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(54) Title: ANTI-LGR5 ANTIBODIES AND USES THEREOF

(57) Abstract: The invention provides anti-LgR5 antibodies and methods of using the same.

FIG. 5A





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ANTI-LGR5 ANTIBODIES AND USES THEREOF

[0001] This application claims the benefit of US Provisional Application No. 62/010,637, filed June 11, 2014, which is incorporated by reference herein in its entirety for any purpose.

FIELD OF THE INVENTION

[0002] The present invention relates to anti-LgR5 antibodies and methods of using the same.

BACKGROUND

[0003] The cancer stem cell hypothesis posits that similar to normal tissue, a distinct subset of specialized cells has the capacity to self-renew and continuously populates the tumor. Cancer stem cells (CSCs) are implicated in tumor initiation, progression, metastasis and relapse making them desirable targets for therapeutic intervention.

[0004] One of the most well-characterized tissue stem cell populations is the leucine-rich repeat-containing G protein-coupled receptor 5 (Lgr5) crypt cells in the gastrointestinal tract which give rise to all the differentiated cell types within the homeostatic intestinal epithelia. LgR5 is a seven-transmembrane protein found on the surface of actively cycling intestinal stem cells (ISCs). Human LgR5 is a 907 amino acid protein, of which ~540 amino acids are predicted to be in the extracellular space following cleavage of the amino-terminal signal sequence. LgR5 comprises 17 imperfect leucine-rich repeat motifs in the ectodomain, and a cysteine-rich region located between the leucine-rich repeats and the first transmembrane domain.

[0005] LgR5-expressing ISCs are sensitive to Wnt modulation and are primarily responsible for homeostatic regeneration of the intestinal epithelium. Elimination of LgR5-expressing cells in mice does not affect homeostasis of intestinal epithelium, however, suggesting that other cell types can compensate for loss of this cell population. Tian et al., Nature 478: 255-259 (2011). R-spondins enhance WNT signaling by WNT3A, and all four R-spondins, RSPO1, RSPO2, RSPO3, and RSPO4, are able to bind to LgR5. Lau et al., Nature 476: 293-297 (2011).

[0006] LgR5+ cells are proposed also to serve as the cells of origin for intestinal cancers and act as CSCs suggesting that elimination of the LgR5+ cells could have a profound impact on tumor growth and maintenance.

[0007] Lineage tracing of APC mutant tumors from LgR5+ cells demonstrates that multiple cell types in intestinal tumors are derived from an LgR5+ progenitor. Moreover LgR5+ cells are proposed to initiate and continuously contribute progeny to the tumor mass, suggesting that elimination of the LgR5+ cells could have a profound impact on tumor growth and maintenance. However, a long-standing issue in determining the expression of LgR5 has been the lack of a quality Immunohistochemistry (IHC) reactive antibody.

[0008] There is a need in the art for agents that target LgR5 for the diagnosis and treatment of LgR5-associated conditions, such as cancer. The invention fulfills that need and provides other benefits.

SUMMARY

[0009] Anti-LgR5 antibodies and immunoconjugates and methods of using the same are provided. Anti-LgR5 antibodies useful for immunohistochemistry are provided.

[0010] In some embodiments, an isolated antibody that binds to LgR5 is provided. In some embodiments, the antibody comprises: (a) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 14, HVR-L3 comprising the amino acid sequence of SEQ ID NO: 11, and HVR-H2 comprising the amino acid sequence of SEQ ID NO: 13; or (b) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 20, HVR-L3 comprising the amino acid sequence of SEQ ID NO: 17, and HVR-H2 comprising the amino acid sequence of SEQ ID NO: 19. In some embodiments, the antibody comprises: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 12, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 13, and HVR-H3 comprising the amino acid sequence of SEQ ID NO: 14; or (b) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 18, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 19, and HVR-H3 comprising the amino acid sequence of SEQ ID NO: 20. In some embodiments, the antibody comprises: (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 9, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 10, and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 11; or (b) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 15, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 16, and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 17.

[0011] In some embodiments, the antibody comprises: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 12, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 13, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 14, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 9, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 10, and HVR-L3 comprising the amino acid sequence of SEQ ID NO:

11; or (b) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 18, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 19, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 20, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 15, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 16, and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 17.

[0012] In some embodiments, the antibody comprises: (a)(i) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 6; (ii) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 5; or (iii) a VH sequence as in (i) and a VL sequence as in (ii); or (b)(i) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 8; (ii) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 7; or (iii) a VH sequence as in (i) and a VL sequence as in (ii).

[0013] In some embodiments, the antibody comprises a VH sequence of SEQ ID NO: 6 or SEQ ID NO: 8. In some embodiments, the antibody comprises a VL sequence of SEQ ID NO: 7 or SEQ ID NO: 9.

[0014] In some embodiments, the antibody is a monoclonal antibody. In some embodiments, the antibody is a mouse, rabbit, human, humanized, or chimeric antibody. In some embodiments, the antibody is an IgG selected from IgG1, IgG2a, IgG2b, IgG3, and IgG4.

[0015] In some embodiments, nucleic acids encoding an antibody described herein are provided. In some embodiments, a host cell comprising a nucleic acid encoding an antibody described herein is provided. In some embodiments, methods of producing antibodies are provided, comprising culturing a host cell comprising a nucleic acid encoding an antibody described herein.

[0016] In some embodiments, an immunoconjugate is provided comprising an antibody described herein and a cytotoxic agent. In some embodiments, a pharmaceutical formulation is provided comprising an immunoconjugate comprising an antibody described herein and a cytotoxic agent and a pharmaceutically acceptable carrier.

[0017] In some embodiments, an antibody described herein conjugated to a label is provided. In some embodiments, the label is a positron emitter. In some embodiments, the positron emitter is ⁸⁹Zr.

[0018] In some embodiments, a method of detecting human LgR5 in a biological sample is provided. In some embodiments, the method comprises contacting the biological sample with an anti-LgR5 antibody described herein under conditions permissive for binding of the anti-LgR5 antibody to human LgR5. In some embodiments, the method further comprises detecting

whether a complex is formed between the anti- LgR5 antibody and human LgR5 in the biological sample. In some embodiments, the biological sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

[0019] In some embodiments, methods for detecting a LgR5-positive cancer are provided. In some embodiments, a method comprises (i) administering a labeled anti-LgR5 antibody to a subject having or suspected of having a LgR5-positive cancer, wherein the labeled anti-LgR5 antibody comprises an anti-LgR5 antibody described herein, and (ii) detecting the labeled anti-LgR5 antibody in the subject, wherein detection of the labeled anti-LgR5 antibody indicates a LgR5-positive cancer in the subject. In some embodiments, the labeled anti-LgR5 antibody comprises an anti-LgR5 antibody conjugated to a positron emitter. In some embodiments, the positron emitter is ^{89}Zr .

[0020] In some embodiments, methods of identifying a cancer patient as having a LgR5-positive cancer are provided. In some embodiments, the method comprises contacting a cancer sample from the patient with an anti-LgR5 antibody described herein under conditions permissive for binding of the anti-LgR5 antibody to human LgR5. In some embodiments, the method further comprises detecting whether a complex is formed between the anti-LgR5 antibody and human LgR5 in the cancer sample. In some embodiments, the cancer patient is identified as having a LgR5-positive cancer if a complex is between the anti-LgR5 antibody and human LgR5 in the cancer sample is detected. In some embodiments, the cancer sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

[0021] In some embodiments, methods of selecting cancer patients for treatment with an immunoconjugate comprising an anti-LgR5 antibody are provided. In some embodiments, a method comprises determining the level of LgR5 expression in a cancer sample from the patient using immunohistochemistry (IHC). In some embodiments, an elevated level of LgR5 expression indicates that the cancer patient is more likely to benefit from treatment with an immunoconjugate comprising an anti-LgR5 antibody. In some embodiments, an elevated level of LgR5 expression is 2+ or 3+ staining by IHC. In some embodiments, an elevated level of LgR5 expression is 3+ staining by IHC. In some embodiments, IHC is performed using an antibody described herein. In some embodiments, the cancer sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

[0022] In some embodiments, a method of selecting a cancer patient for treatment with an immunoconjugate comprising an anti-LgR5 antibody are provided, wherein the method comprises contacting a cancer sample from the patient with an anti-LgR5 antibody described herein under conditions permissive for binding of the anti-LgR5 antibody to human LgR5, and detecting whether a complex is formed between the anti-LgR5 antibody and human LgR5 in the cancer sample. In some embodiments, the cancer patient is selected if a complex is between the anti-LgR5 antibody and human LgR5 in the cancer sample is detected. In some embodiments, the cancer sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

[0023] In some embodiments, methods of treating cancer patients are provided, comprising administering to the patient a therapeutically effective amount of an an immunoconjugate comprising an anti-LgR5 antibody, wherein a cancer sample from the patient has been determined to have an elevated level of LgR5 expression using immunohistochemistry (IHC). In some embodiments, an elevated level of LgR5 expression is 2+ or 3+ staining by IHC. In some embodiments, an elevated level of LgR5 expression is 3+ staining by IHC. In some embodiments, IHC is performed using an antibody described herein. In some embodiments, the cancer sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

[0024] In some embodiments, the immunoconjugate comprises an anti-LgR5 antibody comprising: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 55, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 56, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 57, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 52; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 53; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 54; or (b) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 73, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 74, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 75, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 70; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 71; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 72; or (c) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 79, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 80, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 81, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 76; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 77; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 78; or (d) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 85, HVR-

H2 comprising the amino acid sequence of SEQ ID NO: 86, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 87, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 82; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 83; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 84. In some embodiments, the immunoconjugate comprises an anti-LgR5 antibody comprising (a) a VH sequence of SEQ ID NO: 33 and a VL sequence of SEQ ID NO: 32; or (b) a VH sequence of SEQ ID NO: 51 and a VL sequence of SEQ ID NO: 50. In some embodiments, the immunoconjugate comprises an anti-LgR5 antibody conjugated to a cytotoxic agent.

BRIEF DESCRIPTION OF THE FIGURES

[0025] **Figure 1** shows a graphic representation of the levels of human LgR5 gene expression in various tissues, as described in Example A. The inset in Figure 1 shows a graphic representation of the levels of human LgR5 gene expression in normal colon tissues and colon tumors, as described in Example A.

[0026] **Figure 2** shows expression of LgR5 in colon tumors by in situ hybridization, as described in Example B.

[0027] **Figures 3A and 3B** show (A) the prevalence of various levels of LgR5 expression in a colon tumor tissue microarray, and (B) the heterogeneity of LgR5 expression in three cores from each colorectal adenocarcinoma sample, both determined by in situ hybridization, as described in Example B.

[0028] **Figures 4A and 4B** show an alignment of the (A) light chain and (B) heavy chain of antibody LGR5.1-12 and antibody LGR5.26-1. The contact region, Chothia, and Kabat complementarity determining regions (CDRs, also referred to as hypervariable regions, or HVRs) are indicated. The Kabat HVRs are underlined.

[0029] **Figures 5A, 5B, and 5C** show staining of (A) colon tissue, (B) hair follicle, and (C) spinal cord with antibody LGR5.1-12, as described in Example E.

[0030] **Figures 6A, 6B, 6C, and 6D** show detection of LgR5 on the surface of (A) LoVo X 1.1 xenograft tumor cells and (B) D5124 xenograft tumor cells by FACS using antibody YW353, and staining of (C) LoVo X 1.1 xenograft tumors and (D) D5124 xenograft tumors by immunohistochemistry, using antibody LGR5.1-12, as described in Example F.

[0031] **Figures 7A, 7B, 7C, and 7D** show exemplary 0, 1+, 2+, and 3+ staining of colon tumors using antibody LGR5.1-12, as described in Example G.

[0032] **Figures 8A and 8B** show staining of a CXF233 xenograft tumor sample using (A) antibody LGR5.1-12 and (B) antibody LGR5.26-1, as described in Example H.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

I. DEFINITIONS

[0033] An “acceptor human framework” for the purposes herein is a framework comprising the amino acid sequence of a light chain variable domain (VL) framework or a heavy chain variable domain (VH) framework derived from a human immunoglobulin framework or a human consensus framework, as defined below. An acceptor human framework “derived from” a human immunoglobulin framework or a human consensus framework may comprise the same amino acid sequence thereof, or it may contain amino acid sequence changes. In some embodiments, the number of amino acid changes are 10 or less, 9 or less, 8 or less, 7 or less, 6 or less, 5 or less, 4 or less, 3 or less, or 2 or less. In some embodiments, the VL acceptor human framework is identical in sequence to the VL human immunoglobulin framework sequence or human consensus framework sequence.

[0034] “Affinity” refers to the strength of the sum total of noncovalent interactions between a single binding site of a molecule (e.g., an antibody) and its binding partner (e.g., an antigen). Unless indicated otherwise, as used herein, “binding affinity” refers to intrinsic binding affinity which reflects a 1:1 interaction between members of a binding pair (e.g., antibody and antigen). The affinity of a molecule X for its partner Y can generally be represented by the dissociation constant (K_d). Affinity can be measured by common methods known in the art, including those described herein. Specific illustrative and exemplary embodiments for measuring binding affinity are described in the following.

[0035] An “affinity matured” antibody refers to an antibody with one or more alterations in one or more hypervariable regions (HVRs), compared to a parent antibody which does not possess such alterations, such alterations resulting in an improvement in the affinity of the antibody for antigen.

[0036] The terms “anti-LgR5 antibody” and “an antibody that binds to LgR5” refer to an antibody that is capable of binding LgR5 with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting LgR5. In one embodiment, the extent of binding of an anti-LgR5 antibody to an unrelated, non-LgR5 protein is less than about 10% of the binding of the antibody to LgR5 as measured, e.g., by a radioimmunoassay (RIA) or by scatchard analysis or by surface plasmon resonance, such as, for example, Biacore. In certain embodiments, an antibody that binds to LgR5 has a dissociation constant (K_d) of $\leq 1\mu\text{M}$, $\leq 100\text{ nM}$, $\leq 10\text{ nM}$, $\leq 5\text{ nM}$, $\leq 4\text{ nM}$, $\leq 3\text{ nM}$, $\leq 2\text{ nM}$, $\leq 1\text{ nM}$, $\leq 0.1\text{ nM}$, $\leq 0.01\text{ nM}$, or $\leq 0.001\text{ nM}$ (e.g., 10^{-8} M or less, e.g. from 10^{-8} M to 10^{-13} M , e.g., from 10^{-9} M to 10^{-13} M). In certain

embodiments, an anti-LgR5 antibody binds to an epitope of LgR5 that is conserved among LgR5 from different species.

[0037] The term “antibody” is used herein in the broadest sense and encompasses various antibody structures, including but not limited to monoclonal antibodies, polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies), and antibody fragments so long as they exhibit the desired antigen-binding activity.

[0038] The term “antibody drug conjugate” (ADC) as used herein is equivalent to the term “immunoconjugate”.

[0039] An “antibody fragment” refers to a molecule other than an intact antibody that comprises a portion of an intact antibody and that binds the antigen to which the intact antibody binds. Examples of antibody fragments include but are not limited to Fv, Fab, Fab', Fab'-SH, F(ab')₂; diabodies; linear antibodies; single-chain antibody molecules (e.g. scFv); and multispecific antibodies formed from antibody fragments.

[0040] An “antibody that binds to the same epitope” as a reference antibody refers to an antibody that blocks binding of the reference antibody to its antigen in a competition assay by 50% or more, and conversely, the reference antibody blocks binding of the antibody to its antigen in a competition assay by 50% or more. An exemplary competition assay is provided herein.

[0041] The terms “cancer” and “cancerous” refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth/proliferation. Examples of cancer include, but are not limited to, carcinoma, lymphoma (e.g., Hodgkin's and non-Hodgkin's lymphoma), blastoma, sarcoma, and leukemia. More particular examples of such cancers include squamous cell cancer, small-cell lung cancer, non-small cell lung cancer, adenocarcinoma of the lung, squamous carcinoma of the lung, cancer of the peritoneum, hepatocellular cancer, gastrointestinal cancer, pancreatic cancer, glioma, cervical cancer, ovarian cancer, liver cancer, bladder cancer, hepatoma, breast cancer, colon cancer, colorectal cancer, endometrial or uterine carcinoma, salivary gland carcinoma, kidney cancer, liver cancer, prostate cancer, vulval cancer, thyroid cancer, hepatic carcinoma, leukemia and other lymphoproliferative disorders, and various types of head and neck cancer.

[0042] The term “chimeric” antibody refers to an antibody in which a portion of the heavy and/or light chain is derived from a particular source or species, while the remainder of the heavy and/or light chain is derived from a different source or species.

[0043] The “class” of an antibody refers to the type of constant domain or constant region possessed by its heavy chain. There are five major classes of antibodies: IgA, IgD, IgE,

IgG, and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG₁, IgG₂, IgG₃, IgG₄, IgA₁, and IgA₂. The heavy chain constant domains that correspond to the different classes of immunoglobulins are called α , δ , ϵ , γ , and μ , respectively.

[0044] The term “cytotoxic agent” as used herein refers to a substance that inhibits or prevents a cellular function and/or causes cell death or destruction. Cytotoxic agents include, but are not limited to, radioactive isotopes (e.g., At²¹¹, I¹³¹, I¹²⁵, Y⁹⁰, Re¹⁸⁶, Re¹⁸⁸, Sm¹⁵³, Bi²¹², P³², Pb²¹² and radioactive isotopes of Lu); chemotherapeutic agents or drugs (e.g., methotrexate, adriamycin, vinca alkaloids (vincristine, vinblastine, etoposide), doxorubicin, melphalan, mitomycin C, chlorambucil, daunorubicin or other intercalating agents); growth inhibitory agents; enzymes and fragments thereof such as nucleolytic enzymes; antibiotics; toxins such as small molecule toxins or enzymatically active toxins of bacterial, fungal, plant or animal origin, including fragments and/or variants thereof; and the various antitumor or anticancer agents disclosed below.

[0045] “Effector functions” refer to those biological activities attributable to the Fc region of an antibody, which vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity (CDC); Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (e.g. B cell receptor); and B cell activation.

[0046] An “effective amount” of an agent, e.g., a pharmaceutical formulation, refers to an amount effective, at dosages and for periods of time necessary, to achieve the desired therapeutic or prophylactic result.

[0047] The term “epitope” refers to the particular site on an antigen molecule to which an antibody binds.

[0048] The term “Fc region” herein is used to define a C-terminal region of an immunoglobulin heavy chain that contains at least a portion of the constant region. The term includes native sequence Fc regions and variant Fc regions. In one embodiment, a human IgG heavy chain Fc region extends from Cys226, or from Pro230, to the carboxyl-terminus of the heavy chain. However, the C-terminal lysine (Lys447) of the Fc region may or may not be present. Unless otherwise specified herein, numbering of amino acid residues in the Fc region or constant region is according to the EU numbering system, also called the EU index, as described in Kabat et al., *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD, 1991.

[0049] “Framework” or “FR” refers to variable domain residues other than hypervariable region (HVR) residues. The FR of a variable domain generally consists of four FR domains:

FR1, FR2, FR3, and FR4. Accordingly, the HVR and FR sequences generally appear in the following sequence in VH (or VL): FR1-H1(L1)-FR2-H2(L2)-FR3-H3(L3)-FR4.

[0050] The terms “full length antibody,” “intact antibody,” and “whole antibody” are used herein interchangeably to refer to an antibody having a structure substantially similar to a native antibody structure or having heavy chains that contain an Fc region as defined herein.

[0051] The term “glycosylated forms of LgR5” refers to naturally occurring forms of LgR5 that are post-translationally modified by the addition of carbohydrate residues.

[0052] The terms “host cell,” “host cell line,” and “host cell culture” are used interchangeably and refer to cells into which exogenous nucleic acid has been introduced, including the progeny of such cells. Host cells include “transformants” and “transformed cells,” which include the primary transformed cell and progeny derived therefrom without regard to the number of passages. Progeny may not be completely identical in nucleic acid content to a parent cell, but may contain mutations. Mutant progeny that have the same function or biological activity as screened or selected for in the originally transformed cell are included herein.

[0053] A “human antibody” is one which possesses an amino acid sequence which corresponds to that of an antibody produced by a human or a human cell or derived from a non-human source that utilizes human antibody repertoires or other human antibody-encoding sequences. This definition of a human antibody specifically excludes a humanized antibody comprising non-human antigen-binding residues.

[0054] A “rabbit antibody” is one which possesses an amino acid sequence which corresponds to that of an antibody produced by a rabbit or a rabbit cell or derived from a non-rabbit source that utilizes rabbit antibody repertoires or other rabbit antibody-encoding sequences.

[0055] A “human consensus framework” is a framework which represents the most commonly occurring amino acid residues in a selection of human immunoglobulin VL or VH framework sequences. Generally, the selection of human immunoglobulin VL or VH sequences is from a subgroup of variable domain sequences. Generally, the subgroup of sequences is a subgroup as in Kabat et al., *Sequences of Proteins of Immunological Interest*, Fifth Edition, NIH Publication 91-3242, Bethesda MD (1991), vols. 1-3. In one embodiment, for the VL, the subgroup is subgroup kappa I as in Kabat et al., *supra*. In one embodiment, for the VH, the subgroup is subgroup III as in Kabat et al., *supra*.

[0056] A “humanized” antibody refers to a chimeric antibody comprising amino acid residues from non-human HVRs and amino acid residues from human FRs. In certain embodiments, a humanized antibody will comprise substantially all of at least one, and typically

two, variable domains, in which all or substantially all of the HVRs (e.g., CDRs) correspond to those of a non-human antibody, and all or substantially all of the FRs correspond to those of a human antibody. A humanized antibody optionally may comprise at least a portion of an antibody constant region derived from a human antibody. A “humanized form” of an antibody, e.g., a non-human antibody, refers to an antibody that has undergone humanization.

[0057] The term “hypervariable region” or “HVR,” as used herein, refers to each of the regions of an antibody variable domain which are hypervariable in sequence and/or form structurally defined loops (“hypervariable loops”). Generally, native four-chain antibodies comprise six HVRs; three in the VH (H1, H2, H3), and three in the VL (L1, L2, L3). HVRs generally comprise amino acid residues from the hypervariable loops and/or from the “complementarity determining regions” (CDRs), the latter being of highest sequence variability and/or involved in antigen recognition. Exemplary hypervariable loops occur at amino acid residues 26-32 (L1), 50-52 (L2), 91-96 (L3), 26-32 (H1), 53-55 (H2), and 96-101 (H3). (Chothia and Lesk, *J. Mol. Biol.* 196:901-917 (1987).) Exemplary CDRs (CDR-L1, CDR-L2, CDR-L3, CDR-H1, CDR-H2, and CDR-H3) occur at amino acid residues 24-34 of L1, 50-56 of L2, 89-97 of L3, 31-35B of H1, 50-65 of H2, and 95-102 of H3. (Kabat et al., *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD (1991).) With the exception of CDR1 in VH, CDRs generally comprise the amino acid residues that form the hypervariable loops. CDRs also comprise “specificity determining residues,” or “SDRs,” which are residues that contact antigen. SDRs are contained within regions of the CDRs called abbreviated-CDRs, or a-CDRs. Exemplary a-CDRs (a-CDR-L1, a-CDR-L2, a-CDR-L3, a-CDR-H1, a-CDR-H2, and a-CDR-H3) occur at amino acid residues 31-34 of L1, 50-55 of L2, 89-96 of L3, 31-35B of H1, 50-58 of H2, and 95-102 of H3. (See Almagro and Fransson, *Front. Biosci.* 13:1619-1633 (2008).) Unless otherwise indicated, HVR residues and other residues in the variable domain (e.g., FR residues) are numbered herein according to Kabat et al., *supra*.

[0058] An “immunoconjugate” is an antibody conjugated to one or more heterologous molecule(s), including but not limited to a cytotoxic agent. An immunoconjugate is equivalent to the term “antibody drug conjugate” (ADC).

[0059] An “individual” or “patient” or “subject” is a mammal. Mammals include, but are not limited to, domesticated animals (e.g., cows, sheep, cats, dogs, and horses), primates (e.g., humans and non-human primates such as monkeys), rabbits, and rodents (e.g., mice and rats). In certain embodiments, the individual or subject is a human.

[0060] An “isolated antibody” is one which has been separated from a component of its natural environment. In some embodiments, an antibody is purified to greater than 95% or 99% purity as determined by, for example, electrophoretic (e.g., SDS-PAGE, isoelectric focusing (IEF), capillary electrophoresis) or chromatographic (e.g., ion exchange or reverse phase HPLC). For review of methods for assessment of antibody purity, see, e.g., Flatman et al., *J. Chromatogr. B* 848:79-87 (2007).

[0061] An “isolated nucleic acid” refers to a nucleic acid molecule that has been separated from a component of its natural environment. An isolated nucleic acid includes a nucleic acid molecule contained in cells that ordinarily contain the nucleic acid molecule, but the nucleic acid molecule is present extrachromosomally or at a chromosomal location that is different from its natural chromosomal location.

[0062] “Isolated nucleic acid encoding an anti-LgR5 antibody” refers to one or more nucleic acid molecules encoding antibody heavy and light chains (or fragments thereof), including such nucleic acid molecule(s) in a single vector or separate vectors, and such nucleic acid molecule(s) present at one or more locations in a host cell.

[0063] The term “LgR5,” as used herein, refers to any native, mature LgR5 which results from processing of an LgR5 precursor protein in a cell. The term includes LgR5 from any vertebrate source, including mammals such as primates (e.g. humans and cynomolgus or rhesus monkeys) and rodents (e.g., mice and rats), unless otherwise indicated. The term also includes naturally occurring variants of LgR5, e.g., splice variants or allelic variants. The amino acid sequence of an exemplary human LgR5 precursor protein, with signal sequence (amino acids 1-21) is shown in SEQ ID NO: 21. The amino acid sequence of an exemplary mature human LgR5 is shown in SEQ ID NO: 22. The predicted sequence for amino acids 33 to 907 of an exemplary cynomolgus monkey LgR5 is shown in SEQ ID NO: 23. The amino acid sequences for exemplary rat LgR5 precursor (with signal sequence, amino acids 1-21) and mature sequences are shown in SEQ ID NOs: 24 and 25, respectively. The amino acid sequences for exemplary mouse LgR5 precursor (with signal sequence, amino acids 1-21) and mature sequences are shown in SEQ ID NOs: 26 and 27, respectively.

[0064] The term “LgR5-positive cancer” refers to a cancer comprising cells that express LgR5 on their surface. For the purposes of determining whether a cell expresses LgR5 on the surface, LgR5 mRNA expression is considered to correlate to LgR5 expression on the cell surface. In some embodiments, expression of LgR5 mRNA is determined by a method selected from in situ hybridization and RT-PCR (including quantitative RT-PCR). Alternatively,

expression of LgR5 on the cell surface can be determined, for example, using antibodies to LgR5 in a method such as immunohistochemistry, FACS, etc.

[0065] The term “LgR5-positive cancer cell” refers to a cancer cell that expresses LgR5 on its surface.

[0066] The term “monoclonal antibody” as used herein refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies comprising the population are identical and/or bind the same epitope, except for possible variant antibodies, e.g., containing naturally occurring mutations or arising during production of a monoclonal antibody preparation, such variants generally being present in minor amounts. In contrast to polyclonal antibody preparations, which typically include different antibodies directed against different determinants (epitopes), each monoclonal antibody of a monoclonal antibody preparation is directed against a single determinant on an antigen. Thus, the modifier “monoclonal” indicates the character of the antibody as being obtained from a substantially homogeneous population of antibodies, and is not to be construed as requiring production of the antibody by any particular method. For example, the monoclonal antibodies to be used in accordance with the present invention may be made by a variety of techniques, including but not limited to the hybridoma method, recombinant DNA methods, phage-display methods, and methods utilizing transgenic animals containing all or part of the human immunoglobulin loci, such methods and other exemplary methods for making monoclonal antibodies being described herein.

[0067] A “naked antibody” refers to an antibody that is not conjugated to a heterologous moiety (e.g., a cytotoxic moiety) or radiolabel. The naked antibody may be present in a pharmaceutical formulation.

[0068] “Native antibodies” refer to naturally occurring immunoglobulin molecules with varying structures. For example, native IgG antibodies are heterotetrameric glycoproteins of about 150,000 daltons, composed of two identical light chains and two identical heavy chains that are disulfide-bonded. From N- to C-terminus, each heavy chain has a variable region (VH), also called a variable heavy domain or a heavy chain variable domain, followed by three constant domains (CH1, CH2, and CH3). Similarly, from N- to C-terminus, each light chain has a variable region (VL), also called a variable light domain or a light chain variable domain, followed by a constant light (CL) domain. The light chain of an antibody may be assigned to one of two types, called kappa (κ) and lambda (λ), based on the amino acid sequence of its constant domain.

[0069] The term “package insert” is used to refer to instructions customarily included in commercial packages of therapeutic products, that contain information about the indications, usage, dosage, administration, combination therapy, contraindications and/or warnings concerning the use of such therapeutic products.

[0070] “Percent (%) amino acid sequence identity” with respect to a reference polypeptide sequence is defined as the percentage of amino acid residues in a candidate sequence that are identical with the amino acid residues in the reference polypeptide sequence, after aligning the sequences and introducing gaps, if necessary, to achieve the maximum percent sequence identity, and not considering any conservative substitutions as part of the sequence identity. Alignment for purposes of determining percent amino acid sequence identity can be achieved in various ways that are within the skill in the art, for instance, using publicly available computer software such as BLAST, BLAST-2, ALIGN or Megalign (DNASTAR) software. Those skilled in the art can determine appropriate parameters for aligning sequences, including any algorithms needed to achieve maximal alignment over the full length of the sequences being compared. For purposes herein, however, % amino acid sequence identity values are generated using the sequence comparison computer program ALIGN-2. The ALIGN-2 sequence comparison computer program was authored by Genentech, Inc., and the source code has been filed with user documentation in the U.S. Copyright Office, Washington D.C., 20559, where it is registered under U.S. Copyright Registration No. TXU510087. The ALIGN-2 program is publicly available from Genentech, Inc., South San Francisco, California, or may be compiled from the source code. The ALIGN-2 program should be compiled for use on a UNIX operating system, including digital UNIX V4.0D. All sequence comparison parameters are set by the ALIGN-2 program and do not vary.

[0071] In situations where ALIGN-2 is employed for amino acid sequence comparisons, the % amino acid sequence identity of a given amino acid sequence A to, with, or against a given amino acid sequence B (which can alternatively be phrased as a given amino acid sequence A that has or comprises a certain % amino acid sequence identity to, with, or against a given amino acid sequence B) is calculated as follows:

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

[0072] where X is the number of amino acid residues scored as identical matches by the sequence alignment program ALIGN-2 in that program’s alignment of A and B, and where Y is the total number of amino acid residues in B. It will be appreciated that where the length of amino acid sequence A is not equal to the length of amino acid sequence B, the % amino acid sequence identity of A to B will not equal the % amino acid sequence identity of B to A. Unless

specifically stated otherwise, all % amino acid sequence identity values used herein are obtained as described in the immediately preceding paragraph using the ALIGN-2 computer program.

[0073] The term “pharmaceutical formulation” refers to a preparation which is in such form as to permit the biological activity of an active ingredient contained therein to be effective, and which contains no additional components which are unacceptably toxic to a subject to which the formulation would be administered.

[0074] A “pharmaceutically acceptable carrier” refers to an ingredient in a pharmaceutical formulation, other than an active ingredient, which is nontoxic to a subject. A pharmaceutically acceptable carrier includes, but is not limited to, a buffer, excipient, stabilizer, or preservative.

[0075] A “platinum complex” as used herein refers to anti-cancer chemotherapy drugs such as, for example, but not limited to, cisplatin, oxaliplatin, carboplatin, iproplatin, satraplatin, CI-973, AZ0473, DWA2114R, nedaplatin, and sprioplatin, which exert efficacy against tumors based on their ability to covalently bind to DNA.

[0076] As used herein, “treatment” (and grammatical variations thereof such as “treat” or “treating”) refers to clinical intervention in an attempt to alter the natural course of the individual being treated, and can be performed either for prophylaxis or during the course of clinical pathology. Desirable effects of treatment include, but are not limited to, preventing occurrence or recurrence of disease, alleviation of symptoms, diminishment of any direct or indirect pathological consequences of the disease, preventing metastasis, decreasing the rate of disease progression, amelioration or palliation of the disease state, and remission or improved prognosis. In some embodiments, anti-LgR5 antibodies are used to delay development of a disease or to slow the progression of a disease.

[0077] The term “variable region” or “variable domain” refers to the domain of an antibody heavy or light chain that is involved in binding the antibody to antigen. The variable domains of the heavy chain and light chain (VH and VL, respectively) of a native antibody generally have similar structures, with each domain comprising four conserved framework regions (FRs) and three hypervariable regions (HVRs). (See, e.g., Kindt et al. *Kuby Immunology*, 6th ed., W.H. Freeman and Co., page 91 (2007).) A single VH or VL domain may be sufficient to confer antigen-binding specificity. Furthermore, antibodies that bind a particular antigen may be isolated using a VH or VL domain from an antibody that binds the antigen to screen a library of complementary VL or VH domains, respectively. See, e.g., Portolano et al., *J. Immunol.* 150:880-887 (1993); Clarkson et al., *Nature* 352:624-628 (1991).

[0078] The term “vector,” as used herein, refers to a nucleic acid molecule capable of propagating another nucleic acid to which it is linked. The term includes the vector as a self-replicating nucleic acid structure as well as the vector incorporated into the genome of a host cell into which it has been introduced. Certain vectors are capable of directing the expression of nucleic acids to which they are operatively linked. Such vectors are referred to herein as “expression vectors.”

II. COMPOSITIONS AND METHODS

[0079] In one aspect, the invention is based, in part, on antibodies that bind to LgR5 and immunoconjugates comprising such antibodies. Antibodies and immunoconjugates of the invention are useful, e.g., for the diagnosis or treatment of LgR5-positive cancers.

A. Exemplary Anti-LgR5 Antibodies

[0080] In some embodiments, the invention provides isolated antibodies that bind to LgR5. LgR5 is a seven-transmembrane protein found, for example, on the surface of actively cycling intestinal stem cells. LgR5 is expressed in about 77% of colon tumor sections examined. *See, e.g.*, PCT Publication No. WO 2013/149159. An exemplary naturally occurring human LgR5 precursor protein sequence, with signal sequence (amino acids 1-21) is provided in SEQ ID NO: 21, and the corresponding mature LgR5 protein sequence is shown in SEQ ID NO: 22 (corresponding to amino acids 22-907 of SEQ ID NO: 21).

[0081] In some embodiments, the invention provides isolated antibodies that bind to an epitope within amino acids 22 to 322 of human LgR5. In some embodiments, the invention provides isolated antibodies that bind to an epitope within the human LgR5 extracellular domain that is outside of amino acids 22 to 322. In some embodiments, the invention provides isolated antibodies that bind to an epitope within amino acids 323 to 558 of human LgR5.

Antibody α LgR5.1-12 and other embodiments

[0082] In one aspect, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:12; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:14; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11.

[0083] In one aspect, the invention provides an antibody comprising at least one, at least two, or all three VH HVR sequences selected from (a) HVR-H1 comprising the amino acid

sequence of SEQ ID NO:12; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13; and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:14. In one embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:14. In another embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:14 and HVR-L3 comprising the amino acid sequence of SEQ ID NO:11. In a further embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:14, HVR-L3 comprising the amino acid sequence of SEQ ID NO:11, and HVR-H2 comprising the amino acid sequence of SEQ ID NO:13. In a further embodiment, the antibody comprises (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:12; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13; and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:14.

[0084] In another aspect, the invention provides an antibody comprising at least one, at least two, or all three VL HVR sequences selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11. In one embodiment, the antibody comprises (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11.

[0085] In another aspect, an antibody of the invention comprises (a) a VH domain comprising at least one, at least two, or all three VH HVR sequences selected from (i) HVR-H1 comprising the amino acid sequence of SEQ ID NO:12, (ii) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13, and (iii) HVR-H3 comprising an amino acid sequence selected from SEQ ID NO:14; and (b) a VL domain comprising at least one, at least two, or all three VL HVR sequences selected from (i) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9, (ii) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10, and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11.

[0086] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:12; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:14; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11.

[0087] In any of the above embodiments, an anti-LgR5 antibody is humanized. In one embodiment, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and

further comprises a human acceptor framework, e.g. a human immunoglobulin framework or a human consensus framework. In some embodiments, an anti-LgR5 antibody comprises the HVRs described above and rabbit framework regions.

[0088] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:6. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO:6. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). Optionally, the anti-LgR5 antibody comprises the VH sequence of SEQ ID NO:6, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:12, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:13, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:14.

[0089] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:5. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO:5. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). Optionally, the anti-LgR5 antibody comprises the VL sequence of SEQ ID NO:5, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:9; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:10; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:11.

[0090] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL

sequences in SEQ ID NO:6 and SEQ ID NO:5, respectively, including post-translational modifications of those sequences.

[0091] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:6 and a VL sequence of SEQ ID NO:5. In some embodiments, an antibody that competes with an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:6 and a VL sequence of SEQ ID NO:5 for binding to human LgR5 is provided. In some embodiments, an antibody that competes with an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:6 and a VL sequence of SEQ ID NO:5 for binding to human LgR5 is provided. In some embodiments, an antibody that binds an epitope within the LgR5 extracellular domain that is outside of amino acids 22 to 322 is provided. In some embodiments, an antibody that does not compete for binding to human LgR5 with antibody either huYW353 or 8E11. In some embodiments, an antibody that binds to an epitope within amino acids 323 to 558 of human LgR5 is provided.

[0092] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, e.g., a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, e.g., an IgG1 antibody or other antibody class or isotype as defined herein.

[0093] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below:

Antibody α LgR5.26-1 and other embodiments

[0094] In one aspect, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:19; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:16; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO:17.

[0095] In one aspect, the invention provides an antibody comprising at least one, at least two, or all three VH HVR sequences selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18; (b) HVR-H2 comprising the amino acid sequence of SEQ ID

NO:19; and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20. In one embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:20. In another embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:20, and HVR-L3 comprising the amino acid sequence of SEQ ID NO:17. In a further embodiment, the antibody comprises HVR-H3 comprising the amino acid sequence of SEQ ID NO:20, HVR-L3 comprising the amino acid sequence of SEQ ID NO:17, and HVR-H2 comprising the amino acid sequence of SEQ ID NO:19. In a further embodiment, the antibody comprises (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:19; and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20.

[0096] In another aspect, the invention provides an antibody comprising at least one, at least two, or all three VL HVR sequences selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:16; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:17. In one embodiment, the antibody comprises (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:16; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:17.

[0097] In another aspect, an antibody of the invention comprises (a) a VH domain comprising at least one, at least two, or all three VH HVR sequences selected from (i) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18, (ii) HVR-H2 comprising the amino acid sequence of SEQ ID NO:19, and (iii) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20; and (b) a VL domain comprising at least one, at least two, or all three VL HVR sequences selected from (i) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15, (ii) HVR-L2 comprising the amino acid sequence of SEQ ID NO:16, and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:17.

[0098] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:19; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO:16; and (f) HVR-L3 comprising an amino acid sequence selected from SEQ ID NO:17.

[0099] In any of the above embodiments, an anti-LgR5 antibody is humanized. In one embodiment, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises an acceptor human framework, e.g. a human immunoglobulin framework or a

human consensus framework. In some embodiments, an anti-LgR5 antibody comprises the HVRs described above and rabbit framework regions.

[0100] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:8. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO:8. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). Optionally, the anti-LgR5 antibody comprises the VH sequence of SEQ ID NO:8, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO:18, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO:19, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO:20.

[0101] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO:7. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity contains substitutions (e.g., conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO:7. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs). Optionally, the anti-LgR5 antibody comprises the VL sequence of SEQ ID NO:7, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO:15; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO:8; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO:17.

[0102] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL

sequences in SEQ ID NO:8 and SEQ ID NO:7, respectively, including post-translational modifications of those sequences.

[0103] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:8 and a VL sequence of SEQ ID NO:7. In some embodiments, an antibody that competes with an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:8 and a VL sequence of SEQ ID NO:7 for binding to human LgR5 is provided. In some embodiments, an antibody that competes with an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO:8 and a VL sequence of SEQ ID NO:7 for binding to an epitope within amino acids 22 to 322 of human LgR5 is provided.

[0104] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, e.g., a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, e.g., an IgG2a antibody or other antibody class or isotype as defined herein.

[0105] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below:

Antibody 8E11 and other embodiments

[0106] In some embodiments, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 55; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 56; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 57; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 52; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 53; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 54.

[0107] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 55; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 56; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 57; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 52; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 53; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 54.

[0108] In any of the above embodiments, an anti-LgR5 antibody is humanized. In one embodiment, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a human acceptor framework, *e.g.* a human immunoglobulin framework or a human consensus framework. In certain embodiments, the human acceptor framework is the human VL kappa IV consensus (VL_{KIV}) framework and/or the VH framework VH₁. In certain embodiments, the human acceptor framework is the human VL kappa IV consensus (VL_{KIV}) framework and/or the VH framework VH₁ comprising an R71S mutation and an A78V mutation in heavy chain framework region FR3.

[0109] In some embodiments, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a heavy chain framework FR3 sequence selected from SEQ ID NOs: 65 to 68. In some embodiments, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a heavy chain framework FR3 sequence of SEQ ID NO: 66. In some such embodiments, the heavy chain variable domain framework is a modified human VH₁ framework having an FR3 sequence selected from SEQ ID NOs: 65 to 68. In some such embodiments, the heavy chain variable domain framework is a modified human VH₁ framework having an FR3 sequence of SEQ ID NO: 66.

[0110] In some embodiments, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a light chain framework FR3 sequence of SEQ ID NO: 61. In some such embodiments, the heavy chain variable domain framework is a modified VL kappa IV consensus (VL_{KIV}) framework having an FR3 sequence of SEQ ID NO: 61.

[0111] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs: 31, 33, 35, 37, 39, 41, 43, and 45. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to an amino acid sequence selected from SEQ ID NOs: 31, 33, 35, 37, 39, 41, 43, and 45 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in a sequence selected from SEQ ID NOs: 31, 33, 35, 37, 39, 41, 43, and 45. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in a sequence selected from SEQ ID NOs: 31, 33, 35, 37, 39, 41, 43, and 45. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs).

[0112] In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 31. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 33. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 35. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 37. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 39. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 41. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 43. In some embodiments, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 45.

[0113] Optionally, the anti-LgR5 antibody comprises the VH sequence selected from SEQ ID NOs: 31, 33, 35, 37, 39, 41, 43, and 45, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 55, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 56, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 57.

[0114] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to an amino acid sequence selected from SEQ ID NOs: 30, 32, 34, 36, 38, 40, 42, and 44. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to an amino acid sequence selected from SEQ ID NOs: 30, 32, 34, 36, 38, 40, 42, and 44 contains substitutions

(*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in an amino acid sequence selected from SEQ ID NOs: 30, 32, 34, 36, 38, 40, 42, and 44. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in an amino acid sequence selected from SEQ ID NOs: 30, 32, 34, 36, 38, 40, 42, and 44. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs).

[0115] In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 30. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 32. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 34. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 36. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 38. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 40. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 42. In some embodiments, an anti-LgR5 antibody comprises a light chain variable domain (VL) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 44.

[0116] Optionally, the anti-LgR5 antibody comprises the VL sequence of an amino acid sequence selected from SEQ ID NOs: 30, 32, 34, 36, 38, 40, 42, and 44, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID

NO: 52; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 53; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 54.

[0117] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 31 and SEQ ID NO: 30, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 33 and SEQ ID NO: 32, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 35 and SEQ ID NO: 34, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 37 and SEQ ID NO: 36, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 39 and SEQ ID NO: 39, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 41 and SEQ ID NO: 40, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 43 and SEQ ID NO: 42, respectively, including post-translational modifications of those sequences. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 45 and SEQ ID NO: 44, respectively, including post-translational modifications of those sequences.

[0118] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO: 33 and a VL sequence of SEQ ID NO: 32. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping amino acids 22-323. In some embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 1-312.

[0119] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, *e.g.*, a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, *e.g.*, an IgG1 antibody or other antibody class or isotype as defined herein.

[0120] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below.

Antibody YW353 and other embodiments

[0121] In one aspect, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 85; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 86; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 87; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 82; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 83; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 84.

[0122] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 85; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 86; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 87; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 82; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 83; and (f) HVR-L3 comprising an amino acid sequence selected from SEQ ID NO: 84.

[0123] In any of the above embodiments, an anti-LgR5 antibody is a human antibody.

[0124] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 26. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 51 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO: 51. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in SEQ ID NO: 51. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs). Optionally, the anti-LgR5 antibody comprises the VH sequence of SEQ ID NO: 51, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 85, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 86, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 87.

[0125] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 50. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 50 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in SEQ ID NO: 50. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in SEQ ID NO: 50. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs). Optionally, the anti-LgR5 antibody comprises the VL sequence of SEQ ID NO: 50, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 82; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 83; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 84.

[0126] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 51 and SEQ ID NO: 50, respectively, including post-translational modifications of those sequences.

[0127] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO: 51 and a VL sequence of SEQ ID NO: 50. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping amino acids 22-123. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 1-102.

[0128] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, *e.g.*, a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, *e.g.*, an IgG2a antibody or other antibody class or isotype as defined herein.

[0129] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below.

Antibody 3G12 and other embodiments

[0130] In some embodiments, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 73; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 74; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 75; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 70; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 71; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 72.

[0131] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 73; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 74; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 75; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 70; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 71; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 72.

[0132] In any of the above embodiments, an anti-LgR5 antibody is humanized. In one embodiment, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a human acceptor framework, *e.g.* a human immunoglobulin framework or a human consensus framework. In certain embodiments, the human acceptor framework is the human VL kappa consensus (VL_K) framework and/or the human VH subgroup 3 consensus (VH₃) framework.

[0133] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 47. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 47 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 47. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 47. In

certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs).

[0134] Optionally, the anti-LgR5 antibody comprises the VH sequence of SEQ ID NO: 47, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 73, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 74, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 75.

[0135] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 46. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 46 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 46. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 46. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (i.e., in the FRs).

[0136] Optionally, the anti-LgR5 antibody comprises the VL sequence of SEQ ID NO: 46, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 70; (b) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 71; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 72.

[0137] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 47 and SEQ ID NO: 46, respectively, including post-translational modifications of those sequences.

[0138] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO: 47 and a VL sequence of SEQ ID NO: 46. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping

amino acids 324-423. In some embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 303-402. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping amino acids 324-555. In some embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 303-534.

[0139] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, *e.g.*, a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, *e.g.*, an IgG1 antibody or other antibody class or isotype as defined herein.

[0140] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below.

Antibody 2H6 and other embodiments

[0141] In some embodiments, the invention provides an anti-LgR5 antibody comprising at least one, two, three, four, five, or six HVRs selected from (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 79; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 80; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 81; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 76; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 77; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 78.

[0142] In another aspect, the invention provides an antibody comprising (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 79; (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 80; (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 81; (d) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 76; (e) HVR-L2 comprising the amino acid sequence of SEQ ID NO: 77; and (f) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 78.

[0143] In any of the above embodiments, an anti-LgR5 antibody is humanized. In one embodiment, an anti-LgR5 antibody comprises HVRs as in any of the above embodiments, and further comprises a human acceptor framework, *e.g.* a human immunoglobulin framework or a human consensus framework. In certain embodiments, the human acceptor framework is the human VL kappa consensus (VL_K) framework and/or the human VH subgroup 3 (VH₃) framework.

[0144] In another aspect, an anti-LgR5 antibody comprises a heavy chain variable domain (VH) sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 49. In certain embodiments, a VH sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 49 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 49. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 49. In certain embodiments, substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs).

[0145] Optionally, the anti-LgR5 antibody comprises the VH sequence of SEQ ID NO: 49, including post-translational modifications of that sequence. In a particular embodiment, the VH comprises one, two or three HVRs selected from: (a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 79, (b) HVR-H2 comprising the amino acid sequence of SEQ ID NO: 80, and (c) HVR-H3 comprising the amino acid sequence of SEQ ID NO: 81.

[0146] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a light chain variable domain (VL) having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100% sequence identity to the amino acid sequence of SEQ ID NO: 48. In certain embodiments, a VL sequence having at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence of SEQ ID NO: 48 contains substitutions (*e.g.*, conservative substitutions), insertions, or deletions relative to the reference sequence, but an anti-LgR5 antibody comprising that sequence retains the ability to bind to LgR5. In certain embodiments, a total of 1 to 10 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 48. In certain embodiments, a total of 1 to 5 amino acids have been substituted, inserted and/or deleted in the amino acid sequence of SEQ ID NO: 48. In certain embodiments, the substitutions, insertions, or deletions occur in regions outside the HVRs (*i.e.*, in the FRs).

[0147] Optionally, the anti-LgR5 antibody comprises the VL sequence of the amino acid sequence of SEQ ID NO: 48, including post-translational modifications of that sequence. In a particular embodiment, the VL comprises one, two or three HVRs selected from (a) HVR-L1 comprising the amino acid sequence of SEQ ID NO: 76; (b) HVR-L2 comprising the amino acid

sequence of SEQ ID NO: 77; and (c) HVR-L3 comprising the amino acid sequence of SEQ ID NO: 78.

[0148] In another aspect, an anti-LgR5 antibody is provided, wherein the antibody comprises a VH as in any of the embodiments provided above, and a VL as in any of the embodiments provided above. In one embodiment, the antibody comprises the VH and VL sequences in SEQ ID NO: 49 and SEQ ID NO: 48, respectively, including post-translational modifications of those sequences.

[0149] In a further aspect, the invention provides an antibody that binds to the same epitope as an anti-LgR5 antibody provided herein. For example, in certain embodiments, an antibody is provided that binds to the same epitope as an anti-LgR5 antibody comprising a VH sequence of SEQ ID NO: 49 and a VL sequence of SEQ ID NO: 48. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping amino acids 324-423. In some embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 303-402. In certain embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 21 from, within, or overlapping amino acids 324-555. In some embodiments, an antibody is provided that binds to an epitope of SEQ ID NO: 22 from, within, or overlapping amino acids 303-534.

[0150] In a further aspect of the invention, an anti-LgR5 antibody according to any of the above embodiments is a monoclonal antibody, including a chimeric, humanized or human antibody. In one embodiment, an anti-LgR5 antibody is an antibody fragment, *e.g.*, a Fv, Fab, Fab', scFv, diabody, or F(ab')₂ fragment. In another embodiment, the antibody is a substantially full length antibody, *e.g.*, an IgG1 antibody or other antibody class or isotype as defined herein.

[0151] In a further aspect, an anti-LgR5 antibody according to any of the above embodiments may incorporate any of the features, singly or in combination, as described in Sections 1-7 below:

1. Antibody Affinity

[0152] In certain embodiments, an antibody provided herein has a dissociation constant (K_d) of $\leq 1\mu\text{M}$, $\leq 100\text{ nM}$, $\leq 10\text{ nM}$, $\leq 1\text{ nM}$, $\leq 0.1\text{ nM}$, $\leq 0.01\text{ nM}$, or $\leq 0.001\text{ nM}$, and optionally is $\geq 10^{-13}\text{ M}$. (*e.g.* 10^{-8} M or less, *e.g.* from 10^{-8} M to 10^{-13} M , *e.g.*, from 10^{-9} M to 10^{-13} M).

[0153] In one embodiment, K_d is measured by a radiolabeled antigen binding assay (RIA) performed with the Fab version of an antibody of interest and its antigen as described by the following assay. Solution binding affinity of Fabs for antigen is measured by equilibrating Fab with a minimal concentration of (¹²⁵I)-labeled antigen in the presence of a titration series of

unlabeled antigen, then capturing bound antigen with an anti-Fab antibody-coated plate (see, e.g., Chen et al., *J. Mol. Biol.* 293:865-881(1999)). To establish conditions for the assay, MICROTITER® multi-well plates (Thermo Scientific) are coated overnight with 5 µg/ml of a capturing anti-Fab antibody (Cappel Labs) in 50 mM sodium carbonate (pH 9.6), and subsequently blocked with 2% (w/v) bovine serum albumin in PBS for two to five hours at room temperature (approximately 23°C). In a non-adsorbent plate (Nunc #269620), 100 pM or 26 pM [¹²⁵I]-antigen are mixed with serial dilutions of a Fab of interest (e.g., consistent with assessment of the anti-VEGF antibody, Fab-12, in Presta et al., *Cancer Res.* 57:4593-4599 (1997)). The Fab of interest is then incubated overnight; however, the incubation may continue for a longer period (e.g., about 65 hours) to ensure that equilibrium is reached. Thereafter, the mixtures are transferred to the capture plate for incubation at room temperature (e.g., for one hour). The solution is then removed and the plate washed eight times with 0.1% polysorbate 20 (TWEEN-20®) in PBS. When the plates have dried, 150 µl/well of scintillant (MICROSCINT-20™; Packard) is added, and the plates are counted on a TOPCOUNT™ gamma counter (Packard) for ten minutes. Concentrations of each Fab that give less than or equal to 20% of maximal binding are chosen for use in competitive binding assays.

[0154] In some embodiments, K_d is measured using surface plasmon resonance assays using a BIACORE®-2000 or a BIACORE®-3000 (BIAcore, Inc., Piscataway, NJ) at 25°C with immobilized antigen CM5 chips at ~10 response units (RU). Briefly, carboxymethylated dextran biosensor chips (CM5, BIAcore, Inc.) are activated with *N*-ethyl-*N*'-(3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and *N*-hydroxysuccinimide (NHS) according to the supplier's instructions. Antigen is diluted with 10 mM sodium acetate, pH 4.8, to 5 µg/ml (~0.2 µM) before injection at a flow rate of 5 µl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1 M ethanolamine is injected to block unreacted groups. For kinetics measurements, two-fold serial dilutions of Fab (0.78 nM to 500 nM) are injected in PBS with 0.05% polysorbate 20 (TWEEN-20™) surfactant (PBST) at 25°C at a flow rate of approximately 25 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIACORE® Evaluation Software version 3.2) by simultaneously fitting the association and dissociation sensorgrams. The equilibrium dissociation constant (K_d) is calculated as the ratio k_{off}/k_{on}. See, e.g., Chen et al., *J. Mol. Biol.* 293:865-881 (1999). If the on-rate exceeds 10⁶ M⁻¹ s⁻¹ by the surface plasmon resonance assay above, then the on-rate can be determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence

emission intensity (excitation = 295 nm; emission = 340 nm, 16 nm band-pass) at 25°C of a 20 nM anti-antigen antibody (Fab form) in PBS, pH 7.2, in the presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophotometer (Aviv Instruments) or a 8000-series SLM-AMINCO™ spectrophotometer (ThermoSpectronic) with a stirred cuvette.

2. *Antibody Fragments*

[0155] In certain embodiments, an antibody provided herein is an antibody fragment. Antibody fragments include, but are not limited to, Fab, Fab', Fab'-SH, F(ab')₂, Fv, and scFv fragments, and other fragments described below. For a review of certain antibody fragments, see Hudson et al. *Nat. Med.* 9:129-134 (2003). For a review of scFv fragments, see, e.g., Pluckthün, in *The Pharmacology of Monoclonal Antibodies*, vol. 113, Rosenberg and Moore eds., (Springer-Verlag, New York), pp. 269-315 (1994); see also WO 93/16185; and U.S. Patent Nos. 5,571,894 and 5,587,458. For discussion of Fab and F(ab')₂ fragments comprising salvage receptor binding epitope residues and having increased *in vivo* half-life, see U.S. Patent No. 5,869,046.

[0156] Diabodies are antibody fragments with two antigen-binding sites that may be bivalent or bispecific. See, for example, EP 404,097; WO 1993/01161; Hudson et al., *Nat. Med.* 9:129-134 (2003); and Hollinger et al., *Proc. Natl. Acad. Sci. USA* 90: 6444-6448 (1993). Triabodies and tetrabodies are also described in Hudson et al., *Nat. Med.* 9:129-134 (2003).

[0157] Single-domain antibodies are antibody fragments comprising all or a portion of the heavy chain variable domain or all or a portion of the light chain variable domain of an antibody. In certain embodiments, a single-domain antibody is a human single-domain antibody (Domantis, Inc., Waltham, MA; see, e.g., U.S. Patent No. 6,248,516 B1).

[0158] Antibody fragments can be made by various techniques, including but not limited to proteolytic digestion of an intact antibody as well as production by recombinant host cells (e.g. *E. coli* or phage), as described herein.

3. *Chimeric and Humanized Antibodies*

[0159] In certain embodiments, an antibody provided herein is a chimeric antibody. Certain chimeric antibodies are described, e.g., in U.S. Patent No. 4,816,567; and Morrison et al., *Proc. Natl. Acad. Sci. USA*, 81:6851-6855 (1984)). In one example, a chimeric antibody comprises a non-human variable region (e.g., a variable region derived from a mouse, rat, hamster, rabbit, or non-human primate, such as a monkey) and a human constant region. In a further example, a chimeric antibody is a "class switched" antibody in which the class or

subclass has been changed from that of the parent antibody. Chimeric antibodies include antigen-binding fragments thereof.

[0160] In certain embodiments, a chimeric antibody is a humanized antibody. Typically, a non-human antibody is humanized to reduce immunogenicity to humans, while retaining the specificity and affinity of the parental non-human antibody. Generally, a humanized antibody comprises one or more variable domains in which HVRs, e.g., CDRs, (or portions thereof) are derived from a non-human antibody, and FRs (or portions thereof) are derived from human antibody sequences. A humanized antibody optionally will also comprise at least a portion of a human constant region. In some embodiments, some FR residues in a humanized antibody are substituted with corresponding residues from a non-human antibody (e.g., the antibody from which the HVR residues are derived), e.g., to restore or improve antibody specificity or affinity.

[0161] Humanized antibodies and methods of making them are reviewed, e.g., in Almagro and Fransson, *Front. Biosci.* 13:1619-1633 (2008), and are further described, e.g., in Riechmann et al., *Nature* 332:323-329 (1988); Queen et al., *Proc. Nat'l Acad. Sci. USA* 86:10029-10033 (1989); US Patent Nos. 5, 821,337, 7,527,791, 6,982,321, and 7,087,409; Kashmiri et al., *Methods* 36:25-34 (2005) (describing SDR (a-CDR) grafting); Padlan, *Mol. Immunol.* 28:489-498 (1991) (describing “resurfacing”); Dall’Acqua et al., *Methods* 36:43-60 (2005) (describing “FR shuffling”); and Osbourn et al., *Methods* 36:61-68 (2005) and Klimka et al., *Br. J. Cancer*, 83:252-260 (2000) (describing the “guided selection” approach to FR shuffling).

[0162] Human framework regions that may be used for humanization include but are not limited to: framework regions selected using the “best-fit” method (see, e.g., Sims et al. *J. Immunol.* 151:2296 (1993)); framework regions derived from the consensus sequence of human antibodies of a particular subgroup of light or heavy chain variable regions (see, e.g., Carter et al. *Proc. Natl. Acad. Sci. USA*, 89:4285 (1992); and Presta et al. *J. Immunol.*, 151:2623 (1993)); human mature (somatically mutated) framework regions or human germline framework regions (see, e.g., Almagro and Fransson, *Front. Biosci.* 13:1619-1633 (2008)); and framework regions derived from screening FR libraries (see, e.g., Baca et al., *J. Biol. Chem.* 272:10678-10684 (1997) and Rosok et al., *J. Biol. Chem.* 271:22611-22618 (1996)).

4. Human Antibodies

[0163] In certain embodiments, an antibody provided herein is a human antibody. Human antibodies can be produced using various techniques known in the art. Human antibodies are described generally in van Dijk and van de Winkel, *Curr. Opin. Pharmacol.* 5: 368-74 (2001) and Lonberg, *Curr. Opin. Immunol.* 20:450-459 (2008).

[0164] Human antibodies may be prepared by administering an immunogen to a transgenic animal that has been modified to produce intact human antibodies or intact antibodies with human variable regions in response to antigenic challenge. Such animals typically contain all or a portion of the human immunoglobulin loci, which replace the endogenous immunoglobulin loci, or which are present extrachromosomally or integrated randomly into the animal's chromosomes. In such transgenic mice, the endogenous immunoglobulin loci have generally been inactivated. For review of methods for obtaining human antibodies from transgenic animals, see Lonberg, *Nat. Biotech.* 23:1117-1125 (2005). See also, e.g., U.S. Patent Nos. 6,075,181 and 6,150,584 describing XENOMOUSE™ technology; U.S. Patent No. 5,770,429 describing HUMAB® technology; U.S. Patent No. 7,041,870 describing K-M MOUSE® technology, and U.S. Patent Application Publication No. US 2007/0061900, describing VELOCIMOUSE® technology). Human variable regions from intact antibodies generated by such animals may be further modified, e.g., by combining with a different human constant region.

[0165] Human antibodies can also be made by hybridoma-based methods. Human myeloma and mouse-human heteromyeloma cell lines for the production of human monoclonal antibodies have been described. (See, e.g., Kozbor *J. Immunol.*, 133: 3001 (1984); Brodeur et al., *Monoclonal Antibody Production Techniques and Applications*, pp. 51-63 (Marcel Dekker, Inc., New York, 1987); and Boerner et al., *J. Immunol.*, 147: 86 (1991).) Human antibodies generated via human B-cell hybridoma technology are also described in Li et al., *Proc. Natl. Acad. Sci. USA*, 103:3557-3562 (2006). Additional methods include those described, for example, in U.S. Patent No. 7,189,826 (describing production of monoclonal human IgM antibodies from hybridoma cell lines) and Ni, *Xiandai Mianyixue*, 26(4):265-268 (2006) (describing human-human hybridomas). Human hybridoma technology (Trioma technology) is also described in Vollmers and Brandlein, *Histology and Histopathology*, 20(3):927-937 (2005) and Vollmers and Brandlein, *Methods and Findings in Experimental and Clinical Pharmacology*, 27(3):185-91 (2005).

[0166] Human antibodies may also be generated by isolating Fv clone variable domain sequences selected from human-derived phage display libraries. Such variable domain sequences may then be combined with a desired human constant domain. Techniques for selecting human antibodies from antibody libraries are described below.

5. Library-Derived Antibodies

[0167] Antibodies of the invention may be isolated by screening combinatorial libraries for antibodies with the desired activity or activities. For example, a variety of methods are

known in the art for generating phage display libraries and screening such libraries for antibodies possessing the desired binding characteristics. Such methods are reviewed, e.g., in Hoogenboom et al. in *Methods in Molecular Biology* 178:1-37 (O'Brien et al., ed., Human Press, Totowa, NJ, 2001) and further described, e.g., in the McCafferty et al., *Nature* 348:552-554; Clackson et al., *Nature* 352: 624-628 (1991); Marks et al., *J. Mol. Biol.* 222: 581-597 (1992); Marks and Bradbury, in *Methods in Molecular Biology* 248:161-175 (Lo, ed., Human Press, Totowa, NJ, 2003); Sidhu et al., *J. Mol. Biol.* 338(2): 299-310 (2004); Lee et al., *J. Mol. Biol.* 340(5): 1073-1093 (2004); Fellouse, *Proc. Natl. Acad. Sci. USA* 101(34): 12467-12472 (2004); and Lee et al., *J. Immunol. Methods* 284(1-2): 119-132(2004).

[0168] In certain phage display methods, repertoires of VH and VL genes are separately cloned by polymerase chain reaction (PCR) and recombined randomly in phage libraries, which can then be screened for antigen-binding phage as described in Winter et al., *Ann. Rev. Immunol.*, 12: 433-455 (1994). Phage typically display antibody fragments, either as single-chain Fv (scFv) fragments or as Fab fragments. Libraries from immunized sources provide high-affinity antibodies to the immunogen without the requirement of constructing hybridomas. Alternatively, the naive repertoire can be cloned (e.g., from human) to provide a single source of antibodies to a wide range of non-self and also self antigens without any immunization as described by Griffiths et al., *EMBO J*, 12: 725-734 (1993). Finally, naive libraries can also be made synthetically by cloning unrearranged V-gene segments from stem cells, and using PCR primers containing random sequence to encode the highly variable CDR3 regions and to accomplish rearrangement *in vitro*, as described by Hoogenboom and Winter, *J. Mol. Biol.*, 227: 381-388 (1992). Patent publications describing human antibody phage libraries include, for example: US Patent No. 5,750,373, and US Patent Publication Nos. 2005/0079574, 2005/0119455, 2005/0266000, 2007/0117126, 2007/0160598, 2007/0237764, 2007/0292936, and 2009/0002360.

[0169] Antibodies or antibody fragments isolated from human antibody libraries are considered human antibodies or human antibody fragments herein.

6. Multispecific Antibodies

[0170] In certain embodiments, an antibody provided herein is a multispecific antibody, e.g. a bispecific antibody. Multispecific antibodies are monoclonal antibodies that have binding specificities for at least two different sites. In certain embodiments, one of the binding specificities is for LgR5 and the other is for any other antigen. In certain embodiments, bispecific antibodies may bind to two different epitopes of LgR5. Bispecific antibodies may

also be used to localize cytotoxic agents to cells which express LgR5. Bispecific antibodies can be prepared as full length antibodies or antibody fragments.

[0171] Techniques for making multispecific antibodies include, but are not limited to, recombinant co-expression of two immunoglobulin heavy chain-light chain pairs having different specificities (see Milstein and Cuello, *Nature* 305: 537 (1983)), WO 93/08829, and Traunecker et al., *EMBO J.* 10: 3655 (1991)), and “knob-in-hole” engineering (see, e.g., U.S. Patent No. 5,731,168). Multi-specific antibodies may also be made by engineering electrostatic steering effects for making antibody Fc-heterodimeric molecules (WO 2009/089004A1); cross-linking two or more antibodies or fragments (see, e.g., US Patent No. 4,676,980, and Brennan et al., *Science*, 229: 81 (1985)); using leucine zippers to produce bi-specific antibodies (see, e.g., Kostelny et al., *J. Immunol.*, 148(5):1547-1553 (1992)); using “diabody” technology for making bispecific antibody fragments (see, e.g., Hollinger et al., *Proc. Natl. Acad. Sci. USA*, 90:6444-6448 (1993)); and using single-chain Fv (sFv) dimers (see, e.g. Gruber et al., *J. Immunol.*, 152:5368 (1994)); and preparing trispecific antibodies as described, e.g., in Tutt et al. *J. Immunol.* 147: 60 (1991).

[0172] Engineered antibodies with three or more functional antigen binding sites, including “Octopus antibodies,” are also included herein (see, e.g. US 2006/0025576A1).

[0173] The antibody or fragment herein also includes a “Dual Acting FAb” or “DAF” comprising an antigen binding site that binds to LgR5 as well as another, different antigen (see, US 2008/0069820, for example).

7. Antibody Variants

[0174] In certain embodiments, amino acid sequence variants of the antibodies provided herein are contemplated. For example, it may be desirable to improve the binding affinity and/or other biological properties of the antibody. Amino acid sequence variants of an antibody may be prepared by introducing appropriate modifications into the nucleotide sequence encoding the antibody, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of residues within the amino acid sequences of the antibody. Any combination of deletion, insertion, and substitution can be made to arrive at the final construct, provided that the final construct possesses the desired characteristics, e.g., antigen-binding.

a) Substitution, Insertion, and Deletion Variants

[0175] In certain embodiments, antibody variants having one or more amino acid substitutions are provided. Sites of interest for substitutional mutagenesis include the HVRs and

FRs. Conservative substitutions are shown in Table 1 under the heading of “preferred substitutions.” More substantial changes are provided in Table 1 under the heading of “exemplary substitutions,” and as further described below in reference to amino acid side chain classes. Amino acid substitutions may be introduced into an antibody of interest and the products screened for a desired activity, e.g., retained/improved antigen binding, decreased immunogenicity, or improved ADCC or CDC.

TABLE 1

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

[0176] Amino acids may be grouped according to common side-chain properties:

- (1) hydrophobic: Norleucine, Met, Ala, Val, Leu, Ile;
- (2) neutral hydrophilic: Cys, Ser, Thr, Asn, Gln;
- (3) acidic: Asp, Glu;
- (4) basic: His, Lys, Arg;

(5) residues that influence chain orientation: Gly, Pro;

(6) aromatic: Trp, Tyr, Phe.

[0177] Non-conservative substitutions will entail exchanging a member of one of these classes for another class.

[0178] One type of substitutional variant involves substituting one or more hypervariable region residues of a parent antibody (*e.g.* a humanized or human antibody). Generally, the resulting variant(s) selected for further study will have modifications (*e.g.*, improvements) in certain biological properties (*e.g.*, increased affinity, reduced immunogenicity) relative to the parent antibody and/or will have substantially retained certain biological properties of the parent antibody. An exemplary substitutional variant is an affinity matured antibody, which may be conveniently generated, *e.g.*, using phage display-based affinity maturation techniques such as those described herein. Briefly, one or more HVR residues are mutated and the variant antibodies displayed on phage and screened for a particular biological activity (*e.g.* binding affinity).

[0179] Alterations (*e.g.*, substitutions) may be made in HVRs, *e.g.*, to improve antibody affinity. Such alterations may be made in HVR “hotspots,” *i.e.*, residues encoded by codons that undergo mutation at high frequency during the somatic maturation process (see, *e.g.*, Chowdhury, *Methods Mol. Biol.* 207:179-196 (2008)), and/or SDRs (a-CDRs), with the resulting variant VH or VL being tested for binding affinity. Affinity maturation by constructing and reselecting from secondary libraries has been described, *e.g.*, in Hoogenboom et al. in *Methods in Molecular Biology* 178:1-37 (O’Brien et al., ed., Human Press, Totowa, NJ, (2001).) In some embodiments of affinity maturation, diversity is introduced into the variable genes chosen for maturation by any of a variety of methods (*e.g.*, error-prone PCR, chain shuffling, or oligonucleotide-directed mutagenesis). A secondary library is then created. The library is then screened to identify any antibody variants with the desired affinity. Another method to introduce diversity involves HVR-directed approaches, in which several HVR residues (*e.g.*, 4-6 residues at a time) are randomized. HVR residues involved in antigen binding may be specifically identified, *e.g.*, using alanine scanning mutagenesis or modeling. CDR-H3 and CDR-L3 in particular are often targeted.

[0180] In certain embodiments, substitutions, insertions, or deletions may occur within one or more HVRs so long as such alterations do not substantially reduce the ability of the antibody to bind antigen. For example, conservative alterations (*e.g.*, conservative substitutions as provided herein) that do not substantially reduce binding affinity may be made in HVRs. Such alterations may be outside of HVR “hotspots” or SDRs. In certain embodiments of the

variant VH and VL sequences provided above, each HVR either is unaltered, or contains no more than one, two or three amino acid substitutions.

[0181] A useful method for identification of residues or regions of an antibody that may be targeted for mutagenesis is called “alanine scanning mutagenesis” as described by Cunningham and Wells (1989) *Science*, 244:1081-1085. In this method, a residue or group of target residues (e.g., charged residues such as arg, asp, his, lys, and glu) are identified and replaced by a neutral or negatively charged amino acid (e.g., alanine or polyalanine) to determine whether the interaction of the antibody with antigen is affected. Further substitutions may be introduced at the amino acid locations demonstrating functional sensitivity to the initial substitutions. Alternatively, or additionally, a crystal structure of an antigen-antibody complex is used to identify contact points between the antibody and antigen. Such contact residues and neighboring residues may be targeted or eliminated as candidates for substitution. Variants may be screened to determine whether they contain the desired properties.

[0182] Amino acid sequence insertions include amino- and/or carboxyl-terminal fusions ranging in length from one residue to polypeptides containing a hundred or more residues, as well as intrasequence insertions of single or multiple amino acid residues. Examples of terminal insertions include an antibody with an N-terminal methionyl residue. Other insertional variants of the antibody molecule include the fusion to the N- or C-terminus of the antibody to an enzyme (e.g. for ADEPT) or a polypeptide which increases the serum half-life of the antibody.

b) Glycosylation variants

[0183] In certain embodiments, an antibody provided herein is altered to increase or decrease the extent to which the antibody is glycosylated. Addition or deletion of glycosylation sites to an antibody may be conveniently accomplished by altering the amino acid sequence such that one or more glycosylation sites is created or removed.

[0184] Where the antibody comprises an Fc region, the carbohydrate attached thereto may be altered. Native antibodies produced by mammalian cells typically comprise a branched, biantennary oligosaccharide that is generally attached by an N-linkage to Asn297 of the CH2 domain of the Fc region. See, e.g., Wright et al. *TIBTECH* 15:26-32 (1997). The oligosaccharide may include various carbohydrates, e.g., mannose, N-acetyl glucosamine (GlcNAc), galactose, and sialic acid, as well as a fucose attached to a GlcNAc in the “stem” of the biantennary oligosaccharide structure. In some embodiments, modifications of the oligosaccharide in an antibody of the invention may be made in order to create antibody variants with certain improved properties.

[0185] In one embodiment, antibody variants are provided having a carbohydrate structure that lacks fucose attached (directly or indirectly) to an Fc region. For example, the amount of fucose in such antibody may be from 1% to 80%, from 1% to 65%, from 5% to 65% or from 20% to 40%. The amount of fucose is determined by calculating the average amount of fucose within the sugar chain at Asn297, relative to the sum of all glycostructures attached to Asn 297 (e. g. complex, hybrid and high mannose structures) as measured by MALDI-TOF mass spectrometry, as described in WO 2008/077546, for example. Asn297 refers to the asparagine residue located at about position 297 in the Fc region (Eu numbering of Fc region residues); however, Asn297 may also be located about ± 3 amino acids upstream or downstream of position 297, i.e., between positions 294 and 300, due to minor sequence variations in antibodies. Such fucosylation variants may have improved ADCC function. See, e.g., US Patent Publication Nos. US 2003/0157108 (Presta, L.); US 2004/0093621 (Kyowa Hakko Kogyo Co., Ltd). Examples of publications related to “defucosylated” or “fucose-deficient” antibody variants include: US 2003/0157108; WO 2000/61739; WO 2001/29246; US 2003/0115614; US 2002/0164328; US 2004/0093621; US 2004/0132140; US 2004/0110704; US 2004/0110282; US 2004/0109865; WO 2003/085119; WO 2003/084570; WO 2005/035586; WO 2005/035778; WO2005/053742; WO2002/031140; Okazaki et al. *J. Mol. Biol.* 336:1239-1249 (2004); Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614 (2004). Examples of cell lines capable of producing defucosylated antibodies include Lec13 CHO cells deficient in protein fucosylation (Ripka et al. *Arch. Biochem. Biophys.* 249:533-545 (1986); US Pat Appl No US 2003/0157108 A1, Presta, L; and WO 2004/056312 A1, Adams *et al.*, especially at Example 11), and knockout cell lines, such as alpha-1,6-fucosyltransferase gene, *FUT8*, knockout CHO cells (see, e.g., Yamane-Ohnuki et al. *Biotech. Bioeng.* 87: 614 (2004); Kanda, Y. et al., *Biotechnol. Bioeng.*, 94(4):680-688 (2006); and WO2003/085107).

[0186] Antibodies variants are further provided with bisected oligosaccharides, e.g., in which a biantennary oligosaccharide attached to the Fc region of the antibody is bisected by GlcNAc. Such antibody variants may have reduced fucosylation and/or improved ADCC function. Examples of such antibody variants are described, e.g., in WO 2003/011878 (Jean-Mairet et al.); US Patent No. 6,602,684 (Umana et al.); and US 2005/0123546 (Umana *et al.*). Antibody variants with at least one galactose residue in the oligosaccharide attached to the Fc region are also provided. Such antibody variants may have improved CDC function. Such antibody variants are described, e.g., in WO 1997/30087 (Patel et al.); WO 1998/58964 (Raju, S.); and WO 1999/22764 (Raju, S.).

c) **Fc region variants**

[0187] In certain embodiments, one or more amino acid modifications may be introduced into the Fc region of an antibody provided herein, thereby generating an Fc region variant. The Fc region variant may comprise a human Fc region sequence (*e.g.*, a human IgG1, IgG2, IgG3 or IgG4 Fc region) comprising an amino acid modification (*e.g.* a substitution) at one or more amino acid positions.

[0188] In certain embodiments, an antibody variant possesses some but not all effector functions, which make it a desirable candidate for applications in which the half life of the antibody *in vivo* is important yet certain effector functions (such as complement and ADCC) are unnecessary or deleterious. *In vitro* and/or *in vivo* cytotoxicity assays can be conducted to confirm the reduction/depletion of CDC and/or ADCC activities. For example, Fc receptor (FcR) binding assays can be conducted to ensure that the antibody lacks Fc γ R binding (hence likely lacking ADCC activity), but retains FcRn binding ability. The primary cells for mediating ADCC, NK cells, express Fc(RIII only, whereas monocytes express Fc(RI, Fc(RII and Fc(RIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch and Kinet, *Annu. Rev. Immunol.* 9:457-492 (1991). Non-limiting examples of *in vitro* assays to assess ADCC activity of a molecule of interest is described in U.S. Patent No. 5,500,362 (see, *e.g.* Hellstrom, I. et al. *Proc. Nat'l Acad. Sci. USA* 83:7059-7063 (1986)) and Hellstrom, I et al., *Proc. Nat'l Acad. Sci. USA* 82:1499-1502 (1985); 5,821,337 (see Bruggemann, M. et al., *J. Exp. Med.* 166:1351-1361 (1987)). Alternatively, non-radioactive assays methods may be employed (see, for example, ACTITM non-radioactive cytotoxicity assay for flow cytometry (CellTechnology, Inc. Mountain View, CA; and CytoTox 96® non-radioactive cytotoxicity assay (Promega, Madison, WI). Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest may be assessed *in vivo*, *e.g.*, in a animal model such as that disclosed in Clynes et al. *Proc. Nat'l Acad. Sci. USA* 95:652-656 (1998). C1q binding assays may also be carried out to confirm that the antibody is unable to bind C1q and hence lacks CDC activity. See, *e.g.*, C1q and C3c binding ELISA in WO 2006/029879 and WO 2005/100402. To assess complement activation, a CDC assay may be performed (see, for example, Gazzano-Santoro *et al.*, *J. Immunol. Methods* 202:163 (1996); Cragg, M.S. et al., *Blood* 101:1045-1052 (2003); and Cragg, M.S. and M.J. Glennie, *Blood* 103:2738-2743 (2004)). FcRn binding and *in vivo* clearance/half life determinations can also be performed using methods known in the art (see, *e.g.*, Petkova, S.B. et al., *Int'l. Immunol.* 18(12):1759-1769 (2006)).

[0189] Antibodies with reduced effector function include those with substitution of one or more of Fc region residues 238, 265, 269, 270, 297, 327 and 329 (U.S. Patent No. 6,737,056). Such Fc mutants include Fc mutants with substitutions at two or more of amino acid positions 265, 269, 270, 297 and 327, including the so-called "DANA" Fc mutant with substitution of residues 265 and 297 to alanine (US Patent No. 7,332,581).

[0190] Certain antibody variants with improved or diminished binding to FcRs are described. (See, e.g., U.S. Patent No. 6,737,056; WO 2004/056312, and Shields et al., *J. Biol. Chem.* 9(2): 6591-6604 (2001).)

[0191] In certain embodiments, an antibody variant comprises an Fc region with one or more amino acid substitutions which improve ADCC, e.g., substitutions at positions 298, 333, and/or 334 of the Fc region (EU numbering of residues).

[0192] In some embodiments, alterations are made in the Fc region that result in altered (*i.e.*, either improved or diminished) C1q binding and/or Complement Dependent Cytotoxicity (CDC), e.g., as described in US Patent No. 6,194,551, WO 99/51642, and Idusogie et al. *J. Immunol.* 164: 4178-4184 (2000).

[0193] Antibodies with increased half lives and improved binding to the neonatal Fc receptor (FcRn), which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al., *J. Immunol.* 117:587 (1976) and Kim et al., *J. Immunol.* 24:249 (1994)), are described in US2005/0014934A1 (Hinton et al.). Those antibodies comprise an Fc region with one or more substitutions therein which improve binding of the Fc region to FcRn. Such Fc variants include those with substitutions at one or more of Fc region residues: 238, 256, 265, 272, 286, 303, 305, 307, 311, 312, 317, 340, 356, 360, 362, 376, 378, 380, 382, 413, 424 or 434, e.g., substitution of Fc region residue 434 (US Patent No. 7,371,826).

[0194] See also Duncan & Winter, *Nature* 322:738-40 (1988); U.S. Patent No. 5,648,260; U.S. Patent No. 5,624,821; and WO 94/29351 concerning other examples of Fc region variants.

d) Cysteine engineered antibody variants

[0195] In certain embodiments, it may be desirable to create cysteine engineered antibodies, e.g., "thioMAbs," in which one or more residues of an antibody are substituted with cysteine residues. In particular embodiments, the substituted residues occur at accessible sites of the antibody. By substituting those residues with cysteine, reactive thiol groups are thereby positioned at accessible sites of the antibody and may be used to conjugate the antibody to other moieties, such as drug moieties or linker-drug moieties, to create an immunoconjugate, as described further herein. In certain embodiments, any one or more of the following residues

may be substituted with cysteine: V205 (Kabat numbering) of the light chain; A118 (EU numbering) of the heavy chain; and S400 (EU numbering) of the heavy chain Fc region. Cysteine engineered antibodies may be generated as described, e.g., in U.S. Patent No. 7,521,541.

e) Antibody Derivatives

[0196] In certain embodiments, an antibody provided herein may be further modified to contain additional nonproteinaceous moieties that are known in the art and readily available. The moieties suitable for derivatization of the antibody include but are not limited to water soluble polymers. Non-limiting examples of water soluble polymers include, but are not limited to, polyethylene glycol (PEG), copolymers of ethylene glycol/propylene glycol, carboxymethylcellulose, dextran, polyvinyl alcohol, polyvinyl pyrrolidone, poly-1, 3-dioxolane, poly-1,3,6-trioxane, ethylene/maleic anhydride copolymer, polyaminoacids (either homopolymers or random copolymers), and dextran or poly(n-vinyl pyrrolidone)polyethylene glycol, propylene glycol homopolymers, polypropylene oxide/ethylene oxide co-polymers, polyoxyethylated polyols (e.g., glycerol), polyvinyl alcohol, and mixtures thereof. Polyethylene glycol propionaldehyde may have advantages in manufacturing due to its stability in water. The polymer may be of any molecular weight, and may be branched or unbranched. The number of polymers attached to the antibody may vary, and if more than one polymer are attached, they can be the same or different molecules. In general, the number and/or type of polymers used for derivatization can be determined based on considerations including, but not limited to, the particular properties or functions of the antibody to be improved, whether the antibody derivative will be used in a therapy under defined conditions, etc.

[0197] In another embodiment, conjugates of an antibody and nonproteinaceous moiety that may be selectively heated by exposure to radiation are provided. In one embodiment, the nonproteinaceous moiety is a carbon nanotube (Kam et al., *Proc. Natl. Acad. Sci. USA* 102: 11600-11605 (2005)). The radiation may be of any wavelength, and includes, but is not limited to, wavelengths that do not harm ordinary cells, but which heat the nonproteinaceous moiety to a temperature at which cells proximal to the antibody-nonproteinaceous moiety are killed.

B. Recombinant Methods and Compositions

[0198] Antibodies may be produced using recombinant methods and compositions, e.g., as described in U.S. Patent No. 4,816,567. In one embodiment, isolated nucleic acid encoding an anti-LgR5 antibody described herein is provided. Such nucleic acid may encode an amino acid sequence comprising the VL and/or an amino acid sequence comprising the VH of the

antibody (e.g., the light and/or heavy chains of the antibody). In a further embodiment, one or more vectors (e.g., expression vectors) comprising such nucleic acid are provided. In a further embodiment, a host cell comprising such nucleic acid is provided. In one such embodiment, a host cell comprises (e.g., has been transformed with): (1) a vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and an amino acid sequence comprising the VH of the antibody, or (2) a first vector comprising a nucleic acid that encodes an amino acid sequence comprising the VL of the antibody and a second vector comprising a nucleic acid that encodes an amino acid sequence comprising the VH of the antibody. In one embodiment, the host cell is eukaryotic, e.g. a Chinese Hamster Ovary (CHO) cell or lymphoid cell (e.g., Y0, NS0, Sp20 cell). In one embodiment, a method of making an anti-LgR5 antibody is provided, wherein the method comprises culturing a host cell comprising a nucleic acid encoding the antibody, as provided above, under conditions suitable for expression of the antibody, and optionally recovering the antibody from the host cell (or host cell culture medium).

[0199] For recombinant production of an anti-LgR5 antibody, nucleic acid encoding an antibody, e.g., as described above, is isolated and inserted into one or more vectors for further cloning and/or expression in a host cell. Such nucleic acid may be readily isolated and sequenced using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of the antibody).

[0200] Suitable host cells for cloning or expression of antibody-encoding vectors include prokaryotic or eukaryotic cells described herein. For example, antibodies may be produced in bacteria, in particular when glycosylation and Fc effector function are not needed. For expression of antibody fragments and polypeptides in bacteria, see, e.g., U.S. Patent Nos. 5,648,237, 5,789,199, and 5,840,523. (See also Charlton, *Methods in Molecular Biology*, Vol. 248 (B.K.C. Lo, ed., Humana Press, Totowa, NJ, 2003), pp. 245-254, describing expression of antibody fragments in *E. coli*.) After expression, the antibody may be isolated from the bacterial cell paste in a soluble fraction and can be further purified.

[0201] In addition to prokaryotes, eukaryotic microbes such as filamentous fungi or yeast are suitable cloning or expression hosts for antibody-encoding vectors, including fungi and yeast strains whose glycosylation pathways have been “humanized,” resulting in the production of an antibody with a partially or fully human glycosylation pattern. See Gerngross, *Nat. Biotech.* 22:1409-1414 (2004), and Li et al., *Nat. Biotech.* 24:210-215 (2006).

[0202] Suitable host cells for the expression of glycosylated antibody are also derived from multicellular organisms (invertebrates and vertebrates). Examples of invertebrate cells

include plant and insect cells. Numerous baculoviral strains have been identified which may be used in conjunction with insect cells, particularly for transfection of *Spodoptera frugiperda* cells.

[0203] Plant cell cultures can also be utilized as hosts. See, e.g., US Patent Nos. 5,959,177, 6,040,498, 6,420,548, 7,125,978, and 6,417,429 (describing PLANTIBODIES™ technology for producing antibodies in transgenic plants).

[0204] Vertebrate cells may also be used as hosts. For example, mammalian cell lines that are adapted to grow in suspension may be useful. Other examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7); human embryonic kidney line (293 or 293 cells as described, e.g., in Graham et al., *J. Gen Virol.* 36:59 (1977)); baby hamster kidney cells (BHK); mouse sertoli cells (TM4 cells as described, e.g., in Mather, *Biol. Reprod.* 23:243-251 (1980)); monkey kidney cells (CV1); African green monkey kidney cells (VERO-76); human cervical carcinoma cells (HELA); canine kidney cells (MDCK; buffalo rat liver cells (BRL 3A); human lung cells (W138); human liver cells (Hep G2); mouse mammary tumor (MMT 060562); TRI cells, as described, e.g., in Mather et al., *Annals N.Y. Acad. Sci.* 383:44-68 (1982); MRC 5 cells; and FS4 cells. Other useful mammalian host cell lines include Chinese hamster ovary (CHO) cells, including DHFR⁻ CHO cells (Urlaub et al., *Proc. Natl. Acad. Sci. USA* 77:4216 (1980)); and myeloma cell lines such as Y0, NS0 and Sp2/0. For a review of certain mammalian host cell lines suitable for antibody production, see, e.g., Yazaki and Wu, *Methods in Molecular Biology*, Vol. 248 (B.K.C. Lo, ed., Humana Press, Totowa, NJ), pp. 255-268 (2003).

C. Assays

[0205] Anti-LgR5 antibodies provided herein may be identified, screened for, or characterized for their physical/chemical properties and/or biological activities by various assays known in the art.

[0206] In one aspect, an antibody of the invention is tested for its antigen binding activity, e.g., by known methods such as ELISA, FACS or Western blot.

[0207] In another aspect, competition assays may be used to identify an antibody that competes with any of the antibodies described herein for binding to LgR5. In certain embodiments, such a competing antibody binds to the same epitope (e.g., a linear or a conformational epitope) that is bound by an antibody described herein. Detailed exemplary methods for mapping an epitope to which an antibody binds are provided in Morris (1996)

“Epitope Mapping Protocols,” in *Methods in Molecular Biology* vol. 66 (Humana Press, Totowa, NJ).

[0208] In an exemplary competition assay, immobilized LgR5 is incubated in a solution comprising a first labeled antibody that binds to LgR5 (e.g., any of the antibodies described herein) and a second unlabeled antibody that is being tested for its ability to compete with the first antibody for binding to LgR5. The second antibody may be present in a hybridoma supernatant. As a control, immobilized LgR5 is incubated in a solution comprising the first labeled antibody but not the second unlabeled antibody. After incubation under conditions permissive for binding of the first antibody to LgR5, excess unbound antibody is removed, and the amount of label associated with immobilized LgR5 is measured. If the amount of label associated with immobilized LgR5 is substantially reduced in the test sample relative to the control sample, then that indicates that the second antibody is competing with the first antibody for binding to LgR5. See Harlow and Lane (1988) *Antibodies: A Laboratory Manual* ch.14 (Cold Spring Harbor Laboratory, Cold Spring Harbor, NY).

D. Immunoconjugates

[0209] The invention also provides immunoconjugates comprising an anti- LgR5 antibody herein conjugated to one or more cytotoxic agents, such as chemotherapeutic agents or drugs, growth inhibitory agents, toxins (e.g., protein toxins, enzymatically active toxins of bacterial, fungal, plant, or animal origin, or fragments thereof), or radioactive isotopes (i.e., a radioconjugate).

[0210] Immunoconjugates allow for the targeted delivery of a drug moiety to a tumor, and, in some embodiments intracellular accumulation therein, where systemic administration of unconjugated drugs may result in unacceptable levels of toxicity to normal cells (Polakis P. (2005) *Current Opinion in Pharmacology* 5:382-387).

[0211] Antibody-drug conjugates (ADC) are targeted chemotherapeutic molecules which combine properties of both antibodies and cytotoxic drugs by targeting potent cytotoxic drugs to antigen-expressing tumor cells (Teicher, B.A. (2009) *Current Cancer Drug Targets* 9:982-1004), thereby enhancing the therapeutic index by maximizing efficacy and minimizing off-target toxicity (Carter, P.J. and Senter P.D. (2008) *The Cancer Jour.* 14(3):154-169; Chari, R.V. (2008) *Acc. Chem. Res.* 41:98-107).

[0212] The ADC compounds of the invention include those with anticancer activity. In some embodiments, the ADC compounds include an antibody conjugated, i.e. covalently attached, to the drug moiety. In some embodiments, the antibody is covalently attached to the

drug moiety through a linker. The antibody-drug conjugates (ADC) of the invention selectively deliver an effective dose of a drug to tumor tissue whereby greater selectivity, i.e. a lower efficacious dose, may be achieved while increasing the therapeutic index (“therapeutic window”).

[0213] The drug moiety (D) of the antibody-drug conjugates (ADC) may include any compound, moiety or group that has a cytotoxic or cytostatic effect. Drug moieties may impart their cytotoxic and cytostatic effects by mechanisms including but not limited to tubulin binding, DNA binding or intercalation, and inhibition of RNA polymerase, protein synthesis, and/or topoisomerase. Exemplary drug moieties include, but are not limited to, a maytansinoid, dolastatin, auristatin, calicheamicin, pyrrolbenzodiazepine (PBD), nemorubicin and its derivatives, PNU-159682, anthracycline, duocarmycin, vinca alkaloid, taxane, trichothecene, CC1065, camptothecin, elinafide, and stereoisomers, isosteres, analogs, and derivatives thereof that have cytotoxic activity.

E. Methods and Compositions for Diagnostics and Detection

[0214] In certain embodiments, any of the anti-LgR5 antibodies provided herein is useful for detecting the presence of LgR5 in a biological sample. The term “detecting” as used herein encompasses quantitative or qualitative detection. A “biological sample” comprises, e.g., a cell or tissue (*e.g.*, biopsy material, including cancerous or potentially cancerous colon, colorectal, small intestine, endometrial, pancreatic, or ovarian tissue).

[0215] In one embodiment, an anti-LgR5 antibody for use in a method of diagnosis or detection is provided. In a further aspect, a method of detecting the presence of LgR5 in a biological sample is provided. In certain embodiments, the method comprises contacting the biological sample with an anti-LgR5 antibody as described herein under conditions permissive for binding of the anti-LgR5 antibody to LgR5, and detecting whether a complex is formed between the anti-LgR5 antibody and LgR5 in the biological sample. Such method may be an *in vitro* or *in vivo* method. In one embodiment, an anti-LgR5 antibody is used to select subjects eligible for therapy with an anti-LgR5 antibody, *e.g.* where LgR5 is a biomarker for selection of patients. In a further embodiment, the biological sample is a cell or tissue (*e.g.*, biopsy material, including cancerous or potentially cancerous colon, colorectal, small intestine, endometrial, pancreatic, or ovarian tissue).

[0216] In a further embodiment, an anti-LgR5 antibody is used *in vivo* to detect, *e.g.*, by *in vivo* imaging, an LgR5-positive cancer in a subject, *e.g.*, for the purposes of diagnosing, prognosing, or staging cancer, determining the appropriate course of therapy, or monitoring

response of a cancer to therapy. One method known in the art for *in vivo* detection is immuno-positron emission tomography (immuno-PET), as described, *e.g.*, in van Dongen et al., *The Oncologist* 12:1379-1389 (2007) and Verel et al., *J. Nucl. Med.* 44:1271-1281 (2003). In such embodiments, a method is provided for detecting an LgR5-positive cancer in a subject, the method comprising administering a labeled anti-LgR5 antibody to a subject having or suspected of having an LgR5-positive cancer, and detecting the labeled anti-LgR5 antibody in the subject, wherein detection of the labeled anti-LgR5 antibody indicates an LgR5-positive cancer in the subject. In certain of such embodiments, the labeled anti-LgR5 antibody comprises an anti-LgR5 antibody conjugated to a positron emitter, such as ^{68}Ga , ^{18}F , ^{64}Cu , ^{86}Y , ^{76}Br , ^{89}Zr , and ^{124}I . In a particular embodiment, the positron emitter is ^{89}Zr . Nonlimiting exemplary methods of making and using ^{89}Zr -labeled antibodies are described, *e.g.*, in PCT Publication No. WO 2011/056983. In some embodiments, the labeled anti-LgR5 antibody is a cysteine engineered antibody conjugated to one or more zirconium complexes. *See, e.g.*, WO 2011/056983.

[0217] In further embodiments, a method of diagnosis or detection comprises contacting a first anti-LgR5 antibody immobilized to a substrate with a biological sample to be tested for the presence of LgR5, exposing the substrate to a second anti-LgR5 antibody, and detecting whether the second anti-LgR5 is bound to a complex between the first anti-LgR5 antibody and LgR5 in the biological sample. A substrate may be any supportive medium, *e.g.*, glass, metal, ceramic, polymeric beads, slides, chips, and other substrates. In certain embodiments, a biological sample comprises a cell or tissue (*e.g.*, biopsy material, including cancerous or potentially cancerous colon, colorectal, small intestine, endometrial, pancreatic or ovarian tissue). In certain embodiments, the first or second anti-LgR5 antibody is any of the antibodies described herein. In such embodiments, the second anti-LgR5 antibody may be $\alpha\text{LgR5.1-12}$ or antibodies derived from $\alpha\text{LgR5.1-12}$ as described herein. In such embodiments, the second anti-LgR5 antibody may be $\alpha\text{LgR5.26-1}$ or antibodies derived from $\alpha\text{LgR5.26-1}$ as described herein.

[0218] Exemplary disorders that may be diagnosed or detected according to any of the above embodiments include LgR5-positive cancers, such as LgR5-positive colorectal cancer (including adenocarcinoma), LgR5-positive small intestine cancer (including adenocarcinoma, sarcoma (*e.g.*, leiomyosarcoma), carcinoid tumors, gastrointestinal stromal tumor, and lymphoma) LgR5-positive ovarian cancer (including ovarian serous adenocarcinoma), LgR5-positive pancreatic cancer (including pancreatic ductal adenocarcinoma), and LgR5-positive endometrial cancer.

[0219] In some embodiments, an LgR5-positive cancer is a cancer that receives a LgR5 immunohistochemistry (IHC) score greater than “0,” which corresponds to very weak or no

staining, under the conditions described herein in the Examples (*see, e.g.*, Examples F, H, and I). In another embodiment, a LgR5-positive cancer expresses LgR5 at a 1+, 2+ or 3+ level, as defined under the conditions described herein in the Examples (*see, e.g.*, Examples F, H, and I). In some embodiments, one or more cell lines may be used as a control for staining level. For example, in some embodiments, a cell line shown in Table 4 in Example I may be used as a control for staining level. For example, in some embodiments, cell line SW480, RKO, COLO741, HCT-15, CX-1, HT-29, SW1116, HCA-7, and/or COLO-205 may be used as a control for 0 staining; cell line SW948, CACO-2, and/or C2BBel may be used as a control for 1+ staining; and/or cell line T84, SW1463, SK-CO-1, and/or LOVO may be used as a control for 2+ staining. In some embodiments, an LgR5-positive cancer is a cancer that receives an H score of 50 or greater, as defined under the conditions described herein in Example H (corresponding to an overall score of 1+, 2+ or 3+ using 50%+ criteria). In some embodiments, a LgR5-positive cancer is a cancer that receives an H score of 10 or greater, as defined under the conditions described herein in Example H (corresponding to an overall score of 1+, 2+, or 3+ using 10%+ criteria).

[0220] In some embodiments, an LgR5-positive cancer is a cancer that expresses LgR5 according to a reverse-transcriptase PCR (RT-PCR) assay that detects LgR5 mRNA. In some embodiments, the RT-PCR is quantitative RT-PCR.

[0221] In certain embodiments, labeled anti-LgR5 antibodies are provided. Labels include, but are not limited to, labels or moieties that are detected directly (such as fluorescent, chromophoric, electron-dense, chemiluminescent, and radioactive labels), as well as moieties, such as enzymes or ligands, that are detected indirectly, *e.g.*, through an enzymatic reaction or molecular interaction. Exemplary labels include, but are not limited to, the radioisotopes ^{32}P , ^{14}C , ^{125}I , ^3H , and ^{131}I , fluorophores such as rare earth chelates or fluorescein and its derivatives, rhodamine and its derivatives, dansyl, umbelliferone, luciferases, *e.g.*, firefly luciferase and bacterial luciferase (U.S. Patent No. 4,737,456), luciferin, 2,3-dihydrophthalazinediones, horseradish peroxidase (HRP), alkaline phosphatase, β -galactosidase, glucoamylase, lysozyme, saccharide oxidases, *e.g.*, glucose oxidase, galactose oxidase, and glucose-6-phosphate dehydrogenase, heterocyclic oxidases such as uricase and xanthine oxidase, coupled with an enzyme that employs hydrogen peroxide to oxidize a dye precursor such as HRP, lactoperoxidase, or microperoxidase, biotin/avidin, spin labels, bacteriophage labels, stable free radicals, and the like. In another embodiment, a label is a positron emitter. Positron emitters include but are not limited to ^{68}Ga , ^{18}F , ^{64}Cu , ^{86}Y , ^{76}Br , ^{89}Zr , and ^{124}I . In a particular embodiment, a positron emitter is ^{89}Zr .

F. Pharmaceutical Formulations

[0222] Pharmaceutical formulations of an anti-LgR5 antibody or immunoconjugate as described herein are prepared by mixing such antibody or immunoconjugate having the desired degree of purity with one or more optional pharmaceutically acceptable carriers (*Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed. (1980)), in the form of lyophilized formulations or aqueous solutions. Pharmaceutically acceptable carriers are generally nontoxic to recipients at the dosages and concentrations employed, and include, but are not limited to: buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid and methionine; preservatives (such as octadecyldimethylbenzyl ammonium chloride; hexamethonium chloride; benzalkonium chloride; benzethonium chloride; phenol, butyl or benzyl alcohol; alkyl parabens such as methyl or propyl paraben; catechol; resorcinol; cyclohexanol; 3-pentanol; and m-cresol); low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, histidine, arginine, or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrans; chelating agents such as EDTA; sugars such as sucrose, mannitol, trehalose or sorbitol; salt-forming counter-ions such as sodium; metal complexes (*e.g.* Zn-protein complexes); and/or non-ionic surfactants such as polyethylene glycol (PEG). Exemplary pharmaceutically acceptable carriers herein further include interstitial drug dispersion agents such as soluble neutral-active hyaluronidase glycoproteins (sHASEGP), for example, human soluble PH-20 hyaluronidase glycoproteins, such as rHuPH20 (HYLENEX[®], Baxter International, Inc.). Certain exemplary sHASEGPs and methods of use, including rHuPH20, are described in US Patent Publication Nos. 2005/0260186 and 2006/0104968. In one aspect, a sHASEGP is combined with one or more additional glycosaminoglycanases such as chondroitinases.

[0223] Exemplary lyophilized antibody or immunoconjugate formulations are described in US Patent No. 6,267,958. Aqueous antibody or immunoconjugate formulations include those described in US Patent No. 6,171,586 and WO2006/044908, the latter formulations including a histidine-acetate buffer.

[0224] The formulation herein may also contain more than one active ingredient as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. For example, in some instances, it may be desirable to further provide Avastin[®] (bevacizumab), *e.g.*, for the treatment of LgR5-positive cancer such as LgR5-positive colon cancer or LgR5-positive colorectal cancer.

[0225] Active ingredients may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacrylate) microcapsules, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules) or in macroemulsions. Such techniques are disclosed in *Remington's Pharmaceutical Sciences* 16th edition, Osol, A. Ed. (1980).

[0226] Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the antibody or immunoconjugate, which matrices are in the form of shaped articles, e.g. films, or microcapsules.

[0227] The formulations to be used for *in vivo* administration are generally sterile. Sterility may be readily accomplished, e.g., by filtration through sterile filtration membranes.

G. Therapeutic Methods and Compositions

[0228] Any of the anti-LgR5 antibodies or immunoconjugates provided herein may be used in methods, e.g., therapeutic methods.

[0229] In one aspect, an anti-LgR5 antibody or immunoconjugate provided herein is used in a method of inhibiting proliferation of a LgR5-positive cell, the method comprising exposing the cell to the anti-LgR5 antibody or immunoconjugate under conditions permissive for binding of the anti-LgR5 antibody or immunoconjugate to LgR5 on the surface of the cell, thereby inhibiting the proliferation of the cell. In certain embodiments, the method is an *in vitro* or an *in vivo* method. In further embodiments, the cell is a colon, colorectal, small intestine, ovarian, pancreatic, or endometrial cell.

[0230] In some embodiments, an anti-LgR5 antibody or immunoconjugate provided herein is used in a method of treating cancer that comprises a mutation in a Kras gene and/or a mutation in an adenomatous polyposis coli (APC) gene in at least a portion of the cells of the cancer. In various embodiments, the cancer is selected from colon, colorectal, small intestine, ovarian, pancreatic, and endometrial cancer. In some embodiments, an anti-LgR5 antibody or immunoconjugate provided herein is used in a method of treating a colon or colorectal cancer that comprises a mutation in a Kras gene and/or a mutation in an APC gene in at least a portion of the cells of the cancer. Nonlimiting exemplary Kras mutations found in cancers (including colon and colorectal cancers) include mutations at Kras codon 12 (e.g., G12D, G12V, G12R, G12C, G12S, and G12A), codon 13 (e.g., G13D and G13C), codon 61 (e.g., G61H, G61L, G61E, and G61K), and codon 146. See, e.g., Yokota, *Anticancer Agents Med. Chem.*, 12: 163-

171 (2012); Wicki et al., *Swiss Med. Wkly*, 140: w13112 (2010). Nonlimiting exemplary APC mutations found in cancers include mutations in the mutation cluster region (MCR), such as stop codons and frameshift mutations that result in a truncated APC gene product. *See, e.g.*, Chandra et al., *PLoS One*, 7: e34479 (2012); and Kohler et al., *Hum. Mol. Genet.*, 17: 1978-1987 (2008).

[0231] In some embodiments, a method of treating cancer comprises administering an anti-LgR5 antibody or immunoconjugate to a subject, wherein the subject has a cancer comprising a Kras mutation and/or an APC mutation in at least a portion of the cancer cells. In some embodiments, the cancer is selected from colon, colorectal, small intestine, ovarian, pancreatic, and endometrial cancer. In some embodiments, the cancer is colon and/or colorectal cancer. In some embodiments, the subject has previously been determined to have a cancer comprising a Kras mutation and/or an APC mutation in at least a portion of the cancer cells. In some embodiments, the cancer is LgR5-positive.

[0232] Presence of various biomarkers in a sample can be analyzed by a number of methodologies, many of which are known in the art and understood by the skilled artisan, including, but not limited to, immunohistochemistry (“IHC”), Western blot analysis, immunoprecipitation, molecular binding assays, ELISA, ELIFA, fluorescence activated cell sorting (“FACS”), MassARRAY, proteomics, quantitative blood based assays (as for example Serum ELISA), biochemical enzymatic activity assays, in situ hybridization, Southern analysis, Northern analysis, whole genome sequencing, polymerase chain reaction (“PCR”) including quantitative real time PCR (“qRT-PCR”) and other amplification type detection methods, such as, for example, branched DNA, SISBA, TMA and the like, RNA-Seq, FISH, microarray analysis, gene expression profiling, and/or serial analysis of gene expression (“SAGE”), as well as any one of the wide variety of assays that can be performed by protein, gene, and/or tissue array analysis. Typical protocols for evaluating the status of genes and gene products are found, for example in Ausubel *et al.*, eds., 1995, *Current Protocols In Molecular Biology*, Units 2 (Northern Blotting), 4 (Southern Blotting), 15 (Immunoblotting) and 18 (PCR Analysis). Multiplexed immunoassays such as those available from Rules Based Medicine or Meso Scale Discovery (“MSD”) may also be used.

[0233] Inhibition of cell proliferation *in vitro* may be assayed using the CellTiter-Glo™ Luminescent Cell Viability Assay, which is commercially available from Promega (Madison, WI). That assay determines the number of viable cells in culture based on quantitation of ATP present, which is an indication of metabolically active cells. *See* Crouch et al. (1993) *J. Immunol. Meth.* 160:81-88, US Pat. No. 6602677. The assay may be conducted in 96- or 384-well format, making it amenable to automated high-throughput screening (HTS). *See* Cree et al.

(1995) *AntiCancer Drugs* 6:398-404. The assay procedure involves adding a single reagent (CellTiter-Glo® Reagent) directly to cultured cells. This results in cell lysis and generation of a luminescent signal produced by a luciferase reaction. The luminescent signal is proportional to the amount of ATP present, which is directly proportional to the number of viable cells present in culture. Data can be recorded by luminometer or CCD camera imaging device. The luminescence output is expressed as relative light units (RLU).

[0234] In another aspect, an anti-LgR5 antibody or immunoconjugate for use as a medicament is provided. In further aspects, an anti-LgR5 antibody or immunoconjugate for use in a method of treatment is provided. In certain embodiments, an anti-LgR5 antibody or immunoconjugate for use in treating LgR5-positive cancer is provided. In certain embodiments, the invention provides an anti-LgR5 antibody or immunoconjugate for use in a method of treating an individual having a LgR5-positive cancer, the method comprising administering to the individual an effective amount of the anti-LgR5 antibody or immunoconjugate. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, e.g., as described below.

[0235] In a further aspect, the invention provides for the use of an anti-LgR5 antibody or immunoconjugate in the manufacture or preparation of a medicament. In one embodiment, the medicament is for treatment of LgR5-positive cancer. In a further embodiment, the medicament is for use in a method of treating LgR5-positive cancer, the method comprising administering to an individual having LgR5-positive cancer an effective amount of the medicament. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, e.g., as described below.

[0236] In a further aspect, the invention provides a method for treating LgR5-positive cancer. In one embodiment, the method comprises administering to an individual having such LgR5-positive cancer an effective amount of an anti-LgR5 antibody or immunoconjugate. In one such embodiment, the method further comprises administering to the individual an effective amount of at least one additional therapeutic agent, as described below.

[0237] An LgR5-positive cancer according to any of the above embodiments may be, e.g., LgR5-positive colon or colorectal cancer (including adenocarcinoma), LgR5-positive small intestine cancer (including adenocarcinoma, sarcoma (e.g., leiomyosarcoma), carcinoid tumors, gastrointestinal stromal tumor, and lymphoma), LgR5-positive ovarian cancer (including ovarian serous adenocarcinoma), LgR5-positive pancreatic cancer (including pancreatic ductal adenocarcinoma), and LgR5-positive endometrial cancer.

[0238] In some embodiments, an LgR5-positive cancer is a cancer that receives a LgR5 immunohistochemistry (IHC) score greater than “0,” which corresponds to very weak or no staining, under the conditions described herein in the Examples (*see, e.g.*, Examples F, H, and I). In another embodiment, a LgR5-positive cancer expresses LgR5 at a 1+, 2+ or 3+ level, as defined under the conditions described herein in the Examples (*see, e.g.*, Examples F, H, and I). In some embodiments, one or more cell lines may be used as a control for staining level. For example, in some embodiments, a cell line shown in Table 4 in Example I may be used as a control for staining level. For example, in some embodiments, cell line SW480, RKO, COLO741, HCT-15, CX-1, HT-29, SW1116, HCA-7, and/or COLO-205 may be used as a control for 0 staining; cell line SW948, CACO-2, and/or C2BBel may be used as a control for 1+ staining; and/or cell line T84, SW1463, SK-CO-1, and/or LOVO may be used as a control for 2+ staining. In some embodiments, an LgR5-positive cancer is a cancer that receives an H score of 50 or greater, as defined under the conditions described herein in Example H (corresponding to an overall score of 1+, 2+ or 3+ using 50%+ criteria). In some embodiments, a LgR5-positive cancer is a cancer that receives an H score of 10 or greater, as defined under the conditions described herein in Example H (corresponding to an overall score of 1+, 2+, or 3+ using 10%+ criteria).

[0239] In some embodiments, an LgR5-positive cancer is a cancer that expresses LgR5 according to a reverse-transcriptase PCR (RT-PCR) assay that detects LgR5 mRNA. In some embodiments, the RT-PCR is quantitative RT-PCR.

[0240] An “individual” according to any of the above embodiments may be a human.

[0241] In a further aspect, the invention provides pharmaceutical formulations comprising any of the anti-LgR5 antibodies or immunoconjugate provided herein, *e.g.*, for use in any of the above therapeutic methods. In one embodiment, a pharmaceutical formulation comprises any of the anti-LgR5 antibodies or immunoconjugates provided herein and a pharmaceutically acceptable carrier. In another embodiment, a pharmaceutical formulation comprises any of the anti-LgR5 antibodies or immunoconjugates provided herein and at least one additional therapeutic agent, *e.g.*, as described below.

[0242] Antibodies or immunoconjugates of the invention can be used either alone or in combination with other agents in a therapy. For instance, an antibody or immunoconjugate of the invention may be co-administered with at least one additional therapeutic agent. In certain embodiments, an additional therapeutic agent is Avastin® (bevacizumab), *e.g.*, for the treatment of LgR5-positive cancer such as LgR5-positive colon cancer or LgR5-positive colorectal cancer.

[0243] Such combination therapies noted above encompass combined administration (where two or more therapeutic agents are included in the same or separate formulations), and separate administration, in which case, administration of the antibody or immunoconjugate of the invention can occur prior to, simultaneously, and/or following, administration of the additional therapeutic agent and/or adjuvant. Antibodies or immunoconjugates of the invention can also be used in combination with radiation therapy.

[0244] An antibody or immunoconjugate (and any additional therapeutic agent) can be administered by any suitable means, including parenteral, intrapulmonary, and intranasal, and, if desired for local treatment, intralesional administration. Parenteral infusions include intramuscular, intravenous, intraarterial, intraperitoneal, or subcutaneous administration. Dosing can be by any suitable route, e.g. by injections, such as intravenous or subcutaneous injections, depending in part on whether the administration is brief or chronic. Various dosing schedules including but not limited to single or multiple administrations over various time-points, bolus administration, and pulse infusion are contemplated herein.

[0245] Antibodies or immunoconjugates would be formulated, dosed, and administered in a fashion consistent with good medical practice. Factors for consideration in this context include the particular disorder being treated, the particular mammal being treated, the clinical condition of the individual patient, the cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners. The antibody or immunoconjugate need not be, but is optionally formulated with one or more agents currently used to prevent or treat the disorder in question. The effective amount of such other agents depends on the amount of antibody or immunoconjugate present in the formulation, the type of disorder or treatment, and other factors discussed above. These are generally used in the same dosages and with administration routes as described herein, or about from 1 to 99% of the dosages described herein, or in any dosage and by any route that is empirically/clinically determined to be appropriate.

[0246] For the prevention or treatment of disease, the appropriate dosage of an antibody or immunoconjugate (when used alone or in combination with one or more other additional therapeutic agents) will depend on the type of disease to be treated, the type of antibody or immunoconjugate, the severity and course of the disease, whether the antibody or immunoconjugate is administered for preventive or therapeutic purposes, previous therapy, the patient's clinical history and response to the antibody or immunoconjugate, and the discretion of the attending physician. The antibody or immunoconjugate is suitably administered to the patient at one time or over a series of treatments. Depending on the type and severity of the

disease, about 1 µg/kg to 15 mg/kg (e.g. 0.1mg/kg-10mg/kg) of antibody or immunoconjugate can be an initial candidate dosage for administration to the patient, whether, for example, by one or more separate administrations, or by continuous infusion. One typical daily dosage might range from about 1 µg/kg to 100 mg/kg or more, depending on the factors mentioned above. For repeated administrations over several days or longer, depending on the condition, the treatment would generally be sustained until a desired suppression of disease symptoms occurs. One exemplary dosage of the antibody or immunoconjugate would be in the range from about 0.05 mg/kg to about 10 mg/kg. Thus, one or more doses of about 0.5 mg/kg, 2.0 mg/kg, 4.0 mg/kg or 10 mg/kg (or any combination thereof) may be administered to the patient. Such doses may be administered intermittently, e.g. every week or every three weeks (*e.g.* such that the patient receives from about two to about twenty, or *e.g.* about six doses of the antibody). An initial higher loading dose, followed by one or more lower doses may be administered. However, other dosage regimens may be useful. The progress of this therapy is easily monitored by conventional techniques and assays.

[0247] It is understood that any of the above formulations or therapeutic methods may be carried out using both an immunoconjugate and an anti-LgR5 antibody.

H. Articles of Manufacture

[0248] In another aspect, an article of manufacture containing materials useful for the treatment, prevention and/or diagnosis of the disorders described above is provided. The article of manufacture comprises a container and a label or package insert on or associated with the container. Suitable containers include, for example, bottles, vials, syringes, IV solution bags, etc. The containers may be formed from a variety of materials such as glass or plastic. The container holds a composition which is by itself or combined with another composition effective for treating, preventing and/or diagnosing the disorder and may have a sterile access port (for example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection needle). At least one active agent in the composition is an anti-LgR5 antibody or immunoconjugate. The label or package insert indicates that the composition is used for treating the condition of choice. Moreover, the article of manufacture may comprise (a) a first container with a composition contained therein, wherein the composition comprises an antibody or immunoconjugate; and (b) a second container with a composition contained therein, wherein the composition comprises a further cytotoxic or otherwise therapeutic agent. The article of manufacture in this embodiment may further comprise a package insert indicating that the compositions can be used to treat a particular condition. Alternatively, or additionally, the

article of manufacture may further comprise a second (or third) container comprising a pharmaceutically-acceptable buffer, such as bacteriostatic water for injection (BWI), phosphate-buffered saline, Ringer's solution or dextrose solution. It may further include other materials desirable from a commercial and user standpoint, including other buffers, diluents, filters, needles, and syringes.

III. EXAMPLES

[0249] The following are examples of methods and compositions of the invention. It is understood that various other embodiments may be practiced, given the general description provided above.

A. Human LgR5 Gene Expression

[0250] Human LgR5 gene expression was analyzed using a proprietary database containing gene expression information (GeneExpress®, Gene Logic Inc., Gaithersburg, MD). Graphical analysis of the GeneExpress® database was conducted using a microarray profile viewer. Figure 1 is a graphic representation of human LgR5 gene expression in various tissues. The scale on the y-axis indicates gene expression levels based on hybridization signal intensity. Dots appear both to the left and to the right of the line extending from the name of each listed tissue. The dots appearing to the left of the line represent gene expression in normal tissue, and the dots appearing to the right of the line represent gene expression in tumor and diseased tissue. Figure 1 shows increased LgR5 gene expression in certain tumor or diseased tissues relative to their normal counterparts. In particular, LgR5 is substantially overexpressed in colorectal, endometrial, and ovarian tumors. Figure 1, inset, shows that LgR5 is overexpressed in at least the following colon tumors: adenocarcinoma, benign tumors, and metastatic colon tumors, and also in tissue with a colon tumor content of less than 50% ("low tumor" in Figure 1 inset); but is not overexpressed in normal colon, Crohn's disease, or ulcerative colitis. Human LgR5 expression is much lower in normal tissues, with low levels of expression in normal brain, muscle, ovarian, and placental tissues.

B. Prevalence of Human LgR5 in Colon Tumors

[0251] To evaluate the expression of LgR5 in colorectal cancer, 57 primary colorectal adenocarcinomas were acquired from multiple sources (Asterand, Detroit, MI; Bio-Options, Fullerton, CA; University of Michigan, Ann Arbor, MI; Cytomyx, Rockville, MD; Cooperative Human Tissue Network, Nashville, TN; Indivumed, Hamburg, Germany; ProteoGenex, Culver City, CA). Forty-four percent of samples were from men, and the average age of the patients

was 66 years (range 31 to 93 years). Tissue microarrays (TMAs) were assembled using duplicate cores as described in Bubendorf L, et al., *J Pathol.* 2001 Sep;195(1):72-9, and included five normal colorectal mucosa samples from matched cases.

[0252] LgR5 expression was determined by in situ hybridization using the oligonucleotide probes shown in Table 2. *See, e.g.,* Jubb AM, et al., *Methods Mol Biol* 2006; 326:255-64. ISH for β -actin was used to confirm mRNA integrity in colorectal cancer tissues prior to analysis.

Table 2. Primer sequences for isotopic in situ hybridization probes.					
Gene	Genbank Accession	Nucleotide s Complementary to Probe	Anti-sense (AS) or Sense (S)	Forward Primer (5' to 3')	Reverse Primer (5' to 3')
Lgr5	NM_003667	508	AS	ACCAACTGCATCCTAAACTG (SEQ ID NO: 92)	ACCGAGTTTCACCTCAGCTC (SEQ ID NO: 93)
Lgr5	NM_003667	496	S	ACATTGCCCTGTTGCTCTTC (SEQ ID NO: 94)	ACTGCTCTGATATACTCAATC (SEQ ID NO: 95)

[0253] LgR5 hybridization intensity was scored by a trained pathologist according to the scheme below, taking into account the intensity (silver grains) as well as breadth of staining.

0 (negative): very weak or no hybridization in >90% of tumor cells

1+ (mild): predominant hybridization pattern is weak

2+ (moderate): predominant hybridization pattern is moderately strong in the majority (>50%) of neoplastic cells

3+ (strong): predominant hybridization pattern is strong in the majority (>50%) of neoplastic cells

Sense probes were used to control for the specificity of hybridization.

[0254] Figure 2 shows exemplary colon tumor sections with 1+, 2+, and 3+ levels of staining. The top panels show dark field images and the bottom panels show bright field images. The deposition of silver grains in the dark field images indicates hybridization of the probe and expression of LgR5 mRNA. ~77% (41/53) of colon tumor sections analyzed were LgR5 positive, showing staining at the 1+, 2+, or 3+ levels, with 34% (18/53) showing 2+ or 3+ staining. Four of the 57 samples analyzed were noninformative for LgR5 expression.

[0255] To evaluate the significance of Lgr5 expression in colon tumors, a population-based series of patients who had undergone surgical resections for colorectal adenocarcinoma was compiled retrospectively from the pathology archives at St James' University Hospital

(Leeds, UK) from 1988 to 2003. Tissue microarrays (TMAs) were constructed with one core of normal mucosa and three cores of adenocarcinoma per patient as described in Bubendorf L, et al., *J Pathol.* 2001 Sep;195(1):72-9. ISH was performed and scored as described above. The heterogeneity of expression across three cores from the same tumor was also determined, and is expressed as the proportion of tumors that showed a particular level of discordance in one of the three cores. For example, if three cores had scores of +1, +3, and +3, one of the three cores from that tumor is discordant by 2.

[0256] Figure 3A shows the prevalence of 0, 1+, 2+, and 3+ levels of LgR5 staining in the colon tumor tissue microarray, measured by in situ hybridization. 75% of the colon tumor tissues showed staining at the 1+, 2+, or 3+ levels, with 37% showing 2+ or 3+ staining. Figure 3B shows the heterogeneity of LgR5 expression. 67% of tumors showed no heterogeneity across the three cores. 32% shows a discordance of 1 in one of the three cores, and only 1% showed a discordance greater than 1.

C. Commercially Available Antibodies Not Suitable for Immunohistochemistry

[0257] A long-standing issue in determining the expression of Lgr5 was the lack of a quality Immunohistochemistry (IHC) reactive antibody. RNA expression of Lgr5 has been limitedly examined previously; however, there is little data about the normal tissue expression pattern in humans outside of the stomach, colon, and hair follicle.

[0258] Six different commercial antibodies that are marketed as IHC antibodies were tested for suitability as antibodies for immunohistochemistry. Rabbit polyclonal antibody MC-1235 (MBL International Corp., Woburn, MA) was tested for binding to LgR5 expressed on the surface of 293 cells, and no LgR5 detection was observed. Rabbit polyclonal antibody MC-1236 (MBL International Corp., Woburn, MA) was able to stain LgR5 when it was overexpressed on 293 cells, but no specific LgR5 staining was observed on LoVo colon cancer cells, compared to 293 cells transfected with vector only. Further, brain tissue stained with MC-1236 showed a high level of staining within blood vessels, suggesting possible background staining of serum.

[0259] Rabbit monoclonal antibody 2495-1 (Epitomics, Burlingame, CA) was found to specifically stain LgR5 expressed on the surface of 293 cells. LoVo and D5124 colon cancer cells showed weak cytoplasmic staining, and some SW116 colon cancer cells showed very weak staining. Human colon and small intestine tissues showed weak staining in the epithelial compartment, characterized as broadly diffuse cytoplasmic staining throughout the intestinal

crypt. No specific staining in the basal portion of the crypt was noted, however, and no membrane-specific staining was observed in any of the cell lines or tissues tested.

[0260] Three additional commercial antibodies were tested for specific LgR5 staining: rabbit polyclonal antibody HPA012530 (Sigma-Aldrich, St. Louis, MO), rabbit monoclonal antibody LS-C105455 (LifeSpan BioSciences, Inc., Seattle, WA), and mouse monoclonal antibody TA503316 (OriGene, Rockville, MD). None of the antibodies showed specific membranous staining of normal human small intestine and/or colon tissue samples, nor was LgR5 detected in the crypt base in those tissues.

D. Rabbit Monoclonal Antibody Generation

[0261] After several failed attempts to develop IHC reactive antibodies in mice, we generated an IHC reactive antibody in rabbits. Rabbits were immunized with an LgR5 extracellular domain (ECD) huFc (SEQ ID NO: 96) fusion protein, which was produced in CHO cells. Serum titers against LgR5 using test bleeds were evaluated using standard protocols. Two rabbits were found to have a good immune response, and were chosen as the candidate for splenectomy and monoclonal fusion.

[0262] Splenectomies were performed, splenocytes were isolated, and 200×10^6 lymphocyte cells were fused with 100×10^6 fusion partner cells and plated onto 96-well plates (Epitomics, Burlingame, CA). The plates were cultured under standard conditions.

[0263] Plates were screened using a standard ELISA protocol, with plates coated with LgR5 extracellular domain (ECD)-huFc fusion. Three clones were selected and expanded into 24-well plates. Thirty-six of the expanded clones were tested by ELISA and immunohistochemistry (IHC) using 293 cells expressing human or mouse LgR5.

[0264] After further testing, including determining whether the clones produced antibodies that recognized LgR5 on human intestine crypt base columnar cells, antibodies 1-12 and 26-1 were selected for cloning. Briefly, mRNA from hybridoma cells was isolated using TurboCapture Kit (Qiagen: Catalog #72232) following the manufacturer's instructions and then reverse transcribed into cDNA using oligo-dT primer. The variable region of the heavy chain (VH) was PCR amplified. The entire light chain (LC) was PCR. The PCR-amplified VH region was digested using restriction enzymes HindIII and KpnI. The PCR-amplified LC was digested using restriction enzymes HindIII and NotI. Digested products were purified using Qiagen QIAquick PCR Purification Kit (catalog #28014). After purification, the VH and LC were ligated into heavy or light chain expression vectors and transformed into DH5 α cells (MC Lab, catalog #DA-100). Transformed colonies were picked and inserts were confirmed by expected

size using the corresponding restriction enzymes. Plasmids with inserts of the expected size were sequenced using TT5 primer. The sequences of the heavy chain variable region and the light chain variable region are shown in Figure 4, and in SEQ ID NOs: 6 and 5, respectively, for antibody 1-12; and in Figure 4, and in SEQ ID NOs: 8 and 7, respectively, for antibody 26-1.

[0265] Light chain and heavy chain expression vectors were co-transfected into CHO cells and purified from the cell culture supernatants using Protein A.

E. Antibody Epitope Determination

[0266] A FACS competition assay was used to map the epitopes recognized by antibodies 1-12 and 26-1. Briefly, human LgR5 was expressed in 293 cells and competition assays were performed using antibody huYW353 (heavy chain and light chain sequences shown in SEQ ID NOs: 98 and 88, respectively), which has previously been shown to bind to an epitope on LgR5 comprising amino acids 22 to 122, and antibody 8E11 (heavy and light chain variable regions shown in SEQ ID NOs: 29 and 28, respectively), which has previously been shown to bind to an epitope on LgR5 comprising amino acids 22 to 322.

[0267] Antibody 26-1 was found to compete for LgR5 binding with huYW353 and 8E11, while antibody 1-12 did not compete for LgR5 binding with either huYW353 or 8E11. (Data not shown.) Thus, it appears that antibody 26-1 binds an epitope in the region of amino acids 22 to 322 of human LgR5, while antibody 1-12 binds an epitope outside of that region.

F. Detection of LgR5 on Normal Tissues

[0268] Antibody LGR5.1-12 was used to detect expression of LgR5 on normal human tissues. Immunohistochemistry (IHC) for Lgr5 was performed on a Dako Universal Autostainer (Dako, Carpinteria, CA). Briefly, formalin-fixed, paraffin-embedded whole tissue and tissue microarray sections were deparaffinized and antigen unmasking was performed in a PT Module (Thermo Scientific, Kalamazoo, MI) with Target Retrieval pH 6 (Dako) at 99°C for 20 minutes. Endogenous peroxidase was inhibited with treatment of 3% H₂O₂ in PBS for 4 minutes and endogenous biotin was blocked using the Avidin/Biotin blocking kit (Vector Labs, Burlingame, CA). Endogenous IgGs were blocked using 10% donkey serum in 3% BSA/PBS and primary antibody to Lgr5 (LGR5.1-12) was incubated at 4 µg/ml for 60 minutes at room temperature. Biotinylated donkey anti-rabbit IgG (Jackson ImmunoResearch, West Grove, PA) was incubated for 30 minutes at room temperature followed by treatment with Vectastain ABC Elite-HRP (Vector Labs) for 30 minutes at room temperature. Antibody binding was detected with Metal enhanced DAB (Pierce Rockford, IL) for 5 minutes at room temperature and sections were counterstained with Mayer's Hematoxylin (Rowley Biochemical, Danvers, MA).

[0269] Antibody LGR5.1-12 stained normal intestinal crypts in the expected pattern. *See* Figure 5A. Moderate staining was also observed in hair follicle (Figure 5B), and weak staining was observed in fallopian tube, endometrium, adrenal gland, and spinal cord (Figure 5C).

G. Detection of LgR5 on Xenograft Tumors

[0270] Tumors isolated from LoVo X 1.1 and D5124 xenograft model mice were analyzed by flow cytometry to determine surface expression of LgR5 using antibody YW353. Briefly, Lovo1.1 or D5124 tumors were harvested and treated with 1% bovine serum albumin (BSA) in phosphate-buffered saline (PBS) with a collagenase enzyme mixture. Tumors were incubated for 15 minutes at 37°C, and cells were washed in PBS with 1% BSA. Cells were spun down and resuspended in ammonium chloride-potassium lysis buffer to lyse the red blood cells. Cells were washed in PBS with 1% BSA and RRMI 1640 media with 10% fetal bovine serum (FBS). Cells were resuspended in fluorescence-activated cell sorting buffer (PBS with 1% BSA) and incubated for 45 minutes with anti-LgR5 antibody, followed by a 30 minute incubation with anti human secondary antibody conjugated to PE. Analysis was performed with a FACSCalibur™ flow cytometer (BD Biosciences).

[0271] Figure 6 shows the results of that experiment. LgR5 on the surface of (A) LoVo X 1.1 xenograft tumor cells and (B) D5124 xenograft tumor cells was detectable by FACS using antibody YW353. By immunohistochemistry, expression of LgR5 was 2+ for both (C) LoVo X 1.1 xenograft tumors and (D) D5124 xenograft tumors, using antibody LGR5.1-12. At the top of the panels shown in (C) are the percentages of cells in the field showing each level of staining.

H. Prevalence of LgR5 on Colon Tumors by Immunohistochemistry

[0272] To determine the prevalence of LgR5 in colon tumors, immunohistochemistry was performed on a tissue microarray containing cores from 143 different colon tumors, using antibody LGR5.1-12, as described above in Example (E).

[0273] Forty percent of the colon tumors were positive for LgR5, with 29% (41/143) scoring 1+, 9% (13/143) scoring 2+, and 2% (3/143) scoring 3+, using the following criteria:

- 0 = no staining,
- 1+ = weak staining,
- 2+ = moderate staining, and
- 3+ = strong staining.

[0274] The remaining colon tumors (86/143) scored 0 by IHC using antibody LGR5.1-12. Figure 7A to D shows exemplary 0, 1+, 2+, and 3+ staining of colon tumors using antibody LGR5.1-12.

[0275] Substantial heterogeneity in IHC staining was observed. IHC was therefore performed on 19 colon cancer tumor sections using antibody LGR5.1-12. Three of the sections were negative for LgR5 expression; in two sections, greater than 50% of the cells were positive for LgR5; the remaining sections showed between 0 and 50% staining. Table 3 shows the percentage of cells in each section that stained at each level, and the overall score using a 50% criteria (i.e., 50% or more of the cells are positive for LgR5) or a 10% criteria (i.e., 10% of the cells are positive for LgR5). For comparison, the staining observed in the D5124 and LoVo xenograft tumors described above are also included. H score is equal to (% cells staining at 1+) + (% cells staining at 2+)x2 + (% cells staining at 3+)x3. H score takes into consideration the percentage of cells at each staining intensity.

Table 3: Immunohistochemistry of colon tumor sections using antibody LGR5.1-12

Sample	0	+1	+2	+3	H-score	Overall score (50%+ criteria)	Overall score (10%+ criteria)
HP-2889	40	45	15	0	75	1+	1+
HP-9328	80	17	3	0	23	0	1+
HP-11394	85	10	5	0	20	0	1+
HP-19862	85	0	15	0	30	0	2+
HP-19882	75	25	0	0	25	0	1+
HP-20531	60	40	0	0	40	0	1+
HP-21638	25	65	10	0	85	1+	1+
HP-23099	85	15	0	0	15	0	1+
HP-23301	15	20	65	0	150	2+	2+
HP-23302	50	45	5	0	55	1+	1+
HP-23433	55	5	35	5	90	0	2+
HP-23451	95	5	0	0	5	0	0
HP-24574	75	10	15	0	40	0	2+
HP-24583	100	0	0	0	0	0	0
HP-24586	85	10	5	0	20	0	1+
HP-24589	100	0	0	0	0	0	0
HP-24592	90	10	0	0	10	0	1+

HP-24671	100	0	0	0	0	0	0
HP-24672	95	5	0	0	5	0	0
D5124 xeno model	10	20	70	0	160	2+	2+
LOVO xeno model	45	20	25	10	100	2+	2+

[0276] These results demonstrate that antibody LGR5.1-12 is able to detect Lgr5 expression in colon tumors. In summary, Lgr5 RNA and protein expression is observed within multiple normal tissue compartments and although heterogeneous, Lgr5 is expressed in colon tumors.

I. Immunohistochemistry with Antibody LGR5.26-1

[0277] Staining with antibody LGR5.26-1 was compared to staining with antibody LGR5.1-12 in CXF233 (human colon tumor model; Oncotest) xenograft tumors and in various colon cancer cell lines. Immunohistochemistry (IHC) for Lgr5 was performed on a Dako Universal Autostainer (Dako, Carpinteria, CA). Briefly, formalin-fixed, paraffin-embedded tumor tissue were deparaffinized and antigen unmasking was performed in a PT Module (Thermo Scientific, Kalamazoo, MI) with Target Retrieval pH 6 (Dako) at 99°C for 20 minutes. Endogenous peroxidase was inhibited with treatment of 3% H₂O₂ in PBS for 4 minutes and endogenous biotin was blocked using the Avidin/Biotin blocking kit (Vector Labs, Burlingame, CA). Endogenous IgGs were blocked using 10% donkey serum in 3% BSA/PBS and primary antibody to Lgr5 (LGR5.1-12 or 26-1) was incubated at 4 µg/ml for 60 minutes at room temperature. Biotinylated donkey anti-rabbit IgG (Jackson ImmunoResearch, West Grove, PA) was incubated for 30 minutes at room temperature followed by treatment with Vectastain ABC Elite-HRP (Vector Labs) for 30 minutes at room temperature. Antibody binding was detected with Metal enhanced DAB (Pierce Rockford, IL) for 5 minutes at room temperature and sections were counterstained with Mayer's Hematoxylin (Rowley Biochemical, Danvers, MA).

[0278] As shown in Figure 8, antibody LGR5.1-12 (A) and antibody LGR5.26-1 (B) shows similar staining patterns in a CXF233 xenograft tumor sample.

[0279] Each cell line was also characterized by *lgr5* gene expression using RNAseq data into the following levels of expression: none, very low, low, moderate, and high. In addition, Lgr5 levels were determined in the cell lines by IHC, substantially as described above. The results of that experiment are shown in Table 4.

Table 4: IHC staining of colon cancer cell lines using antibodies LGR5.1-12 and LGR5.26-1

RNAseq expression	Cell Line	FACS	Ab1-12	Ab26-1
None	SW480		0	0
None	RKO		0	0
None	COLO741		0	0
Very low	HCT-15		0	0
Very low	CX-1		0	0
Very low	HT-29		0	0
Very low	SW403		2+ (60%)	1+ (65%)
Low	SW1116		0	0
Low	HCA-7		0	0
Low	COLO-205		0	0
Low	LS180	-	0	1+ (10%)
Low	SW948		1+ (15%)	1+ (10%)
Moderate	CACO-2		1+ (15%)	1+ (15%)
Moderate	T84		2+ (40%)	2+ (40%)
Moderate	KM-12		2+ (25%)	1+ (60%)
Moderate	C2BBel1		1+ (10%)	1+ (15%)
High	DLD-1	-	0	1+ (10%)
High	SW620	-	0	1+ (20%)
High	SW1463	+/-	2+ (50%)	2+ (25%)
High	SK-CO-1	+/-	2+ (80%)	2+ (85%)
High	LS174T	-	0	0
High	LOVO	++	2+ (50%)	2+ (50%)

[0280] Both antibody LGR5.1-12 and antibody LGR5.26-1 were able to detect LgR5 on the surface of many different colon cancer cell lines.

[0281] Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, the descriptions and examples should not be construed as limiting the scope of the invention. The disclosures of all patent and scientific literature cited herein are expressly incorporated in their entirety by reference.

TABLE OF SEQUENCES

SEQ ID NO	Description	Sequence
1	α LgR5.1-12 light chain	AYDMTQTPAS VEVAVGGTVT IKCQASQSIG SNLAWYQQKP GQPPKLLIYG ASNLASGVSS RFKSGSGSGTE FTLTISDLEC ADAATYYCQT TYGSSSDGFF WTFGGGTEVV VKGDPVAPTV LIFPPAADQV ATGVTIIVCV ANKYFPDVTV TWEVDGTTQT TGIENSKTPQ NSADCTYNLS STLTLTSTQY NSHKEYTCKV TQGTTSVVQS FNRGDC
2	α LgR5.1-12 heavy chain	QSLEESGGGL VQPEGSLTLT CTASGFSFSR TYWICWDRQA PGKGLEWIAI IYAGGSDNTY YASWAKGRFT ISKTSSTTVT LQVTSLSAAD TATYFCARYY AGSSEYFNLW GPGLTVTVSS ASTKGPSVFP LAPCCGDTPS STVTLGCLVK GYLPEPVTVT WNSGTLTNGV RTFPSVRQSS GLYSLSSVVS VTSSSQPVTC NVAHPATNTK VDKTVAPSTC SKPTCPPPEL LGGPSVFIIFP PKPKDTLMIS RTPEVTCVVV DVSQDDPEVQ FTWYINNEQV RTARPPLREQ QFNSTIRVVS TLPIAHQDWL RGKEFKCKVH NKALPAPIEK TISKARGQPL EPKVYTMGPP REELSSRSVS LTCMINGFYP SDISVEWEKN GKAEDNYKTT PAVLDSGDSY FLYSKLSVPT SEWQRGDVFT CSVMHEALHN HYTQKSISRS PGK
3	α LgR5.26-1 light chain	AFELTQTPSS VEAAGVGGTVT IKCQASQSIG VGLAWYQQKP GQPPKLLIYK ASTLASGVPS RFKGSRSRGTE FTLTISDLEC ADAATYYCQS YYDSSTTANV FGGGTEVVVK GDPVAPTVLI FPPAADQVAT GTVTIIVCVAN KYFPDVTVTW EVDGTTQTIG IENSKTPQNS ADCTYNLSST LTLTSTQYNS HKEYTCKVTO GTTSVVQSFN RGDC
4	α LgR5.26-1 heavy chain	QSLEESGGDL VKPGGTLTLT CTASGIDFSY YSYMCWVRQA PGKGLEWIAI IYAGTSGSTY YASWAKGRFT ISKTSSTTVT LQMISLSAAD TATYFCARSY YTFGVNGYAW DLWGPGLTVT VSSASTKGPS VFPLAPCCGD TPSSTVTLGC LVKGYLPEPV TVTWNSTLT NGVRTFPSVR QSSGLYSLSS VVSSTSSSQP VTCNVAHPAT NTKVDKTVP STCSKPTCPP PELLGGPSVF IFPPKPKDTL MISRTPEVTC VVVDVSQDDP EVQFTWYINN EQVRTARPPL REQQFNSTIR VVSTLPIAHQ DWLRGKEFKC KVHNKALPAP IEKTISKARG QPLEPKVYTM GPPREELSSR SVSLTCMING FYPSDISVEW EKNGKAEDNY KTPAVLDS GSYFLYSKLS VPTSEWQRGD VFTCSVMHEA LHNHYTQKSI SRSPGK
5	α LgR5.1-12 light chain variable region	AYDMTQTPAS VEVAVGGTVT IKCQASQSIG SNLAWYQQKP GQPPKLLIYG ASNLASGVSS RFKSGSGSGTE FTLTISDLEC ADAATYYCQT TYGSSSDGFF WTFGGGTEVV VK
6	α LgR5.1-12 heavy chain variable region	QSLEESGGGL VQPEGSLTLT CTASGFSFSR TYWICWDRQA PGKGLEWIAI IYAGGSDNTY YASWAKGRFT ISKTSSTTVT LQVTSLSAAD TATYFCARYY AGSSEYFNLW GPGLTVTVSS
7	α LgR5.26-1 light chain variable region	AFELTQTPSS VEAAGVGGTVT IKCQASQSIG VGLAWYQQKP GQPPKLLIYK ASTLASGVPS RFKGSRSRGTE FTLTISDLEC ADAATYYCQS YYDSSTTANV FGGGTEVVVK
8	α LgR5.26-1 heavy chain variable region	QSLEESGGDL VKPGGTLTLT CTASGIDFSY YSYMCWVRQA PGKGLEWIAI IYAGTSGSTY YASWAKGRFT ISKTSSTTVT LQMISLSAAD TATYFCARSY YTFGVNGYAW DLWGPGLTVT VSS
9	α LgR5.1-12 HVR-L1	QASQSIGSNL A
10	α LgR5.1-12	GASNLAS

	HVR-L2	
11	α LgR5.1-12 HVR-L3	QTTYGSSSDG FFWT
12	α LgR5.1-12 HVR-H1	RTYWIC
13	α LgR5.1-12 HVR-H2	CIYAGGSDNT YYASWAK
14	α LgR5.1-12 HVR-H3	YYAGSSEYFN L
15	α LgR5.26-1 HVR-L1	QASQSISVGL A
16	α LgR5.26-1 HVR-L2	KASTLAS
17	α LgR5.26-1 HVR-L3	QSYIDSSTTA NV
18	α LgR5.26-1 HVR-H1	YYSYMC
19	α LgR5.26-1 HVR-H2	CIYAGTSGST YYASWAK
20	α LgR5.26-1 HVR-H3	SYTTFGVNGY AWDL
21	Human LgR5 precursor; LGR5_human NP_003658; signal sequence = amino acids 1-21; 22 to 558 are extracellular domain (ECD)	MDTSRLGVLL SLPVLLQLAT GGSSPRSGVL LRGCPHCHC EPDGRMLLRV DCSDLGLSEL PSNLSVFTSY LDLSMNNISQ LLPNPLPSLR FLEELRLAGN ALTYIPKGAF TGLYSLKVLM LQNNQLRHVP TEALQNLRSL QSLRLDANHI SYVPPSCFSG LHSLRHLWLD DNALTEIPVQ AFRSLSALQA MTLALNKIHH IPDYAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSLETLD LNYNNLDEFP TAIRTLNLK ELGFHSNNIR SIPEKAFVGN PSLITIHFYD NPIQFVGRSA FQHLPELRTL TLNGASQITE FPDLTG TANL ES LTLTGAQI SSLPQTVCNQ LPNLQVLDLS YNLLEDLP SF SVCQKLQKID LRHNEIYEIK VDTFQQLLSL RSLNLAWNKI AIIHPNAFST LP SLIKLDLS SNLLSFPIT GLHGLTHLKL TGNHALQSLI SSENFPPELV IEMPYAYQCC AFGVCENAYK ISNQWNKGDN SSMDDLHKKD AGMFAQQDER DLEDFLDFE EDLKALHSVQ CSPSPGPFKP CEHLLDGWLI RIGVWTIAVL ALTCNALVTS TVFRSPYIS PIKLLIGVIA AVNMLTGVSS AVLAGVDAFT FGSFARHGAW WENGVGCHVI GFLSIFASES SVFLLTLAAL ERGFSVKYSA KFETKAPFSS LKVIILLCAL LALTMAAVPL LGGSKYGASP LCLPLPFGE STMGYMVALI LLNSLCFLMM TIAYTKLYCN LDKGDLENIW DCSMVKHIAL LLFTNCILNC PVAFLSFSSL INLTFISPEV IKFILLVVVP LPACLNPLLY ILFNPHFKED LVSLRKQTYV WTRSKHPSLM SINSDDVEKQ SCDSTQALVT FTSSSITYDL PPSSVPSPAY PVTESCHLSS VAFVPCL
22	Human LgR5 mature, without signal sequence; amino acids 22 to 907	GSSPRSGVL LRGCPHCHC EPDGRMLLRV DCSDLGLSEL PSNLSVFTSY LDLSMNNISQ LLPNPLPSLR FLEELRLAGN ALTYIPKGAF TGLYSLKVLM LQNNQLRHVP TEALQNLRSL QSLRLDANHI SYVPPSCFSG LHSLRHLWLD DNALTEIPVQ AFRSLSALQA MTLALNKIHH IPDYAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSLETLD LNYNNLDEFP TAIRTLNLK ELGFHSNNIR SIPEKAFVGN PSLITIHFYD NPIQFVGRSA FQHLPELRTL TLNGASQITE FPDLTGTANL ES LTLTGAQI SSLPQTVCNQ LPNLQVLDLS YNLLEDLP SF SVCQKLQKID

		LRHNEIYEIK VDTFQQLLSL RSLNLAWNKI AIIHPNAFST LPSLIKLDLS SNLLSSFPIT GLHGLTHLKL TGNHALQSLI SSNFPELVK IEMPYAYQCC AFGVCENAYK ISNQWNKGDN SSMDDLHKKD AGMFAQQDER DLEDFLLDFE EDLKALHSVQ CSPSPGPFKP CEHLLDGWL I RIGVWTIAVL ALTCNALVTS TVFRSPLYIS PIKLLIGVIA AVNMLTGVSS AVLAGVDAFT FGSFARHGAW WENGVGCHVI GFLSIFASES SVFLLTLAAL ERGFSVKYSA KFETKAPFSS LKVIILLCAL LALTMAAVPL LGGSKYGASP LCLPLPFGE STMGYMVALI LLNSLCFLMM TIAYTKLYCN LDKGDLENIW DCSMVKHIAL LLFTNCILNC PVAFLSFSS INLTFISPEV IKFILLVVVP LPACLNPLLY ILFNPHFKED LVSLRKQTYV WTRSKHPSLM SINSDDVEKQ SCDSTQALVT FTSSSITYDL PPSSVPSPAY PVTESCHLSS VAFVPCL
23	Cynomolgus monkey LgR5 partial sequence, predicted; predicted to correspond to amino acids 33 to 907 of full-length precursor	GCPTHCHCEP DGRMLLRVDC SDLGLSELPS NLSVFTSYLD LSMNNISQLL PNPLPSLRFL EELRLAGNAL TYIPKGAFTG LYSCLKVLMQ NNQLRQVPT ALQNLRSLSQSLDANHISY VPPSCFSG LH SLRHLWLDN ALTEIPVQAF RSLSALQAMT LALNKIHHIP DYAFGNLSSL VVLHLHNNRI HSLGKKCFDG LHSLETLDL YNNLDEFPTA IRTLSNLKEL GFHSNNIRSI PEKAFVGNPS LITIHFYDNP IQFVGRSAFQ HLPRLTLTL NGASQITEFP DLTGTANLES LTLTGAQISS LPQTVCNQLP NLQVLDLSYN LLEDLPSFSV CQKLQKIDLR HNEIYEIKVD TFQQLLSLR LNLAWNKIAI IHPNAFSTLP SLIKLDLSSN LLSSFPVTGL HGLTHLKL TG NHALQSLISS ENFPELKIIE MPYAYQCCAF GVCENAYKIS NQWNKGDNS MDDLHKKDAG MFQVQDERDL EDFLLDFEED LKALHSVQCS PSPGPFKPCE HLLDGWLIRI GVWTIAVLAL TCNALVTSTV FRSPYISPI KLLIGVIAV NMLTGVSSAV LAGVDAFTFG SFARHGAWWE NGVGCQVIGF LSIFASESSV FLLTLAALER GFSVKCSAKF ETKAPFSSLK VIILLCALLA LTMAAVPLL GSEYGASPLC LPLPFGEPT TGYMVALILL NSLCFLMMTI AYTKLYCNLD KGDLENIWDC SMVKHIALLL FTNCILYCPV AFLSFSSLLN LTFISPEVIK FILLVIVPLP ACLNPLLYIL FNPHFKEKDLV SLGKQTYFWT RSKHPSLMSI NSDDVEKQSC DSTQALVTFT SSSIAYDLPP SSVPSPAYPV TESCHLSSVA FVPCL
24	Rat LgR5 precursor; LGR5_rat NP_001100254; signal sequence = amino acids 1-21	MDTSRVRMLL SLLALLQLVA AGSPRPDTM PRGCPSYCHC ELDGRMLLRV DCDLGLSEL PSNLSVFTSY LDLSMNNISQ LPASLLHRLR FLEELRLAGN ALTHIPKGAF AGLHSLKVLM LQNNQLRQVP EEALQNLRS L QSLRLDANHI SYVPPSCFSG LHSLRHLWLD DNALTDVPVQ AFRSLSALQA MTLALNKIHH IADHAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSETLD LNYNNLDEF TAIKTLNLK ELGFHSNNIR SIPERAFVGN PSLITIHFYD NPIQFVGISA FQHLPELRTL TLNGASQITE FPDLTGTATL ESLLTGAKI SSLPQTVCDO LPNLQVLDLS YNLLEDLPSL SGCQKLQKID LRHNEIYEIK GGTQQLFNL RSLNLARNKI AIIHPNAFST LPSLIKLDLS SNLLSSFPVT GLHGLTHLKL TGNRALQSLI PSANFPELKI IEMPYAYQCC AFGGCENVYK IPNQWNKDD SSVDDLKKD AGLFQVQDER DLEDFLLDFE EDLKVLSHVQ CSPPPGPFKP CEHLFGSWLI RIGVWTTAVL ALSCNALVAF TVFRTPLYIS SIKLLIGVIA VVDILMGVSS AILAVVDFT FGSFAQHGA WEGGIGCQIV GFLSIFASES SVFLLTLAAL ERGFSVKCSS KFEMKAPLSS LKAIILLCVL LALTIA TVPL LGGSEYNASP LCLPLPFGE STTGYMVALV LLNSLCFLIM TIAYTRYCS LEKGELENLW DCSMVKHIAL LLFTNCILYC PVAFLSFSS LNLTFISPEV IKFILLVIVP LPACLNPLLY IVFNPHFKED MGS LGKQTRF WTRAKHPSLL SINSDDVEKR SCDSTQALVS FTHASIAIDL PSDSGSSPAY PMTESCHLSS VAFVPCL
25	Rat LgR5 mature,	GSPRPDTM PRGCPSYCHC ELDGRMLLRV DCDLGLSEL PSNLSVFTSY LDLSMNNISQ LPASLLHRLR FLEELRLAGN

	without signal sequence; amino acids 22 to 907	ALTHIPKGAF AGLHSLKVLML QNNQLRQVP EEALQNLRSL QSLRLDANHI SYVPPSCFSG LHSRLHLWLD DNALTDVPVQ AFRSLSALQA MTLALNKIHH IADHAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSLETLD LNYNNLDEFP TAIKTLNLK ELGFHSNNIR SIPERAFVGN PSLITIHFYD NPIQFVGISA FQHLPELRTL TLNGASQITE FPDLTGTATL ESLLTGTAKI SSLPQTVCDQ LPNLQVLDLS YNLEDLPSL SGCQKLQKID LRHNEIYEIK GGTQQQLFNL RSLNLARNKI AIIHPNAFST LPSLIKLDLS SNLLSSFPVT GLHGLTHLKL TGNRALQSLI PSANFPELKI IEMPYAYQCC AFGGCENVYK IPNQWNKDD SSVDDLKRD AGLFQVQDER DLEDFLDDE EDLKVLSHVQ CSPSPGPFKP CEHLFGSWLI RIGVWTTAVL ALSCNALVAL TVFRTPLYIS SIKLLIGVIA VVDILMGVSS AILAVVDFT FGSFAQHGA WEGGIGCQIV GFLSIFASES SVFLLTLAAL ERGFSVKCSS KFEMKAPLSS LKAIILLCVL LALTIATVPL LGGSEYNASP LCLPLPFGE STTGVMVALV LLNSLCFLIM TIAYTRYCS LEKGELENLW DCSMVKHTAL LLFTNCILYC PVAFLSFSSL LNLTFISPEV IKFILLVIVP LPACLNPLLY IVFNPHFKED MGS LGKQTRF WTRAKHPSLL SINSDDVEKR SCDSTQALVS FTHASIAIDL PSDSGSSPAY PMTESCHLSS VAFVPCL
26	Mouse LgR5 precursor; LGR5_mouse NP_034325; signal sequence = amino acids 1-21	MDTSCVHMLL SLLALLQLVA AGSSPGPDAI PRGCPSHCHC ELDGRLMLRV DCSDLGLSEL PSNLSVFTSY LDLSMNNISQ LPASLLHRLC FLEELRLAGN ALTHIPKGAF TGLHSLKVLML QNNQLRQVP EEALQNLRSL QSLRLDANHI SYVPPSCFSG LHSRLHLWLD DNALTDVPVQ AFRSLSALQA MTLALNKIHH IADYAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSLETLD LNYNNLDEFP TAIKTLNLK ELGFHSNNIR SIPERAFVGN PSLITIHFYD NPIQFVGISA FQHLPELRTL TLNGASHITE FPHLTGTATL ESLLTGTAKI SSLPQAVCDQ LPNLQVLDLS YNLEDLPSL SGCQKLQKID LRHNEIYEIK GSTQQQLFNL RSLNLAWNKI AIIHPNAFST LPSLIKLDLS SNLLSSFPVT GLHGLTHLKL TGNRALQSLI PSANFPELKI IEMPYAYQCC AFGGCENVYK ISNQWNKDDG NSVDDLHKKD AGLFQVQDER DLEDFLDDE EDLKVLSHVQ CSPSPGPFKP CEHLFGSWLI RIGVWTTAVL ALSCNALVAL TVFRTPLYIS SIKLLIGVIA VVDILMGVSS AVLA AVDAFT FGRFAQHGA WEDGIGCQIV GFLSIFASES SIFLLTLAAL ERGFSVKCSS KFEVKAPLFS LRAIVLLCVL LALTIATVPL LGGSEYNASP LCLPLPFGE STTGVMVALV LLNSLCFLIM TIAYTRYCS LEKGELENLW DCSMVKHIAL LLFANCILYC PVAFLSFSSL LNLTFISPDV IKFILLVIVP LPACLNPLLY IVFNPHFKED MGS LGKHTRF WMRKHASLL SINSDDVEKR SCDSTQALVS FTHASIAIDL PSTSGASPAY PMTESCHLSS VAFVPCL
27	Mouse LgR5 mature, without signal sequence; amino acids 22 to 907	GSSPGPDAI PRGCPSHCHC ELDGRLMLRV DCSDLGLSEL PSNLSVFTSY LDLSMNNISQ LPASLLHRLC FLEELRLAGN ALTHIPKGAF TGLHSLKVLML QNNQLRQVP EEALQNLRSL QSLRLDANHI SYVPPSCFSG LHSRLHLWLD DNALTDVPVQ AFRSLSALQA MTLALNKIHH IADYAFGNLS SLVVLHLHNN RIHSLGKKCF DGLHSLETLD LNYNNLDEFP TAIKTLNLK ELGFHSNNIR SIPERAFVGN PSLITIHFYD NPIQFVGISA FQHLPELRTL TLNGASHITE FPHLTGTATL ESLLTGTAKI SSLPQAVCDQ LPNLQVLDLS YNLEDLPSL SGCQKLQKID LRHNEIYEIK GSTQQQLFNL RSLNLAWNKI AIIHPNAFST LPSLIKLDLS SNLLSSFPVT GLHGLTHLKL TGNRALQSLI PSANFPELKI IEMPYAYQCC AFGGCENVYK ISNQWNKDDG NSVDDLHKKD AGLFQVQDER DLEDFLDDE EDLKVLSHVQ CSPSPGPFKP CEHLFGSWLI RIGVWTTAVL ALSCNALVAL TVFRTPLYIS SIKLLIGVIA VVDILMGVSS AVLA AVDAFT FGRFAQHGA WEDGIGCQIV GFLSIFASES SIFLLTLAAL ERGFSVKCSS KFEVKAPLFS LRAIVLLCVL LALTIATVPL

		LGGSKYNASP LCLPLPFGE STTGMYVALV LLNSLCFLIM TIAYTKLYCS LEKGELLENLW DCSMVKHIAL LLFANCILYC PVAFLSFSS LNLTFISPDV IKFILLVIVP LPSCNLPLLY IVFNPHFKED MGS LGKHTRF WMRKSHASLL SINSDDVEKR SCESTQALVS FTHAS IAYDL PSTSGASPAY PMTESCHLSS VAFVPCL
28	mu8E11 light chain variable region	NIVLTQSPAS LAVSLGQRAT ISCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPARFSGSG SRTDFTLTID PVEADDAATY YCQQNYEDPF TFGSGTKVEI KR
29	mu8E11 heavy chain variable region	QVQLVQSGTE LMKPGASVKI SCKATGYTFS AYWIEWIKQR PGHGLEWIGE ILPGSDSTDY NEKFKVKATF SSDTSSNTVY IQLNSLTIED SAVYYCARGG HYGSLDYWGQ GTTLKVSS
30	hu8E11.v1 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SGTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
31	hu8E11.v1 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TSDTSTSTVY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
32	hu8E11.v2 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SGTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
33	hu8E11.v2 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRATF TSDTSTSTVY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
34	hu8E11.v3 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SRTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
35	hu8E11.v3 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TSDTSTSTVY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
36	hu8E11.v4 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SRTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
37	hu8E11.v4 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRATF TSDTSTSTVY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
38	hu8E11.v5 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SGTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
39	hu8E11.v5 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TRDTSTSTAY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
40	hu8E11.v6 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SGTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
41	hu8E11.v6 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TADTSTSTAY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
42	hu8E11.v7 light chain variable region	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SRTDFTLTIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
43	hu8E11.v7 heavy chain variableregion	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TRDTSTSTAY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
44	hu8E11.v8 light	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SRTDFTLTIS

	chain variable region	SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KR
45	hu8E11.v8 heavy chain variable region	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFKVRVTI TADTSTSTAY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSS
46	mu3G12 light chain variable region	DVVMQTPTLS LPVSLGDQAS ISCRSSQSLV HSNNGTYLQW YLQKPGQSPK LLIYKVSNR FSGVPDRFSGS GSGDTFTLKI SRVEAEDLGI YFCSQSTHFP YTFGGGTKLE IKR
47	mu3G12 heavy chain variable region	QVQLQPGAE MVKPGASVKL SCKASVDTFN SYWMHWVKQR PGQGLEWIGE INPSNGRTNY IEKFKNRATV TVDKSSSTAF MQLSSLTSED SAVYYCATGW YFDVWGAGTT VTVSS
48	mu2H6 light chain variable region	DIVMTQSPSS LTVTAGEKVT MSCKSSQSLL NSGNQKNYLT WFQKPGQPP KLLIYWASTR ESGVPDRFTG SSGDTFTLT ISNVQAEDLA VYYCQNDYSF PFTFGQGTKV EIKR
49	mu2H6 heavy chain variable region	EVQLQSGPE LVKPGTSMKI SCKASGYSFT GYTMNWVKQS HKNGLEWIGL INCYNGGTNY NQKFKGKATL TVDKSSSTAF MELLSSLTSED SAVYYCARGG STMITPRFAY WQGTGLVTVS S
50	YW353 light chain variable region	DIQMTQSPSS LSASVGDRTV ITCRASQDVS TAVAWYQQK GKAPKLLIYS ASFLYSGVPS RFSGSGSGTD FTLTISLQ EDFATYYCQQ SYTTPPTFGQ GTKVEIKR
51	YW353 heavy chain variable region	EVQLVESGGG LVQPGGSLRL SCAASGFTFT SYSISWVRQA PGKGLEWVAE IYPPGGYTDY ADSVKGRFTI SADTSKNTAY LQMNSLRAED TAVYYCAKAR LFFDYWGQGT LVTVSS
52	mu8E11 HVR L1	RASESVDNYG NSFMH
53	mu8E11 HVR L2	LASNLES
54	mu8E11 HVR L3	QQNYEDPFT
55	mu8E11 HVR H1	GYTFSAYWIE
56	mu8E11 HVR H2	EILPGSDSTD YNEKFKV
57	mu8E11 HVR H3	GGHYGSLDY
58	Hu8E11 light chain (LC) framework 1 (FR1)	DIVMTQSPDS LAVSLGERAT INC
59	Hu8E11 LC FR2	WYQKPGQPP KLLIY
60	Hu8E11.v1 LC FR3 Hu8E11.v2 LC FR3 Hu8E11.v5 LC FR3 Hu8E11.v6 LC FR3	GVPDRFSGSG SGTDTFTLTIS SLQAEDVAVY YC
61	Hu8E11.v3 LC FR3 Hu8E11.v4 LC FR3 Hu8E11.v7 LC FR3 Hu8E11.v8 LC FR3	GVPDRFSGSG SRTDTFTLTIS SLQAEDVAVY YC
62	Hu8E11 LC FR4	FGQGTKVEIK R
63	Hu8E11 heavy chain (HC) framework1 (FR1)	EVQLVQSGAE VKKPGASVKV SCKAS
64	Hu8E11 HC FR2	WVRQAPGQGL EWIG

65	Hu8E11.v1 HC FR3 Hu8E11.v3 HC FR3	RVTITSdTST STVYLELSSL RSEDTAVYYC AR
66	Hu8E11.v2 HC FR3 Hu8E11.v4 HC FR3	RATFTSDTST STVYLELSSL RSEDTAVYYC AR
67	Hu8E11.v5 HC FR3 Hu8E11.v7 HC FR3	RVTITRDTST STAYLELSSL RSEDTAVYYC AR
68	Hu8E11.v6 HC FR3 Hu8E11.v8 HC FR3	RVTITADTST STAYLELSSL RSEDTAVYYC AR
69	Hu8E11 HC FR4	WGQGTlVTVS S
70	mu3G12 HVR L1	RSSQSLVHSN GNTYLQ
71	mu3G12 HVR L2	KVSNRFS
72	mu3G12 HVR L3	SQSTHFPYT
73	mu3G12 HVR H1	VDTFNSYWMH
74	mu3G12 HVR H2	EINPSNGRTN YIEKFKN
75	mu3G12 HVR H3	GWYFDV
76	mu2H6 HVR L1	KSSQSLLNSG NQKNYLT
77	mu2H6 HVR L2	WASTRES
78	mu2H6 HVR L3	QNDYSFPFT
79	mu2H6 HVR H1	GYSFTGYTMN
80	mu2H6 HVR H2	LINCYNNGTN YNQKFKG
81	mu2H6 HVR H3	GGSTMITPRF AY
82	YW353 HVR L1	RASQDVSTAV A
83	YW353 HVR L2	SASFLYS
84	YW353 HVR L3	QQSYTTPPT
85	YW353 HVR H1	GFTFTSYSIS
86	YW353 HVR H2	EIYPPGGYTD YADSVKG
87	YW353 HVR H3	ARLFFDY
88	hu8E11.v2 light chain	DIVMTQSPDS LAVSLGERAT INCRASESVD NYGNSFMHWY QQKPGQPPKL LIYLASNLES GVPDRFSGSG SGTDFLTITIS SLQAEDVAVY YCQQNYEDPF TFGQGTKVEI KRTVAAPSVF IFPPSDEQLK SGTASVVCLL NNFYPREAKV QWKVDNALQS GNSQESVTEQ DSKDSTYSLs STLTLsKADY EKHKVYACEV THQGLSSPVT KSFNRGEC
89	hu8E11.v2 heavy chain	EVQLVQSGAE VKKPGASVKV SCKASGYTFS AYWIEWVRQA PGQGLEWIGE ILPGSDSTDY NEKFVVRATF TSDTSTSTVY LELSSLRSED TAVYYCARGG HYGSLDYWGQ GTLVTVSSAS TKGPSVFPLA PSSKSTSGGT AALGCLVKDY FPEPVTVSWN SGALTSGVHT FPAVLQSSGL YSLSSVVTVP SSSLGTQTYI CNVNHKPSNT KVDKKVEPKS CDKTHTCPPC PAPELLGGPS VFLFPPKPKD TLMISRTPEV TCVVVDVSHE DPEVKFNWYV DGVEVHNAKT KPREEQYNST YRVVSVLTVL HQDWLNGKEY KCKVSNKALP APIEKTISKA KGQPREPQVY TLPPSREEMT KNQVSLTCLV KGFYPSDIAV EWESNGQPEN NYKTTTPVLD SDGSFFLYSK LTVDKSRWQQ GNVFSCSVMH EALHNHYTQK SLSLSPGK
90	YW353 light chain	DIQMTQSPSS LSASVGDRTV ITCRASQDVS TAVAWYQQKP GKAPKLLIYS ASFLYSGVPS RFSGSGSGTD FTLTISSLQP EDFATYYCQQ SYTTPPTFGQ GTKVEIKRTV AAPSVFIFPP SDEQLKSGTA SVVCLLNNFY PREAKVQWKV DNALQSGNSQ

		ESVTEQDSKD STYSLSSSTLT LSKADYEKHK VYACEVTHQG LSSPVTKSFN RGE C
91	YW353 heavy chain	EVQLVESGGG LVQPGGSLRL SCAASGFTFT SYSISWVRQA PGKGLEWVAE IYPPGGYTDY ADSVKGRFTI SADTSKN TAY LQMNSLRAED TAVYYCAKAR LFFDYWGQGT LVTIVSSASTK GPSVFPLAPS SKSTSGGTAA LGCLVKDYFP EPVTVSWNSG ALTSGVHTFP AVLQSSGLYS LSSVVTVPSS SLGTQTYICN VNHKPSNTKV DKKVEPKSCD KTHTCPPCPA PELLGGPSVF LFPPKPKDTL MISRTPEVTC VVVDVSHEDP EVKFNWYVDG VEVHNAKTKP REEQYNSTYR VVSVLTVLHQ DWLNGKEYKC KVSNAKALPAP IEKTISKAKG QPREPQVYTL PPSREEMTKN QVSLTCLVKG FYPSDIAVEW ESNGQPENNY KTPPVLDSD GSFFLYSKLT VDKSRWQQGN VFSCSVMHEA LHNHYTQKSL SLSPGK
92	Antisense forward primer	ACCAACTGCATCCTAAACTG
93	Antisense reverse primer	ACCGAGTTTCACCTCAGCTC
94	Sense forward primer	ACATTGCCCTGTTGCTCTTC
95	Sense reverse primer	ACTGCTCTGATATACTCAATC
96	LgR5 ECD huFc (1 to 537 are LgR5 ECD)	GSSPRSGVLL RGCPTHCHCE PDGRMLLRVD CSDLGLSEL P SNLSVFTSYL DLSMNNISQL LPNPLPSLRF LEELRLAGNA LTYIPKGAFT GLYSLKVLML QNNQLRHVPT EALQNLRS LQ SLRLDANHIS YVPPSCFSG L HSLRHLWLDD NALTEIPVQA FRSLSALQAM TLALNKIHHI PDYAFGNLSS LVVLHLHNNR IHSLGKKCFD GLHSLETLDL NYNNLDEFPT AIRTLSNLKE LGFHSNNIRS IPEKAFVGNP SLITIHFYDN PIQFVGRSAF QHLPELRTLT LNGASQITEF PDLTG TANLE SLTLTGAQIS SLPQTVCNQL PNLQVLDLSY NLEDLPSFS VCQKLQKIDL RHNEIYEIKV DTFQQLSLR SLNLAWN KIA I IHPNAFSTL PSLIKLDLSS NLLSSFPITG LHGLTHLKLT GNHALQSLIS SENFPELKVI EMPYAYQCCA FGVCENAYKI SNQWNKGDNS SMDDLHKKDA GMFQAQDERD LEDFLLDFEE DLKALHSVQC SPSPGPFPKPC EHLLDGWGRA QVTDKTHTCP PCPAPELLGG PSVFLFPPKP KDTLMIS RTP EVTCVVVDVS HEDPEVKFNW YVDGVEVHNA KTKPREEQYN STYRVVSVLT VLHQDWLNGK EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ VYTLPPSREE MTKNQVSLTC LVKGFYPSDI AVEWESNGQP ENNYKTT PPV LDSDGSFFLY SKLTVDKSRW QQGNVFSCSV MHEALHNHYT QKSLSLSPGK

WHAT IS CLAIMED IS:

1. An isolated antibody that binds to LgR5, wherein the antibody comprises:
 - a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 12, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 13, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 14, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 9, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 10, and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 11; or
 - b) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 18, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 19, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 20, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 15, HVR-L2 comprising the amino acid sequence of SEQ ID NO: 16, and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 17.
2. The antibody of claim 1, comprising:
 - a) (i) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 6; (ii) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 5; or (iii) a VH sequence as in (i) and a VL sequence as in (ii); or
 - b) (i) a VH sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 8; (ii) a VL sequence having at least 95% sequence identity to the amino acid sequence of SEQ ID NO: 7; or (iii) a VH sequence as in (i) and a VL sequence as in (ii).
3. The antibody of claim 1 or claim 2, comprising a VH sequence of SEQ ID NO: 6 or SEQ ID NO: 8.
4. The antibody of any one of the preceding claims, comprising a VL sequence of SEQ ID NO: 7 or SEQ ID NO: 9.
5. An antibody comprising a VH sequence of SEQ ID NO: 6 and a VL sequence of SEQ ID NO: 5.
6. An antibody comprising a VH sequence of SEQ ID NO: 8 and a VL sequence of SEQ ID NO: 7.
7. The antibody of any one of the preceding claims, which is a monoclonal antibody.

8. The antibody of claim 7, which is a mouse, rabbit, human, humanized, or chimeric antibody.
9. The antibody of any one of claims 1 to 8, which is an IgG selected from IgG1, IgG2a, IgG2b, IgG3, and IgG4.
10. Isolated nucleic acid encoding the antibody of any one of the preceding claims.
11. A host cell comprising the nucleic acid of claim 10.
12. A method of producing an antibody comprising culturing the host cell of claim 11 so that the antibody is produced.
13. An immunoconjugate comprising the antibody of any one of claims 1 to 9 and a cytotoxic agent.
14. A pharmaceutical formulation comprising the immunoconjugate of claim 13 and a pharmaceutically acceptable carrier.
15. The antibody of any one of claims 1 to 9 conjugated to a label.
16. The antibody of claim 15, wherein the label is a positron emitter.
17. The antibody of claim 16, wherein the positron emitter is ^{89}Zr .
18. A method of detecting human LgR5 in a biological sample comprising contacting the biological sample with the anti-LgR5 antibody of any one of claims 1 to 9 and 15 to 17 under conditions permissive for binding of the anti-LgR5 antibody to human LgR5, and detecting whether a complex is formed between the anti-LgR5 antibody and human LgR5 in the biological sample.
19. The method of claim 18, wherein the anti-LgR5 antibody is an antibody of claim 4 or claim 5.
20. The method of claim 18 or claim 19, wherein the biological sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.
21. A method for detecting a LgR5-positive cancer comprising (i) administering a labeled anti-LgR5 antibody to a subject having or suspected of having a LgR5-positive cancer, wherein the labeled anti-LgR5 antibody comprises the anti-LgR5 antibody of any one of claims 1 to 9, and (ii) detecting the labeled anti-LgR5 antibody in the subject, wherein detection of the labeled anti-LgR5 antibody indicates a LgR5-positive cancer in the subject.
22. The method of claim 21, wherein the labeled anti-LgR5 antibody is an antibody of claim 4 or claim 5 that is labeled.
23. The method of claim 21 or claim 22, wherein the labeled anti-LgR5 antibody comprises an anti-LgR5 antibody conjugated to a positron emitter.

24. The method of claim 23, wherein the positron emitter is ^{89}Zr .
25. A method of identifying a cancer patient as having a LgR5-positive cancer, comprising contacting a cancer sample from the patient with the anti-LgR5 antibody of any one of claims 1 to 9 and 15 to 17 under conditions permissive for binding of the anti-LgR5 antibody to human LgR5, and detecting whether a complex is formed between the anti-LgR5 antibody and human LgR5 in the cancer sample.
26. The method of claim 25, wherein the cancer patient is identified as having a LgR5-positive cancer if a complex is between the anti-LgR5 antibody and human LgR5 in the cancer sample is detected.
27. A method of selecting a cancer patient for treatment with an immunoconjugate comprising an anti-LgR5 antibody, comprising determining the level of LgR5 expression in a cancer sample from the patient using immunohistochemistry (IHC), wherein an elevated level of LgR5 expression indicates that the cancer patient is more likely to benefit from treatment with an immunoconjugate comprising an anti-LgR5 antibody.
28. The method of claim 27, wherein an elevated level of LgR5 expression is 2+ or 3+ staining by IHC.
29. The method of claim 28, wherein an elevated level of LgR5 expression is 3+ staining by IHC.
30. The method of any one of claims 27 to 29, wherein IHC is performed using an antibody of any one of claims 1 to 9 and 15 to 17.
31. A method of selecting a cancer patient for treatment with an immunoconjugate comprising an anti-LgR5 antibody, comprising contacting a cancer sample from the patient with the anti-LgR5 antibody of any one of claims 1 to 9 and 15 to 17 under conditions permissive for binding of the anti-LgR5 antibody to human LgR5, and detecting whether a complex is formed between the anti-LgR5 antibody and human LgR5 in the cancer sample.
32. The method of claim 31, wherein the cancer patient is selected if a complex is between the anti-LgR5 antibody and human LgR5 in the cancer sample is detected.
33. A method of treating a cancer patient comprising administering to the patient a therapeutically effective amount of an immunoconjugate comprising an anti-LgR5 antibody, wherein a cancer sample from the patient has been determined to have an elevated level of LgR5 expression using immunohistochemistry (IHC).
34. The method of claim 33, wherein an elevated level of LgR5 expression is 2+ or 3+ staining by IHC.

35. The method of claim 34, wherein an elevated level of LgR5 expression is 3+ staining by IHC.
36. The method of any one of claims 33 to 35, wherein IHC is performed using an antibody of any one of claims 1 to 9 and 15 to 17.
37. The method of any one of claims 27 to 36, wherein the immunoconjugate comprises an anti-LgR5 antibody comprising:
- a) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 55, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 56, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 57, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 52; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 53; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 54; or
 - b) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 73, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 74, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 75, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 70; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 71; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 72; or
 - c) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 79, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 80, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 81, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 76; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 77; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 78; or
 - d) HVR-H1 comprising the amino acid sequence of SEQ ID NO: 85, HVR-H2 comprising the amino acid sequence of SEQ ID NO: 86, HVR-H3 comprising the amino acid sequence of SEQ ID NO: 87, HVR-L1 comprising the amino acid sequence of SEQ ID NO: 82; HVR-L2 comprising the amino acid sequence of SEQ ID NO: 83; and HVR-L3 comprising the amino acid sequence of SEQ ID NO: 84.
38. The method of claim 37, wherein the anti-LgR5 antibody comprises:
- a) a VH sequence of SEQ ID NO: 33 and a VL sequence of SEQ ID NO: 32; or
 - b) a VH sequence of SEQ ID NO: 51 and a VL sequence of SEQ ID NO: 50.

39. The method of any one of claims 27 to 38, wherein the immunoconjugate comprises an anti-LgR5 antibody conjugated to a cytotoxic agent.

40. The method of any one of claims 25 to 39, wherein the cancer sample is a colon cancer sample, a colorectal cancer sample, small intestine cancer sample, endometrial cancer sample, pancreatic cancer sample, or ovarian cancer sample.

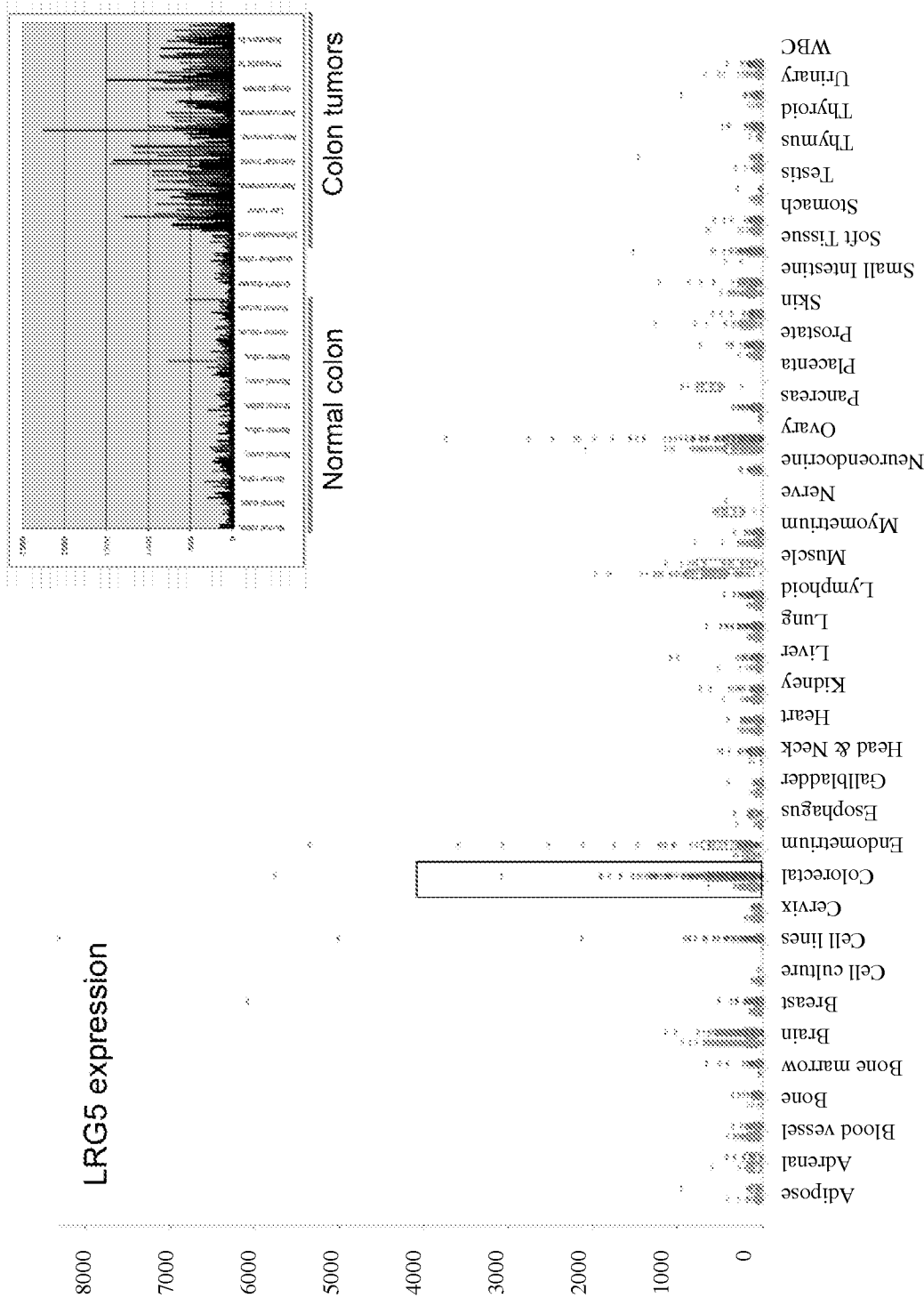


FIG. 1

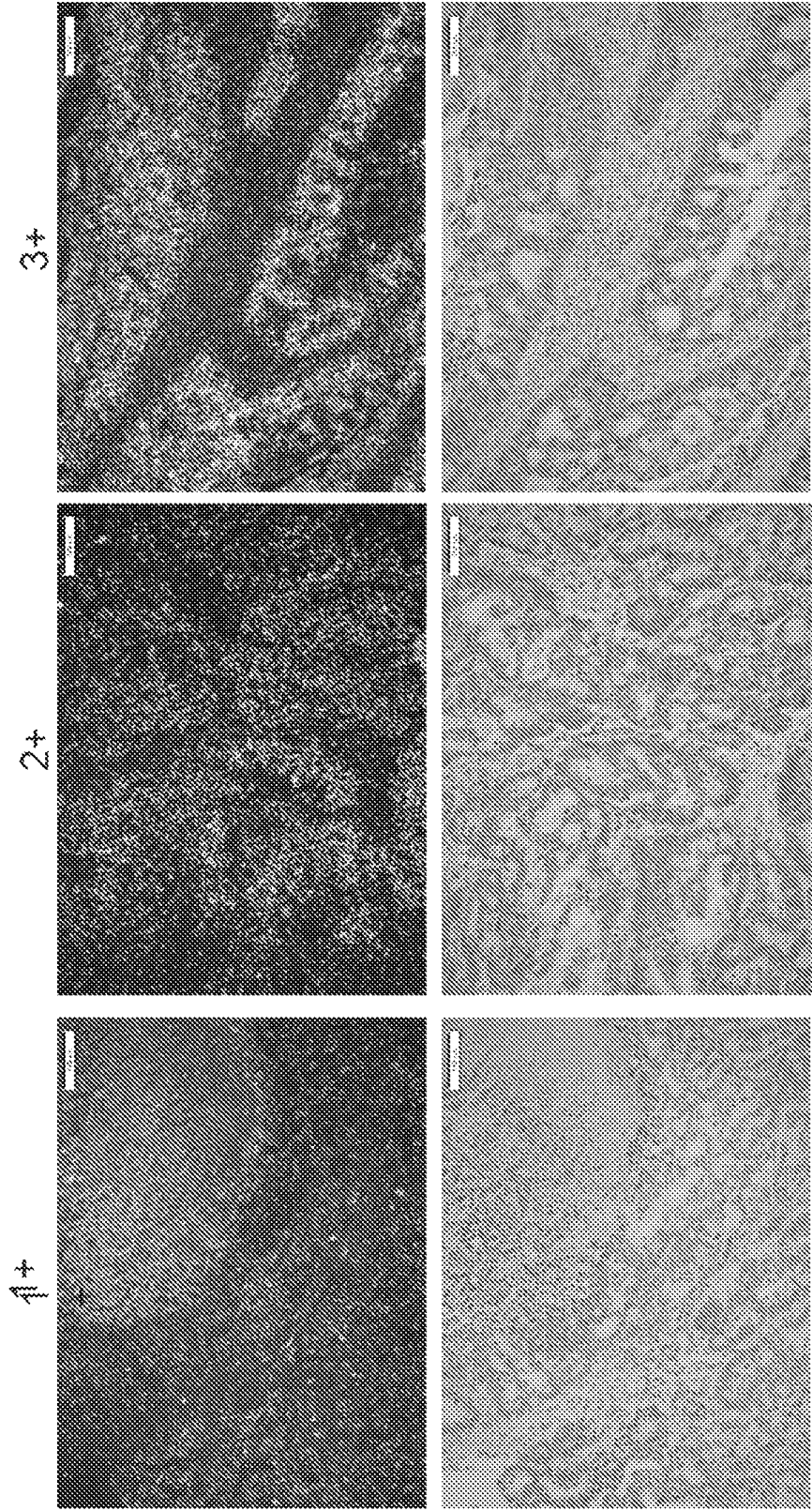


FIG. 2

FIG. 3A

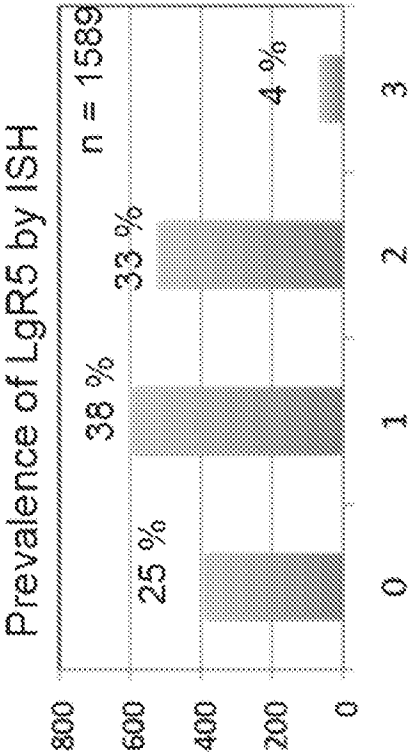
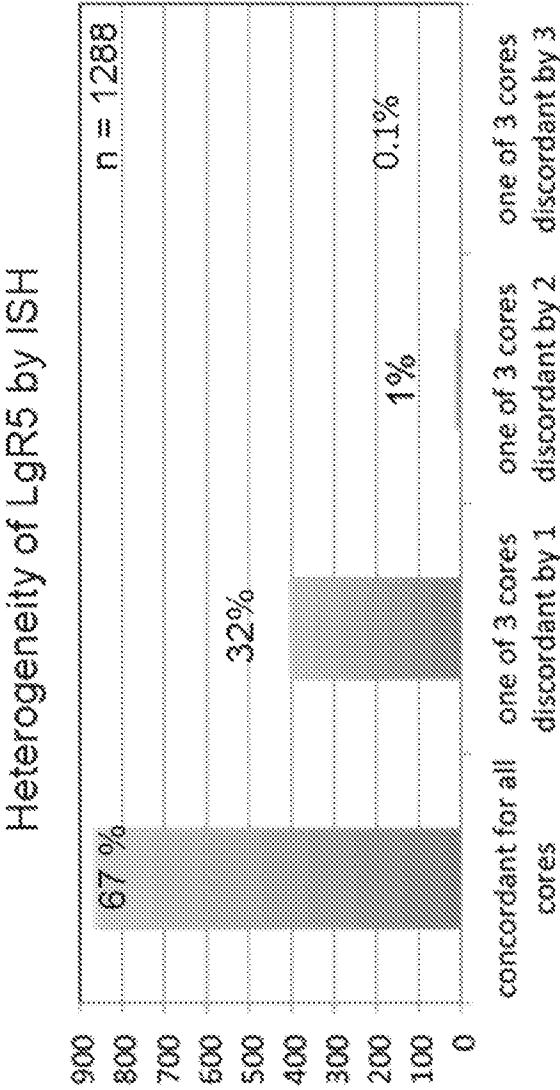


FIG. 3B



Kabat number GEN89.LGR5.1-12 GEN89.LGR5.26-1	CDR L1 - Contact																			
	CDR L1 - Kabat																			
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	A	Y	D	M	T	Q	T	P	A	S	V	E	A	V	G	G	T	V	T	I
	A	F	E	L	T	Q	T	P	S	S	V	E	A	V	G	G	T	V	T	I
Kabat number GEN89.LGR5.1-12 GEN89.LGR5.26-1	CDR L2 - Contact																			
	CDR L2 - Kabat																			
	84	83	82	81	80	79	78	77	76	75	74	73	72	71	70	69	68	67	66	65
	P	P	K	L	L	I	Y	G	A	S	N	L	A	S	G	V	S	S	R	F
	P	P	K	L	L	I	Y	K	A	S	T	L	A	S	G	V	P	S	R	F
Kabat number GEN89.LGR5.1-12 GEN89.LGR5.26-1	CDR L3 - Contact																			
	CDR L3 - Kabat																			
	107	106	105	104	103	102	101	100	99	98	97	96	95	94	93	92	91	90	89	88
	T	Y	Y	C	Q	T	T	Y	G	S	S	S	D	G	F	F	W	T	F	G
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FIG. 4A

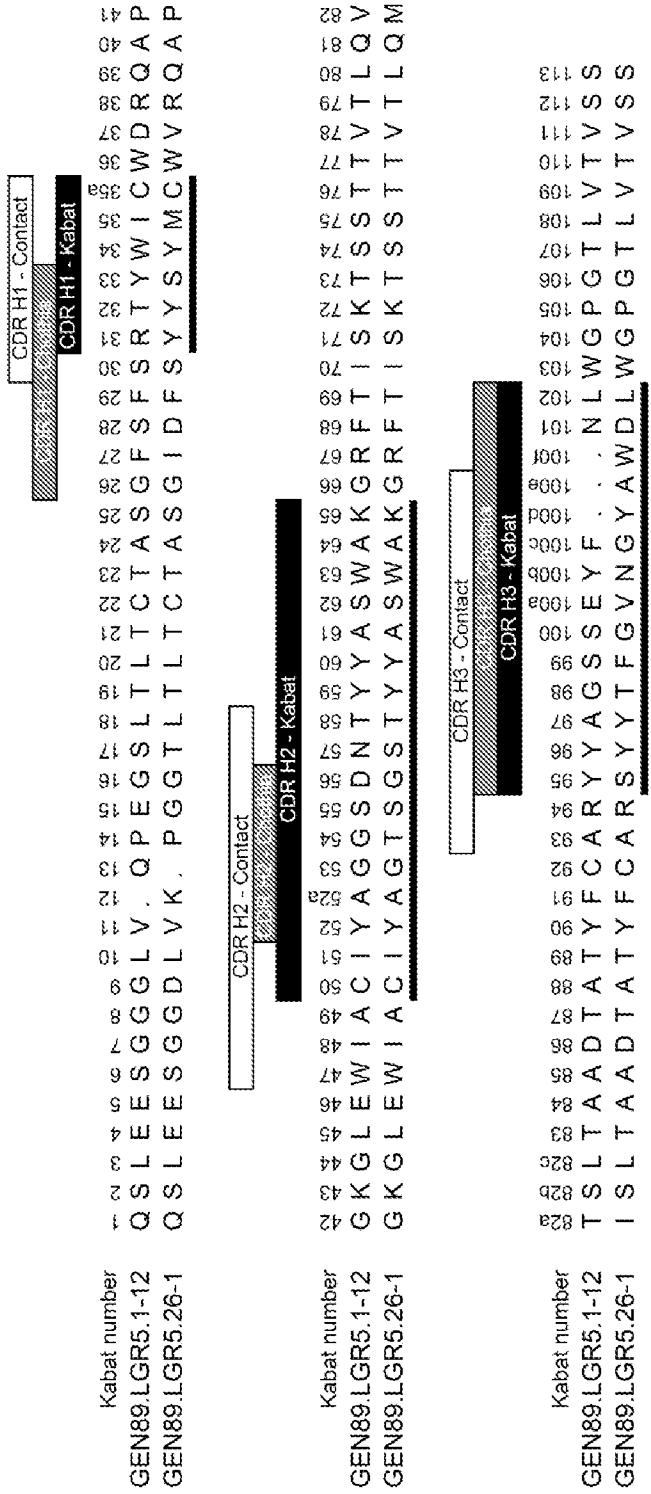


FIG. 4B

FIG. 5A

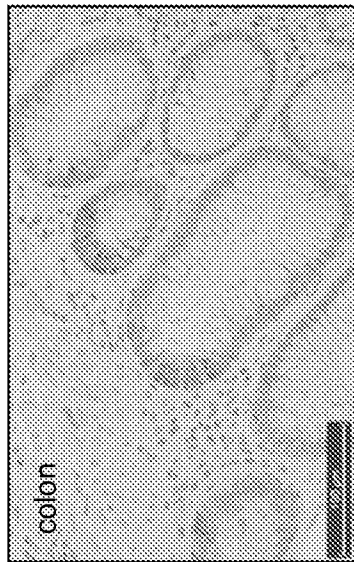


FIG. 5B

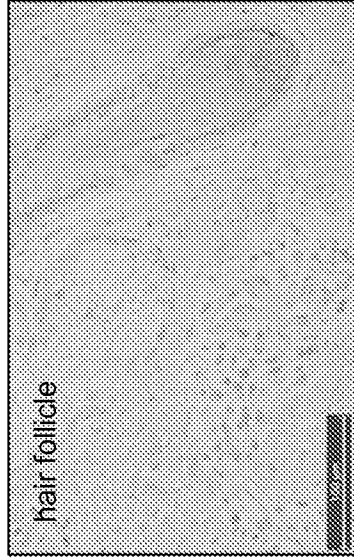
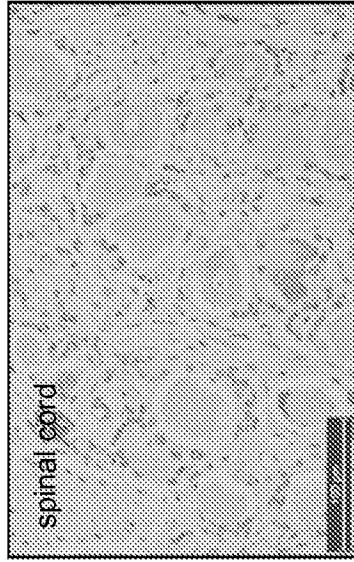
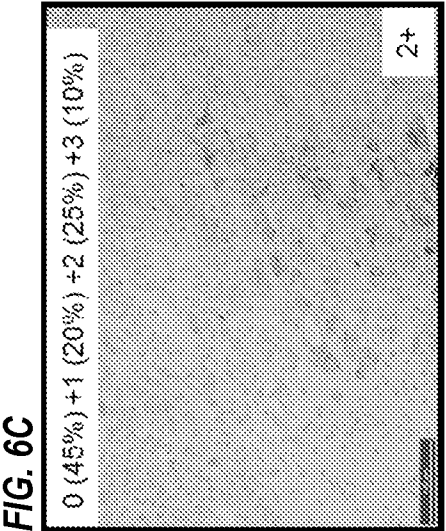
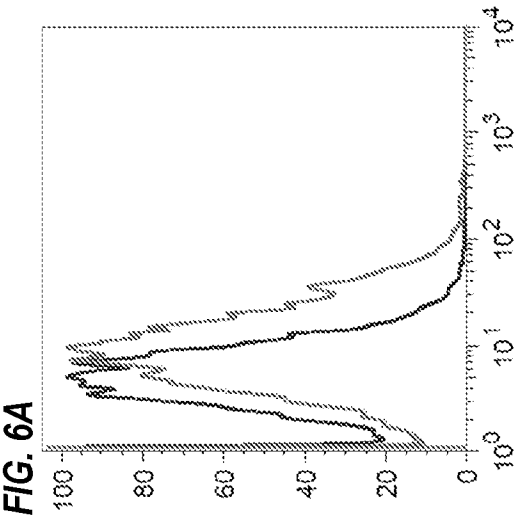
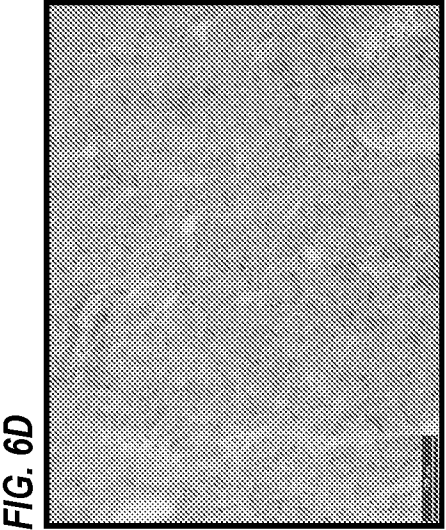
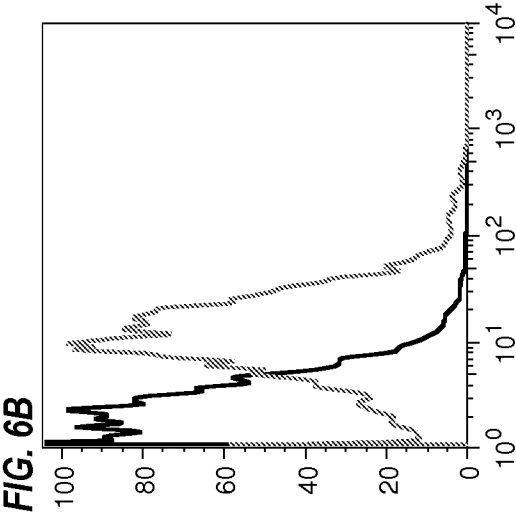
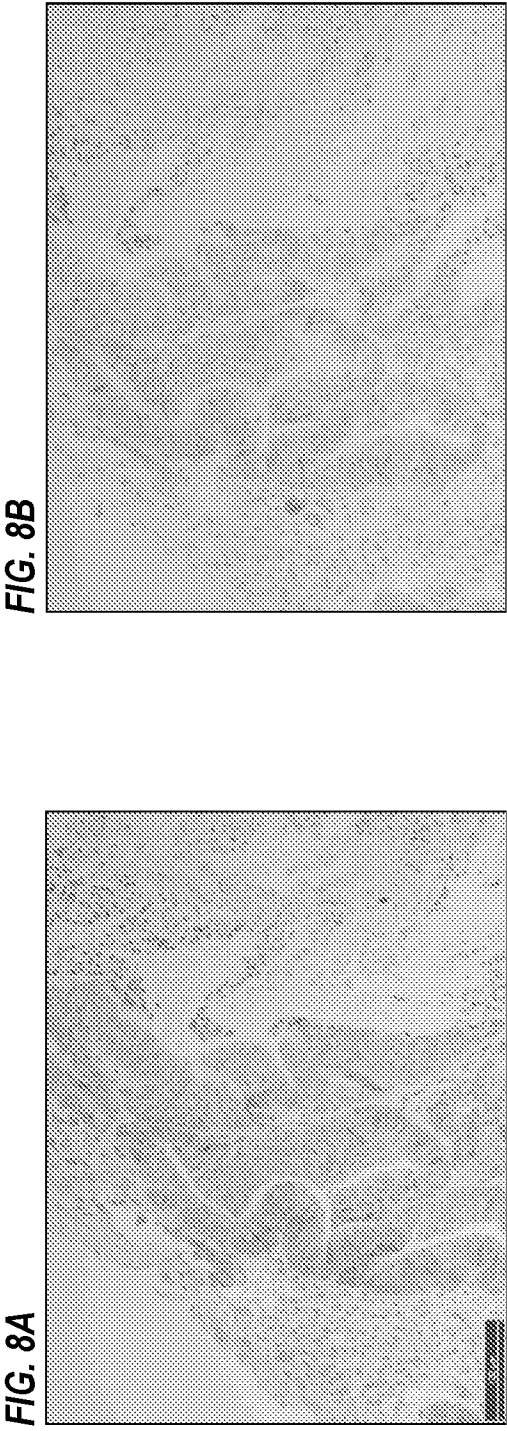
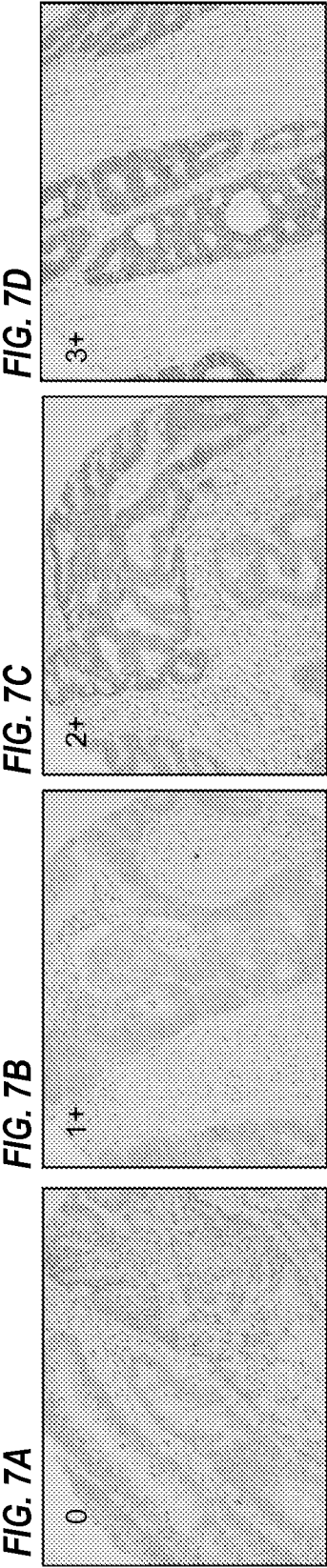


FIG. 5C







INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/035111

A. CLASSIFICATION OF SUBJECT MATTER
INV. C07K16/28 A61P35/00 G01N33/577
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data, BIOSIS, EMBASE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FENG-JUAN GAO ET AL: "Lgr5 over-expression is positively related to the tumor progression and HER2 expression in stage pTNM IV colorectal cancer", INT J CLIN EXP PATHOL, vol. 7, no. 4, 1 January 2014 (2014-01-01), pages 1572-1579, XP055206734, tables 1, 2 figures 1, 2 ----- -/--	1-26, 30-32, 36-40

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

13 August 2015

Date of mailing of the international search report

30/10/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Brouns, Gaby

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/035111

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	XIAO-SONG WU ET AL: "Lgr5 is a potential marker of colorectal carcinoma stem cells that correlates with patient survival", WORLD JOURNAL OF SURGICAL ONCOLOGY, BIOMED CENTRAL, LONDON, GB, vol. 10, no. 1, 15 November 2012 (2012-11-15), page 244, XP021121711, ISSN: 1477-7819, DOI: 10.1186/1477-7819-10-244 figure 1 page 2, right-hand column, paragraph 3 -----	1-26, 30-32, 36-40
Y	HIDEKAZU TAKAHASHI ET AL: "Significance of Lgr5Cancer Stem Cells in the Colon and Rectum", ANNALS OF SURGICAL ONCOLOGY, SPRINGER-VERLAG, NE, vol. 18, no. 4, 2 December 2010 (2010-12-02), pages 1166-1174, XP019888799, ISSN: 1534-4681, DOI: 10.1245/S10434-010-1373-9 page 1168, left-hand column, paragraph 2; figure 2 -----	1-26, 30-32, 36-40
Y	WO 2013/149159 A1 (GENENTECH INC [US]; HONGO JO-ANNE [US]; MAO WEIGUANG [US]; POLAKIS PAU) 3 October 2013 (2013-10-03) cited in the application paragraphs [0098], [0408], [0412] examples L-U figures 13-34 claims 44, 48, 50-52, 57-59 -----	15-17, 19,20, 22-24, 30,36-40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035111

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

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

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

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

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

see additional sheet

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

1-26, 30-32, 36-40(all partially)

Remark on Protest

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/035111

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		US 2013336885 A1	19-12-2013
		WO 2013149159 A1	03-10-2013

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

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

1. claims: 1-26, 30-32, 36-40(all partially)

Relating to antibody LgR5.1-12 defined by CDRs as shown in SEQ ID NOs 9-14, optionally comprising a VH as defined by SEQ ID NO:6, and/or a VL as defined by SEQ ID NO:5, and uses thereof

2. claims: 1-26, 30-32, 36-40(all partially)

Relating to antibody LgR5.26-1 defined by CDRs as shown in SEQ ID NOs 15-20, optionally comprising a VH as defined by SEQ ID NO:8 and/or a VL as defined by SEQ ID NO:7, and uses thereof

3. claims: 27-29, 33-35(completely); 30, 36-40(partially)

Relating to selecting a cancer patient or treating a cancer patient with an anti-LgR5 immunoconjugate, based on detection of an elevated level of LgR5 in a sample of said patient using immunohistochemistry.
