeptide that has been subjected to one or more purification techniques may be considered to be an “isolated” polypeptide to the extent that it has been separated from other components a) with which it is associated in nature; and/or b) with which it was associated when initially produced.

As used herein, the term “ K_D ” refers to the dissociation constant of a binding agent (e.g., an antibody or binding component thereof) from a complex with its partner (e.g., the epitope to which the antibody or binding component thereof binds).

As used herein, the term “macrophage” refers to a cell of the monocyte/macrophage lineage which is found in the spleen or has differentiated into a tissue macrophage. These cells include follicular dendritic cells (FDC), dendritic cells, Langerhans cells, as well as other tissue macrophages. Macrophages are phagocytes and antigen presenting cells that differentiate from monocytes in circulating peripheral blood. They play an important role in both innate and adaptive immunity by activating T lymphocytes. Macrophages that activate Th1 T lymphocytes provide an inflammatory response and are denoted M1 macrophages. M1 macrophages, also referred to as “killer macrophages,” inhibit cell proliferation, cause tissue damage, and are aggressive against bacteria. Macrophages that activate Th2 T lymphocytes provide an anti-inflammatory response and are denoted M2 macrophages. M2 macrophages, also referred to as “repair macrophages,” promote cell proliferation and tissue repair and are anti-inflammatory. As used herein, the term “tumor associated macrophages” (TAMs) generally refers to macrophages that exist in the microenvironment of a cancer, for example, a tumor.

As used herein, the term “operably linked” refers to a juxtaposition wherein the components described are in a relationship permitting them to function in their intended manner. A control element “operably linked” to a functional element is associated in such a way that expression and/or activity of the functional element is achieved under conditions compatible with the

control element. In some embodiments, “operably linked” control elements are contiguous (e.g., covalently linked) with the coding elements of interest; in some embodiments, control elements act in trans to or otherwise at a from the functional element of interest.

5 As used herein, the term “pharmaceutical composition” refers to a composition in which an active agent is formulated together with one or more pharmaceutically acceptable carriers. In some embodiments, the composition is suitable for administration to a human or animal subject. In some embodiments, the active agent is present in unit dose amount appropriate for administration in a therapeutic regimen that shows a statistically significant probability of achieving a predetermined therapeutic effect when administered to a relevant population.

10 As used herein, the term “polypeptide” generally has its art-recognized meaning of a polymer of at least three amino acids. Those of ordinary skill in the art will appreciate that the term “polypeptide” is intended to be sufficiently general as to encompass not only polypeptides having a complete sequence recited herein, but also to encompass polypeptides that represent functional fragments (i.e., fragments retaining at least one activity) of such complete polypeptides. Moreover, those of ordinary skill in the art understand that protein sequences generally tolerate some substitution without destroying activity. Thus, any polypeptide that retains activity and shares at least about 30-40% overall sequence identity, often greater than about 50%, 60%, 70%, or 80%, and further usually including at least one region of much higher identity, often greater than 90% or even 95%, 96%, 97%, 98%, or 99% in one or more highly conserved regions, usually encompassing at least 3-4 and often up to 20 or more amino acids, with another polypeptide of the same class, is encompassed within the relevant term “polypeptide” as used herein. Polypeptides may contain L-amino acids, D-amino acids, or both and may contain any of a variety of amino acid modifications or analogs known in the art. Useful

25 modifications include, e.g., terminal acetylation, amidation, methylation, etc. In some embodiments, proteins may comprise natural amino acids, non-natural amino acids, synthetic amino acids, and combinations thereof. The term “peptide” is generally used to refer to a polypeptide having a length of less than about 100 amino acids, less than about 50 amino acids, less than 20 amino acids, or less than 10 amino acids. In some embodiments, proteins are antibodies, antibody fragments, biologically active portions thereof, and/or characteristic portions thereof.

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As used herein, the term “prevent” or “prevention” when used in connection with the occurrence of a disease, disorder, and/or condition, refers to reducing the risk of developing the disease, disorder and/or condition and/or to delaying onset and/or severity of one or more characteristics or symptoms of the disease, disorder or condition. In some embodiments, prevention is assessed on a population basis such that an agent is considered to “prevent” a particular disease, disorder or condition if a statistically significant decrease in the development, frequency, and/or intensity of one or more symptoms of the disease, disorder or condition is observed in a population susceptible to the disease, disorder, or condition.

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As used herein, the term “recombinant” is intended to refer to polypeptides that are designed, engineered, prepared, expressed, created, manufactured, and/or or isolated by recombinant means, such as polypeptides expressed using a recombinant expression vector transfected into a host cell; polypeptides isolated from a recombinant, combinatorial human polypeptide library; polypeptides isolated from an animal (e.g., a mouse, rabbit, sheep, fish, etc) that is transgenic for or otherwise has been manipulated to express a gene or genes, or gene components that encode and/or direct expression of the polypeptide or one or more component(s), portion(s), element(s), or domain(s) thereof; and/or polypeptides prepared, expressed, created or isolated by any other means that involves splicing or ligating selected nucleic acid sequence elements to one another, chemically synthesizing selected sequence elements, and/or otherwise generating a nucleic acid that encodes and/or directs expression of the polypeptide or one or more component(s), portion(s), element(s), or domain(s) thereof. In some embodiments, one or more of such selected sequence elements is found in nature. In some embodiments, one or more of such selected sequence elements is designed in silico. In some embodiments, one or more such selected sequence elements results from mutagenesis (e.g., *in vivo* or *in vitro*) of a known sequence element, e.g., from a natural or synthetic source such as, for example, in the germline of a source organism of interest (e.g., of a human, a mouse, etc).

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As used herein, the term “specific binding” refers to an ability to discriminate between possible binding partners in the environment in which binding is to occur. A binding agent that interacts with one particular target when other potential targets are present is said to “bind specifically” to

the target with which it interacts. In some embodiments, specific binding is assessed by detecting or determining degree of association between the binding agent and its partner; in some embodiments, specific binding is assessed by detecting or determining degree of dissociation of a binding agent-partner complex; in some embodiments, specific binding is assessed by detecting
5 or determining ability of the binding agent to compete an alternative interaction between its partner and another entity. In some embodiments, specific binding is assessed by performing such detections or determinations across a range of concentrations.

As used herein, the term “subject” refers an organism, typically a mammal (e.g., a human, in
10 some embodiments including prenatal human forms). In some embodiments, a subject is suffering from a relevant disease, disorder or condition. In some embodiments, a subject is susceptible to a disease, disorder, or condition. In some embodiments, a subject displays one or more symptoms or characteristics of a disease, disorder or condition. In some embodiments, a subject does not display any symptom or characteristic of a disease, disorder, or condition. In
15 some embodiments, a subject is someone with one or more features characteristic of susceptibility to or risk of a disease, disorder, or condition. In some embodiments, a subject is a patient. In some embodiments, a subject is an individual to whom diagnosis and/or therapy is and/or has been administered.

20 As used herein, the phrase “therapeutic agent” in general refers to any agent that elicits a desired pharmacological effect when administered to an organism. In some embodiments, an agent is considered to be a therapeutic agent if it demonstrates a statistically significant effect across an appropriate population. In some embodiments, the appropriate population may be a population of model organisms. In some embodiments, an appropriate population may be defined by various
25 criteria, such as a certain age group, gender, genetic background, preexisting clinical conditions, etc. In some embodiments, a therapeutic agent is a substance that can be used to alleviate, ameliorate, relieve, inhibit, prevent, delay onset of, reduce severity of, and/or reduce incidence of one or more symptoms or features of a disease, disorder, and/or condition. In some embodiments, a “therapeutic agent” is an agent that has been or is required to be approved by a
30 government agency before it can be marketed for administration to humans. In some

embodiments, a “therapeutic agent” is an agent for which a medical prescription is required for administration to humans.

As used herein, the term “therapeutically effective amount” means an amount that is sufficient, when administered to a population suffering from or susceptible to a disease, disorder, and/or condition in accordance with a therapeutic dosing regimen, to treat the disease, disorder, and/or condition. In some embodiments, a therapeutically effective amount is one that reduces the incidence and/or severity of, stabilizes one or more characteristics of, and/or delays onset of, one or more symptoms of the disease, disorder, and/or condition. Those of ordinary skill in the art will appreciate that the term “therapeutically effective amount” does not in fact require successful treatment be achieved in a particular individual. Rather, a therapeutically effective amount may be that amount that provides a particular desired pharmacological response in a significant number of subjects when administered to patients in need of such treatment. For example, in some embodiments, term “therapeutically effective amount”, refers to an amount which, when administered to an individual in need thereof in the context of inventive therapy, will block, stabilize, attenuate, or reverse a cancer-supportive process occurring in said individual, or will enhance or increase a cancer-suppressive process in said individual. In the context of cancer treatment, a “therapeutically effective amount” is an amount which, when administered to an individual diagnosed with a cancer, will prevent, stabilize, inhibit, or reduce the further development of cancer in the individual. A particularly preferred “therapeutically effective amount” of a composition described herein reverses (in a therapeutic treatment) the development of a malignancy such as a pancreatic carcinoma or helps achieve or prolong remission of a malignancy. A therapeutically effective amount administered to an individual to treat a cancer in that individual may be the same or different from a therapeutically effective amount administered to promote remission or inhibit metastasis. As with most cancer therapies, the therapeutic methods described herein are not to be interpreted as, restricted to, or otherwise limited to a “cure” for cancer; rather the methods of treatment are directed to the use of the described compositions to “treat” a cancer, i.e., to effect a desirable or beneficial change in the health of an individual who has cancer. Such benefits are recognized by skilled healthcare providers in the field of oncology and include, but are not limited to, a stabilization of patient condition, a decrease in tumor size (tumor regression), an improvement in vital functions (e.g.,

improved function of cancerous tissues or organs), a decrease or inhibition of further metastasis, a decrease in opportunistic infections, an increased survivability, a decrease in pain, improved motor function, improved cognitive function, improved feeling of energy (vitality, decreased malaise), improved feeling of well-being, restoration of normal appetite, restoration of healthy weight gain, and combinations thereof. In addition, regression of a particular tumor in an individual (e.g., as the result of treatments described herein) may also be assessed by taking samples of cancer cells from the site of a tumor such as a pancreatic adenocarcinoma (e.g., over the course of treatment) and testing the cancer cells for the level of metabolic and signaling markers to monitor the status of the cancer cells to verify at the molecular level the regression of the cancer cells to a less malignant phenotype. For example, tumor regression induced by employing the methods of this invention would be indicated by finding a decrease in any of the pro-angiogenic markers discussed above, an increase in anti-angiogenic markers described herein, the normalization (i.e., alteration toward a state found in normal individuals not suffering from cancer) of metabolic pathways, intercellular signaling pathways, or intracellular signaling pathways that exhibit abnormal activity in individuals diagnosed with cancer. Those of ordinary skill in the art will appreciate that, in some embodiments, a therapeutically effective amount may be formulated and/or administered in a single dose. In some embodiments, a therapeutically effective amount may be formulated and/or administered in a plurality of doses, for example, as part of a dosing regimen.

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As used herein in the context of molecules, e.g., nucleic acids, proteins, or small molecules, the term “variant” refers to a molecule that shows significant structural identity with a reference molecule but differs structurally from the reference molecule, e.g., in the presence or absence or in the level of one or more chemical moieties as compared to the reference entity. In some embodiments, a variant also differs functionally from its reference molecule. In general, whether a particular molecule is properly considered to be a “variant” of a reference molecule is based on its degree of structural identity with the reference molecule. As will be appreciated by those skilled in the art, any biological or chemical reference molecule has certain characteristic structural elements. A variant, by definition, is a distinct molecule that shares one or more such characteristic structural elements but differs in at least one aspect from the reference molecule. To give but a few examples, a polypeptide may have a characteristic sequence element

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comprised of a plurality of amino acids having designated positions relative to one another in linear or three-dimensional space and/or contributing to a particular structural motif and/or biological function; a nucleic acid may have a characteristic sequence element comprised of a plurality of nucleotide residues having designated positions relative to on another in linear or three-dimensional space. In some embodiments, a variant polypeptide or nucleic acid may differ from a reference polypeptide or nucleic acid as a result of one or more differences in amino acid or nucleotide sequence. In some embodiments, a variant polypeptide or nucleic acid shows an overall sequence identity with a reference polypeptide or nucleic acid that is at least 85%, 86%, 87%, 88%, 89%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, or 99%. In some embodiments, a variant polypeptide or nucleic acid does not share at least one characteristic sequence element with a reference polypeptide or nucleic acid. In some embodiments, a reference polypeptide or nucleic acid has one or more biological activities. In some embodiments, a variant polypeptide or nucleic acid shares one or more of the biological activities of the reference polypeptide or nucleic acid.

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As used herein, the term “vector” refers to a nucleic acid molecule capable of transporting another nucleic acid to which it has been linked. One type of vector is a “plasmid”, which refers to a circular double stranded DNA loop into which additional DNA segments may be ligated. Another type of vector is a viral vector, wherein additional DNA segments may be ligated into the viral genome. Certain vectors are capable of autonomous replication in a host cell into which they are introduced (e.g., bacterial vectors having a bacterial origin of replication and episomal mammalian vectors). Other vectors (e.g., non-episomal mammalian vectors) can be integrated into the genome of a host cell upon introduction into the host cell, and thereby are replicated along with the host genome. Moreover, certain vectors are capable of directing the expression of genes to which they are operatively linked. Such vectors are referred to herein as “expression vectors.” Standard techniques may be used for recombinant DNA, oligonucleotide synthesis, and tissue culture and transformation (e.g., electroporation, lipofection). Enzymatic reactions and purification techniques may be performed according to manufacturer's specifications or as commonly accomplished in the art or as described herein. The foregoing techniques and procedures may be generally performed according to conventional methods well known in the art and as described in various general and more specific references that are cited and discussed

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throughout the present specification. See e.g., Sambrook et al., *Molecular Cloning: A Laboratory Manual* (2nd ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989)), which is incorporated herein by reference for any purpose.

5 **Macrophages in Cancer**

Macrophages are phagocytes and antigen presenting cells that differentiate from monocytes in circulating peripheral blood. These cells have been known to play an important role in both innate and adaptive immunity by activating T lymphocytes. Macrophages that activate Th1 T lymphocytes provide an inflammatory response and are denoted M1 macrophages. M1
10 macrophages, also referred to as “killer macrophages,” inhibit cell proliferation, cause tissue damage, and are aggressive against bacteria. Macrophages that activate Th2 T lymphocytes provide an anti-inflammatory response and are denoted M2 macrophages. M2 macrophages, also referred to as “repair macrophages,” promote cell proliferation and tissue repair and are anti-inflammatory.

15 While macrophages are formed through differentiation of monocytes, monocytes mature into either M1 (CD 68⁺ and CD80⁺) or M2 (CD68⁺ and CD163⁺) macrophages depending on the cytokines and growth factors that cause them to differentiate. Lipopolysaccharide (LPS) and interferon gamma (IFN γ) activate monocytes to differentiate into M1 macrophages that secrete high levels of interleukin-1 (IL-1) and interleukin-12 (IL-12) and low levels of interleukin-10
20 (IL-10). Alternatively, interleukin-4 (IL-4), IL-10, interleukin-1 receptor antagonist (IL-1ra) and transforming growth factor beta (TGF β) activate monocytes to differentiate into M2 macrophages that secrete high levels of IL-10, TGF β , and insulin-like growth factor 1 (IGF-1) and low levels of IL-12.

The role of immunity in oncogenesis has been increasingly appreciated. Since macrophages are
25 known to play important roles in both innate and adaptive immunity and they have been recognized as key components of tumors and their microenvironment. Tumor associated macrophages (TAMs) generally refer to macrophages that exist in the microenvironment of a cancer. The role of tumor-associated macrophages (TAMs) in the growth, invasion and metastasis of tumors has been extensively investigated and it is known that TAMs display a
30 broad spectrum of phenotypes, ranging from the M1-like phenotype in early stages of selected tumors to the M2-like phenotype in most advanced tumors. As evidence to its role in promoting

tumorigenesis, the M2 macrophages display the characteristic phenotype of elevated expression of IL-10, IL4, MMP, and VEGF, but decreased expression of pro-inflammatory cytokines and cytotoxic iNOs and ROIs, which are implicated in tumoricidal activities. Besides its intrinsic function in promoting tumorigenesis, TAMs also contribute to the suppression of anti-tumor immunity by alternating T-cell responses and balance in the tumor microenvironment.

Other than promoting cell proliferation playing an anti-inflammatory role, in cancer, M2 macrophages can induce vascularization in an area of a tumor. Therefore, in such scenarios it would be useful to inhibit the M2 polarization of macrophages and induce the M1 polarization of macrophages, which are known to attack tumor cells.

VSIG4

VSIG4 (V-set immunoglobulin-domain-containing 4) is a B7 family-related membrane protein belonging to complement receptor of the immunoglobulin superfamily (CRIg) which is known to negatively regulate CD8⁺ T cell proliferation and IL-2 production by binding iC3b and C3b. The expression of VSIG4 is restricted to tissue macrophages, including peritoneal macrophages and liver-residential Kupffer cells. Figures 2A and 2B shows VSIG4's relationship (homology and phylogeny relationships, respectively) with other B7 family of proteins (VSIG4 is referred to as EU103 in Figures 2A and 2B). Figure 2A shows amino acid sequence alignment of VSIG4 with various other B7 family proteins. Figures 2B shows evolutionary relationship between VSIG4 and other B family proteins.

Anti-VSIG4 Antibody to Treat Cancer

Tumor associated macrophages (TAM) are the key cells that create an immunosuppressive tumor microenvironment (TME) providing multiple targets for immunotherapies. Macrophages are also known to be highly plastic and can also repolarize and acquire an anti-tumorigenic M1-like phenotype.

Tumor-associated macrophages (TAMs) are typically known for their protumoral functions such as promotion of cancer cell motility, metastasis formation and angiogenesis. Formation of TAMs is dependent on microenvironmental factors which are present in developing tumors. TAMs are abundant in many cancers, especially in the tumor microenvironment, and often display an immune-suppressive M2-like phenotype that fosters tumor growth and promotes resistance to

therapy. TAMs also produce immunosuppressive cytokines like IL-10, TGF β and PGE₂, very small amount of NO or ROI and low levels of inflammatory cytokines such as IL-12, IL-1 β , TNF α , and IL-6. Conversion of macrophages to TAMs result in reduced ability to present tumor-associated antigens and stimulate anti-tumor functions of T and NK cells. Further, TAMs are not able to lyse tumor cells. Therefore, targeting of TAMs is a new therapeutic strategy for suppressing or treating cancer, for example by delivering agents to either alter the recruitment and distribution of TAMs, depleting existing TAMs, or inducing the re-education (or converting) of TAMs from an M2 to an M1 phenotype.

The present disclosure is based on the discovery that VSIG4 expressing M2 macrophages can be treated with humanized anti-VSIG4 antibodies to convert (or repolarize) the M2 macrophages to tumor-suppressive M1 macrophages, thereby inducing CD8⁺ T cell proliferation and proinflammatory cytokine production leading to tumor suppression. Further, the use of anti-VSIG4 antibodies can suppress cancer effectively by target both (1) conversion of M2 macrophages into M1 macrophages, and (2) inducing CD8⁺ T cell proliferation and proinflammatory cytokine production, thereby influencing the tumor microenvironment itself. This approach of using an anti-VSIG4 antibody to suppress cancer is superior to other therapies that only induce T cell proliferation or only block macrophages tumor-assisting activities. *See* Figure 1 (schematically showing the effects of anti-VSIG4 antibodies on macrophage function, its effects on T-cell proliferation, and subsequent cancer suppression.)

Humanization of Mouse Antibody

Although monoclonal antibodies can be rapidly produced by the mouse immune system for biological studies, in a clinical setting, the use of these murine antibodies can result in a human anti-mouse antibody response (HAMA). While chimeric antibodies can reduce anti-IgG responses in human, murine variable domains may still have provocative T-cell epitope content, necessitating “humanization” of their framework regions.

Classical antibody humanization generally begins by transferring all six murine complementarity determining regions (CDRs) onto a human antibody framework (Jones et al., *Nature* 321, 522-525 (1986)). These CDR-grafted antibodies generally do not retain their original affinity for antigen binding, and in fact, affinity is often severely impaired. Besides the CDRs, certain non-

human framework residues must also be incorporated into the variable domains to maintain proper CDR conformation (Chothia et al., *Nature* 342:877 (1989)). The incorporation of murine residues at key positions in the human frameworks to restore function is generally referred to as “back-mutations.” Back-mutations can support structural conformation of the grafted CDRs and restore antigen binding and affinity. Many of the framework positions that are likely to affect affinity have been identified, thus structural modeling to select new residues in a stepwise fashion can generally lead to variants with restored antigen binding. Alternatively, phage antibody libraries targeted at these residues can also be used to enhance and speed up the affinity maturation process (Wu et al., *J. Mol. Biol.* 294:151-162 (1999) and Wu, H., *Methods in Mol. Biol.* 207:197-212 (2003)).

Antibody Affinity Maturation

Affinity maturation is a process by which T_{FH} cell-activated B cells produce antibodies with increased affinity for a specific antigen during the course of an immune response. With repeated exposures to the same antigen, a host will produce antibodies of successively greater affinities. A secondary response can elicit antibodies with several fold greater affinity than in a primary response. Affinity maturation is an important strategy in antibody optimization to generate safe and efficacious second-generation therapeutics. Classically, therapeutic antibodies are obtained by immunizing mice or transgenic animals expressing human immunoglobulin genes with the desired antigen. Antigen-stimulated immune cells from these animals were transformed into hybridomas and subsequently screened to identify monoclonal antibodies with low nanomolar affinities for their target antigen. *In vivo*, natural affinity maturation by the immune system takes place by somatic hypermutation and clonal selection, while *in vitro*, in the laboratory affinity maturation, can be obtained by mutation and selection. Further, other methods for affinity maturation besides those using T_{FH} cell-activated B cells are known in the art, and are within the scope of the present disclosure.

EXAMPLES

The invention is further described in the following examples, which do not limit the scope of the invention described in the claims.

5

METHODS AND MATERIALS

The following methods and materials were used for the experiments described in the Examples.

CD14⁺ monocyte isolation from Human PBMC

10 Differentiation of macrophages into M1 or M2 macrophages was performed by isolating PBMC from subjects and incubating the macrophages in 50ng/ml hGM-CSF for 6 days to convert to M1 macrophages or incubating the macrophages in 100ng/ml M-CSF for 6d to convert to M2 macrophages (Figure 5).

Conversion of macrophages to M1 or M2 macrophages were confirmed by phenotype check
15 (Figures 6 and 7).

Subsequent conversion of M1 or M2 macrophages to M1 macrophages was performed by incubating the macrophages in LPS(100ng/ml)+IFN γ (100ng/ml) or 500ng/ml anti-VSIG4 antibody (EU103.2) for 24 hours (Figure 12).

Conversion of M1 or M2 macrophages into M2 macrophages was performed by incubating the
20 macrophages in 20ng/ml IL-4 for 24h (Figure 12).

Humanized Anti-VSIG4 Antibody – EU103.2 Antibody

EU103.2 antibody is a humanized anti-VSIG4 antibody generated from the mouse anti-VSIG4 antibody mu6H8. Figure 4A and 4B show biochemical characterization of EU103.2 antibody
25 using size-exclusion HPLC (Figure 4A) and surface plasmon resonance experiments, showing binding of VSIG4 to EU103.2 Antibody (Figure 4B). A summary of EU103.2 antibody purification data is shown in TABLE 1, below.

TABLE 1: SUMMARY OF SIZE EXCLUSION HPLC DATA FOR EU103.2 ANTIBODY

	concentration	Total per 30ml (x5) Expi293F transfection
EU103.2	1.2 mg/ml x 7ml 0.37 mg/ml x 2ml	9.14 mg

Humanization of Mouse Anti-VSIG4 Antibody – EU103.3 Antibody

Humanized anti-VSIG4 antibody hu6H8 (or EU103.3) was produced as described below.

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mu6H8 VH humanization

Framework for the humanized variant of VH was produced using mouse 6H8 antibody and Blast (<https://blast.ncbi.nlm.nih.gov/Blast.cgi?PAGE=Proteins>) (germline gene: VH2-5 / D3-3 / JH6c). Kabat numbering was used to classify the CDRs, and the humanized VH was designed with the framework and classified mu6H8 VH CDRs, back-mutations of VH2, VH27, VH30, VH93, and VH94. (hu6H8.3 VH)

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mu6H8 VL humanization

Framework for the humanized variant of VL was produced using mouse 6H8 antibody and Blast (<https://blast.ncbi.nlm.nih.gov/Blast.cgi?PAGE=Proteins>) (germline gene: A17 / JK2). Kabat numbering was used to classify the CDRs, and the humanized VL was designed with the framework and classified mu6H8 VL CDRs, back-mutations of VH2, VH4, VH36, and VH46. (hu6H8.3 VL)

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Cloning and Expressions of IgG antibody – EU103.3 Antibody

The heavy chain variable region sequence was modified by FES (L234F, L235E, P331S) mutations to construct heavy chain pOptivec (Invitrogen) expression plasmid without Fc effector functions, as shown in **Figure 21A**. The light chain variable region sequence was constructed using pcDNA3.3 (Invitrogen) and synthesized using IDT, as shown in **Figure 21B**. The gene encoding the heavy chain (HC) was flanked with EcoR1, Nhe1 restriction enzyme to construct the pOptivec (FES) plasmid vector and the gene encoding the light chain (LC) was flanked with EcoR1, BsiW1 restriction enzyme to construct the pcDNA3.3 plasmid vector. Cloning was done with the mutation sites sub-cloned into the hu6H8.3 backbone. The resulting insert genes and

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linearized vectors were each cloned with In-Fusion® HD Cloning Kit(Clontech) and the sequencing primer was identified with CMV Forward, EMCV IRES reverse primer.

VSIG4 Knock Out Mice

5 VSIG K/O mice were generated by homologous recombination replacing exon 1 with the neomycin resistance gene. A targeting vector was generated for use in homologous recombination in ES cells. E1 and E1 and E2 indicate exon 1 and 2 of the CRIG gene (Figure 41A). Homologous recombination of the CRIG allele in heterozygous female offspring from ES cell clone 1 and 2 (C1, C2) chimeric mice bred to WT mice was confirmed by Southern blot
10 (Figure 41B). Numbers of leukocytes in the peripheral blood of WT and K/O male and female mice were compared. Total blood cell counts were determined using a hemacytometer. Leukocytes were incubated with fluorochrome-conjugated antibodies specific to several cell surface markers and the numbers of different leukocyte subsets were determined by flow cytometry. Data represent mean + SD of 5–7 mice (Figure 41C).

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A1, A2, A1.3 and A2.3 Antibodies

A1 and A2 antibodies are generated by affinity maturation of EU103.3 antibody (see Table 2, below), where light chain variable regions at positions 76, 90, and/or 92 (kabat number) are mutated, as shown in Table 2 below.

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A1.3 and A2.3 antibodies are generated from A1 and A2 antibodies, respectively, to further improve affinity to VSIG4.

Figure 40 provides amino acid sequences alignment for heavy chains and light chains of
25 EU103.3, A1, A2, A1.3, and A2.3 are shown, along with consensus amino acid sequences for the heavy chain and light chain. Amino acid residues that differ between the different antibodies are shown in rectangular boxes.

TABLE 2: CLONES OF HUMANIZED ANTI-VSIG4 ANTIBODIES SCREENED IN AFFINITY MATURATION EXPERIMENTS

Ab name	Library	HC	LC	Mutation sites (HC) (Kabat number)	Mutation sites (LC) (Kabat number)
T01.01 (A1)	L3A	WT	T01L1	-	H90Q, R92G
T01.02 (A2)	L3A	WT	T01L2	-	L76F, H90Q, R92G
T01.03	L3B	WT	T01L3	-	L76F, H90Q, R92F
T01.04	L3B	WT	T01L4	-	L76F, H90Q, R92L
T01.05	H3B	T01H1	WT	N99H	-
T01.06	H3B	T01H2	WT	Q1K, N99S	-
T01.07	H3B	T01H3	WT	K98E, N99K	-
T01.08	L2	WT	T01L5	-	S52E, M106I
T01.09	L2	WT	T01L6	-	L54R, M106I
T01.10	L2	WT	T01L7	-	S52E, L54R, M106I
T01.11	H1	T01H4	WT	S32Y	-
T01.12	H1	T01H5	WT	S32F	-
T01.13	H2A	T01H6	WT	D50E, F52Y, W53S, D54G, D55E	-
T01.14	H2A	T01H7	WT	D50E, W53S	-
T01.15	L1C	WT	T01L8	-	L76F
T01.16	L1C	WT	T01L9	-	M33V, L76F
T01.17	L1A	WT	T01L10	-	K27E, L76F

T01.18	L1B	WT	T01L11	-	T27E, L76F
T01.19	L1B	WT	T01L12	-	T27K, L76F
T01.20	H1	T01H8	WT	S32W	-

Producing antibodies with high binding affinity

The humanized antibody gene was inserted into a plasmid and expressed in IgG form using the Expi293 expression system (Invitrogen) then purified using AktaPure (GE healthcare),

- 5 AktaPrime purifier (GE healthcare) and MabselectSURE column (GE healthcare, Cat#11-0034-95). The purified antibodies were run through a Desalting column (GE healthcare, Cat#17-1408-01) with PBS buffer change and the antibody concentration was measured with Multiskan GO (Thermo).

10 **TABLE 3: PRODUCTION YIELDS OF ANTIBODIES WITH HIGH BINDING AFFINITY**

Ab name	Culture volume (mL)	Con. Of Ab (mg/mL)	Yield (mg)
T01.01 (A1)	30	0.68	1.020
T01.02 (A2)	30	0.22	0.330
T01.03	30	0.87	0.104
T01.04	30	0.99	0.119
T01.05	30	0.26	0.390
T01.06	30	1.2	0.144
T01.07	30	0.33	0.495
T01.08	30	1.46	0.292
T01.09	30	1.73	0.346

T01.10	30	2.07	0.414
T01.11	30	0.27	0.054
T01.12	30	1.26	0.252
T01.13	30	0.72	0.144
T01.14	30	0.89	0.178
T01.15	30	0.21	0.042
T01.16	30	1.05	0.21
T01.17	30	0.76	0.15
T01.18	30	0.33	0.07
T01.19	30	0.44	0.09
T01.20	30	0.99	0.198

PBMC-derived Macrophages Differentiation

M1 and M2 macrophages were obtained from PBMC using the protocol below.

- 5 1. Blood mixture with PBS(1:1) 20ml overlay on to 10 ml of Ficoll-Paque™ Plus (GE Healthcare, Cat#17-1440-02)
2. Centrifugate at 400xg for 35min (2 accel, 0 brake)
3. PBMC isolation and washing by RPMI-1640 medium (WelGene, Cat#LB011-01) at 2000rpm for 5 min x2 times
- 10 4. Counting
5. MACs buffer (2% FBS(Millipore, Cat#TMS-013-BKR) in PBS(WelGene, Cat#LB004-02) 1~2 ml suspension
6. Add CD14-microbead (20ul/10⁷ cells) (Miltenyi Biotec, Cat#130-050-201)
7. Incubation for 30 min on ice
- 15 8. Washing by MACs buffer at 2000rpm for 5min x2times
9. Counting

10. Load the cells into MACs column (Miltenyi Biotec, Cat#130-042-401)
11. Positive selection and counting
12. Suspension by culture medium (RPMI-1640 +10% FBS +Penicillin/Streptomycin (Gibco, Cat#15140-122) +Glutamax (Gibco, Cat#35050-061) +20~40ng/ml of rhM-CSF (Biolegend, Cat#574806)
- 5 13. Seed the CD14⁺ cells in 100mm culture dish (1x10⁶cells/10ml/dish) (Thermo Scientific, Cat#150466)
14. Every 3days later, fresh culture medium change
15. After 7~10days, M0 macrophages differentiation check by FACs
- 10 16. Differentiation of M0 to M1 or M2 macrophages by LPS 20ng/ml (Sigma-Aldrich, Cat#L4391) +rhIFN γ 20ng/ml (Biolegend, Cat#570204) (M1) and rhIL4 20ng/ml (Biolegend, Cat#574002) +rhIL13 20ng/ml (Biolegend, Cat#571102) (M2) culture medium (RPMI-1640 +10% FBS + Penicillin/Streptomycin +Glutamax) for 2 days
17. After M1 or M2 differentiation, cell phenotype check by FACs
- 15 18. For M2 to M1 macrophages conversion, add the antibodies 20ug/ml or LPS 20ng/ml + rhIFN γ 20ng/ml (positive control) in fresh culture medium (RPMI-1640 +10% FBS + Penicillin/Streptomycin +Glutamax) for 2 days
19. After M2 to M1 conversion, cell phenotype check by FACs and cytokines/chemokines check in cultured sup by LEGENDplexTM (Biolegend, Cat#740502)

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FACs analysis

The following antibodies were used for FACs analysis:

- hCD14-BV650 (BD Bioscience, Cat#563419)
- hCD14-BV421 (BD Bioscience, Cat#565283)
- 25 • hIFN γ -PE/Cy7 (BD Bioscience, Cat#557844)
- hCD3-BV510 (BD Bioscience, Cat#563109)
- hCD8-V450 (BD Bioscience, Cat#560347)
- hCD68-PE (Biolegend, Cat#333808)
- hCD93-PE (Biolegend, Cat#336108)
- 30 • HLA-DR-BV421 (Biolegend, Cat#307636)
- hCD45-PE (Biolegend, Cat#304008)

- hCD64-APC (Biolegend, Cat#305014)
- hCD163-APC/Cy7 (Biolegend, Cat#333622)
- hCD86-PerCP/Cy5.5 (Biolegend, Cat#305420)
- hCD86-BV421 (BD Bioscience, Cat#562432)

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EXAMPLE 1: VSIG4 EXPRESSION IN MACROPHAGES

VSIG4 is expressed in M2 macrophages. **Figures 3A and 3B** show correlative data for VSIG4 expression (as measured by mRNA) to that of various genes associated with type 2 macrophages (M2) and tumor-associated macrophages. As shown in **Figure 3A**, VSIG4 expression correlates negatively with [CXCL11, CXCL13, ZNMB, IFNAR1, IFNAR2] expression, but while it correlates positively with CCL19, IRF5, and IL1A expression. Figure 3B shows VSIG 4 expression correlates positively with CD163, CSF1R, MSR1, TGFBR2, STAT6, IL1R1, IL10RA, MS4A4A, CCL2, CCL14, CCL17, and MS4A6A expression.

Figure 5 shows expression of VSIG4 in M2 macrophages. The two panels in the top row of **Figure 5** shows light microscope images showing M1 and M2 macrophages' morphology. The second and third rows show flow cytometry data for lymphocytes stained for CD14 and VSIG4, demonstrating that M2 cells (stained positive for CD14) also expressing VSIG4.

EXAMPLE 2: HUMAN ANTI-VSIG4 ANTIBODY INDUCES CYTOKINE AND CHEMOKINE SECRETION IN M2 MACROPHAGES

M1 and M2 macrophages were treated with EU103.2 antibody and secretion of proinflammatory cytokines and chemokines were measured. As shown in **Figure 6**, treatment of M2 macrophages with EU103.2 resulted in induction of the cytokines and chemokines IL12, IFN γ , IL10, and IL23.

EXAMPLE 3: HUMANNIZED ANTI-VSIG4 ANTIBODY CONVERTS M2 MACROPHAGES INTO M1 MACROPHAGES

To further test the effects of EU103.2 on macrophages, M2 macrophages were treated with EU103.2 antibody and stained for the M2 macrophage marker CD163. As shown in **Figure 7**, EU103.2 treatment decreased the expression of M2 macrophage marker CD163 in M2

macrophages, which suggested blocking of VSIG4 using EU103.2 resulted in conversion of M2 macrophages into a different cell type.

Next, the effects of EU103.2 antibody on macrophage-T cell interaction was tested by co-incubating M2 macrophages with CD8⁺ T cells with or without EU103.2 antibody treatment. As shown in **Figure 8**, EU103.2 treated M2 macrophages, when co-incubated with CD8⁺ T cells, resulted in proliferation of the CD8⁺ T cells, indicating that M2 macrophages are converted into M1 macrophages when treated with EU103.2 antibody, since M1 macrophages induce CD8⁺ T cell proliferation while M2 macrophages suppress CD8⁺ T cell proliferation.

Next, to further investigate the effects of EU103.2 antibody on human macrophages in the context of cancer biology, abdominal fluid samples from ovarian cancer patients were collected and first analyzed for VSIG4 expression. As shown in **Figure 9**, macrophages obtained from abdominal fluid of ovarian cancer patients included M2 macrophages that co-expressed VSIG4 and CD14, and as shown in **Figures 10 and 11**, induced CD8⁺ T cell proliferation.

Further, microscope images confirm that EU103.2 antibody treatment converted M2 macrophages into M1 macrophages, as shown in **Figure 12**.

The role of VSIG4 signaling in CD8⁺ T cell proliferation by macrophages was further confirmed by co-culturing of HeLa cells expressing VSIG4 with PBMC, with or without anti-VSIG4 antibody to block VSIG4, as shown in **Figure 13**. This experiment showed blocking the interaction between VSIG4 and CD8⁺ T cells leads to enhanced proliferation of CD8⁺ T cells.

To further examine the role of VSIG4 in CD8⁺ T cells, the monocytic THP-1 cells were co-incubated at various ratios with T cells, either in the presence of anti-VSIG4 antibody or a control IgG antibody, to show that anti-VSIG4 antibody was able to increase CD8⁺ T cells at 4 divisions, as compared to the control IgG.

EXAMPLE 4: ANTITUMOR EFFECTS BLOCKING VSIG4 SIGNALING USING ANTI-VSIG4 ANTIBODY OR VSIG4 KNOCK OUT MOUSE MODEL

To determine the antitumor effects of anti-VSIG4 antibody, three mouse tumor models were used: MC38 colon adenocarcinoma mouse tumor model, B16F10 melanoma mouse tumor model, and 3LL lung carcinoma mouse tumor model using VSIG4 knock out mice, and compared to wild-type mice, as shown in **Figures 15A, 15B, and 15C**, respectively. Tumor

growth was suppressed, especially for MC38 and 3LL mouse tumor models in VSIG4 knock out mice, as compared to wild type mice (see **Figures 15A and 15C**, respectively), confirming that tumor growth is suppressed in the absence of VSIG4 signaling.

Similar suppression of tumor growth was observed in MC38 mouse tumor model in wild type mice that were injected with anti-VSIG4 antibody, as compared to mice injected with control IgG, as shown in **Figure 16**. The extent of tumor growth suppression by anti-VSIG4 antibody was at least as pronounced, if not greater, than those in VSIG4 knock out mice.

Next, activation status of lymphocytes from tumor-draining lymph nodes were examined in VSIG4 knock out mice and compared to wild-type mice. As shown in **Figures 17A and 17B**, comparable levels of CD4⁺ and CD8⁺ lymphocytes were observed in the VSIG4 knock out mice as compared to their wild-type counterparts, and comparable CD62L expression was observed in those lymphocytes expressing CD4 and CD8 between the VSIG4 knock out mice and wild-type mice. Further, VSIG4 knock out mice had increased CD8 β ⁺ T cells, as compared to wild-type mice, as shown in **Figure 17C**, but comparable levels of CD11 β ⁺/Gr-1- lymphocytes, as shown in **Figure 17D**.

To further evaluate the role of VSIG4 signaling in tumor growth, CD38 colon adenocarcinoma mouse tumor model was used in both VSIG4 knock out mice and wild-type mice, where the chemotherapy agent Claforan (CTX) was injected interperitoneally at days 18 and 23 after tumor injection in the subject mice, as shown in the schematic diagram at the top of **Figure 18A**.

Claforan injection resulted in a greater reduction of tumor volume in VSIG4 knock out mice as compared to wild type mice, and this reduction in tumor size was maintained 40 days after tumor injection. In contrast, in wild-type mice, CTX injection resulted in a slight reduction in tumor size, followed by continued growth of tumor size, as shown in **Figure 18A**. Images of mice and micrographs of tumor sections for both VSIG4 knock out mice and a wild-type mouse at day 24 after tumor injection are shown in **Figure 18B**. Tumor sections were collected from VSIG4^{+/+} and VSIG4^{-/-} C57BL/6 mice at day 24 and paraffin sections of tumor tissues were stained with H&E.

The effects of anti-VSIG4 on tumor suppression in humanized mouse model was evaluated by injecting 10 mg/kg of anti-VSIG4 antibody at days 19, 22, 25, 28, and 31 after HT29 cancer cell injection in humanized mice, as shown in Figure 19. Significant suppression of tumor growth

was observed in mice that received anti-VSIG4 antibody as compared to those that received IgG control injection.

These experiments demonstrated, as shown schematically in **Figure 20**, that VSIG4 signaling modulates suppression of T cell proliferation by M2 macrophages, and that blocking of VSIG4 signaling results in (1) abrogation of T cell proliferation induced by M2 macrophages, which leads to CD8⁺ T cell proliferation and tumor suppression; and (2) conversion of M2 macrophages into M1 macrophages.

EXAMPLE 5: EVALUATION OF A1, A2, A1.3, and A2.3 ANTIBODIES

Antibody clones A1, A2, A1.3, and A2.3 were developed by affinity maturation of EU103.2 antibodies. Protein profile by size exclusion HPLC shown in Figures 22, 23, 24, and 25, respectively, and summarized below in Table 4.

TABLE 4: SEC HPLC DATA FOR A1, A2, A1.3, and A2.3 antibodies

Ab	Time	Area	Height	Width	% Area	Log(MW)	MW
A1	7.551	8.57E+02	29.91175	0.4484	100.000	2.135	136.605
A2	7.567	2.62E+02	8.96929	0.4567	100.000	2.128	134.380
A1.3	7.525	2.02E+03	106.8666	0.2842	100.000	2.134	136.081
A2.3	7.542	6.61E+02	34.47963	0.2898	100.000	2.126	133.730

As shown in **Figures 26A and 26B**, A1 or A2 antibodies were applied to differentiated M2 macrophages for 2 days and FACs analysis showed a decrease in CD163, a marker for M2 macrophages, and a significant increase in CD86, a marker for M1 macrophages. Treatment with LPS/IFN γ for two days was used as positive control. Treatment with both A1 and A2 antibodies showed increased M1/M2 ratio. Specifically, A2 antibody showed a ratio increase close to that of the positive control group.

Next, as shown in **Figure 27**, A1 or A2 antibodies were applied to differentiated M2 macrophages for 2 days repolarizing them to M1 macrophages and the changes in production of cytokines and chemokines in the culture medium was measured using LEGENDplexTM. This is to confirm repolarization of M2 macrophages to M1 macrophages. Treatment with LPS/IFN γ for two days was used as positive control. Both A1 and A2 groups showed an

increase of M1 type cytokine/chemokine (TNF α , IL6, IFN γ , IP-10, and IL12p40) compared to M2 macrophages while the production of M2 type cytokine/chemokine (IL-10, Arginase, TARC, and IL-1RA) decreased. Specifically, the increase of production of TNF α and IL6 was comparable to that of the positive control group.

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Further, as shown in **Figure 28**, A1 or A2 antibodies were applied to differentiated M2 macrophages for 2 days and FACs analysis were performed to show a decrease in expression of CD163, a marker for M2 macrophages, and a significant increase in expression CD86, a marker for M1 macrophages. Treatment with LPS/IFN γ for two days was used as positive control.

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To further ascertain the repolarization of M2 macrophages to M1 macrophages by A1 and A2 antibodies, A1 or A2 antibodies were applied with different concentrations (5, 10 and 20 μ g/ml) to differentiated M2 macrophages for 2 days and cytokine and chemokine production by the macrophages were assessed, as shown in **Figure 29**. The change in the production of cytokine/chemokines in the culture medium was measured using LEGENDplexTM. Treatment with LPS/IFN γ for two days was used as positive control. Both A1 and A2 groups showed an increase of TNF α , IL6, and IP-10, which are associated with M1 macrophages, and this trend was especially pronounced with when the M2 macrophages were treated with A2 antibody. The production of Arginase, which is associated with M2 macrophages, decreased regardless of concentration of the antibodies.

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The chemotactic ability of macrophages after conversion of M2 macrophages into M1 macrophages by A2 antibody was assessed by chemotaxis assay. Using a Transwell 24well 5 μ m pore size chamber (Corning, Cat#CLS3421-48EA), the lower chamber was treated with the chemoattractant rhCCL19 (Biolegend, Cat#582104), which is a M1 type chemokine, at a concentration of 100ng/ml (volume 400 μ l) and the upper chamber was treated with repolarized M1 macrophages at 1.5~5 $\times$ 10⁵ cells/600 μ l, where M2 or A2 was applied for 2 days. (treatment with LPS/IFN γ for two days was used as positive control) After a 4 hour incubation period at 37 °C and 5% CO₂, 100 μ l of the cells in the lower chamber were moved to a 96 well plate. Then 10 μ l of CCK-8 solution (Dojindo, Cat#CK04) were added to each well and after a 1 hour incubation period the absorbance was measured (450nm). As shown in Figure 30, M1

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macrophages from the A2 group showed chemotactic ability, confirming macrophage conversion from M2 to M1 by A2 antibody.

Gene array analysis was performed to analyze change in gene expression after conversion of M2 macrophages to M1 macrophages by A2 antibodies, as shown in Figure 42. M2 macrophages were treated with A2 antibodies and the cells were harvested after two days. (Macrogen, Agilent Human GE 8x60K V3) Analysis shows increase of expression of M1 phenotype marker and M1 type cytokines/chemokines, similar to cells treated with LPS/IFN γ as a positive control, and decrease of expression of M2 phenotype marker and M2 type cytokines/chemokines.

EXAMPLE 6: ANTI-TUMOR EFFECTS OF A1, A2, A1.3, and A2.3 ANTIBODIES

Anti-tumor effect of A1 and A2 antibodies were assessed using a humanized mouse model. human CD34 cells were injected into NBSGW mice, after that blood samples were collected and human CD45 cells in the PBMC were measured to observe humanization of the mice over a 12~14 weeks period. HCT-15 colon cancer cells were injected, 1×10^7 cells/mouse, into the humanized mice and after 5 days the mice were divided into three groups each receiving injections of hIgG (Sigma-Aldrich, Cat#I4506), A1 antibody, or A2 antibody. The antibodies were injected every three days for a total of 5 injections, as schematically shown in **Figure 31A**. Tumor sizes were observed and after the mice were sacrificed, serum from the blood was used to measure IFN γ using ELISA (invitrogen, Cat#88-7316-88) and the tumor samples were used to analyze infiltrated leukocytes.

As shown in **Figures 31B and 31C**, no anti-tumor effect from A1 antibodies was observed but the samples from the A2 antibody group showed smaller tumor size and increase of IFN γ , confirming the anti-tumor effect of A2 antibodies.

Next, the effect of conversion of M2 macrophages into M1 macrophages by A2 antibody in the context of tumor growth was assessed *in vivo*. As shown schematically in **Figure 32A**, SW480 colon cancer cells were injected to mice (1×10^7 cells/mouse) and once the tumor size grew to a certain size (1000mm³~), differentiated M2 macrophages (7×10^5 cells/mouse) were injected with hIgG or A2 antibody. The antibodies were injected every 2 days for a total of 5 injections, and after the first injection blood samples were collected at days 4, 7 and 11 after tumor injection,

and the blood samples were used to isolate serum or PBMCs to analyze the change in macrophage phenotype using FACs analysis.

At day 7 after the tumor cell injection, a change in M1 macrophage phenotype was observed from the A2 antibody group, as shown in **Figure 32B**. While there was no change in CD163, a M2 macrophages marker, the expression of CD86 and HLA-DR a M1 macrophages markers, noticeably increased compared to the hIgG group which confirms M2 to M1 macrophage conversion by A2 antibody, as shown in **Figure 32C**.

Next, the effect of M2 conversion to M1 macrophages on tumor growth was analyzed.

As shown schematically in **Figure 33A**, a mixture of HCT-15 colon cancer cells (8×10^6 cells/mouse) and varying concentrations of M2 macrophages (2.5×10^5 / 5×10^5 / 1×10^6 cells/mouse) were injected to the mice. After 2 days, hIgG or A2 antibody was injected every 3 days for a total of 5 injections.

As shown in **Figures 33B**, A2 antibody reduced or slowed the growth of the tumor in a dose-dependent manner at day 14 after the tumor injection, as compared to the hIgG control mice, and this effect persisted at day 25 after the tumor injection.

Next, the anti-tumor effects of A2 antibody in a humanized mouse model was assessed using a different mouse tumor model. As shown schematically in **Figure 34A**, human CD34 cells were injected into NBSGW mice, after that blood samples were collected and human CD45 cells in the PBMC were measured to observe humanization of the mice over a 12~14 weeks period. SW480 colon cancer cells (1×10^7 cells/mouse) were injected to mice and after 5 days the mice were divided into two groups each injected with hIgG or A2 antibody (20mg/kg). The antibodies were injected every 3 days for a total of 5 injections for each group. Tumor size was observed and after the mice were sacrificed, serum from the blood was used to measure IFN γ using ELISA and the tumor samples were used to analyze infiltrated leukocytes.

No anti-tumor effect from A1 antibodies was observed but, as shown in **Figures 34B and 34C**, the samples from the A2 antibodies group showed smaller tumor size, and increase of IFN γ was observed, further confirming the anti-tumor effects of A2 antibody.

Overall, the group with A2 antibody injections showed smaller tumor size and increase of IFN γ in the serum. Further, as shown in **Figure 34D**, an increase in CD8 $^+$ T cells, specifically IFN γ

secreting CD8 γ T cells was observed. As shown in **Figure 34E**, decreased CD93 and CD163 expression (M2 macrophages marker), and increased expression of CD86 (a M1 macrophages marker) was observed, while no change in HLA-DR was seen. These data confirm that A2 antibody mediates cytotoxic activity of CD8 $^{+}$ T cells.

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Next, anti-tumor effect of A2 and A2.3 antibodies were compared in a humanized mouse model. As schematically shown in Figure 35A, human CD34 cells were injected into NBSGW mice, after that blood samples were collected and human CD45 cells in the PBMC were measured to observe humanization of the mice over a 12~14 weeks period. HCT-15 colon cancer cells were injected, at 1×10^7 cells/mouse, into the humanized mice and once the tumor size was grown to a certain size ($\sim 100\text{mm}^3$) the mice were divided into three groups each receiving injections of hIgG, A2, or A2.3 antibodies (20mg/kg). The antibodies were injected every three days for a total of 5 injections. Tumor size was observed and after the first injection blood samples were collected at D5 and D13 where inflammatory cytokines were observed in serum from the blood.

15 As shown in **Figure 35B**, both A2 and A2.3 antibodies reduced tumor size.

Next, the four anti-VSIG4 antibodies, A1, A1.3, A2, and A2.3 were evaluated for their effects on CD8 $^{+}$ T cell proliferation. A1, A1.3, A2, and A2.3 antibodies were added to macrophages isolated from donors to convert M2 macrophages into M1 macrophages and co-cultured with CD8 $^{+}$ T cells isolated from PBMCs from the same donor for a co-culture assay. The CD8 $^{+}$ T cells were labeled with CFSE (Life technologies, Cat#V12883) and co-cultured in an anti-CD3 coated 96 well plate (BD Biocoat, Cat#354725) at a 2:1 ratio with the macrophages after conversion (CD8 T : Macrophage = 2×10^5 cells/well : 1×10^5 cells/well). After 5 days, the harvested cells were stained with hCD8-V450 and analyzed by FACs analysis. CD8 $^{+}$ T cells proliferation was confirmed by the observation of decrease of CFSE levels. While M2 macrophages negatively regulated the CD8 $^{+}$ T cell proliferation, the co-cultures of A1, A1.3, A2 and A2.3 antibodies resulted in conversion of M2 macrophages into M1 macrophages, and resulted in increased CD8 $^{+}$ T cell proliferation, as shown in **Figures 36A** and **36B**.

30 Similar experiments comparing the effects of A2 antibody and A2.3 antibodies were performed using macrophages and T cells isolated from different donors than in the above experiment (i.e.,

different from those donors in Figure 36). A2 and A2.3 antibodies were applied to macrophages to convert M2 macrophages into M1 macrophages, and CD8⁺ T cells were isolated from PBMCs from the same donor were used for a co-culture assay. The CD8 T cells were labeled CFSE (Life technologies, Cat#V12883) and co-cultured in a anti-CD3 coated 96 well plate (BD Biocoat, Cat#354725) at a 1:1 or 2:1 ratio with the macrophages after conversion (CD8⁺ T : Macrophage = 2x10⁵ cells/well : 2x10⁵ cells/well or 2x10⁵ cells/well : 1x10⁵ cells/well). After 5 days, the harvested cells were stained with hCD8-V450 and analyzed by FACs analysis. CD8⁺ T cells proliferation was confirmed by the observation of decrease of CFSE levels. While M2 macrophages negatively regulated the CD8⁺ T cell proliferation, addition of A2 and A2.3 antibodies to convert M2 macrophages into M1 macrophages resulted in increased CD8⁺ T cell proliferation.

Next, the hVSIG4 expressing HeLa cells (HeLa-hVSIG4 cells) were used to confirm the role of VSIG4 signaling on A2 and A2.3 antibody-mediated induction of CD8⁺ T cell proliferation. CD8⁺ T cells were isolated from PBMCs from a healthy donor, labeled with CFSE and applied to a anti-CD3 coated plate (2x10⁵ cells/well). After 1 day, the HeLa or HeLa-hVSIG4 cells were added to the wells after 30Gy irradiation (x-ray) (1x10⁵ or 0.5x10⁵ cells/well). After 5 days, CD8⁺ T cell proliferation was analyzed by measuring CFSE levels using FACs analysis. The CD8⁺ T cells were also treated with anti-CD3 (Miltenyi Biotech, Cat#130-093-387) at different concentrations and after 1 day, the HeLa or HeLa-hVSIG4 cells were added to the wells after 30Gy irradiation (x-ray) - (1x10⁵ cells/well). After 5 days, 100 µl of the cultured cells was moved to a separate 96 well plate and CCK-8 was added to each well (10ul/well). After 5 hours, the absorbance was measured at 450nm confirming CD8⁺ T cell proliferation. As shown in Figures 38A and 38B, HeLa-hVSIG4 negatively regulated CD8⁺ T cell proliferation, while treatment with A2 or A2.3 induces T cell proliferation.

Human phosphor-kinase array was used to examine the signal pathway through which macrophage is repolarized by A2 antibody. As shown in **Figure 39**, conversion of M2 macrophages into M1 macrophages by A2 antibody treatment resulted in significant increase in phosphorylation of JNK, MSK1/2, and p38a, as measured using Proteome Profiler™ Antibody Arrays (R&D Systems, Cat#ARY003B).

ANTIBODY SEQUENCE AND BINDING AFFINITY INFORMATION

Sequence information and binding affinity information for the various anti-VSIG4 antibodies described herein are provided in TABLES 5-12, below.

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TABLE 5: VH AND VL SEQUENCES OF EU103.2 ANTIBODY

Ab name	Sequence
EU103.2_VH (amino acid)	QVQLQESGPGLVKPSQTLSTCSFSGISLTSSGMGVGWIRQPPGKGLEWLADIFWDDNKYYNP SLKSRVTISVDTSKNQFSLKLSSVTAADTAVYYCVRVYYKNDGYFDVWGQGTLLTVSS (SEQ ID NO: 2)
EU103.2_VL (amino acid)	EIVMTQSPATLSVSPGERATLSCRASKSVTTSGYSFMHWYQQKPGQAPRLLIYLASNLEPGIPAR FSGSGSGTEFTLTISLSQSEDAVYYCQHSRELPYTFGQGTKLEIK (SEQ ID NO: 4)

TABLE 6: VH AND VL SEQUENCES OF EU103.3 ANTIBODY

Ab name	Sequence
EU103.3_VH (hu6H8.3_VH) (amino acid)	QVTLKESGPTLVKPTQTTLTCTFSGISLTSSGMGVGWIRQPPGKALEWLADIFWDDNKYYN PSLKSRLTITKDTSKNQVVLMTNMDPVDATYYCVRVYYKNDGYFDVWGKGTLLTVSS (SEQ ID NO: 6)
EU103.3_VL (hu6H8.3_VL) (amino acid)	DIVLTQSPLSLPVTLGQPASISCRASKSVTTSGYSFMHWYQRPQGSPRLLIYLASNLEPGVP DRFSGSGSGTDFTLKISRVEAEDVGVYYCQHSRELPYTFGQGTKLEIK (SEQ ID NO: 8)

10

TABLE 7: VH AND VL SEQUENCES OF A1 ANTIBODY

Ab name	Sequence
A1_VH (amino acid)	QVTLKESGPTLVKPTQTLTLTCTFSGISLTSSGMGVGWIRQPPGKALEWLADIFWDDNKYYNPS LKSRITITKDTSKNQVLTMTNMDPVDATYYCVRVYYKNDGYFDVWGKTTVTVSS (SEQ ID NO: 6)
A1_VL (amino acid)	DIVLTQSPLSLPVTLGQPASISCRASKSVTTSGYSFMHWYQQRPGQSPRLLIYASNLEPGVPDR FSGSGSGTDFTLKISRVEAEDVGVYYCQSGELPYTFGQGTKLEIK (SEQ ID NO: 10)

TABLE 8: VH AND VL SEQUENCES OF A2 ANTIBODY

Ab name	Sequence
A2_VH (amino acid)	QVTLKESGPTLVKPTQTLTLTCTFSGISLTSSGMGVGWIRQPPGKALEWLADIFWDDNKYYNPS LKSRITITKDTSKNQVLTMTNMDPVDATYYCVRVYYKNDGYFDVWGKTTVTVSS (SEQ ID NO: 6)
A2_VL (amino acid)	DIVLTQSPLSLPVTLGQPASISCRASKSVTTSGYSFMHWYQQRPGQSPRLLIYASNLEPGVPDR FSGSGSGTDFTLKIFRVEAEDVGVYYCQSGELPYTFGQGTKLEIK (SEQ ID NO: 12)

5 **TABLE 9: VH AND VL SEQUENCES OF A1.3 ANTIBODY**

Ab name	Sequence
A1.3_VH (amino acid)	QVTLVESGPTLVKPGQTLTLTCTFSGISLTSSGMGVGWIRQPPGKALEWLADIFWDDNKYYNPS LKGRLITITKDTSKNQVLTMTNMDPVDATYYCVRVYYKNDGYFDVWGKTTVTVSS (SEQ ID NO: 14)
A1.3_VL (amino acid)	DIVLTQSPLSLPVTLGQPASISCRASKSVTTSGYSFMHWYQQRPGQSPRLLIYASNLEPGVPDR FSGSGSGTDFTLKISRVEAEDVGVYYCQSGELPYTFGQGTKLEIK (SEQ ID NO: 10)

TABLE 10: VH AND VL SEQUENCES OF A2.3 ANTIBODY

Ab name	Sequence
A2.3_VH (amino acid)	QVTLVESGPTLVKPGQTLTLCTFSGISLTTS GMGVGWIRQPPGKALEWLADIFWDDNKYYNPS LKGRLTITKDTSKNQVYLTMTNMDPVDATYYCVRVYYKNDGYFDVWVGKTTVTVSS (SEQ ID NO: 16)
A2.3_VL (amino acid)	DIVLTQSPLSLPVTLGQPASISCRASKSVTTS GYSFMHWYQQRPGQSPRLLIYLASNLEPGVPDR FSGSGSGTDFTLKIFRVEAEDVGVYYCQSGELPYTFGQGTKLEIK (SEQ ID NO: 12)

5 **TABLE 11: CDR SEQUENCES OF EU103.2, EU103.3, A1, A2, A1.3, and A2.3 ANTIBODIES**

	VH CDR1	VH CDR2	VH CDR3	VL CDR1	VL CDR2	VL CDR3
EU103.2	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QHSRELPY T (SEQ ID NO: 22)
EU103.3	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QHSRELPY T (SEQ ID NO: 22)
A1	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QQSGELPY T (SEQ ID NO: 23)
A2	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QQSGELPY T (SEQ ID NO: 23)
A1.3	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QQSGELPY T (SEQ ID NO: 23)

A2.3	GISLTT (SEQ ID NO: 17)	IFWDDNK (SEQ ID NO: 18)	VRVYYKN DGYFDV (SEQ ID NO: 19)	KSVTTS (SEQ ID NO: 20)	LAS (SEQ ID NO: 21)	QQSGELPY T (SEQ ID NO: 23)
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TABLE 12: BINDING AFFINITY (K_D) OF EU103.2, EU103.3, A1, A2, A1.3, and A2.3 ANTIBODIES FOR VSIG4

Antibody	$K_a(1/Ms)$	$K_d(1/s)$	$K_D (M)$
EU103.2	1.834E+5	0.01313	7.156E-8
A1	3.779E+5	0.003283	8.688E-9
A1.3	4.022E+5	0.003198	7.952E-9
A2	3.604E+5	0.002964	8.226E-9
A2.3	4.037E+5	0.003083	7.636E-9

OTHER EMBODIMENTS

It is to be understood that while the invention has been described in conjunction with the detailed description thereof, the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

CLAIMS

What is claimed is:

- 5 1. An isolated humanized antibody or antigen-binding fragment thereof, comprising:
- a. a heavy chain CDR1 comprising the amino acid sequence of SEQ ID NO: 17, a heavy chain CDR2 comprising the amino acid sequence of SEQ ID NO: 18, a heavy chain CDR3 sequence comprising the amino acid sequence of SEQ ID NO: 19; and
- 10 b. a light chain CDR1 comprising the amino acid sequence of SEQ ID NO: 20, a light chain CDR2 comprising the amino acid sequence of SEQ ID NO: 21, and a light chain CDR3 comprising the amino acid sequence of SEQ ID NO: 22 or SEQ ID NO: 23.
- 15 2. The antibody or antigen-binding fragment of claim 1, wherein the antibody or antigen-binding fragment comprises any one of the following:
- a. a heavy chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16;
- 20 b. a light chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12; or
- c. a heavy chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16, and a light chain variable domain comprising an amino acid sequence at least 80%, 90%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12.
- 25 3. The antibody or antigen-binding fragment of any one of claims 1-2, wherein the antibody or antigen-binding fragment comprises any one of the following:
- 30 4. The antibody or antigen-binding fragment of any one of claims 1-2, wherein the antibody or antigen-binding fragment comprises any one of the following:

- 5
- a. a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16;
 - b. a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12; or
 - c. a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 6, SEQ ID NO: 14, or SEQ ID NO: 16, and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4, SEQ ID NO: 8, SEQ ID NO: 10, or SEQ ID NO: 12.
- 10
4. The antibody or antigen-binding fragment of claim 1, wherein the antibody wherein light chain CDR3 comprising the amino acid sequence of SEQ ID NO: 23.
- 15
5. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 2 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 4.
- 20
6. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 8.
- 25
7. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 10.
- 30
8. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 6 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 12.

- 5 9. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 14 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 10.
- 10 10. The antibody or antigen-binding fragment of claim 2, wherein the antibody or antigen-binding fragment comprises a heavy chain variable domain comprising the amino acid sequence of SEQ ID NO: 16 and a light chain variable domain comprising the amino acid sequence of SEQ ID NO: 12.
- 15 11. The antibody or antigen-binding fragment of any one of claims 1-10, wherein the antibody or antigen-binding fragment has a binding affinity (K_D) for a human V-Set And Immunoglobulin Domain Containing 4 (VSIG4) molecule of 1×10^{-7} to 1×10^{-9} .
12. The antibody or antigen-binding fragment of any one of claims 1-11, wherein the antibody or antigen-binding fragment has a binding affinity (K_D) for a VSIG4 molecule of about 7.156×10^{-8} to about 7.636×10^{-9} .
- 20 13. The antibody or antigen-binding fragment of any one of claims 1-11, wherein the antibody or antigen-binding fragment has a binding affinity (K_D) for a VSIG4 molecule of about 7.156×10^{-8} , about 7.636×10^{-9} , about 7.952×10^{-9} , about 8.226×10^{-9} , or about 8.688×10^{-9} .
- 25 14. A nucleic acid molecule encoding the antibody or antigen-binding fragment of any one of claims 1-13.
15. A recombinant vector comprising the nucleic acid molecule of claim 14.
- 30 16. The recombinant vector of claim 15, wherein the nucleic acid molecule of claim 14 is operatively linked to a promoter.

17. The recombinant vector of claim 15 or 16, wherein the vector comprises two separate vectors, each comprising the nucleic acid sequence corresponding to the heavy chain and the light chain of the antibody or antigen-binding fragment.
- 5
18. A host cell comprising the nucleic acid molecule of claim 14 or the recombinant vector of any one of claims 15-17.
19. The host cell of claim 18, wherein the host cell is a mammalian cell, a yeast cell, or a bacterial cell.
- 10
20. The host cell of claim 19, wherein the host cell is a cell selected from the group consisting of *E.coli*, *P.pastoris*, Sf9, COS, HEK293, Expi293, CHO-S, CHO-DG44, CHO-K1, and a mammalian lymphocyte.
- 15
21. The host cell of claim 20, wherein the host cell is the Expi293 cell.
22. A pharmaceutical composition comprising:
the antibody or antigen-binding fragment of any one of claims 1-13, the nucleic acid molecule of claim 14, the recombinant vector of any one of claims 15-17, or the host cell of any one of claims 18-21; and
a pharmaceutically acceptable carrier.
- 20
23. A method of treating a subject in need thereof, the method comprising the steps of:
- 25
- a. administering to the subject a composition that comprises or delivers the antibody or antigen-binding fragment of any one of claims 1-13, the nucleic acid molecule of claim 14, the recombinant vector of any one of claims 15-17, or the host cell of any one of claims 18-21, thereby treating a disease or a condition.
- 30
24. The method of claim 23, wherein the subject has, or is at risk for developing, cancer.

25. The method of claim 24, where in the cancer is selected from a bladder cancer, breast cancer, cervical cancer, colon cancer, endometrial cancer, esophageal cancer, fallopian tube cancer, gall bladder cancer, gastrointestinal cancer, head and neck cancer, hematological cancer, laryngeal cancer, liver cancer, lung cancer, lymphoma, melanoma, mesothelioma, ovarian cancer, primary peritoneal cancer, salivary gland cancer, sarcoma, stomach cancer, thyroid cancer, pancreatic cancer, renal cell carcinoma, glioblastoma, and prostate cancer.
26. The method of any one of claims 23-25, wherein the subject has been administered or will be administered one or more additional anticancer therapies selected from ionizing radiation, a chemotherapeutic agent, an antibody agent, and a cell-based therapy, such that the subject receives treatment with both.
27. The method of claim 26, wherein the one or more additional anticancer therapies comprise an immune checkpoint inhibitor, IL-12, GM-CSF, an anti-CD4 agent, cisplatin, fluorouracil, doxorubicin, irinotecan, paclitaxel, indoleamine 2,3 -di oxygenase- 1 (IDO1) inhibitor, or cyclophosphamide.
28. A method of increasing secretion of cytokines or chemokines in M2 macrophages comprising:
- Contacting the M2 macrophages with the antibody or antigen-binding fragment of any one of claims 1-13.
29. A method of inducing CD8⁺ T cell proliferation, the method comprising:
- contacting an M2 macrophage with the antibody or antigen-binding fragment of any one of claims 1-13; and
 - co-incubating the M2 macrophage with a CD8⁺ T cells.
30. A method of converting an M2 macrophage into an M1 macrophage, the method comprising contacting the M2 macrophage with the antibody or antigen-binding fragment of any one of claims 1-13.