ANTI-GLUCAGON ANTIBODIES AND USES THEREOF

FIELD OF THE INVENTION

[0001] The present invention relates to antibodies, and antigen-binding fragments thereof, which specifically bind glucagon, compositions comprising these antibodies and methods of use thereof, for example, for the treatment of disorders responsive to the modulation of glucagon levels, such as diabetic and other glucagon related metabolic disorders, and the like.

BACKGROUND

[0002] Glucagon is a 29 residue polypeptide hormone, which in cooperation with insulin, mediates homeostatic regulation of the amount of glucose in the blood. Glucagon primarily acts by stimulating certain cells, for example, liver cells, to release glucose when blood glucose levels fall. The action of glucagon is opposite to that of insulin, which stimulates cells to take up and store glucose whenever blood glucose levels rise. Glucagon is produced in the alpha cells of the pancreas, whereas insulin is secreted from the neighboring beta cells.

[0003] It is an imbalance of glucagon and insulin that may play an important role in several diseases, such as diabetes mellitus and diabetic ketoacidosis. In particular, studies have shown that higher basal glucagon levels and lack of suppression of postprandial glucagon secretion contribute to diabetic conditions in humans (Muller *et al.*, N Eng J Med 283: 109-115 (1970)).

[0004] It is believed that glucagon's effects on elevating blood glucose levels are mediated in part by the activation of certain cellular pathways following the binding of glucagon (GCG) to its receptor (designated GCGR). GCGR is a member of the secretin subfamily (family B) of G-protein-coupled receptors and is predominantly expressed in the liver. The binding of glucagon to its receptor triggers a G-protein signal transduction cascade, activating intracellular cyclic AMP and leading to an increase in glucose output through de novo synthesis (gluconeogenesis) and glycogen breakdown (glycogenolysis) (Wakelam *et al.*, Nature, (1986) 323:68-71; Unson *et al.*, Peptides, (1989), 10:1171-1177; and Pittner and Fain, Biochem. J. (1991), 277:371-378).

[0005] The action of glucagon can be suppressed by providing an antagonist, such as a glucagon antibody, such as those described herein. Such antibodies may prove useful in lowering blood glucose levels in diabetes or in other conditions, such as stress hyperglycemia. Furthermore, by lowering glucose levels, it may be possible to prevent or ameliorate certain of the long-term complications associated with elevated glucose levels in diabetic patients.

[0006] Anti-glucagon antibodies are mentioned, *e.g.*, in US Patent Nos. 4,206,199; 4,221,777; 4,423,034; 4,272,433; 4,407,965; 5,712,105; WO2007/124463 and

WO2013/081993. Nonetheless, there is a need in the art for novel glucagon antagonists, such as the anti-glucagon antibodies described herein, for lowering blood glucose levels in patients suffering from diabetes and other disorders associated with elevated glucagon levels.

BRIEF SUMMARY OF THE INVENTION

[0007] The present invention provides antibodies and antigen-binding fragments thereof that bind specifically to glucagon (GCG) and neutralize its activity.

[0008] In a first aspect, the invention provides isolated monoclonal antibodies (mAbs) and antigen-binding fragments thereof that bind to glucagon and inhibit or block its activity, for example, block the binding of glucagon to its receptor, thereby blocking the elevation of blood glucose levels. The antibodies or antigen binding fragments thereof may be useful for lowering blood glucose levels in a subject that suffers from a disease or condition characterized in part by increased blood glucose levels, such as diabetes mellitus, or stress hyperglycemia. The antibodies may also be used to treat a wide range of conditions and disorders in which blocking the interaction of glucagon with the glucagon receptor is desired, thereby having a beneficial effect. The antibodies may ultimately be used to prevent the long-term complications associated with elevated blood glucose levels in diabetic patients, or to ameliorate at least one symptom associated with elevated blood glucose levels in diabetic patients.

[0009] In one embodiment, the invention provides an isolated monoclonal antibody or antigen-binding fragment thereof that binds specifically to and neutralizes GCG activity, wherein the antibody or fragment thereof exhibits one or more of the following characteristics:

(a) is a fully human monoclonal antibody;

(b) binds human GCG at 25°C with a K_D of less than about 1nM and less than about 5nM at 37°C as measured by surface plasmon resonance;

(c) lowers blood glucose levels by at least about 10% when administered to a mammal as a single dose, or as multiple doses of less than about 40 mg/kg;

(d) inhibits GCG-mediated activation of cells expressing human glucagon receptor (GCGR) with an IC_{50} of less than about 1 nM;

(e) comprises a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NO: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; or

(f) comprises a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NO: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

[0010] In one embodiment, the antibody or antigen-binding fragment thereof binds

human GCG at 25°C with a K_D ranging from about 50pM to about 750pM and from about 300pM to about 5nM at 37°C as measured by surface plasmon resonance.

[0011] In one embodiment, the antibody or antigen-binding fragment thereof lowers blood glucose levels by about 10% to about 35% when administered to a mammal as a single dose, or as multiple doses ranging from about 3 mg/kg to about 30 mg/kg.

[0012] In one embodiment, the antibody or antigen-binding fragment thereof inhibits GCG-mediated activation of cells expressing human glucagon receptor (GCGR) with an IC_{50} ranging from about 7 pM to about 950 pM.

[0013] In one embodiment, the antibody or antigen-binding fragment thereof reduces blood glucose levels in a mammal when administered at a dose of about 30 mg/kg every 1, 2, 3, 4 or 5 days.

[0014] In one embodiment, the antibody or antigen-binding fragment thereof reduces blood glucose levels in a mammal when administered at a dose of about 30 mg/kg every 5 days.

[0015] In one embodiment the isolated antibody or antigen-binding fragment thereof reduces blood glucose levels in a mammal when administered subcutaneously, intravenously, or intramuscularly.

[0016] The antibodies of the invention can be full-length (for example, an IgG1 or IgG4 antibody) or may comprise only an antigen-binding portion (for example, a Fab, $F(ab')_2$ or scFv fragment), and may be modified to affect functionality, e.g., to eliminate residual effector functions (Reddy et al., 2000, J. Immunol. 164:1925-1933).

[0017] Exemplary anti-glucagon (anti-GCG) antibodies of the present invention are listed in Tables 1 and 2 herein. Table 1 sets forth the amino acid sequence identifiers of the heavy chain variable regions (HCVRs), light chain variable regions (LCVRs), heavy chain complementarity determining regions (HCDR1, HCDR2 and HCDR3), and light chain complementarity determining regions (LCDR1, LCDR2 and LCDR3) of the exemplary anti-GCG antibodies. Table 2 sets forth the nucleic acid sequence identifiers of the HCVRs, LCVRs, HCDR1, HCDR2, HCDR3, LCDR1, LCDR2 and LCDR3 of the exemplary anti-GCG antibodies.

[0018] The present invention provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising an HCVR comprising an amino acid sequence selected from any of the HCVR amino acid sequences listed in Table 1, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0019] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising an LCVR comprising an amino acid sequence selected from any of the LCVR amino acid sequences listed in Table 1, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or

at least 99% sequence identity thereto.

[0020] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising an HCVR and an LCVR amino acid sequence pair (HCVR/LCVR) comprising any of the HCVR amino acid sequences listed in Table 1 paired with any of the LCVR amino acid sequences listed in Table 1. According to certain embodiments, the present invention provides antibodies, or antigen-binding fragments thereof, comprising an HCVR/LCVR amino acid sequence pair contained within any of the exemplary anti-GCG antibodies listed in Table 1.

[0021] In one embodiment, the present invention provides an isolated antibody or antigen-binding fragment thereof that specifically binds to GCG and neutralizes at least one activity associated with GCG, wherein the antibody or antigen-binding fragment thereof comprises: (a) three heavy chain complementarity determining regions (HCDR1, HCDR2 and HCDR3) contained within a heavy chain variable region (HCVR) amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; and (b) three light chain CDRs (LCDR1, LCDR2 and LCDR3) contained within a light chain variable region (LCVR) amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

[0022] In one embodiment, the present invention provides an isolated antibody or antigen-binding fragment thereof that specifically binds to GCG and neutralizes at least one activity associated with GCG, wherein the antibody or antigen-binding fragment comprises an HCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146 and a LCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

[0023] In one embodiment, the present invention provides an isolated antibody or antigen-binding fragment thereof that specifically binds to GCG and neutralizes at least one activity associated with GCG, wherein the antibody or antigen-binding fragment comprises a HCVR/LCVR amino acid sequence pair selected from the group consisting of SEQ ID NOs: 2/10; 18/26; 34/42; 50/58; 66/74; 82/90; 98/106; 114/122; 130/138 and 146/154.

[0024] In certain embodiments, the HCVR/LCVR amino acid sequence pair comprises SEQ ID NOs: 18/26.

[0025] In certain embodiments, the HCVR/LCVR amino acid sequence pair comprises SEQ ID NOs: 34/42.

[0026] In one embodiment, the present invention provides an isolated antibody or antigen-binding fragment thereof that specifically binds to GCG and neutralizes at least one activity associated with GCG, wherein the antibody or antigen-binding fragment comprises:

(a) a HCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 4, 20, 36, 52, 68, 84, 100, 116, 132 and 148;

(b) a HCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 6, 22, 38, 54, 70, 86, 102, 118, 134 and 150;

(c) a HCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 8, 24, 40, 56, 72, 88, 104, 120, 136 and 152;

(d) a LCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 12, 28, 44, 60, 76, 92, 108, 124, 140 and 156;

(e) a LCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 14, 30, 46, 62, 78, 94, 110, 126, 142, and 158; and

(f) a LCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 16, 32, 48, 64, 80, 96, 112, 128, 144 and 160.

[0027] In one embodiment, the invention provides an antibody that specifically binds GCG and neutralizes at least one activity associated with GCG, wherein the antibody comprises:

(a) a HCDR1 domain comprising the amino acid sequence of SEQ ID NO: 20;

(b) a HCDR2 domain comprising the amino acid sequence of SEQ ID NO: 22;

(c) a HCDR3 domain comprising the amino acid sequence of SEQ ID NO: 24;

(d) a LCDR1 domain comprising the amino acid sequence of SEQ ID NO: 28;

(e) a LCDR2 domain comprising the amino acid sequence of SEQ ID NO: 30; and

(f) a LCDR3 domain comprising the amino acid sequence of SEQ ID NO: 32.

[0028] In one embodiment, the invention provides an antibody that specifically binds GCG and neutralizes at least one activity associated with GCG, wherein the antibody comprises:

(a) a HCDR1 domain comprising the amino acid sequence of SEQ ID NO: 36;

(b) a HCDR2 domain comprising the amino acid sequence of SEQ ID NO: 38;

(c) a HCDR3 domain comprising the amino acid sequence of SEQ ID NO: 40;

(d) a LCDR1 domain comprising the amino acid sequence of SEQ ID NO: 44;

(e) a LCDR2 domain comprising the amino acid sequence of SEQ ID NO: 46; and

(f) a LCDR3 domain comprising the amino acid sequence of SEQ ID NO: 48.

[0029] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a heavy chain CDR1 (HCDR1) comprising an amino acid sequence selected from any of the HCDR1 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0030] The present invention also provides antibodies or antigen-binding fragments

thereof that specifically bind GCG, comprising a heavy chain CDR2 (HCDR2) comprising an amino acid sequence selected from any of the HCDR2 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0031] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a heavy chain CDR3 (HCDR3) comprising an amino acid sequence selected from any of the HCDR3 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0032] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a light chain CDR1 (LCDR1) comprising an amino acid sequence selected from any of the LCDR1 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0033] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a light chain CDR2 (LCDR2) comprising an amino acid sequence selected from any of the LCDR2 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0034] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a light chain CDR3 (LCDR3) comprising an amino acid sequence selected from any of the LCDR3 amino acid sequences listed in Table 1 or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity.

[0035] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising an HCDR3 and an LCDR3 amino acid sequence pair (HCDR3/LCDR3) comprising any of the HCDR3 amino acid sequences listed in Table 1 paired with any of the LCDR3 amino acid sequences listed in Table 1. According to certain embodiments, the present invention provides antibodies, or antigen-binding fragments thereof, comprising an HCDR3/LCDR3 amino acid sequence pair contained within any of the exemplary anti-GCG antibodies listed in Table 1. In certain embodiments, the HCDR3/LCDR3 amino acid sequence pair comprises SEQ ID NOs: 24/32.

[0036] The present invention also provides antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising a set of six CDRs (*i.e.*, HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3) contained within any of the exemplary anti-GCG antibodies listed in Table 1. In certain embodiments, the HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 amino acid sequence set comprises SEQ ID NOs: 20-22-24-28-

30-32. In certain embodiments, the HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 amino acid sequence set comprises SEQ ID NOs: 36-38-40-44-46-48.

[0037] In a related embodiment, the present invention provides antibodies, or antigen-binding fragments thereof that specifically bind GCG, comprising a set of six CDRs (*i.e.*, HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3) contained within an HCVR/LCVR amino acid sequence pair as defined by any of the exemplary anti-GCG antibodies listed in Table 1. For example, the present invention includes antibodies or antigen-binding fragments thereof that specifically bind GCG, comprising the HCDR1-HCDR2-HCDR3-LCDR1-LCDR2-LCDR3 amino acid sequences set contained within an HCVR/LCVR amino acid sequence pair selected from the group consisting of: 18/26; 34/42; 50/58; 66/74; 82/90; 98/106; 114/122; 130/138 and 146/154. Methods and techniques for identifying CDRs within HCVR and LCVR amino acid sequences are well known in the art and can be used to identify CDRs within the specified HCVR and/or LCVR amino acid sequences disclosed herein. Exemplary conventions that can be used to identify the boundaries of CDRs include, *e.g.*, the Kabat definition, the Chothia definition, and the AbM definition. In general terms, the Kabat definition is based on sequence variability, the Chothia definition is based on the location of the structural loop regions, and the AbM definition is a compromise between the Kabat and Chothia approaches. *See*, *e.g.*, Kabat, "Sequences of Proteins of Immunological Interest," National Institutes of Health, Bethesda, Md. (1991); Al-Lazikani *et al.*, *J. Mol. Biol. 273*:927-948 (1997); and Martin *et al.*, *Proc. Natl. Acad. Sci. USA 86*:9268-9272 (1989). Public databases are also available for identifying CDR sequences within an antibody.

[0038] In one embodiment, the invention provides a fully human monoclonal antibody or antigen-binding fragment thereof that neutralizes GCG activity, wherein the antibody or fragment thereof exhibits one or more of the following characteristics: (i) comprises a HCVR having an amino acid sequence selected from the group consisting of SEQ ID NO: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; (ii) comprises a LCVR having an amino acid sequence selected from the group consisting of SEQ ID NO: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154; (iii) comprises a HCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 8, 24, 40, 56, 72, 88, 104, 120, 136 and 152, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; and a LCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 16, 32, 48, 64,80, 96, 112, 128, 144 and 160, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; (iv) comprises a HCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 4, 20, 36, 52, 68, 84, 100, 116, 132 and 148, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence

identity; a HCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 6, 22, 38, 54, 70, 86, 102, 118, 134 and 150, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; a LCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 12, 28, 44, 60, 76, 92, 108, 124, 140 and 156, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; and a LCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NO: 14, 30, 46, 62, 78, 94, 110, 126, 142 and 158, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity; (v) demonstrates a K_D of less than about 1nM at 25°C and less than about 5nM at 37°C as measured by surface plasmon resonance; (vi) lowers blood glucose levels by at least 10% when administered to a mammal at a single dose or at multiple doses of less than about 40 mg/kg; (vi) inhibits GCG activation of cells expressing the human glucagon receptor with an IC_{50} of less than about 1nM.

[0039] In a second aspect, the present invention also provides nucleic acid molecules encoding anti-GCG antibodies or portions thereof. For example, the present invention provides nucleic acid molecules encoding any of the HCVR amino acid sequences listed in Table 1; in certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the HCVR nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0040] The present invention also provides nucleic acid molecules encoding any of the LCVR amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the LCVR nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0041] The present invention also provides nucleic acid molecules encoding any of the HCDR1 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the HCDR1 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0042] The present invention also provides nucleic acid molecules encoding any of the HCDR2 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the HCDR2 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0043] The present invention also provides nucleic acid molecules encoding any of the

HCDR3 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the HCDR3 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0044] The present invention also provides nucleic acid molecules encoding any of the LCDR1 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the LCDR1 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0045] The present invention also provides nucleic acid molecules encoding any of the LCDR2 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the LCDR2 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0046] The present invention also provides nucleic acid molecules encoding any of the LCDR3 amino acid sequences listed in Table 1. In certain embodiments the nucleic acid molecule comprises a polynucleotide sequence selected from any of the LCDR3 nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto.

[0047] The present invention also provides nucleic acid molecules encoding an HCVR, wherein the HCVR comprises a set of three CDRs (*i.e.*, HCDR1-HCDR2-HCDR3), wherein the HCDR1-HCDR2-HCDR3 amino acid sequence set is as defined by any of the exemplary anti-GCG antibodies listed in Table 1.

[0048] The present invention also provides nucleic acid molecules encoding an LCVR, wherein the LCVR comprises a set of three CDRs (*i.e.*, LCDR1-LCDR2-LCDR3), wherein the LCDR1-LCDR2-LCDR3 amino acid sequence set is as defined by any of the exemplary anti-GCG antibodies listed in Table 1.

[0049] The present invention also provides nucleic acid molecules encoding both an HCVR and an LCVR, wherein the HCVR comprises an amino acid sequence of any of the HCVR amino acid sequences listed in Table 1, and wherein the LCVR comprises an amino acid sequence of any of the LCVR amino acid sequences listed in Table 1. In certain embodiments, the nucleic acid molecule comprises a polynucleotide sequence selected from any of the HCVR nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto, and a polynucleotide sequence selected from any of the LCVR nucleic acid sequences listed in Table 2, or a substantially similar sequence thereof having at least 90%, at least 95%, at least 98% or at least 99% sequence identity thereto. In certain embodiments according to this aspect of the

invention, the nucleic acid molecule encodes an HCVR and LCVR, wherein the HCVR and LCVR are both derived from the same anti-GCG antibody listed in Table 1.

[0050] The present invention also provides recombinant expression vectors capable of expressing a polypeptide comprising a heavy or light chain variable region of an anti-GCG antibody. For example, the present invention includes recombinant expression vectors comprising any of the nucleic acid molecules mentioned above, *i.e.*, nucleic acid molecules encoding any of the HCVR, LCVR, and/or CDR sequences as set forth in Table 1. Also included within the scope of the present invention are host cells into which such vectors have been introduced, as well as methods of producing the antibodies or portions thereof by culturing the host cells under conditions permitting production of the antibodies or antibody fragments, and recovering the antibodies and antibody fragments so produced.

[0051] The present invention includes anti-GCG antibodies having a modified glycosylation pattern. In some embodiments, modification to remove undesirable glycosylation sites may be useful, or an antibody lacking a fucose moiety present on the oligosaccharide chain, for example, to increase antibody dependent cellular cytotoxicity (ADCC) function (see Shield et al. (2002) JBC 277:26733). In other applications, modification of galactosylation can be made in order to modify complement dependent cytotoxicity (CDC).

[0052] In a third aspect, the invention provides a pharmaceutical composition comprising a recombinant human antibody or fragment thereof, which specifically binds GCG and a pharmaceutically acceptable carrier. In a related aspect, the invention features a composition, which is a combination of an anti-GCG antibody and a second therapeutic agent. In one embodiment, the second therapeutic agent is any agent that is advantageously combined with an anti-GCG antibody.

[0053] In one embodiment, the second therapeutic agent may be an agent capable of lowering blood glucose or reducing at least one symptom in a patient suffering from a disease or condition characterized by high blood glucose levels, such as diabetes mellitus.

[0054] In certain embodiments, the second therapeutic agent may be an agent that helps to counteract or reduce any possible side effect(s) associated with the antibody or antigen-binding fragment of an antibody of the invention, if such side effect(s) should occur. For example, in the event that any of the anti-GCG antibodies increases lipid or cholesterol levels, it may be beneficial to administer a second agent that is effective to lower lipid or cholesterol levels.

[0055] The second therapeutic agent may be a small molecule drug, a protein/polypeptide, an antibody, a nucleic acid molecule, such as an anti-sense molecule, or a siRNA. The second therapeutic agent may be synthetic or naturally

derived.

[0056] In one embodiment, the second therapeutic agent may be a glucagon receptor antagonist, or a second glucagon antagonist, such as another antibody to glucagon, such as those described herein, or an antibody that is different than the antibodies described herein. It will also be appreciated that the antibodies and pharmaceutically acceptable compositions of the present invention can be employed in combination therapies, that is, the antibodies and pharmaceutically acceptable compositions can be administered concurrently with, prior to, or subsequent to, one or more other desired therapeutics or medical procedures. The particular combination of therapies (therapeutics or procedures) to employ in a combination regimen will take into account compatibility of the desired therapeutics and/or procedures and the desired therapeutic effect to be achieved. It will also be appreciated that the therapies employed may achieve a desired effect for the same disorder (for example, an antibody may be administered concurrently with another agent used to treat the same disorder), or they may achieve different effects (*e.g.,* control of any adverse effects). As used herein, additional therapeutic agents that are normally administered to treat or prevent a particular disease, or condition, are appropriate for the disease, or condition, being treated.

[0057] In one embodiment, the anti-GCG antibodies of the invention may be used in combination with one or more of the following diabetes treatments currently available. These include a biguanide (metformin), a sulfonylurea (such as glyburide, glipizide), a peroxisome proliferator-activated receptor (PPAR) gamma agonist (for example, pioglitazone, rosiglitazone), an alpha glucosidase inhibitor (for example, acarbose, voglibose). Additional treatments include injectable treatments such as a glucagon-like peptide 1 agonist or analogue (for example, BYETTA® (exenatide), VICTOZA® (liraglutide), TANZEUM™ (albiglutide), TRULICITY™ (dulaglutide), or LYXUMIA® (lixisenatide)), or with an analogue of amylin, such as SYMLIN® (pramlintide).

[0058] In certain embodiments, the composition may include a second agent selected from the group consisting of non-sulfonylurea secretagogues, insulin, insulin analogs, including fast acting (*e.g.* Lispro, Aspart, Glulisine) and long acting (*e.g.* Detemir insulin, Degludec insulin, or Glargine insulin, exendin-4 polypeptides, beta 3 adrenoceptor agonists, PPAR agonists, a dipeptidyl peptidase IV (DPP-4) inhibitor (for example, saxagliptin (ONGLYZA®), sitaliptin (JANUVIA®), and vildagliptin (GALVUS®)), a sodium-glucose co-transporter 2 (SGLT2) inhibitor (for example, INVOKANA™ (canagliflozin)), FORXIGA® (dapagliflozin), empagliflozin, ipragliflozin, tofogliflozin, statins and statin-containing combinations, inhibitors of cholesterol uptake and/or bile acid re-absorption, LDL-cholesterol antagonists, cholesteryl ester transfer protein antagonists, endothelin receptor antagonists, growth hormone antagonists, insulin

sensitizers, amylin mimetics or agonists, cannabinoid receptor antagonists, glucagon-like peptide-1 receptor agonists, melanocortins, melanin-concentrating hormone receptor agonists, SNRIs, a fibroblast growth factor 21 (FGF21) mimetic (See, for example, US20110002845 and US20080261236), a fibroblast growth factor receptor 1c (FGFR1c) agonist (See, for example, US20110150901), an inhibitor of advanced glycation endproduct formation, such as, but not limited to, aminoguanidine, and protein tyrosine phosphatase inhibitors.

[0059] In certain embodiments, the composition may include a second agent to help lower lipid or cholesterol levels and may include an agent such as a 3-hydroxy-3-methylglutaryl-coenzyme A (HMG-CoA) reductase inhibitor (for example, a statin such as atorvastatin, (LIPITOR®), fluvastatin (LESCOL®), lovastatin (MEVACOR®), pitavastatin (LIVALO®), pravastatin (PRAVACHOL®), rosuvastatin (CRESTOR®) and simvastatin (ZOCOR®) and the like. Alternatively, the antibodies of the invention may be combined with an agent such as VYTORIN®, which is a preparation of a statin and another agent, such as ezetimibe/simvastatin.

[0060] In certain embodiments, it may be beneficial to administer the antibodies of the invention in combination with any one or more of the following: (1) niacin, which increases lipoprotein catabolism; (2) fibrates or amphipathic carboxylic acids, which reduce low-density lipoprotein (LDL) level, improve high-density lipoprotein (HDL) and triglycerides (TG) levels, and reduce the number of non-fatal heart attacks; and (3) activators of the LXR transcription factor that plays a role in cholesterol elimination such as 22-hydroxycholesterol, or fixed combinations such as VYTORIN®) (ezetimibe plus simvastatin); a statin with a bile resin (*e.g.*, cholestyramine, colestipol, colesevelam), a fixed combination of niacin plus a statin (*e.g.*, niacin with lovastatin); or with other lipid lowering agents such as omega-3-fatty acid ethyl esters (for example, omacor). Furthermore, the second therapeutic agent can be one or more other inhibitors of glucagon or the glucagon receptor, as well as inhibitors of other molecules, such as angiopoietin-like protein 3 (ANGPTL3), angiopoietin-like protein 4 (ANGPTL4), angiopoietin-like protein 5 (ANGPTL5), angiopoietin-like protein 6 (ANGPTL6), angiopoietin-like protein 8 (ANGPTL8), which are involved in lipid metabolism, in particular, cholesterol and/or triglyceride homeostasis. Inhibitors of these molecules include small molecules and antibodies that specifically bind to these molecules and block their activity.

[0061] In certain embodiments, it may be beneficial to administer the anti-GCG antibodies of the invention in combination with a nucleic acid that inhibits the activity of hPCSK9, such as an antisense molecule, a double stranded RNA, or a siRNA molecule. Exemplary nucleic acid molecules that inhibit the activity of PCSK9 are described in US2011/0065644, US2011/0039914, US2008/0015162 (now US9045754) and

US2007/0173473.

[0062] In certain embodiments, it may be beneficial to administer the anti-GCG antibodies of the invention in combination with an antibody that specifically binds to and inhibits the activity of hPCSK9, wherein such antibody acts to lower lipid or cholesterol levels. Exemplary anti-hPCSK9 antibodies are described in US2010/0166768 (now US8062640). The isolated antibody that specifically binds to human PCSK9, or an antigen-binding fragment thereof, may be administered at a dose ranging from about 0.01 mg/kg to about 30 mg/kg. It may be administered as a single dose or as multiple doses. The anti-hPCSK9 antibody may be administered concurrently with the anti-GCG antibody, or it may be administered prior to, or after the anti-GCG antibody.

[0063] In a fourth aspect, the invention features a human anti-hGCGR antibody or antigen-binding fragment of an antibody comprising a HCVR encoded by nucleotide sequence segments derived from V_H, D_H and J_H germline sequences, and a LCVR encoded by nucleotide sequence segments derived from V_K and J_K germline sequences, with combinations as shown in Table 3.

[0064] In a fifth aspect, the invention features methods for inhibiting GCG activity using an anti-GCG antibody or antigen-binding portion of the antibody of the invention, wherein the therapeutic methods comprise administering a therapeutically effective amount of a pharmaceutical composition comprising an antibody or antigen-binding fragment thereof. The antibodies of the invention may be used to treat any condition or disorder, which is improved, ameliorated, inhibited or prevented by removal, inhibition or reduction of GCG activity.

[0065] In one embodiment, the antibodies may be used to prevent the onset of a disease or disorder characterized in part by elevated blood glucose levels, or to prevent the likelihood of developing such disease or disorder, or to mitigate the severity of the disease or disorder, or at least one symptom associated with the disease or disorder. It is envisioned that the antibodies of the invention may be used alone, or as adjunct therapy with other agents or methods known to be standard care for treating patients suffering from diseases or conditions characterized in part by elevated blood glucose or ketone levels, such as, but not limited to, diabetes. Such standard therapy may include fluid administration, or administration of any other pharmaceutical agents useful for lowering blood glucose, ketones, or lipids, or for weight reduction.

[0066] The anti-GCG antibodies of the invention may function to block the interaction between glucagon and its receptor, thereby inhibiting the glucose elevating effects of glucagon. The use of glucagon antagonists, such as the antibodies described herein, may be an effective means of achieving normal levels of glucose, thereby ameliorating, or preventing one or more symptoms of, or long term complications associated with, for example, diabetes. The use of glucagon antagonists, such as the antibodies described

herein, may also be an effective means of achieving normal levels of glucose in non-diabetic patients, who experience hyperglycemia as a result of conditions or disorders not related to diabetes, such as perioperative hyperglycemia (hyperglycemia observed in patients just prior to surgery, or after surgery). In certain embodiments, methods of lowering blood glucose levels or ketone levels in diabetic ketoacidosis are envisioned using the antibodies of the invention. In certain embodiments, methods of treating patients to achieve a reduction in body weight, or to prevent weight gain, or to maintain a normal body weight, are also envisioned using the antibodies of the invention.

[0067] The antibodies of the present invention may be useful for ameliorating conditions such as, for example, impaired glucose tolerance, obesity, or for preventing weight gain, or for treating diabetic conditions, or for preventing or reducing the severity of any one or more of the long-term complications associated with diabetes, such as nephropathy, neuropathy, retinopathy, cataracts, stroke, atherosclerosis, impaired wound healing and other complications associated with diabetes, known to those skilled in the art.

[0068] In one embodiment, the antibodies of the invention may be used for treating stress hyperglycemia, or for preventing the likelihood of onset of stress hyperglycemia in a patient, (also referred to as “stress-induced hyperglycemia”), the method comprising administering to a patient a therapeutically effective amount of a composition comprising a glucagon antibody of the invention, wherein the patient exhibits elevated levels of blood glucose caused, or exacerbated by, one or more stress-inducing stimulus or one or more glucose elevating stimulus. In one embodiment, the patient is identified on the basis of having a blood glucose level greater than about 140 mg/dL.

[0069] In one embodiment, the stress-inducing stimulus or the glucose elevating stimulus is selected from the group consisting of: pre-existing type 1 or type 2 diabetes; hypertonic dehydration; infusion of catecholamine pressors; glucocorticoid therapy; obesity; aging; excessive dextrose administration; parenteral nutrition, enteral nutrition, pancreatitis; sepsis; stroke; traumatic head injury; hypothermia; hypoxemia; uremia; cirrhosis; anesthesia; pre-operative or post-operative hospital stays (peri-operative hyperglycemia); admission to an emergency room, a trauma center, or an intensive care unit; prolonged hospital stays; surgical procedures; an infection; or a chronic illness.

[0070] Other conditions or disorders treatable by the therapeutic methods of the invention include diabetic ketoacidosis, perioperative hyperglycemia, hyperglycemia in the intensive care unit patient, hyperosmolar hyperglycemia syndrome, hyperglycemia in burn patients, hyperglycemia is patients suffering from a cardiac condition, hyperinsulinemia, the metabolic syndrome, insulin resistance syndrome, impaired fasting glucose, or hyperglycemia associated with hypercholesterolemia, hypertriglyceridemia, hyperlipidemia, and general dyslipidemias.

[0071] The therapeutic methods according to this aspect of the invention comprise administering a therapeutically effective amount of a pharmaceutical composition comprising an antibody or antigen-binding fragment of an antibody of the invention to a subject in need thereof. The disorder treated is any disease or condition which is improved, ameliorated, inhibited or prevented by targeting GCG.

[0072] The antibodies may be useful for treating patients with inoperable glucagonoma (pancreatic endocrine tumor with or without necrolytic migratory erythema and hyperglycemia).

[0073] The antibodies of the invention may be used as short-term therapy in an acute setting, or they may be envisioned for long-term use as chronic therapy.

[0074] Other embodiments will become apparent from a review of the ensuing detailed description.

DETAILED DESCRIPTION

[0075] Before the present invention is described, it is to be understood that this invention is not limited to particular methods and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims.

[0076] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. As used herein, the term "about," when used in reference to a particular recited numerical value, means that the value may vary from the recited value by no more than 1%. For example, as used herein, the expression "about 100" includes 99 and 101 and all values in between (*e.g.*, 99.1, 99.2, 99.3, 99.4, etc.).

[0077] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described. All patents, applications and non-patent publications mentioned in this specification are incorporated herein by reference in their entireties.

Definitions

[0078] "Glucagon" or, "GCG," and the like, as used herein, refers to human glucagon (unless glucagon from another species is specifically noted), comprising the amino acid sequence as set forth in SEQ ID NO: 161. See also amino acid residues 53-81 of accession number NP_002045.1.

[0079] All references to proteins, polypeptides and protein fragments herein are intended to refer to the human version of the respective protein, polypeptide or protein fragment unless explicitly specified as being from a non-human species. Thus, the

expression "GCG" means human GCG unless specified as being from a non-human species, *e.g.*, "mouse GCG," "monkey GCG," etc.

[0080] The term "human proprotein convertase subtilisin/kexin type 9" or "hPCSK9", as used herein, refers to hPCSK9 encoded by the nucleic acid sequence shown in SEQ ID NO:162 and having the amino acid sequence of SEQ ID NO:163, or a biologically active fragment thereof.

[0081] The specific embodiments, antibody or antibody fragments of the invention may be conjugated to a therapeutic moiety ("immunoconjugate"), such as a second GCG antagonist, or to biguanide (metformin), a sulfonylurea (such as glyburide, glipizide), a PPAR gamma agonist (such as pioglitazone, or rosiglitazone), an alpha glucosidase inhibitor (such as acarbose, or voglibose), BYETTA® (glucagon-like peptide 1), SYMLIN® (pramlintide), or any other therapeutic moiety useful for treating a disease or condition caused in part by unwanted glucagon activity.

[0082] As used herein, the expression "anti-GCG antibody" includes both monovalent antibodies with a single specificity, as well as bispecific antibodies comprising a first arm that binds GCG and a second arm that binds a second (target) antigen, wherein the anti-GCG arm comprises any of the HCVR/LCVR or CDR sequences as set forth in Table 1 herein.

[0083] The term "antibody", as used herein, means any antigen-binding molecule or molecular complex comprising at least one complementarity determining region (CDR) that specifically binds to or interacts with a particular antigen (*e.g.*, GCG). The term "antibody" includes immunoglobulin molecules comprising four polypeptide chains, two heavy (H) chains and two light (L) chains inter-connected by disulfide bonds, as well as multimers thereof (*e.g.*, IgM). Each heavy chain comprises a heavy chain variable region (abbreviated herein as HCVR or V_H) and a heavy chain constant region. The heavy chain constant region comprises three domains, C_H1, C_H2 and C_H3. Each light chain comprises a light chain variable region (abbreviated herein as LCVR or V_L) and a light chain constant region. The light chain constant region comprises one domain (C_L1). The V_H and V_L regions can be further subdivided into regions of hypervariability, termed complementarity determining regions (CDRs), interspersed with regions that are more conserved, termed framework regions (FR). Each V_H and V_L is composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. In different embodiments of the invention, the FRs of the anti-GCG antibody (or antigen-binding portion thereof) may be identical to the human germline sequences, or may be naturally or artificially modified. An amino acid consensus sequence may be defined based on a side-by-side analysis of two or more CDRs.

[0084] The term "antibody", as used herein, also includes antigen-binding fragments of

full antibody molecules. The terms "antigen-binding portion" of an antibody, "antigen-binding fragment" of an antibody, and the like, as used herein, include any naturally occurring, enzymatically obtainable, synthetic, or genetically engineered polypeptide or glycoprotein that specifically binds an antigen to form a complex. Antigen-binding fragments of an antibody may be derived, *e.g.*, from full antibody molecules using any suitable standard techniques such as proteolytic digestion or recombinant genetic engineering techniques involving the manipulation and expression of DNA encoding antibody variable and optionally constant domains. Such DNA is known and/or is readily available from, *e.g.*, commercial sources, DNA libraries (including, *e.g.*, phage-antibody libraries), or can be synthesized. The DNA may be sequenced and manipulated chemically or by using molecular biology techniques, for example, to arrange one or more variable and/or constant domains into a suitable configuration, or to introduce codons, create cysteine residues, modify, add or delete amino acids, etc.

[0085] Non-limiting examples of antigen-binding fragments include: (i) Fab fragments; (ii) F(ab')2 fragments; (iii) Fd fragments; (iv) Fv fragments; (v) single-chain Fv (scFv) molecules; (vi) dAb fragments; and (vii) minimal recognition units consisting of the amino acid residues that mimic the hypervariable region of an antibody (*e.g.*, an isolated complementarity determining region (CDR) such as a CDR3 peptide), or a constrained FR3-CDR3-FR4 peptide. Other engineered molecules, such as domain-specific antibodies, single domain antibodies, domain-deleted antibodies, chimeric antibodies, CDR-grafted antibodies, diabodies, triabodies, tetrabodies, minibodies, nanobodies (*e.g.* monovalent nanobodies, bivalent nanobodies, etc.), small modular immunopharmaceuticals (SMIPs), and shark variable IgNAR domains, are also encompassed within the expression "antigen-binding fragment," as used herein.

[0086] An antigen-binding fragment of an antibody will typically comprise at least one variable domain. The variable domain may be of any size or amino acid composition and will generally comprise at least one CDR, which is adjacent to or in frame with one or more framework sequences. In antigen-binding fragments having a V_H domain associated with a V_L domain, the V_H and V_L domains may be situated relative to one another in any suitable arrangement. For example, the variable region may be dimeric and contain V_H-V_H, V_H-V_L or V_L-V_L dimers. Alternatively, the antigen-binding fragment of an antibody may contain a monomeric V_H or V_L domain.

[0087] In certain embodiments, an antigen-binding fragment of an antibody may contain at least one variable domain covalently linked to at least one constant domain. Non-limiting, exemplary configurations of variable and constant domains that may be found within an antigen-binding fragment of an antibody of the present invention include: (i) V_H-C_H1; (ii) V_H-C_H2; (iii) V_H-C_H3; (iv) V_H-C_H1-C_H2; (v) V_H-C_H1-C_H2-C_H3; (vi) V_H-C_H2-C_H3; (vii) V_H-C_L; (viii) V_L-C_H1; (ix) V_L-C_H2; (x) V_L-C_H3; (xi) V_L-C_H1-C_H2; (xii) V_L-C_H1-C_H2-

C_H3; (xiii) V_L-C_H2-C_H3; and (xiv) V_L-C_L. In any configuration of variable and constant domains, including any of the exemplary configurations listed above, the variable and constant domains may be either directly linked to one another or may be linked by a full or partial hinge or linker region. A hinge region may consist of at least 2 (*e.g.*, 5, 10, 15, 20, 40, 60 or more) amino acids which result in a flexible or semi-flexible linkage between adjacent variable and/or constant domains in a single polypeptide molecule. Moreover, an antigen-binding fragment of an antibody of the present invention may comprise a homo-dimer or hetero-dimer (or other multimer) of any of the variable and constant domain configurations listed above in non-covalent association with one another and/or with one or more monomeric V_H or V_L domain (*e.g.*, by disulfide bond(s)).

[0088] As with full antibody molecules, antigen-binding fragments may be monospecific or multispecific (*e.g.*, bispecific). A multispecific antigen-binding fragment of an antibody will typically comprise at least two different variable domains, wherein each variable domain is capable of specifically binding to a separate antigen or to a different epitope on the same antigen. Any multispecific antibody format, including the exemplary bispecific antibody formats disclosed herein, may be adapted for use in the context of an antigen-binding fragment of an antibody of the present invention using routine techniques available in the art.

[0089] The term "human antibody", as used herein, is intended to include non-naturally occurring human antibodies. The term includes antibodies that are recombinantly produced in a non-human mammal, or in cells of a non-human mammal. The term is not intended to include antibodies isolated from or generated in a human subject.

[0090] The antibodies of the invention may, in some embodiments, be recombinant human antibodies. The term "recombinant human antibody", as used herein, is intended to include all human antibodies that are prepared, expressed, created or isolated by recombinant means, such as antibodies expressed using a recombinant expression vector transfected into a host cell (described further below), antibodies isolated from a recombinant, combinatorial human antibody library (described further below), antibodies isolated from an animal (e.g., a mouse) that is transgenic for human immunoglobulin genes (see e.g., Taylor et al. (1992) Nucl. Acids Res. 20:6287-6295) or antibodies prepared, expressed, created or isolated by any other means that involves splicing of human immunoglobulin gene sequences to other DNA sequences. In certain embodiments, such recombinant human antibodies are subjected to *in vitro* mutagenesis (or, when an animal transgenic for human Ig sequences is used, *in vivo* somatic mutagenesis) and thus the amino acid sequences of the V_H and V_L regions of the recombinant antibodies are sequences that, while related to human germline V_H and V_L sequences, may not naturally exist within the human antibody germline repertoire *in vivo*.

[0091] Human antibodies can exist in two forms that are associated with hinge

heterogeneity. In one form, an immunoglobulin molecule comprises a stable four chain construct of approximately 150-160 kDa in which the dimers are held together by an interchain heavy chain disulfide bond. In a second form, the dimers are not linked via inter-chain disulfide bonds and a molecule of about 75-80 kDa is formed composed of a covalently coupled light and heavy chain (half-antibody). These forms have been extremely difficult to separate, even after affinity purification.

[0092] The frequency of appearance of the second form in various intact IgG isotypes is due to, but not limited to, structural differences associated with the hinge region isotype of the antibody. A single amino acid substitution in the hinge region of the human IgG4 hinge can significantly reduce the appearance of the second form (Angal et al. (1993) Molecular Immunology 30:105) to levels typically observed using a human IgG1 hinge. The instant invention encompasses antibodies having one or more mutations in the hinge, C_H2 or C_H3
region which may be desirable, for example, in production, to improve the yield of the desired antibody form.

[0093] The term "specifically binds", or “binds specifically to”, or the like, means that an antibody or antigen-binding fragment thereof forms a complex with an antigen that is relatively stable under physiologic conditions. Specific binding can be characterized by an equilibrium dissociation constant of at least about $1x10^{-6}$ M or less (*e.g.*, a smaller K_D denotes a tighter binding). Methods for determining whether two molecules specifically bind are well known in the art and include, for example, equilibrium dialysis, surface plasmon resonance, and the like. As described herein, antibodies have been identified by surface plasmon resonance, *e.g.*, BIACORE™, which bind specifically to GCG. Moreover, multi-specific antibodies that bind to GCG protein and one or more additional antigens or a bi-specific that binds to two different regions of GCG are nonetheless considered antibodies that “specifically bind”, as used herein.

[0094] The antibodies of the invention may be isolated antibodies. An "isolated antibody," as used herein, means an antibody that has been identified and separated and/or recovered from at least one component of its natural environment. For example, an antibody that has been separated or removed from at least one component of an organism, or from a tissue or cell in which the antibody naturally exists or is naturally produced, is an "isolated antibody" for purposes of the present invention. An isolated antibody also includes an antibody *in situ* within a recombinant cell. Isolated antibodies are antibodies that have been subjected to at least one purification or isolation step. According to certain embodiments, an isolated antibody may be substantially free of other cellular material and/or chemicals.

[0095] The anti-GCG antibodies disclosed herein may comprise one or more amino acid substitutions, insertions and/or deletions in the framework and/or CDR regions of

the heavy and light chain variable domains. Such mutations can be readily ascertained by comparing the amino acid sequences disclosed herein to sequences available from, for example, public antibody sequence databases. Once obtained, antibodies and antigen-binding fragments that contain one or more mutations can be easily tested for one or more desired property such as, improved binding specificity, increased binding affinity, improved or enhanced antagonistic or agonistic biological properties (as the case may be), reduced immunogenicity, etc. Antibodies and antigen-binding fragments obtained in this general manner are encompassed within the present invention.

[0096] The present invention also includes anti-GCG antibodies comprising variants of any of the HCVR, LCVR, and/or CDR amino acid sequences disclosed herein having one or more conservative substitutions. For example, the present invention includes anti-GCG antibodies having HCVR, LCVR, and/or CDR amino acid sequences with, *e.g.*, 10 or fewer, 8 or fewer, 6 or fewer, 4 or fewer, etc. conservative amino acid substitutions relative to any of the HCVR, LCVR, and/or CDR amino acid sequences set forth in Table 1 herein.

[0097] A “blocking antibody” or a "neutralizing antibody", as used herein (or an "antibody that neutralizes GCG activity"), is intended to refer to an antibody whose binding to glucagon prevents or blocks its binding to the glucagon receptor, which results in inhibition of at least one biological activity of GCG. For example, an antibody of the invention may aid in preventing the increase in blood glucose levels associated with elevation of glucagon levels. Alternatively, an antibody of the invention may demonstrate the ability to block cAMP production in response to glucagon. This inhibition of the biological activity of GCG can be assessed by measuring one or more indicators of GCG biological activity by one or more of several standard *in vitro* or *in vivo* assays known in the art.

[0098] The term "surface plasmon resonance", as used herein, refers to an optical phenomenon that allows for the analysis of real-time biomolecular interactions by detection of alterations in protein concentrations within a biosensor matrix, for example using the BIACORE™ system (Pharmacia Biosensor AB, Uppsala, Sweden and Piscataway, N.J.).

[0099] The term "K_D ", as used herein, is intended to refer to the equilibrium dissociation constant of a particular antibody-antigen interaction.

[0100] The term "epitope" refers to an antigenic determinant that interacts with a specific antigen binding site in the variable region of an antibody molecule known as a paratope. A single antigen may have more than one epitope. Thus, different antibodies may bind to different areas on an antigen and may have different biological effects. Epitopes may be either conformational or linear. A conformational epitope is produced by spatially juxtaposed amino acids from different segments of the linear polypeptide

chain. A linear epitope is one produced by adjacent amino acid residues in a polypeptide chain. In certain circumstance, an epitope may include moieties of saccharides, phosphoryl groups, or sulfonyl groups on the antigen.

[0101] The term "substantial identity" or "substantially identical," when referring to a nucleic acid or fragment thereof, indicates that, when optimally aligned with appropriate nucleotide insertions or deletions with another nucleic acid (or its complementary strand), there is nucleotide sequence identity in at least about 95%, and more preferably at least about 96%, 97%, 98% or 99% of the nucleotide bases, as measured by any well-known algorithm of sequence identity, such as FASTA, BLAST or Gap, as discussed below. A nucleic acid molecule having substantial identity to a reference nucleic acid molecule may, in certain instances, encode a polypeptide having the same or substantially similar amino

acid sequence as the polypeptide encoded by the reference nucleic acid molecule.

[0102] As applied to polypeptides, the term "substantial similarity" or "substantially similar" means that two peptide sequences, when optimally aligned, such as by the programs GAP or BESTFIT using default gap weights, share at least 95% sequence identity, even more preferably at least 98% or 99% sequence identity. Preferably, residue positions which are not identical differ by conservative amino acid substitutions. A "conservative amino acid substitution" is one in which an amino acid residue is substituted by another amino acid residue having a side chain (R group) with similar chemical properties (e.g., charge or hydrophobicity). In general, a conservative amino acid substitution will not substantially change the functional properties of a protein. In cases where two or more amino acid sequences differ from each other by conservative substitutions, the percent sequence identity or degree of similarity may be adjusted upwards to correct for the conservative nature of the substitution. Means for making this adjustment are well-known to those of skill in the art. *See, e.g.*, Pearson (1994) Methods Mol. Biol. 24: 307-331, herein incorporated by reference. Examples of groups of amino acids that have side chains with similar chemical properties include (1) aliphatic side chains: glycine, alanine, valine, leucine and isoleucine; (2) aliphatic-hydroxyl side chains: serine and threonine; (3) amide-containing side chains: asparagine and glutamine; (4) aromatic side chains: phenylalanine, tyrosine, and tryptophan; (5) basic side chains: lysine, arginine, and histidine; (6) acidic side chains: aspartate and glutamate, and (7) sulfur-containing side chains are cysteine and methionine. Preferred conservative amino acids substitution groups are: valine-leucine-isoleucine, phenylalanine-tyrosine, lysine-arginine, alanine-valine, glutamate-aspartate, and asparagine-glutamine. Alternatively, a conservative replacement is any change having a positive value in the PAM250 log-likelihood matrix disclosed in Gonnet *et al.* (1992) Science 256: 1443-1445, herein incorporated by reference. A "moderately conservative" replacement is any change

having a nonnegative value in the PAM250 log-likelihood matrix.

[0103] Sequence similarity for polypeptides, which is also referred to as sequence identity, is typically measured using sequence analysis software. Protein analysis software matches similar sequences using measures of similarity assigned to various substitutions, deletions and other modifications, including conservative amino acid substitutions. For instance, GCG software contains programs such as Gap and Bestfit which can be used with default parameters to determine sequence homology or sequence identity between closely related polypeptides, such as homologous polypeptides from different species of organisms or between a wild type protein and a mutein thereof. *See, e.g.*, GCG Version 6.1. Polypeptide sequences also can be compared using FASTA using default or recommended parameters, a program in GCG Version 6.1. FASTA (e.g., FASTA2 and FASTA3) provides alignments and percent sequence identity of the regions of the best overlap between the query and search sequences (Pearson (2000) supra). Another preferred algorithm when comparing a sequence of the invention to a database containing a large number of sequences from different organisms is the computer program BLAST, especially BLASTP or TBLASTN, using default parameters. *See, e.g.*, Altschul *et al.* (1990) J. Mol. Biol. 215:403-410 and Altschul *et al.* (1997) Nucleic Acids Res. 25:3389-402, each herein incorporated by reference.

[0104] By the phrase “therapeutically effective amount” is meant an amount that produces the desired effect for which it is administered. The exact amount will depend on the purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques (see, for example, Lloyd (1999) The Art, Science and Technology of Pharmaceutical Compounding).

[0105] The term "blood glucose level", or “level of blood glucose” shall mean blood glucose concentration. In certain embodiments, a blood glucose level is a plasma glucose level. Plasma glucose may be determined in accordance with Etgen *et al.*, (Metabolism 2000; 49(5): 684-688) or calculated from a conversion of whole blood glucose concentration in accordance with D'Orazio *et al.*, (Clin. Chem. Lab. Med. 2006; 44(12): 1486-1490).

[0106] “Normal glucose levels” refers to mean plasma glucose values in humans of less than about 100 mg/dL for fasting levels, and less than 110-120 mg/dL for 2- hour post-prandial levels or 125 mg/dL for a random glucose. Plasma glucose may be determined in accordance with Etgen *et al.*, (Metabolism 2000; 49(5): 684-688) or calculated from a conversion of whole blood glucose concentration in accordance with D'Orazio *et al.*, (Clin. Chem. Lab. Med. 2006; 44(12): 1486-1490). In certain embodiments of the invention, the anti-GCG antibodies may be useful to lower blood glucose levels to within the normal range.

[0107] The term "elevated blood glucose level" or “elevated levels of blood glucose” shall mean an elevated blood glucose level such as that found in a subject demonstrating clinically inappropriate basal and postprandial hyperglycemia or such as that found in a subject in oral glucose tolerance test (oGTT), with “elevated levels of blood glucose” being greater than about 100 mg/dL when tested under fasting conditions, and greater than about 200 mg/dL when tested at 1 hour.

[0108] The term “stress hyperglycemia”, which is used interchangeably with “stress-induced hyperglycemia”, refers to a condition whereby a patient suffers from a transient increase in blood glucose (>140 mg/dL) that is temporally linked to the stress of an acute injury or illness. Stress hyperglycemia can occur in patients with or without a history of diabetes. The cause is thought to be directly related to the stress of the underlying medical illness, anesthesia, surgery, or trauma.

[0109] Stress hyperglycemia is the result of, or may be exacerbated by, any one or more of the following risk factors, conditions or therapies: pre-existing type 1 or type 2 diabetes; hypertonic dehydration; infusion of catecholamine pressors; glucocorticoid therapy; obesity; aging; excessive dextrose administration; parenteral nutrition, enteral nutrition, pancreatitis; sepsis; stroke; traumatic head injury; hypothermia; hypoxemia; uremia; cirrhosis; anesthesia; pre-operative or post-operative hospital stays (peri-operative hyperglycemia); admission to an emergency room, a trauma center, or an intensive care unit; prolonged hospital stays; surgical procedures; an infection; or a worsening chronic illness.

[0110] The term “critically ill”, as used herein, generally refers to a patient suffering from a disease, disorder, injury, surgical procedure, or other condition who requires treatment or monitoring in a critical care unit, or an intensive care unit of a hospital. In its broadest sense, the term a "critically ill” patient, as used herein refers to a patient who has sustained or is at risk of sustaining acutely life-threatening single or multiple organ system failure. A critically ill patient may be a “diabetic patient”, *e.g.* a patient having been diagnosed as having diabetes using standard tests known to those skilled in the art; or a “non-diabetic patient”, *e.g.* a patient who has been diagnosed as not having diabetes using standard methods known to those skilled in the art.

[0111] The term “not-critically ill”, or “non-critically ill” refers to a hospitalized patient suffering from a disease, disorder, or condition that does not require treatment or monitoring in a critical care unit, or intensive care unit of a hospital. In its broadest sense, the term a "not-critically ill” patient, as used herein refers to a patient other than one who has sustained or is at risk of sustaining acutely life-threatening single or multiple organ system failure due to disease, injury, surgical procedure, or other condition.

[0112] The term "Intensive Care Unit" (herein designated ICU), as used herein refers to the part of a hospital where critically ill patients are treated. This might vary from

country to country and even from hospital to hospital and this part of the hospital may not necessary, officially, bear the name "Intensive Care Unit" or a translation or derivation thereof. The term "Intensive Care Unit" also covers any health care unit that treats patients with life-threatening conditions requiring constant, close monitoring and support from equipment and medication in order to maintain normal bodily functions.

[0113] The term “treating” or “treatment”, as used herein, refers to an approach for obtaining beneficial or desired clinical results. For purposes of this invention, beneficial or desired clinical results include, but are not limited to, one or more of the following: improvement in blood glucose to within about 80-180 mg/dL, or to within about 80-140 mg/dL, or an improvement in any one or more conditions, diseases, or symptoms associated with, or resulting from, elevated levels of blood glucose, including, but not limited to susceptibility to infections, organ failure, disability after stroke, polyneuropathy, arrhythmia, or mortality in patients. In addition, “treating” with a glucagon antagonist/antibody of the invention may result in a beneficial or desired clinical result which may include an improvement in blood glucose level to within about 80-180 mg/dL, or to within about 80-140 mg/dL, in any condition or disease resulting from exposure to any one or more stress-inducing stimulus or glucose elevating stimulus selected from the group consisting of: pre-existing type 1 or type 2 diabetes; infusion of catecholamine pressors; parenteral nutrition; enteral nutrition; glucocorticoid therapy; obesity; aging; excessive dextrose administration; pancreatitis; sepsis; stroke; traumatic head injury; hypothermia; hypoxemia; uremia; cirrhosis; anesthesia; pre-operative or post-operative hospital stays (peri-operative hyperglycemia); admission to an emergency room, a trauma center, or an intensive care unit; prolonged hospital stays; surgical procedures; an infection; and a chronic illness. “Treating” with a glucagon antagonist/antibody of the invention may also lead to prevention of the onset of stress hyperglycemia, or to prevention of the likelihood of onset of stress hyperglycemia.

[0114] A “stress-inducing stimulus”, which is used interchangeably with a “glucose-elevating stimulus”, refers to an event that promotes the elevation of blood glucose to above-normal levels. Examples of a “stress-inducing stimulus”, or a “glucose-elevating stimulus” include any one or more of the following: pre-existing type 1 or type 2 diabetes; hypertonic dehydration; infusion of catecholamine pressors; parenteral nutrition; enteral nutrition; glucocorticoid therapy; obesity; aging; excessive dextrose administration; pancreatitis; sepsis; stroke; traumatic head injury; hypothermia; hypoxemia; uremia; cirrhosis; anesthesia; pre-operative or post-operative hospital stays (peri-operative hyperglycemia); admission to an emergency room, a trauma center, or an intensive care unit; prolonged hospital stays; surgical procedures; an infection; and a chronic illness.

[0115] The term "insulin", as used herein refers to insulin from any species such as human insulin, porcine insulin, bovine insulin and salts thereof, such as zinc salts.

pH-Dependent Binding

[0116] The present invention includes anti-GCG antibodies with pH-dependent binding characteristics. For example, an anti-GCG antibody of the present invention may exhibit reduced binding to GCG at acidic pH as compared to neutral pH. Alternatively, anti-GCG antibodies of the invention may exhibit enhanced binding to GCG at acidic pH as compared to neutral pH. The expression "acidic pH" includes pH values less than about 6.2, *e.g.*, about 6.0, 5.95, 5,9, 5.85, 5.8, 5.75, 5.7, 5.65, 5.6, 5.55, 5.5, 5.45, 5.4, 5.35, 5.3, 5.25, 5.2, 5.15, 5.1, 5.05, 5.0, or less. As used herein, the expression "neutral pH" means a pH of about 7.0 to about 7.4. The expression "neutral pH" includes pH values of about 7.0, 7.05, 7.1, 7.15, 7.2, 7.25, 7.3, 7.35, and 7.4.

[0117] In certain instances, "reduced binding to GCG at acidic pH as compared to neutral pH" is expressed in terms of a ratio of the K_D value of the antibody binding to GCG at acidic pH to the K_D value of the antibody binding to GCG at neutral pH (or vice versa). For example, an antibody or antigen-binding fragment thereof may be regarded as exhibiting "reduced binding to GCG at acidic pH as compared to neutral pH" for purposes of the present invention if the antibody or antigen-binding fragment thereof exhibits an acidic/neutral K_D ratio of about 3.0 or greater. In certain exemplary embodiments, the acidic/neutral K_D ratio for an antibody or antigen-binding fragment of the present invention can be about 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, 13.0, 13.5, 14.0, 14.5, 15.0, 20.0. 25.0, 30.0, 40.0, 50.0, 60.0, 70.0, 100.0 or greater.

[0118] Antibodies with pH-dependent binding characteristics may be obtained, *e.g.*, by screening a population of antibodies for reduced (or enhanced) binding to a particular antigen at acidic pH as compared to neutral pH. Additionally, modifications of the antigen-binding domain at the amino acid level may yield antibodies with pH-dependent characteristics. For example, by substituting one or more amino acids of an antigen-binding domain (*e.g.*, within a CDR) with a histidine residue, an antibody with reduced antigen-binding at acidic pH relative to neutral pH may be obtained.

Anti-GCG Antibodies Comprising Fc Variants

[0119] According to certain embodiments of the present invention, anti-GCG antibodies are provided comprising an Fc domain comprising one or more mutations which enhance or diminish antibody binding to the FcRn receptor, *e.g.*, at acidic pH as compared to neutral pH. For example, the present invention includes anti-GCG antibodies comprising a mutation in the C_H2 or a C_H3 region of the Fc domain, wherein the mutation(s) increases the affinity of the Fc domain to FcRn in an acidic environment (*e.g.,* in an endosome where pH ranges from about 5.5 to about 6.0). Such mutations may result in an increase in serum half-life of the antibody when administered to an animal. Non-limiting examples of such Fc modifications include, *e.g.*, a modification at

position 250 (e.g., E or Q); 250 and 428 (e.g., L or F); 252 (e.g., L/Y/F/W or T), 254 (e.g., S or T), and 256 (e.g., S/R/Q/E/D or T); or a modification at position 428 and/or 433 (e.g., H/L/R/S/P/Q or K) and/or 434 (*e.g.,* A, W, H, F or Y [N434A, N434W, N434H, N434F or N434Y]); or a modification at position 250 and/or 428; or a modification at position 307 or 308 (*e.g.,* 308F, V308F), and 434. In one embodiment, the modification comprises a 428L (*e.g.,* M428L) and 434S (*e.g.,* N434S) modification; a 428L, 259I (*e.g.,* V259I), and 308F (*e.g.,* V308F) modification; a 433K (*e.g.,* H433K) and a 434 (*e.g.,* 434Y) modification; a 252, 254, and 256 (*e.g.,* 252Y, 254T, and 256E) modification; a 250Q and 428L modification (*e.g.,* T250Q and M428L); and a 307 and/or 308 modification (*e.g.,* 308F or 308P). In yet another embodiment, the modification comprises a 265A (*e.g.*, D265A) and/or a 297A (*e.g.*, N297A) modification.

[0120] For example, the present invention includes anti-GCG antibodies comprising an Fc domain comprising one or more pairs or groups of mutations selected from the group consisting of: 250Q and 248L (*e.g.*, T250Q and M248L); 252Y, 254T and 256E (*e.g.*, M252Y, S254T and T256E); 428L and 434S (*e.g.*, M428L and N434S); 257I and 311I (*e.g.*, P257I and Q311I); 257I and 434H (*e.g.*, P257I and N434H); 376V and 434H (*e.g.*, D376V and N434H); 307A, 380A and 434A (*e.g.*, T307A, E380A and N434A); and 433K and 434F (*e.g.*, H433K and N434F). All possible combinations of the foregoing Fc domain mutations, and other mutations within the antibody variable domains disclosed herein, are contemplated within the scope of the present invention.

[0121] The present invention also includes anti-GCG antibodies comprising a chimeric heavy chain constant (C_H) region, wherein the chimeric C_H region comprises segments derived from the C_H regions of more than one immunoglobulin isotype. For example, the antibodies of the invention may comprise a chimeric C_H region comprising part or all of a C_H2 domain derived from a human IgG1, human IgG2 or human IgG4 molecule, combined with part or all of a C_H3 domain derived from a human IgG1, human IgG2 or human IgG4 molecule. According to certain embodiments, the antibodies of the invention comprise a chimeric C_H region having a chimeric hinge region. For example, a chimeric hinge may comprise an "upper hinge" amino acid sequence (amino acid residues from positions 216 to 227 according to EU numbering) derived from a human IgG1, a human IgG2 or a human IgG4 hinge region, combined with a "lower hinge" sequence (amino acid residues from positions 228 to 236 according to EU numbering) derived from a human IgG1, a human IgG2 or a human IgG4 hinge region. According to certain embodiments, the chimeric hinge region comprises amino acid residues derived from a human IgG1 or a human IgG4 upper hinge and amino acid residues derived from a human IgG2 lower hinge. An antibody comprising a chimeric C_H region as described herein may, in certain embodiments, exhibit modified Fc effector functions without adversely affecting the therapeutic or pharmacokinetic properties of the antibody. (*See*,

e.g., U.S. Provisional Appl. No. 61/759,578, filed February 1, 2013, the disclosure of which is hereby incorporated by reference in its entirety).

Biological Characteristics of the Antibodies

[0122] The present invention includes antibodies and antigen-binding fragments thereof that bind GCG with high affinity. For example, the present invention includes anti-GCG antibodies that bind GCG with a K_D of less than about 5.0 nM as measured by surface plasmon resonance at 25°C or 37°C, *e.g.*, using an assay format as defined in Example 3 herein, or a substantially similar assay. According to certain embodiments, anti-GCG antibodies are provided that bind GCG at 37°C with a K_D of less than about 5 nM, less than about 3 nM, less than about 2 nM, less than about 1 nM, less than about 900 pM, less than about 800 pM, less than about 700 pM, less than about 600 pM, less than about 500 pM, less than about 400 pM, or less than about 300 pM, as measured by surface plasmon resonance, *e.g.*, using an assay format as defined in Example 3 herein, or a substantially similar assay.

[0123] The present invention also includes antibodies and antigen-binding fragments thereof that bind GCG with a dissociative half-life (t½) of greater than about 0.5 minutes as measured by surface plasmon resonance at 25°C or 37°C, *e.g.*, using an assay format as defined in Example 3 herein, or a substantially similar assay. According to certain embodiments, anti-GCG antibodies are provided that bind GCG at 37°C with a t½ of greater than or equal to about 0.5 minutes, greater than about 6 minutes, greater than about 8 minutes, greater than about 10 minutes, greater than about 12 minutes, greater than about 14 minutes, greater than about 16 minutes, greater than about 18 minutes, greater than about 20 minutes, greater than about 30 minutes, greater than about 40 minutes, or longer, as measured by surface plasmon resonance, *e.g.*, using an assay format as defined in Example 3 herein, or a substantially similar assay.

[0124] The present invention also includes antibodies and antigen-binding fragments thereof that bind GCG binding to and activation of cells expressing the glucagon receptor (GCGR). For example, the present invention includes anti-GCG antibodies that block binding of glucagon to cells that express the glucagon receptor, with an EC_{50} of less than about 60pM as measured using GCG bioassay format as defined in Example 4 herein, or a substantially similar assay. According to certain embodiments, anti-GCG antibodies are provided that block activation in cells expressing GCGR, with an EC_{50} of less than about 50 nM, less than about 5.0 nM, less than about 1.0 nM, less than about 900 pM, less than about 800 pM, less than about 600 pM, less than about 400 pM, less than about 200 pM, less than about 100 pM, less than about 80 pM, less than about 60 pM, less than about 40 pM, less than about 20 pM as measured using a bioassay format as defined in Example 4 herein, or a substantially similar assay.

[0125] The antibodies of the present invention may possess one or more of the

aforementioned biological characteristics, or any combination thereof. The foregoing list of biological characteristics of the antibodies of the invention is not intended to be exhaustive. Other biological characteristics of the antibodies of the present invention will be evident to a person of ordinary skill in the art from a review of the present disclosure including the working Examples herein.

Epitope Mapping and Related Technologies

[0126] The epitope to which the antibodies of the present invention bind may consist of a single contiguous sequence of 3 or more (*e.g.*, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 or more) amino acids of a GCG protein. Alternatively, the epitope may consist of a plurality of non-contiguous amino acids (or amino acid sequences) of GCG.

[0127] Various techniques known to persons of ordinary skill in the art can be used to determine whether an antibody "interacts with one or more amino acids" within a polypeptide or protein. Exemplary techniques include, *e.g.*, routine cross-blocking assay such as that described Antibodies, Harlow and Lane (Cold Spring Harbor Press, Cold Spring Harb., NY), alanine scanning mutational analysis, peptide blots analysis (Reineke, 2004, Methods Mol Biol 248:443-463), and peptide cleavage analysis. In addition, methods such as epitope excision, epitope extraction and chemical modification of antigens can be employed (Tomer, 2000, Protein Science 9:487-496). Another method that can be used to identify the amino acids within a polypeptide with which an antibody interacts is hydrogen/deuterium exchange detected by mass spectrometry. In general terms, the hydrogen/deuterium exchange method involves deuterium-labeling the protein of interest, followed by binding the antibody to the deuterium-labeled protein. Next, the protein/antibody complex is transferred to water to allow hydrogen-deuterium exchange to occur at all residues except for the residues protected by the antibody (which remain deuterium-labeled). After dissociation of the antibody, the target protein is subjected to protease cleavage and mass spectrometry analysis, thereby revealing the deuterium-labeled residues which correspond to the specific amino acids with which the antibody interacts. *See, e.g.*, Ehring (1999) *Analytical Biochemistry* 267(2):252-259; Engen and Smith (2001) *Anal. Chem. 73*:256A-265A.

[0128] The present invention further includes anti-GCG antibodies that bind to the same epitope as any of the specific exemplary antibodies described herein (*e.g.* antibodies comprising any of the amino acid sequences as set forth in Table 1 herein). Likewise, the present invention also includes anti-GCG antibodies that compete for binding to GCG with any of the specific exemplary antibodies described herein (*e.g.* antibodies comprising any of the amino acid sequences as set forth in Table 1 herein).

[0129] One can easily determine whether an antibody binds to the same epitope as,

or competes for binding with, a reference anti-GCG antibody by using routine methods known in the art and exemplified herein. For example, to determine if a test antibody binds to the same epitope as a reference anti-GCG antibody of the invention, the reference antibody is allowed to bind to a GCG protein. Next, the ability of a test antibody to bind to the GCG molecule is assessed. If the test antibody is able to bind to GCG following saturation binding with the reference anti-GCG antibody, it can be concluded that the test antibody binds to a different epitope than the reference anti-GCG antibody. On the other hand, if the test antibody is not able to bind to the GCG molecule following saturation binding with the reference anti-GCG antibody, then the test antibody may bind to the same epitope as the epitope bound by the reference anti-GCG antibody of the invention. Additional routine experimentation (*e.g.*, peptide mutation and binding analyses) can then be carried out to confirm whether the observed lack of binding of the test antibody is in fact due to binding to the same epitope as the reference antibody or if steric blocking (or another phenomenon) is responsible for the lack of observed binding. Experiments of this sort can be performed using ELISA, RIA, Biacore, flow cytometry or any other quantitative or qualitative antibody-binding assay available in the art. In accordance with certain embodiments of the present invention, two antibodies bind to the same (or overlapping) epitope if, *e.g.*, a 1-, 5-, 10-, 20- or 100-fold excess of one antibody inhibits binding of the other by at least 50% but preferably 75%, 90% or even 99% as measured in a competitive binding assay (see, e.g., Junghans et al., Cancer Res. 1990:50:1495-1502). Alternatively, two antibodies are deemed to bind to the same epitope if essentially all amino acid mutations in the antigen that reduce or eliminate binding of one antibody reduce or eliminate binding of the other. Two antibodies are deemed to have "overlapping epitopes" if only a subset of the amino acid mutations that reduce or eliminate binding of one antibody reduce or eliminate binding of the other.

[0130] To determine if an antibody competes for binding (or cross-competes for binding) with a reference anti-GCG antibody, the above-described binding methodology is performed in two orientations: In a first orientation, the reference antibody is allowed to bind to a GCG protein under saturating conditions followed by assessment of binding of the test antibody to the GCG molecule. In a second orientation, the test antibody is allowed to bind to a GCG molecule under saturating conditions followed by assessment of binding of the reference antibody to the GCG molecule. If, in both orientations, only the first (saturating) antibody is capable of binding to the GCG molecule, then it is concluded that the test antibody and the reference antibody compete for binding to GCG. As will be appreciated by a person of ordinary skill in the art, an antibody that competes for binding with a reference antibody may not necessarily bind to the same epitope as the reference antibody, but may sterically block binding of the reference antibody by binding an overlapping or adjacent epitope.

Preparation of Human Antibodies

[0131] The anti-GCG antibodies of the present invention can be fully human (non-naturally occurring) antibodies. Methods for generating monoclonal antibodies, including fully human monoclonal antibodies are known in the art. Any such known methods can be used in the context of the present invention to make human antibodies that specifically bind to human GCG.

[0132] Using VELOCIMMUNE® technology (see, for example, US 6,596,541, Regeneron Pharmaceuticals, VELOCIMMUNE®) or any other known method for generating monoclonal antibodies, high affinity chimeric antibodies to an antigen are initially isolated having a human variable region and a mouse constant region. The VELOCIMMUNE® technology involves generation of a transgenic mouse having a genome comprising human heavy and light chain variable regions operably linked to endogenous mouse constant region loci such that the mouse produces an antibody comprising a human variable region and a mouse constant region in response to antigenic stimulation. The DNA encoding the variable regions of the heavy and light chains of the antibody are isolated and operably linked to DNA encoding the human heavy and light chain constant regions. The DNA is then expressed in a cell capable of expressing the fully human antibody.

[0133] Generally, a VELOCIMMUNE® mouse is challenged with the antigen of interest, and lymphatic cells (such as B-cells) are recovered from the mice that express antibodies. The lymphatic cells may be fused with a myeloma cell line to prepare immortal hybridoma cell lines, and such hybridoma cell lines are screened and selected to identify hybridoma cell lines that produce antibodies specific to the antigen of interest. DNA encoding the variable regions of the heavy chain and light chain may be isolated and linked to desirable isotypic constant regions of the heavy chain and light chain. Such an antibody protein may be produced in a cell, such as a CHO cell. Alternatively, DNA encoding the antigen-specific chimeric antibodies or the variable domains of the light and heavy chains may be isolated directly from antigen-specific lymphocytes.

[0134] As described in the experimental section below, the high affinity chimeric antibodies, which are isolated having a human variable region and a mouse constant region, are characterized and selected for desirable characteristics, including affinity, selectivity, epitope, etc. The mouse constant regions are then replaced with a desired human constant region to generate the fully human antibody of the invention, for example wild-type or modified IgG1 or IgG4. While the constant region selected may vary according to specific use, high affinity antigen-binding and target specificity characteristics reside in the variable region.

[0135] In general, the antibodies of the instant invention possess very high affinities, typically possessing K_D of from about 10^{-12} through about 10^{-9} M, when measured by

binding to antigen either immobilized on solid phase or in solution phase.

Bioequivalents

[0136] The anti-GCG antibodies and antibody fragments of the present invention encompass proteins having amino acid sequences that vary from those of the described antibodies but that retain the ability to bind human GCG. Such variant antibodies and antibody fragments comprise one or more additions, deletions, or substitutions of amino acids when compared to parent sequence, but exhibit biological activity that is essentially equivalent to that of the described antibodies. Likewise, the anti-GCG antibody-encoding DNA sequences of the present invention encompass sequences that comprise one or more additions, deletions, or substitutions of nucleotides when compared to the disclosed sequence, but that encode an anti-GCG antibody or antibody fragment that is essentially bioequivalent to an anti-GCG antibody or antibody fragment of the invention. Examples of such variant amino acid and DNA sequences are discussed above.

[0137] Two antigen-binding proteins, or antibodies, are considered bioequivalent if, for example, they are pharmaceutical equivalents or pharmaceutical alternatives whose rate and extent of absorption do not show a significant difference when administered at the same molar dose under similar experimental conditions, either single does or multiple dose. Some antibodies will be considered equivalents or pharmaceutical alternatives if they are equivalent in the extent of their absorption but not in their rate of absorption and yet may be considered bioequivalent because such differences in the rate of absorption are intentional and are reflected in the labeling, are not essential to the attainment of effective body drug concentrations on, *e.g.*, chronic use, and are considered medically insignificant for the particular drug product studied.

[0138] In one embodiment, two antigen-binding proteins are bioequivalent if there are no clinically meaningful differences in their safety, purity, and potency.

[0139] In one embodiment, two antigen-binding proteins are bioequivalent if a patient can be switched one or more times between the reference product and the biological product without an expected increase in the risk of adverse effects, including a clinically significant change in immunogenicity, or diminished effectiveness, as compared to continued therapy without such switching.

[0140] In one embodiment, two antigen-binding proteins are bioequivalent if they both act by a common mechanism or mechanisms of action for the condition or conditions of use, to the extent that such mechanisms are known.

[0141] Bioequivalence may be demonstrated by *in vivo* and *in vitro* methods. Bioequivalence measures include, e.g., (a) an *in vivo* test in humans or other mammals, in which the concentration of the antibody or its metabolites is measured in blood, plasma, serum, or other biological fluid as a function of time; (b) an *in vitro* test that has

been correlated with and is reasonably predictive of human *in vivo* bioavailability data; (c) an *in vivo* test in humans or other mammals in which the appropriate acute pharmacological effect of the antibody (or its target) is measured as a function of time; and (d) in a well-controlled clinical trial that establishes safety, efficacy, or bioavailability or bioequivalence of an antibody.

[0142] Bioequivalent variants of anti-GCG antibodies of the invention may be constructed by, for example, making various substitutions of residues or sequences or deleting terminal or internal residues or sequences not needed for biological activity. For example, cysteine residues not essential for biological activity can be deleted or replaced with other amino acids to prevent formation of unnecessary or incorrect intramolecular disulfide bridges upon renaturation. In other contexts, bioequivalent antibodies may include anti-GCG antibody variants comprising amino acid changes, which modify the glycosylation characteristics of the antibodies, *e.g.*, mutations which eliminate or remove glycosylation.

Multispecific Antibodies

[0143] The antibodies of the present invention may be monospecific or multispecific (*e.g.*, bispecific). Multispecific antibodies may be specific for different epitopes of one target polypeptide or may contain antigen-binding domains specific for more than one target polypeptide. See, e.g., Tutt et al., 1991, J. Immunol. 147:60-69; Kufer *et al.*, 2004, Trends Biotechnol. 22:238-244. The anti-GCG antibodies of the present invention can be linked to or co-expressed with another functional molecule, e.g., another peptide or protein. For example, an antibody or fragment thereof can be functionally linked (e.g., by chemical coupling, genetic fusion, noncovalent association or otherwise) to one or more other molecular entities, such as another antibody or antibody fragment to produce a bi-specific or a multispecific antibody with a second binding specificity.

[0144] The present invention includes bispecific antibodies wherein one arm of an immunoglobulin binds human GCG, and the other arm of the immunoglobulin is specific for a second antigen. The GCG-binding arm can comprise any of the HCVR/LCVR or CDR amino acid sequences as set forth in Table 1 herein.

[0145] An exemplary bispecific antibody format that can be used in the context of the present invention involves the use of a first immunoglobulin (Ig) C_H3 domain and a second Ig C_H3 domain, wherein the first and second Ig C_H3 domains differ from one another by at least one amino acid, and wherein at least one amino acid difference reduces binding of the bispecific antibody to Protein A as compared to a bi-specific antibody lacking the amino acid difference. In one embodiment, the first Ig C_H3 domain binds Protein A and the second Ig C_H3 domain contains a mutation that reduces or abolishes Protein A binding such as an H95R modification (by IMGT exon numbering; H435R by EU numbering). The second C_H3 may further comprise a Y96F modification

(by IMGT; Y436F by EU). Further modifications that may be found within the second C_H3 include: D16E, L18M, N44S, K52N, V57M, and V82I (by IMGT; D356E, L358M, N384S, K392N, V397M, and V422I by EU) in the case of IgG1 antibodies; N44S, K52N, and V82I (IMGT; N384S, K392N, and V422I by EU) in the case of IgG2 antibodies; and Q15R, N44S, K52N, V57M, R69K, E79Q, and V82I (by IMGT; Q355R, N384S, K392N, V397M, R409K, E419Q, and V422I by EU) in the case of IgG4 antibodies. Variations on the bispecific antibody format described above are contemplated within the scope of the present invention.

[0146] Other exemplary bispecific formats that can be used in the context of the present invention include, without limitation, *e.g.*, scFv-based or diabody bispecific formats, IgG-scFv fusions, dual variable domain (DVD)-Ig, Quadroma, knobs-into-holes, common light chain (*e.g.*, common light chain with knobs-into-holes, etc.), CrossMab, CrossFab, (SEED)body, leucine zipper, Duobody, IgG1/IgG2, dual acting Fab (DAF)-IgG, and Mab^2 bispecific formats (*see*, *e.g.*, Klein *et al.* 2012, mAbs 4:6, 1-11, and references cited therein, for a review of the foregoing formats). Bispecific antibodies can also be constructed using peptide/nucleic acid conjugation, *e.g.*, wherein unnatural amino acids with orthogonal chemical reactivity are used to generate site-specific antibody-oligonucleotide conjugates which then self-assemble into multimeric complexes with defined composition, valency and geometry. (*See*, *e.g.*, Kazane *et al.*, *J. Am. Chem. Soc.* [*Epub*: *Dec. 4, 2012*]).

Therapeutic Formulation and Administration

[0147] The invention provides pharmaceutical compositions comprising the anti-GCG antibodies or antigen-binding fragments thereof of the present invention. The pharmaceutical compositions of the invention are formulated with suitable carriers, excipients, and other agents that provide improved transfer, delivery, tolerance, and the like. A multitude of appropriate formulations can be found in the formulary known to all pharmaceutical chemists: Remington's Pharmaceutical Sciences, Mack Publishing Company, Easton, PA. These formulations include, for example, powders, pastes, ointments, jellies, waxes, oils, lipids, lipid (cationic or anionic) containing vesicles (such as LIPOFECTIN™, Life Technologies, Carlsbad, CA), DNA conjugates, anhydrous absorption pastes, oil-in-water and water-in-oil emulsions, emulsions carbowax (polyethylene glycols of various molecular weights), semi-solid gels, and semi-solid mixtures containing carbowax. See also Powell et al. "Compendium of excipients for parenteral formulations" PDA (1998) J Pharm Sci Technol 52:238-311.

[0148] The dose of antibody administered to a patient may vary depending upon the age and the size of the patient, target disease, conditions, route of administration, and the like. The preferred dose is typically calculated according to body weight or body surface area. In an adult patient, it may be advantageous to intravenously administer

the antibody of the present invention normally at a single dose of about 0.01 to about 20 mg/kg body weight, more preferably about 0.02 to about 7, about 0.03 to about 5, or about 0.05 to about 3 mg/kg body weight. Depending on the severity of the condition, the frequency and the duration of the treatment can be adjusted. Effective dosages and schedules for administering anti-GCG antibodies may be determined empirically; for example, patient progress can be monitored by periodic assessment, and the dose adjusted accordingly. Moreover, interspecies scaling of dosages can be performed using well-known methods in the art (*e.g.*, Mordenti *et al.*, 1991, *Pharmaceut. Res. 8*:1351).

[0149] Various delivery systems are known and can be used to administer the pharmaceutical composition of the invention, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the mutant viruses, receptor mediated endocytosis (see, e.g., Wu et al., 1987, J. Biol. Chem. 262:4429-4432). Methods of introduction include, but are not limited to, intradermal, intramuscular, intraperitoneal, intravenous, subcutaneous, intranasal, epidural, and oral routes. The composition may be administered by any convenient route, for example by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (e.g., oral mucosa, rectal and intestinal mucosa, etc.) and may be administered together with other biologically active agents. Administration can be systemic or local.

[0150] A pharmaceutical composition of the present invention can be delivered subcutaneously or intravenously with a standard needle and syringe. In addition, with respect to subcutaneous delivery, a pen delivery device readily has applications in delivering a pharmaceutical composition of the present invention. Such a pen delivery device can be reusable or disposable. A reusable pen delivery device generally utilizes a replaceable cartridge that contains a pharmaceutical composition. Once all of the pharmaceutical composition within the cartridge has been administered and the cartridge is empty, the empty cartridge can readily be discarded and replaced with a new cartridge that contains the pharmaceutical composition. The pen delivery device can then be reused. In a disposable pen delivery device, there is no replaceable cartridge. Rather, the disposable pen delivery
device comes prefilled with the pharmaceutical composition held in a reservoir within the device. Once the reservoir is emptied of the pharmaceutical composition, the entire device is discarded.

[0151] Numerous reusable pen and autoinjector delivery devices have applications in the subcutaneous delivery of a pharmaceutical composition of the present invention. Examples include, but are not limited to AUTOPEN™ (Owen Mumford, Inc., Woodstock, UK), DISETRONIC™ pen (Disetronic Medical Systems, Bergdorf, Switzerland), HUMALOG MIX 75/25™ pen, HUMALOG™ pen, HUMALIN 70/30™ pen (Eli Lilly and

Co., Indianapolis, IN), NOVOPEN™ I, II and III (Novo Nordisk, Copenhagen, Denmark), NOVOPEN JUNIOR™ (Novo Nordisk, Copenhagen, Denmark), BD™ pen (Becton Dickinson, Franklin Lakes, NJ), OPTIPEN™, OPTIPEN PRO™, OPTIPEN STARLET™, and OPTICLIK™ (sanofi-aventis, Frankfurt, Germany), to name only a few. Examples of disposable pen delivery devices having applications in subcutaneous delivery of a pharmaceutical composition of the present invention include, but are not limited to the SOLOSTAR™ pen (sanofi-aventis), the FLEXPEN™ (Novo Nordisk), and the KWIKPEN™ (Eli Lilly), the SURECLICK™ Autoinjector (Amgen, Thousand Oaks, CA), the PENLET™ (Haselmeier, Stuttgart, Germany), the EPIPEN (Dey, L.P.), and the HUMIRA™ Pen (Abbott Labs, Abbott Park IL), to name only a few.

[0152] In certain situations, the pharmaceutical composition can be delivered in a controlled release system. In one embodiment, a pump may be used (see Langer, supra; Sefton, 1987, CRC Crit. Ref. Biomed. Eng. 14:201). In another embodiment, polymeric materials can be used; see, Medical Applications of Controlled Release, Langer and Wise (eds.), 1974, CRC Pres., Boca Raton, Florida. In yet another embodiment, a controlled release system can be placed in proximity of the composition's target, thus requiring only a fraction of the systemic dose (see, *e.g.*, Goodson, 1984, in Medical Applications of Controlled Release, supra, vol. 2, pp. 115-138). Other controlled release systems are discussed in the review by Langer, 1990, Science 249:1527-1533.

[0153] The injectable preparations may include dosage forms for intravenous, subcutaneous, intracutaneous and intramuscular injections, drip infusions, etc. These injectable preparations may be prepared by methods publicly known. For example, the injectable preparations may be prepared, *e.g.*, by dissolving, suspending or emulsifying the antibody or its salt described above in a sterile aqueous medium or an oily medium conventionally used for injections. As the aqueous medium for injections, there are, for example, physiological saline, an isotonic solution containing glucose and other auxiliary agents, etc., which may be used in combination with an appropriate solubilizing agent such as an alcohol (e.g., ethanol), a polyalcohol (e.g., propylene glycol, polyethylene glycol), a nonionic surfactant [e.g., polysorbate 80, HCO-50 (polyoxyethylene (50 mol) adduct of hydrogenated castor oil)], etc. As the oily medium, there are employed, e.g., sesame oil, soybean oil, etc., which may be used in combination with a solubilizing agent such as benzyl benzoate, benzyl alcohol, etc. The injection thus prepared is preferably filled in an appropriate ampoule.

[0154] Advantageously, the pharmaceutical compositions for oral or parenteral use described above are prepared into dosage forms in a unit dose suited to fit a dose of the active ingredients. Such dosage forms in a unit dose include, for example, tablets, pills, capsules, injections (ampoules), suppositories, etc. The amount of the aforesaid antibody contained is generally about 5 to about 500 mg per dosage form in a unit dose;

especially in the form of injection, it is preferred that the aforesaid antibody is contained in about 5 to about 100 mg and in about 10 to about 250 mg for the other dosage forms.

Immunoconjugates

[0155] The invention encompasses a human anti-GCG monoclonal antibody conjugated to a therapeutic moiety ("immunoconjugate"), such as an agent that is capable of reducing blood glucose levels, or a radioisotope, or a chemotherapeutic agent. The type of therapeutic moiety that may be conjugated to the anti-GCG antibody will take into account the condition to be treated and the desired therapeutic effect to be achieved. For example, for treating diabetes, or any other condition whereby it is desirable to lower blood glucose, and/or to maintain normal blood glucose levels, an agent such as biguanide (*e.g.* metformin), a sulfonylurea (*e.g.* glyburide, glipizide), a PPAR gamma agonist (*e.g.* pioglitazone, rosiglitazone); an alpha glucosidase inhibitor (*e.g.* acarbose, voglibose), an inhibitor of advanced glycation endproduct formation (*e.g.* aminoguanidine), or a second GCG inhibitor may be conjugated to the GCG antibody. Alternatively, if the desired therapeutic effect is to treat the sequelae or symptoms associated with diabetes, or any other condition resulting from high, or uncontrolled blood glucose levels, it may be advantageous to conjugate an agent appropriate to treat the sequelae or symptoms of the condition Examples of suitable agents for forming immunoconjugates are known in the art, see for example, WO 05/103081.

Therapeutic Uses of the Antibodies

[0156] Due to their interaction with glucagon, the present antibodies are useful for lowering blood glucose levels and also for the treatment of a wide range of conditions and disorders in which blocking the interaction of glucagon with its receptor is beneficial. These disorders and conditions may be selected from any glucagon related metabolic disorder, which involves glucagon receptor signaling that results in the pathophysiology of the disorder, or in the homeostatic response to the disorder. Thus, the antibodies may find use for example to prevent, treat, or alleviate, diseases or conditions or associated symptoms or sequelae, of the endocrine system, the central nervous system, the peripheral nervous system, the cardiovascular system, the pulmonary system, and the gastrointestinal system, while reducing and or eliminating one or more of the unwanted side effects associated with the current treatments. Glucagon related metabolic disorders include, but are not limited to, type 1 and type 2 diabetes, diabetic ketoacidosis, hyperglycemia, hyperglycemic hyperosmolar syndrome, perioperative hyperglycemia, hyperglycemia in the intensive care unit patient, hyperinsulinemia, postprandial hyperglycemia, hyperglycemia associated with burns, or myocardial infarct, or other cardiac problems/conditions, impaired fasting glucose (IFG), metabolic syndrome, hyper-/hypokalemia, poor LDL/HDL ratio, eating disorders, weight gain,

obesity as a consequence of diabetes, pediatric diabetes, gestational diabetes, diabetic late complications, micro-/macroalbuminuria, nephropathy, retinopathy, neuropathy, diabetic foot ulcers, wound healing, impaired glucose tolerance (IGT), insulin resistance syndromes, syndrome X, glucagonomas, gastrointestinal disorders, obesity, diabetes as a consequence of obesity, etc. The present invention further provides; a method of treating conditions resulting from excessive glucagon in a mammal; a method of inhibiting the glucose elevating effects of glucagon in a mammal; a method of inhibiting a glucagon mediated cellular response in a mammal, or a method of reducing the glycemic level in a mammal comprising administering to a mammal in need of such treatment a glucagon inhibiting amount of an anti-GCG antibody or a biologically active fragment thereof.

[0157] In one embodiment, the antibodies of the present invention may be used to prevent the onset of hyperglycemia, for example, stress-induced hyperglycemia, or to reduce the likelihood of onset of hyperglycemia in a patient, or may be used to reduce the severity of a disease or condition resulting in part from elevated blood glucose levels. In such a setting, it is envisioned that the anti-GCG antibodies of the present invention may be used in an acute setting, either alone, or in conjunction with a second therapeutic agent, for example, insulin. In one embodiment, the anti-GCG antibodies may be used as chronic therapy to lower blood glucose or to maintain normal levels of blood glucose when used alone or with a second therapeutic agent, such as insulin.

[0158] The present antibodies are effective in lowering blood glucose, both in the fasting and the postprandial stage. In certain embodiments of the invention, the present antibodies are used for the preparation of a pharmaceutical composition for the treatment of type 2 diabetes. In yet a further embodiment of the invention the present antibodies are used for the preparation of a pharmaceutical composition for the delaying or prevention of the progression from impaired glucose tolerance to type 2 diabetes. In yet another embodiment of the invention the present antibodies are used for the preparation of a pharmaceutical composition for the delaying or prevention of the progression from non-insulin requiring diabetes to insulin requiring diabetes. In a further embodiment of the invention the present antibodies are used for the preparation of a pharmaceutical composition for the treatment of type 1 diabetes.

[0159] In another embodiment, the antibodies of the invention are useful for treating stress hyperglycemia resulting from exposure of a patient to any one or more stressors, or to a stress-inducing stimulus, or to a glucose elevating stimulus selected from the group consisting of pre-existing type 1 or type 2 diabetes, hypertonic dehydration, infusion of catecholamine pressors, parenteral nutrition, enteral nutrition, glucocorticoid therapy, obesity, aging, excessive dextrose administration, pancreatitis, sepsis, stroke, a myocardial infarct or other cardiac condition, burns, traumatic head injury, hypothermia,

hypoxemia, uremia, cirrhosis, anesthesia, pre-operative or post-operative hospital stays (peri-operative hyperglycemia), admission to an emergency room, a trauma center, or an intensive care unit, prolonged hospital stays, surgical procedures, an infection and a chronic illness.

[0160] It is envisioned that the antibodies of the invention may be used in an acute setting (for short term use), or for longer term (chronic) use. Such treatment may be accompanied by insulin therapy, or other glucose lowering therapy.

Combination Therapies

[0161] Combination therapies may include an anti-GCG antibody of the invention and any additional therapeutic agent that may be advantageously combined with an antibody of the invention, or with a biologically active fragment of an antibody of the invention.

[0162] For example, a second therapeutic agent may be employed to aid in further lowering of glucose levels, or to reduce at least one symptom in a patient suffering from a disease or condition characterized by high blood glucose levels, such as diabetes mellitus. Such a second agent may be selected from, for example, a glucagon receptor antagonist (as described in, for example, US8545847), or another GCG antagonist (*e.g.* another different anti-glucagon antibody or an anti-GCGR antibody or small molecule inhibitor of glucagon or GCGR), or may include other therapeutic moieties useful for treating diabetes, or other diseases or conditions associated with, or resulting from elevated blood glucose levels, or impaired glucose metabolism, or agents useful for treating any long term complications associated with elevated and/or uncontrolled blood glucose levels. These agents include biguanides, which decrease glucose production in the liver and increase sensitivity to insulin (*e.g.* metformin), or sulfonylureas, which stimulate insulin production (*e.g.* glyburide, glipizide). Additional treatments directed at maintaining glucose homeostasis including PPAR gamma agonists, such as the thiazolidinediones, which act as insulin sensitizers (*e.g.* pioglitazone, rosiglitazone); and alpha glucosidase inhibitors, which slow starch absorption and glucose production (*e.g.* acarbose, voglibose). Additional treatments include injectable treatments such as a glucagon-like peptide 1 (GLP-1) analogue or agonist, for example, BYETTA® (exenatide) or VICTOZA® (liraglutide). Another treatment may be with SYMLIN® (pramlintide), which is an analogue of amylin, a small peptide hormone that is released into the bloodstream by the β cells of the pancreas along with insulin, after a meal. By augmenting endogenous amylin, pramlintide aids in the absorption of glucose by slowing gastric emptying, promoting satiety via hypothalamic receptors (different receptors than for GLP-1), and inhibiting inappropriate secretion of glucagon. Other compounds that may be used in combination with the antibodies of the invention include dipeptidyl peptidase IV inhibitors, (DPP-4 inhibitors), which reduce glucagon and blood glucose

levels. The mechanism of DPP-4 inhibitors is to increase incretin levels (GLP-1 and GIP), which inhibit glucagon release, which in turn increases insulin secretion, decreases gastric emptying, and decreases blood glucose levels. Examples of DPP-4 inhibitors include saxagliptin (ONGLYZA®), sitaliptin (JANUVIA®), and vildagliptin (GALVUS®). Other compounds that may be used in combination with the antibodies of the invention include sodium-glucose co-transporter 2 (SGLT2) inhibitors, which block the reabsorption of glucose in the kidney, increase glucose excretion and lower blood glucose levels. Examples of SGLT2 inhibitors include INVOKANA™ (canagliflozin), FORXIGA® (dapagliflozin), empagliflozin, ipragliflozin and tofogliflozin.

[0163] In certain other embodiments, the composition may include a second agent selected from the group consisting of non-sulfonylurea secretagogues, insulin, insulin analogs, exendin-4 polypeptides, beta 3 adrenoceptor agonists, statins and statin-containing combinations, cholesterol absorption inhibitors, LDL-cholesterol antagonists, cholesteryl ester transfer protein antagonists, endothelin receptor antagonists, growth hormone antagonists, insulin sensitizers, amylin mimetics or agonists, cannabinoid receptor antagonists, glucagon-like peptide-1 agonists, melanocortins, melanin-concentrating hormone receptor agonists, SNRIs, and protein tyrosine phosphatase inhibitors.

[0164] In certain other embodiments, combination therapy may include administration of a second agent to counteract any potential side effect(s) resulting from administration of an antibody of the invention, if such side effect(s) occur. For example, in the event that any of the anti-GCG antibodies increases lipid or cholesterol levels, it may be beneficial to administer a second agent to lower lipid or cholesterol levels, using an agent such as a HMG-CoA reductase inhibitor (for example, a statin such as atorvastatin, (LIPITOR®), fluvastatin (LESCOL®), lovastatin (MEVACOR®), pitavastatin (LIVALO®), pravastatin (PRAVACHOL®), rosuvastatin (CRESTOR®) and simvastatin (ZOCOR®). Alternatively, the antibodies of the invention may be combined with an agent such as VYTORIN®, which is a preparation of a statin and another agent—such as ezetimibe/simvastatin.

[0165] In certain embodiments, it may be beneficial to administer the antibodies of the invention in combination with any one or more of the following: (1) niacin, which increases lipoprotein catabolism; (2) fibrates or amphipathic carboxylic acids, which reduce low-density lipoprotein (LDL) level, improve high-density lipoprotein (HDL) and TG levels, and reduce the number of non-fatal heart attacks; and (3) activators of the LXR transcription factor that plays a role in cholesterol elimination such as 22-hydroxycholesterol, or a statin with a bile resin (*e.g.*, cholestyramine, colestipol, colesevelam), a fixed combination of niacin plus a statin (*e.g.*, niacin with lovastatin); or with other lipid lowering agents such as omega-3-fatty acid ethyl esters (for example,

omacor).

[0166] Furthermore, the second therapeutic agent can be one or more other inhibitor/antagonist of glucagon or an inhibitor/antagonist of the glucagon receptor (GCGR), as well as inhibitors of other molecules, such as angiopoietin-like protein 3 (ANGPTL3), angiopoietin-like protein 4 (ANGPTL4), angiopoietin-like protein 5 (ANGPTL5), angiopoietin-like protein 6 (ANGPTL6), angiopoietin-like protein 8 (ANGPTL8), which are involved in lipid metabolism, in particular, cholesterol and/or triglyceride homeostasis. Inhibitors of these molecules include small molecules and/or antibodies that specifically bind to these molecules and block their activity.

[0167] In certain embodiments, it may be beneficial to administer the antibodies of the invention in combination with an antibody that acts to lower lipid or cholesterol levels, such as, but not limited to, for example, any anti-PCSK9 (proprotein convertase subtilisin/kexin type 9) antibody, such as those described in US2010/0166768 (now US8062640). Other anti-PCSK9 antibodies are described in US2010/0040611, US2010/0041102, US2010/0040610, US2010/0113575, US2009/0232795, US2009/0246192, US2010/0233177, US2009/0142352, US2009/0326202, US2010/0068199, US2011/0033465, US2011/0027287, US2010/0150937, US2010/0136028 and WO2009/055783.

[0168] In certain embodiments, it may be beneficial to administer the anti-GCG antibodies of the invention in combination with a nucleic acid that inhibits the activity of PCSK9 (proprotein convertase subtilisin/kexin type 9), such as an antisense molecule, a double stranded RNA, or a siRNA molecule. Exemplary nucleic acid molecules that inhibit the activity of PCSK9 are described in US2011/0065644, US2011/0039914, US2008/0015162 and US2007/0173473.

[0169] The additional therapeutically active component(s) may be administered prior to, concurrent with, or after the administration of the anti-GCG antibody of the present invention. For purposes of the present disclosure, such administration regimens are considered the administration of an anti-GCG antibody "in combination with" a second therapeutically active component.

Administration Regimens

[0170] According to certain embodiments of the present invention, multiple doses of an anti-GCG antibody (or a pharmaceutical composition comprising a combination of an anti-GCG antibody and any of the additional therapeutically active agents mentioned herein) may be administered to a subject over a defined time course. The methods according to this aspect of the invention comprise sequentially administering to a subject multiple doses of an anti-GCG antibody of the invention. As used herein, "sequentially administering" means that each dose of anti-GCG antibody is administered to the subject at a different point in time, *e.g.*, on different days separated by a predetermined

interval (*e.g.*, hours, days, weeks or months). The present invention includes methods which comprise sequentially administering to the patient a single initial dose of an anti-GCG antibody, followed by one or more secondary doses of the anti-GCG antibody, and optionally followed by one or more tertiary doses of the anti-GCG antibody.

[0171] The terms "initial dose," "secondary doses," and "tertiary doses," refer to the temporal sequence of administration of the anti-GCG antibody of the invention. Thus, the "initial dose" is the dose which is administered at the beginning of the treatment regimen (also referred to as the "baseline dose"); the "secondary doses" are the doses which are administered after the initial dose; and the "tertiary doses" are the doses which are administered after the secondary doses. The initial, secondary, and tertiary doses may all contain the same amount of anti-GCG antibody, but generally may differ from one another in terms of frequency of administration. In certain embodiments, however, the amount of anti-GCG antibody contained in the initial, secondary and/or tertiary doses varies from one another (*e.g.*, adjusted up or down as appropriate) during the course of treatment. In certain embodiments, two or more (*e.g.*, 2, 3, 4, or 5) doses are administered at the beginning of the treatment regimen as "loading doses" followed by subsequent doses that are administered on a less frequent basis (*e.g.*, "maintenance doses").

[0172] In certain exemplary embodiments of the present invention, each secondary and/or tertiary dose is administered 1 to 26 (*e.g.*, 1, 1½, 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 6½, 7, 7½, 8, 8½, 9, 9½, 10, 10½, 11, 11½, 12, 12½, 13, 13½, 14, 14½, 15, 15½, 16, 16½, 17, 17½, 18, 18½, 19, 19½, 20, 20½, 21, 21½, 22, 22½, 23, 23½, 24, 24½, 25, 25½, 26, 26½, or more) weeks after the immediately preceding dose. The phrase "the immediately preceding dose," as used herein, means, in a sequence of multiple administrations, the dose of anti-GCG antibody, which is administered to a patient prior to the administration of the very next dose in the sequence with no intervening doses.

[0173] The methods according to this aspect of the invention may comprise administering to a patient any number of secondary and/or tertiary doses of an anti-GCG antibody. For example, in certain embodiments, only a single secondary dose is administered to the patient. In other embodiments, two or more (*e.g.*, 2, 3, 4, 5, 6, 7, 8, or more) secondary doses are administered to the patient. Likewise, in certain embodiments, only a single tertiary dose is administered to the patient. In other embodiments, two or more (*e.g.*, 2, 3, 4, 5, 6, 7, 8, or more) tertiary doses are administered to the patient. The administration regimen may be carried out indefinitely over the lifetime of a particular subject, or until such treatment is no longer therapeutically needed or advantageous.

[0174] In embodiments involving multiple secondary doses, each secondary dose may be administered at the same frequency as the other secondary doses. For example,

each secondary dose may be administered to the patient 1 to 2 weeks or 1 to 2 months after the immediately preceding dose. Similarly, in embodiments involving multiple tertiary doses, each tertiary dose may be administered at the same frequency as the other tertiary doses. For example, each tertiary dose may be administered to the patient 2 to 12 weeks after the immediately preceding dose. In certain embodiments of the invention, the frequency at which the secondary and/or tertiary doses are administered to a patient can vary over the course of the treatment regimen. The frequency of administration may also be adjusted during the course of treatment by a physician depending on the needs of the individual patient following clinical examination.

Diagnostic Uses of the Antibodies

[0175] The anti-GCG antibodies of the present invention may also be used to detect and/or measure GCG in a sample, *e.g.*, for diagnostic purposes. For example, an anti-GCG antibody, or fragment thereof, may be used to diagnose a condition or disease characterized by aberrant expression (*e.g.*, over-expression, under-expression, lack of expression, etc.) of GCG. Exemplary diagnostic assays for GCG may comprise, *e.g.*, contacting a sample, obtained from a patient, with an anti-GCG antibody of the invention, wherein the anti-GCG antibody is labeled with a detectable label or reporter molecule or used as a capture ligand to selectively isolate GCG protein from patient samples. Alternatively, an unlabeled anti-GCG antibody can be used in diagnostic applications in combination with a secondary antibody which is itself detectably labeled. The detectable label or reporter molecule can be a radioisotope, such as ^{3}H, ^{14}C, ^{32}P, ^{35}S, or ^{125}I; a fluorescent or chemiluminescent moiety such as fluorescein isothiocyanate, or rhodamine; or an enzyme such as alkaline phosphatase, β-galactosidase, horseradish peroxidase, or luciferase. Specific exemplary assays that can be used to detect or measure GCG in a sample include enzyme-linked immunosorbent assay (ELISA), radioimmunoassay (RIA), and fluorescence-activated cell sorting (FACS).

[0176] Samples that can be used in GCG diagnostic assays according to the present invention include any tissue or fluid sample obtainable from a patient, which contains detectable quantities of GCG protein, or fragments thereof, under normal or pathological conditions. Generally, levels of GCG in a particular sample obtained from a healthy patient (*e.g.*, a patient not afflicted with a disease or condition associated with abnormal GCG levels or activity) will be measured to initially establish a baseline, or standard, level of GCG. This baseline level of GCG can then be compared against the levels of GCG measured in samples obtained from individuals suspected of having a GCG related disease or condition, or symptoms associated with such disease or condition.

EXAMPLES

[0177] Before the present methods are described, it is to be understood that this

invention is not limited to particular methods, and experimental conditions described, as such methods and conditions may vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention will be limited only by the appended claims. Efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is average molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

[0178] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. As used herein, the term "about," when used in reference to a particular recited numerical value, means that the value may vary from the recited value by no more than 1%. For example, as used herein, the expression "about 100" includes 99 and 101 and all values in between (*e.g.*, 99.1, 99.2, 99.3, 99.4, etc.).

[0179] Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, preferred methods and materials are now described. All publications mentioned herein are incorporated herein by reference in their entirety.

Example 1. Generation of Anti-GCG Antibodies

[0180] Anti-GCG antibodies were obtained by immunizing a VELOCIMMUNE® mouse (*i.e.*, an engineered mouse comprising DNA encoding human immunoglobulin heavy and kappa light chain variable regions) with an immunogen comprising human GCG. The antibody immune response was monitored by a GCG-specific immunoassay. When a desired immune response was achieved, several fully human anti-GCG antibodies were generated from antigen-positive B cells as described in US 2007/0280945A1, incorporated by reference herein in its entirety.

[0181] Certain biological properties of the exemplary anti-GCG antibodies generated in accordance with the methods of this Example are described in detail in the Examples set forth below.

Example 2. Heavy and Light Chain Variable Region Amino Acid and Nucleic Acid Sequences

[0182] Table 1 sets forth the amino acid sequence identifiers of the heavy and light chain variable regions and CDRs of selected anti-GCG antibodies of the invention. The corresponding nucleic acid sequence identifiers are set forth in Table 2.

Table 1: Amino Acid Sequence Identifiers

	SEQ ID NOs:							
Antibody Designation	HCVR	HCDR1	HCDR2	HCDR3	LCVR	LCDR1	LCDR2	LCDR3
H1H059P	2	4	6	8	10	12	14	16
H4H10223P	18	20	22	24	26	28	30	32
H4H10231P	34	36	38	40	42	44	46	48
H4H10232P	50	52	54	56	58	60	62	64
H4H10236P	66	68	70	72	74	76	78	80
H4H10237P	82	84	86	88	90	92	94	96
H4H10238P	98	100	102	104	106	108	110	112
H4H10250P	114	116	118	120	122	124	126	128
H4H10256P	130	132	134	136	138	140	142	144
H4H10270P	146	148	150	152	154	156	158	160

Table 2: Nucleic Acid Sequence Identifiers

	SEQ ID NOs:							
Antibody Designation	HCVR	HCDR1	HCDR2	HCDR3	LCVR	LCDR1	LCDR2	LCDR3
H1H059P	1	3	5	7	9	11	13	15
H4H10223P	17	19	21	23	25	27	29	31
H4H10231P	33	35	37	39	41	43	45	47
H4H10232P	49	51	53	55	57	59	61	63
H4H10236P	65	67	69	71	73	75	77	79
H4H10237P	81	83	85	87	89	91	93	95
H4H10238P	97	99	101	103	105	107	109	111
H4H10250P	113	115	117	119	121	123	125	127
H4H10256P	129	131	133	135	137	139	141	143
H4H10270P	145	147	149	151	153	155	157	159

[0183] Antibodies are typically referred to herein according to the following nomenclature: Fc prefix (*e.g.* "H1H," "H1M," "H2M," etc.), followed by a numerical identifier (*e.g.* "10223," "10231," "10232," etc.), followed by a "P" or "N" suffix, as shown in Tables 1 and 2. Thus, according to this nomenclature, an antibody may be referred to herein as, *e.g.*, "H4H10270P", etc. The H4H prefix on the antibody designations used herein indicate the particular Fc region isotype of the antibody. For example, an "H4H" antibody has a human IgG4 Fc, an "H1M" antibody has a mouse IgG1 Fc, and an "H2M" antibody has a mouse IgG2 Fc, (all variable regions are fully human as denoted by the first 'H' in the antibody designation). As will be appreciated by a person of ordinary skill in the art, an antibody having a particular Fc isotype can be converted to an antibody

with a different Fc isotype (*e.g.*, an antibody with a mouse IgG1 Fc can be converted to an antibody with a human IgG4, etc.), but in any event, the variable domains (including the CDRs) – which are indicated by the numerical identifiers shown in Tables 1 and 2 – will remain the same, and the binding properties are expected to be identical or substantially similar regardless of the nature of the Fc domain.

Example 2. Variable Gene Utilization Analysis

[0184] To analyze the structure of antibodies produced, the nucleic acids encoding antibody variable regions were cloned and sequenced. From the nucleic acid sequence and predicted amino acid sequence of the antibodies, gene usage was identified for each Heavy Chain Variable Region (HCVR) and Light Chain Variable Region (LCVR). Table 3 sets forth the gene usage for selected antibodies in accordance with the invention.

Table 3

	HCVR			LCVR	
AbPID	**VH**	**D**	**JH**	**VK**	**JK**
H1H059P	3-30	2-2	4	4-1	1
H4H10223P	3-30	3-3	4	4-1	2
H4H10231P	3-30	3-3	4	4-1	2
H4H10232P	3-30	3-3	4	4-1	2
H4H10236P	3-30	3-3	4	4-1	2
H4H10237P	3-30	3-3	4	4-1	2
H4H10238P	3-30	3-3	4	4-1	2
H4H10250P	3-30	3-3	4	4-1	2
H4H10256P	3-30	3-3	4	4-1	2
H4H10270P	3-30	3-3	4	4-1	2

Example 3. Surface Plasmon Resonance Derived Binding Affinities and Kinetic Constants of Human Monoclonal Anti-GCG Antibodies

[0185] Equilibrium dissociation constants (K_D) values for purified anti-GCG antibodies binding to human GCG were determined using a real-time surface plasmon resonance biosensor assay on a Biacore 4000 instrument. The Biacore sensor surface was derivatized with a monoclonal mouse anti-human Fc antibody (GE Healthcare, # BR-1008-39) to capture each anti-GCG monoclonal antibody. Different concentrations of human GCG (Phoenix Pharmaceuticals, # 028-02) were injected over the anti-GCG monoclonal antibody captured surface at a flow rate of 30μL/min. Binding of GCG to the captured monoclonal antibodies was monitored for 4 minutes while the dissociation was monitored for 10 minutes in HBST running buffer (0.01 M HEPES pH 7.4, 0.15 M NaCl, 3 mM EDTA, 0.05% v/v Surfactant P20). Experiments were performed at 25°C and 37°C.

[0186] Kinetic association (k_a) and dissociation (k_d) rate constants were determined by processing and fitting the data to a 1:1 binding model using Scrubber 2.0c curve fitting

software. Binding dissociation equilibrium constants (K_D) and dissociative half-lives (t½) were calculated from the kinetic rate constants as:

$$K_D\ (M) = kd/ka\ , \quad \text{and} \quad t½\ (min) = \frac{\ln(2)}{60 * kd}$$

[0187] Binding kinetics parameters for different anti-GCG monoclonal antibodies binding to human GCG reagents at 25°C and 37°C are shown in Tables 4 and 5, respectively.

Table 4: Binding kinetics of anti-GCG antibodies binding to human GCG at 25°C.

Human GCG Binding at 25°C				
Antibody	k_a	k_d	K_D	t½
	(1/Ms)	(1/s)	(M)	(min)
H4H10236P	3.08E+06	7.46E-04	2.42E-10	15
H4H10237P	4.96E+06	1.03E-03	2.08E-10	11
H4H10238P	3.89E+06	6.20E-04	1.60E-10	19
H4H10250P	3.32E+06	9.39E-04	2.83E-10	12
H4H10256P	7.72E+06	5.82E-04	7.53E-11	20
H4H10270P	4.80E+06	7.32E-04	1.53E-10	16
H4H10223P	9.36E+06	5.41E-04	5.78E-11	21
H4H10231P	7.39E+06	6.85E-04	9.27E-11	17
H4H10232P	3.19E+06	2.31E-04	7.24E-11	50
H1H059P	2.50E+06	1.78E-03	7.15E-10	6

Table 5: Binding kinetics of anti-GCG antibodies binding to human GCG at 37°C.

Human GCG Binding at 37°C				
Antibody	k_a	k_d	K_D	t½
	(1/Ms)	(1/s)	(M)	(min)
H4H10236P	4.25E+06	8.80E-03	2.08E-09	1
H4H10237P	7.53E+06	6.83E-03	9.07E-10	2
H4H10238P	4.94E+06	2.74E-03	5.55E-10	4
H4H10250P	5.58E+06	7.08E-03	1.27E-09	2
H4H10256P	7.90E+06	2.48E-03	3.14E-10	5
H4H10270P	6.77E+06	3.78E-03	5.59E-10	3
H4H10223P	6.40E+06	2.23E-03	3.47E-10	5

H4H10231P	2.40E+06	2.45E-03	1.01E-09	5
H4H10232P	4.61E+06	1.47E-03	3.18E-10	8
H1H059P	4.90E+06	2.36E-02	4.78E-09	0.5

[0188] As shown in Table 4, all of the anti-GCG antibodies bound human GCG at 25°C with K_D values ranging from 57.8pM to about 715pM. As shown in Table 5, all of the anti-GCG antibodies bound human GCG at 37°C with K_D values ranging from 314pM to about 4.78nM.

Example 4. GCG bioassay with HEK293/CRE-luciferase/hGCGR cells

[0189] GCGR is a G-protein coupled receptor and its ligand, glucagon (GCG), stimulates adenylyl cyclase activity through G□s and phosphoinositol turnover through Gq (Jiang and Zhang, (2003), Amer. J. Physiol.- Endocrinol. And Metabolism, 1 April, Vol. 284, No. E671-E678). A bioassay was developed to detect activation through G□s, subsequent elevation of cAMP levels, and transcriptional activation. HEK293 cell lines were generated to stably express full-length human GCGR (hGCGR; amino acids 1-477 of accession number NP000151.1) along with a luciferase reporter [cAMP response element (CRE, 4X)-luciferase-IRES-GFP]. The stable cell line (HEK293/CRE-luc/hGCGR cells) was isolated and maintained in DMEM containing 10% FBS, NEAA, and pencillin/streptomycin/L-glutamine.

[0190] For the bioassay, HEK293/CRE-luc/hGCGR cells were seeded onto 96-well assay plates at 10,000 cells/well in low serum media (OPTIMEM containing 0.1%FBS), and incubated at 37°C in 5% CO_2 overnight. The next day, human GCG (Phoenix Pharmaceuticals, # 028-02) was serially diluted at 1:3 from 10nM to 0.0002nM and added to cells. A control containing dilution buffer but no GCG was also added to one sample of cells. To measure inhibition, anti-GCG antibodies were serially diluted at 1:3 from 100nM to 0.002nM and added to cells including a control sample containing no antibody with a constant concentration of 40pM GCG. After 5.5 hours of incubation at 37°C in 5% CO_2, luciferase activity was detected using a Victor X plate reader (Perkin Elmer). The results were analyzed using nonlinear regression (4-parameter logistics) with Prism 6 software (GraphPad).

[0191] As shown in Table 6, all 10 anti-GCG antibodies tested inhibited all activation of HEK293/CRE-luc/hGCGR cells by 40pM of GCG with IC_{50} values ranging from 7.3pM to 910pM. The isotype control antibody did not demonstrate any measurable blockade and GCG activated the HEK293/CRE-luc/hGCGR cell line with an EC_{50} value of 53pM.

Table 6: Inhibition of GCG activation of HEK293/CRE-luc/hGCGR cells by anti-GCG antibodies

GCG EC_{50} [M]	5.3E-11
GCG constant used to test antibodies	**40pM**
Antibodies	**IC_{50} [M]**
H4H10223P	9.5E-12
H4H10231P	7.3E-12
H4H10232P	2.3E-11
H4H10236P	2.5E-10
H4H10237P	3.4E-11
H4H10238P	1.8E-11
H4H10250P	3.4E-11
H4H10256P	1.8E-11
H4H10270P	2.2E-11
H1H059P	9.1E-10
Isotype control antibody	Non-blocker

Example 5. The effect of a Single Dose of H4H10223P in diet-induced obesity mouse in an *in vivo* model of type 2 diabetes

[0192] The effects of a single dose of a specific anti-GCG antibody of the invention, H4H10223P, on blood glucose levels was determined in a diet-induced obesity (DIO) mouse model of type 2 diabetes. The DIO model is developed by feeding mice a high fat (60% kcal) diet (HFD) starting at 5~6 weeks of age. After approximately 6 weeks on the HFD, mice develop metabolic abnormalities, including insulin resistance, glucose intolerance, and obesity. Twenty-three 3-month-old male C57BL/6 mice (Taconic farms, Inc., B6-M) were placed on a HFD at 5 weeks of age and were kept on the diet for the subsequent 4 months. At 7 months of age, the mice were divided into 4 groups of 2 to 4 animals. Each group received a single subcutaneous injection of H4H10223P at 3 mg/kg (n=5), 10 mg/kg (n=3), or 30 mg/kg (n=2) or an isotype control antibody, which does not bind to any known mouse protein, at 30 mg/kg (n=5). At days 2, 4, 7, and 9 following antibody dosing, tail bleeds were collected from mice. Blood glucose levels from the tail bleed samples were determined using ACCU-CHEK® Compact Plus (Roche, 075177294001). The percent reduction in blood glucose from the mean blood glucose levels of the control group was calculated for each animal at each time point. The average percent reduction in blood glucose was calculated for each treatment group. Table 7 summarizes the mean blood glucose levels of each treatment group. Results, expressed as (mean ± SEM) of percent blood glucose reduction, are shown in Table 8.

[0193] As shown in Tables 7 and 8, mice treated with a single dose of H4H10223P at 30 mg/kg exhibited significant reductions in blood glucose levels at all time points

measured compared to mice injected with isotype control antibody. Mice treated with a single dose of H4H10223P at 3 mg/kg exhibited a significant reduction in blood glucose levels at day 2 compared to mice injected with isotype control antibody, but there were no significant reductions at this dosage observed at the other time points measured. Mice treated with a single dose of H4H10223P at 10 mg/kg exhibited a significant reduction in blood glucose levels at day 2 compared to mice injected with isotype control antibody, and there were reduction trends at this dosage observed at the other time points measured.

Table 7: Blood glucose levels (mg/dL) from each treatment group

Time (days)	Blood glucose level (mg/dL)			
	Control	H4H10223P		
	30 mg/kg	3 mg/kg	10 mg/kg	30 mg/kg
0	210 ± 6	209 ± 8	209 ± 10	209 ± 12
2	192 ± 8	172 ± 7	164 ± 7	142 ± 5
4	168 ± 10	181 ± 6	152 ± 18	137 ± 2
7	178 ± 12	173 ± 8	169 ± 3	149 ± 1
9	174 ± 10	179 ± 4	170 ± 30	155 ± 7

Table 8: Percent reduction in blood glucose levels from each treatment group as compared to isotype control treatment

Time (days)	Blood glucose reduction (%)		
	H4H10223P		
	3 mg/kg	10 mg/kg	30 mg/kg
2	10 ± 3	14 ± 4	26 ± 2
4	-8 ± 3	9 ± 11	18 ± 1
7	3 ± 5	5 ± 2	16 ± 1
9	-3 ± 3	2 ± 17	11 ± 4

Example 6. The effect of Multiple Doses (chronic administration) of anti-GCG Antibodies H4H10223P and H4H10231P in an *in vivo* diet-induced obesity mouse model of type 2 diabetes

[0194] The chronic effects of specific anti-GCG antibodies of the invention, H4H10223P and H4H10231P, on blood glucose levels were determined in a diet-induced obesity (DIO) mouse model of type 2 diabetes. As noted above, the DIO model is developed by feeding mice a high fat (60% kcal) diet (HFD) starting at approximately 5 to 6 weeks of age.

[0195] In one experiment (Study 1), Thirteen male C57BL/6 mice (Taconic Farms, Inc., # B6-M) were placed on a HFD at 5 weeks of age and were kept on the diet for the subsequent 21 weeks. At 26 weeks of age, the mice were divided into 2 groups of 5 or 8 animals. Each group received subcutaneous injections of H4H10223P (n=5; 30 mg/kg), or an isotype control antibody (n=8; 30 mg/kg), which does not bind to any known mouse protein, every five days. Two, 6, 9, 13, 16 and 20 days following the initial antibody dosing, tail bleeds were collected from mice. Blood glucose levels from the tail bleed

samples were determined using ACCU-CHEK® Compact Plus (Roche, # 075177294001). The percent reduction in blood glucose from the mean blood glucose levels of the control group was calculated for each animal at each time point. The mean percent reduction in blood glucose was calculated for the H4H10223P group at each time point.

[0196] Table 9 summarizes the mean blood glucose levels of each treatment group and mean percent blood glucose reductions of the H4H10223P group.

[0197] In another experiment (Study 2), thirty-one male C57BL/6 mice were placed on a HFD at 5 weeks of age and were kept on the diet for the subsequent 11 weeks. At 16 weeks of age, the mice were divided into 4 groups of 7 or 8 animals. Each group received subcutaneous injections of H4H10223P (30 mg/kg; n=8), H4H10231P (5 or 30 mg/kg; n=8), or the isotype control antibody (30 mg/kg; n=7), every five days. One, 4, 7, 11, 15 and 20 days following the initial antibody dosing, tail bleeds were collected from mice.

[0198] Table 10 summarizes the mean blood glucose levels of each treatment group.

[0199] Table 11 summarizes the mean percent reductions in blood glucose from the mean blood glucose levels of the control group for each treatment group.

Table 9: (Study 1) Blood glucose levels of each treatment group and percent reductions in blood glucose levels as compared to the control group for the H4H10223P group

Time (days)	Control	H4H10223P (30 mg/kg)	
	Blood glucose level (mg/dL)	Blood glucose level (mg/dL)	% Reduction
0	211 ± 7	211 ± 6	0 ± 3
2	212 ± 24	146 ± 9	31 ± 4
6	200 ± 7	154 ± 6	23 ± 3
9	174 ± 8	148 ± 7	15 ± 4
13	182 ± 12	144 ± 5	21 ± 3
16	158 ± 5	122 ± 5	23 ± 3
20	155 ± 11	139 ± 9	10 ± 6

Table 10: (Study 2) Blood glucose levels (mg/dL) of each treatment group

Time (days)	Control	H4H10223P	H4H10231P (5 mg/kg)	H4H10231P (30 mg/kg)
0	225 ± 10	225 ± 10	225 ± 10	225 ± 10
1	206 ± 11	214 ± 5	172 ± 3	192 ± 7
4	194 ± 4	152 ± 7	156 ± 5	141 ± 5
7	215 ± 8	191 ± 6	181 ± 5	167 ± 6
11	199 ± 6	164 ± 8	160 ± 8	149 ± 6
15	227 ± 10	222 ± 14	219 ± 17	191 ± 5
20	204 ± 5	183 ± 9	180 ± 5	171 ± 7

Table 11: (Study 2) Percent reductions in blood glucose levels as compared to the control group for each treatment group

Time (days)	H4H10223P	H4H10231P (5 mg/kg)	H4H10231P (30 mg/kg)
0	0 ± 5	0 ± 4	0 ± 5
1	-4 ± 2	17 ± 2	7 ± 3
4	22 ± 3	20 ± 3	27 ± 2
7	11 ± 3	16 ± 2	23 ± 3
11	18 ± 4	20 ± 4	25 ± 3
15	3 ± 6	4 ± 8	16 ± 2

Results

[0200] As shown in Tables 9 and 10, H4H10223P and H4H10231P decreased blood glucose levels significantly. Maximum percent reductions in blood glucose were 31% for the H4H10223P group in study 1, 22% for the H4H10223P group in study 2, and 27% for the H4H10231P group in study 2 (Tables 9 and 11).

What is claimed is:

1. An isolated monoclonal antibody or antigen-binding fragment thereof that specifically binds to and neutralizes GCG activity, wherein the antibody or fragment thereof exhibits one or more of the following characteristics:

(a) is a fully human monoclonal antibody;

(b) binds human GCG at 25°C with a K_D of less than about 1nM and less than about 5nM at 37°C as measured by surface plasmon resonance;

(c) lowers blood glucose levels by at least about 10% when administered to a mammal as a single dose, or as multiple doses of less than about 40 mg/kg;

(d) inhibits GCG-mediated activation of cells expressing human glucagon receptor (GCGR) with an IC_{50} of less than about 1 nM;

(e) comprises a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; or

(f) comprises a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NO: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

2. The isolated antibody or antigen-binding fragment thereof of claim 1, wherein the antibody binds human GCG at 25°C with a K_D ranging from about 50pM to about 750pM and from about 300pM to about 5nM at 37°C as measured by surface plasmon resonance.

3. The isolated antibody or antigen-binding fragment thereof of either claim 1 or 2, wherein the antibody lowers blood glucose levels by about 10% to about 35% when administered to a mammal as a single dose, or as multiple doses ranging from about 3 mg/kg to about 30 mg/kg.

4. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-3, wherein the antibody inhibits GCG-mediated activation of cells expressing human glucagon receptor (GCGR) with an IC_{50} ranging from about 7 pM to about 950 pM.

5. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-4, wherein the antibody or an antigen-binding fragment thereof reduces blood glucose levels in a mammal when administered subcutaneously, intravenously, or intramuscularly.

6. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-5, wherein the antibody or an antigen-binding fragment thereof reduces blood glucose levels in a mammal suffering from a condition or disease associated with, or characterized in part by high blood glucose levels.

7. The isolated antibody or antigen-binding fragment thereof of claim 6, wherein the condition or disease associated with, or characterized in part by high blood glucose levels is selected from the group consisting of diabetes, impaired glucose tolerance, obesity, hyperglycemia, hyperglycemic hyperosmolar syndrome, perioperative hyperglycemia, hyperglycemia in the intensive care unit patient, hyperinsulinemia, the metabolic syndrome, insulin resistance syndrome and impaired fasting glucose.

8. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-7, wherein the antibody or antigen-binding fragment thereof comprises: (a) three heavy chain complementarity determining regions (HCDR1, HCDR2 and HCDR3) contained within a heavy chain variable region (HCVR) amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; and (b) three light chain CDRs (LCDR1, LCDR2 and LCDR3) contained within a light chain variable region (LCVR) amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

9. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-8, wherein the antibody or antigen-binding fragment comprises an HCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; and a LCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

10. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-9, comprising a HCVR/LCVR amino acid sequence pair selected from the group consisting of SEQ ID NOs: 2/10; 18/26; 34/42; 50/58; 66/74; 82/90; 98/106; 114/122; 130/138 and 146/154.

11. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-10, comprising:

(a) a HCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 4, 20, 36, 52, 68, 84, 100, 116, 132 and 148;

(b) a HCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 6, 22, 38, 54, 70, 86, 102, 118, 134 and 150;

(c) a HCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 8, 24, 40, 56, 72, 88, 104, 120, 136 and 152;

(d) a LCDR1 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 12, 28, 44, 60, 76, 92, 108, 124, 140 and 156;

(e) a LCDR2 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 14, 30, 46, 62, 78, 94, 110, 126, 142, and 158; and

(f) a LCDR3 domain having an amino acid sequence selected from the group consisting of SEQ ID NOs: 16, 32, 48, 64, 80, 96, 112, 128, 144 and 160.

12. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-11, comprising:

(a) a HCDR1 domain comprising the amino acid sequence of SEQ ID NO: 20;

(b) a HCDR2 domain comprising the amino acid sequence of SEQ ID NO: 22;

(c) a HCDR3 domain comprising the amino acid sequence of SEQ ID NO: 24;

(d) a LCDR1 domain comprising the amino acid sequence of SEQ ID NO: 28;

(e) a LCDR2 domain comprising the amino acid sequence of SEQ ID NO: 30; and

(f) a LCDR3 domain comprising the amino acid sequence of SEQ ID NO: 32.

13. The isolated antibody or antigen-binding fragment thereof of any one of claims 1-11, comprising:

(a) a HCDR1 domain comprising the amino acid sequence of SEQ ID NO: 36;

(b) a HCDR2 domain comprising the amino acid sequence of SEQ ID NO: 38;

(c) a HCDR3 domain comprising the amino acid sequence of SEQ ID NO: 40;

(d) a LCDR1 domain comprising the amino acid sequence of SEQ ID NO: 44;

(e) a LCDR2 domain comprising the amino acid sequence of SEQ ID NO: 46; and

(f) a LCDR3 domain comprising the amino acid sequence of SEQ ID NO: 48.

14. An isolated antibody or antigen-binding fragment thereof that competes for specific binding to GCG with an antibody or antigen-binding fragment comprising heavy and light chain sequence pairs selected from the group consisting of SEQ ID NOs: 2/10; 18/26;

34/42; 50/58; 66/74; 82/90; 98/106; 114/122; 130/138 and 146/154.

15. An isolated antibody or antigen-binding fragment thereof that binds to the same epitope on GCG as a reference antibody comprising an HCVR/LCVR amino acid sequence pair selected from the group consisting of SEQ ID NOs: 2/10; 18/26; 34/42; 50/58; 66/74; 82/90; 98/106; 114/122; 130/138 and 146/154.

16. An isolated nucleic acid molecule encoding a monoclonal antibody or fragment thereof that binds specifically to human GCG according to any one of claims 1-13, wherein the antibody or an antigen binding fragment thereof comprises (a) the complementarity determining regions (CDRs) of a heavy chain variable region (HCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146; and (b) the CDRs of a light chain variable region (LCVR) having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

17. An isolated nucleic acid molecule encoding a human antibody or antigen-binding fragment of any one of claims 1-13, wherein the antibody or antigen-binding fragment comprises an HCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 2, 18, 34, 50, 66, 82, 98, 114, 130 and 146 and a LCVR having an amino acid sequence selected from the group consisting of SEQ ID NOs: 10, 26, 42, 58, 74, 90, 106, 122, 138 and 154.

18. A pharmaceutical composition comprising an isolated antibody or antigen-binding fragment thereof that binds to GCG according to any one of claims 1-15 and a pharmaceutically acceptable carrier or diluent.

19. A method for lowering blood glucose levels, or for treating a condition or disease associated with, or characterized in part by high blood glucose levels, or at least one symptom or complication associated with the condition or disease, the method comprising administering the pharmaceutical composition of claim 18, to a patient in need thereof, such that blood glucose levels are lowered or that the condition or disease is mediated, or at least one symptom or complication associated with the condition or disease is alleviated or reduced in severity.

20. The method of claim 19, wherein the condition or disease is selected from the group consisting of diabetes, impaired glucose tolerance, obesity, nephropathy, neuropathy, retinopathy, cataracts, stroke, atherosclerosis, impaired wound healing,

diabetic ketoacidosis, hyperglycemia, hyperglycemic hyperosmolar syndrome, perioperative hyperglycemia, hyperglycemia in the intensive care unit patient, hyperglycemia in burn patients or in patients suffering from a myocardial infarct or another cardiac disorder, hyperinsulinemia, the metabolic syndrome, insulin resistance syndrome and impaired fasting glucose.

21. The method of claim 19, wherein the pharmaceutical composition is administered to the patient in combination with a second therapeutic agent.

22. The method of claim 21, wherein the second therapeutic agent is selected from the group consisting of insulin, a biguanide (metformin), a sulfonylurea (*e.g.* glyburide, glipizide), a PPAR gamma agonist (*e.g.* pioglitazone, rosiglitazone), an alpha glucosidase inhibitor (*e.g.* acarbose, voglibose), a glucagon-like peptide 1 (GLP-1) agonist or analogue (*e.g.,* exenatide, liraglutide, albiglutide, dulaglutide, lixisenatide), a dipeptidyl peptidase IV (DPP-4) inhibitor (*e.g.* saxagliptin, sitaliptin, vildagliptin), a sodium-glucose co-transporter 2 (SGLT2) inhibitor (e.g., canagliflozin), dapagliflozin, empagliflozin, ipragliflozin, tofogliflozin), pramlintide, a glucagon receptor antagonist, and a second GCG antagonist.

23. The method of claim 21, wherein the second therapeutic agent is a 3-hydroxy-3-methyl-glutaryl-CoA reductase (HMG-CoA reductase) inhibitor.

24. The method of claim 23, wherein the HMG-CoA reductase inhibitor is a statin selected from the group consisting of atorvastatin, fluvastatin, lovastatin, pitavastatin, pravastatin, rosuvastatin and simvastatin.

25. The method of claim 21, wherein the second therapeutic agent is selected from the group consisting of an isolated antibody, or an antigen-binding fragment thereof, that specifically binds to angiopoietin-like protein 3 (ANGPTL3), angiopoietin-like protein 4 (ANGPTL4), angiopoietin-like protein 5 (ANGPTL5), angiopoietin-like protein 6 (ANGPTL6), angiopoietin-like protein 8 (ANGPTL8), and human proprotein convertase subtilisin/kexin type 9 (PCSK9).