



(51) International Patent Classification:

C07K 16/00 (2006.01)

(21) International Application Number:

PCT/IB2021/053585

(22) International Filing Date:

29 April 2021 (29.04.2021)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/018,698

01 May 2020 (01.05.2020)

US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

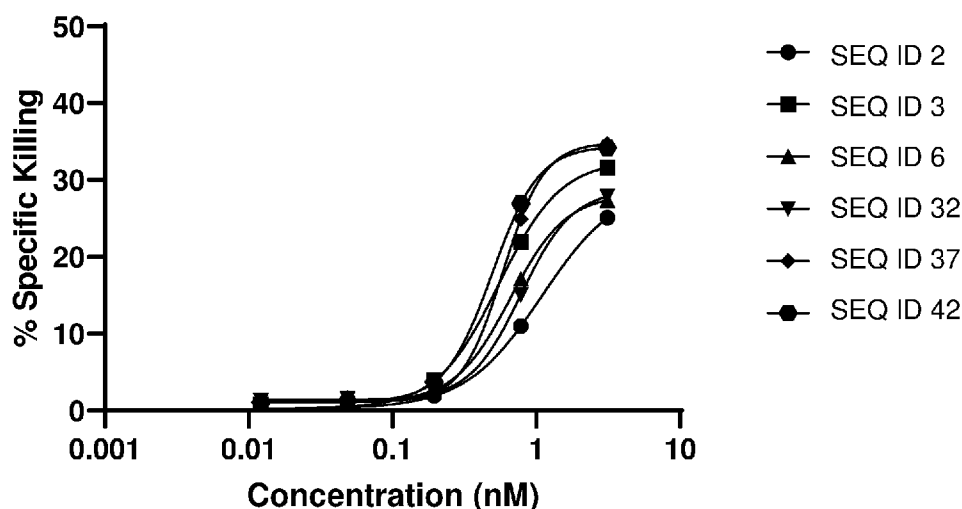
Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

(54) Title: IMMUNOGLOBULIN VARIANTS

Figure 1

SK-BR-3



(57) Abstract: The present invention provides an Fc variant of a parent IgA Fc polypeptide, wherein the Fc variant exhibits altered binding to FcγRs, wherein the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide.

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))
- with sequence listing part of description (Rule 5.2(a))
- in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE

Immunoglobulin Variants

Sequence Listing

The instant application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on April 19, 2021 is named PAT058743-WO-PCT_SL.txt and is 316 Kbytes in size.

Field of the invention

The invention relates to Fc variant polypeptides and antibodies with optimized properties to promote the recruitment of neutrophils and engineering methods for their preparation. The Fc variant polypeptides and antibodies can be useful in the treatment of tumors, particularly solid tumors.

Background of the invention

At present, all clinically approved antibodies comprise the immunoglobulin IgG isotype. Antibody-dependent cell-mediated cytotoxicity (ADCC) is a key mechanism for tumor cell killing mediated by IgG antibodies that recognize and bind to Fc gamma receptors (FcγR). However, in patients with a high tumor burden, relapses can occur and IgG antibody therapeutics may lose efficacy owing to the immunosuppressive environment found in tumors. In the tumor microenvironment, FcγR-bearing effector cells such as macrophages and natural killer cells can be rendered lytically incompetent by immunosuppressive factors such as TGFβ. IgA represents an alternative isotype for antibody therapy by engaging Fc alpha receptors (FcαRI) expressed by myeloid effector cells, such as neutrophils and tumor-resident myeloid-derived suppressor cells (MDSC). IgA is the second most abundant immunoglobulin in human serum after IgG; both monomeric IgA allotypes (IgA1 and IgA2) comprise up to 25% of human serum immunoglobulins. In the past, neutrophils were generally not considered as potential effector cells. However, neutrophils are the most abundant population of circulating white blood cells and have also been shown to infiltrate solid tumors (Gregory & Houghton (2011) *Cancer Res.*, 71: 2411-16; Vogt Sionov *et al.*, (2015) *Cancer Microenviron.*, 8(3): 125-58; Uribe-Querol & Rosales (2015) *J. Immunol. Res.*, Article ID: 983698; Rosales (2018) *Front Physiol.*, 9: 113). MDSCs are also derived from myeloid lineages and are one of the most immunosuppressive cell types. IgA antibodies have been shown to effectively kill tumor cells by recruitment of neutrophils and thereby enhancing ADCC. Unfortunately, the use of IgA antibodies as therapeutics is hampered by several liabilities and limitations such as low expression yields and expensive purification schemes. In addition, the

production suffers from heterogeneous glycosylation. IgA has multiple glycosylation sites that can be susceptible to glycan heterogeneity. Transient expression levels for monomeric IgA have been reported for human IgA1 at 30-70 µg/L (Lombana *et al* (2019) MABS, 11: 1122-38; Meyer *et al* (2016) MABS, 8: 87-98).

Therefore, there remains a need for IgA antibodies that can be developed as therapeutic antibodies. IgA antibodies with improved potency could provide a viable alternative to IgG therapeutic antibodies with the advantage of effective tumor cell killing by the recruitment of neutrophils, MDSC and enhanced ADCC.

Summary of the Invention

The present invention provides Fc variants of a parent Fc polypeptide of the IgA isotype, that have improved binding properties to FcαRI and can be used to recruit and activate neutrophils. The Fc variant of the present disclosure comprises amino modifications, which can comprise independently or in combination amino acid insertion(s), amino acid deletion(s) and/or amino acid substitutions.

In one aspect the present disclosure provides an Fc variant of a parent Fc polypeptide, wherein the Fc variant exhibits altered binding to a FcαR or altered antibody dependent cell-mediated cytotoxicity (ADCC) as compared to the parent Fc polypeptide, wherein the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide. In one embodiment, the amino acid modification is at a position selected from the group consisting of: CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. In a preferred embodiment, the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide, wherein the amino acid modification is selected from the group consisting of: A_CH2.10_S, L_CH2.89_I, G_CH2.91_Q, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_H, N_CH2.97_Y, G_CH2.99_W, S_CH3.45_D, M_CH3.105_Y, E_CH3.109_D, Q_CH3.118_Y and L_CH3.124_F, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. In a further embodiment, the present disclosure provides an Fc variant comprising at least one amino acid modification in the Fc region, wherein the amino acid modification is selected from the group consisting of: Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y, Q_CH2.94_E / S_CH3.45_D, Q_CH2.94_E / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D, N_CH2.97_Y / M_CH3.105_Y, S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y,

Q_CH2.94_E / S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y / Q_CH3.118_Y, A_CH2.10_S, L_CH2.89_I, G_CH2.91_V, N_CH2.97_H, G_CH2.99_W, E_CH3.109_D, L_CH3.124_F, L_CH2.89_I / G_CH2.91_V / Q_CH2.94_E / N_CH2.97_Y / G_CH2.99_W, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain.

In one embodiment, the present disclosure provides an Fc variant of a parent Fc polypeptide comprising an amino acid modification at positions CH2.94, CH2.97, CH3.45, CH3.105 and CH3.118. In one embodiment, the Fc variant of a parent Fc polypeptide comprises the amino acid substitutions Glu at position CH2.94, Tyr at position CH2.97, Asp at position CH3.45, Tyr at position CH3.105 or Tyr at position CH3.118. In a preferred embodiment, the Fc variant of a parent Fc polypeptide comprises the amino acid substitutions Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, and Q_CH3.118_Y.

In one embodiment, the present disclosure provides an Fc variant of a parent Fc polypeptide, wherein the parent Fc polypeptide is comprised within human IgA1, or wherein the parent Fc polypeptide is comprised within human IgA2.

In one embodiment of the present disclosure, the Fc variant exhibits altered binding to a Fc α R compared to the parent Fc polypeptide. Provided herein is an Fc variant of a parent Fc polypeptide wherein the Fc variant has increased affinity to human Fc α RI of at least 50-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance (SPR). In one embodiment, the present disclosure provides an Fc variant of a parent Fc polypeptide wherein the Fc variant has an increased affinity to human Fc α RI of at least about 50, about 100, about 150, about 200, about 250, about 300-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance. In one embodiment, the present disclosure provides an Fc variant of a parent Fc polypeptide wherein the Fc variant has an increased affinity to human Fc α RI of at least about 300-fold relative to the parent Fc polypeptide as measured by SPR.

In one embodiment of the present disclosure, the Fc variant exhibits altered ADCC as compared to the parent Fc polypeptide. Provided herein is an Fc variant of a parent Fc polypeptide wherein the Fc variant increases antibody-dependent cell-mediated cytotoxicity (ADCC) by at least about 5-fold relative to the parent Fc polypeptide as measured in a MDA-MB-453 cell-killing assay. In one embodiment, the present disclosure provides an Fc variant of a parent Fc polypeptide wherein the Fc variant has an increased efficacy of at least about 2-fold in a Calu-3 cell-killing assay relative to the parent Fc polypeptide.

In another aspect, the present disclosure provides an IgA antibody comprising a variant Fc polypeptide, wherein the antibody has increased Fc α R affinity, or increased ADCC, relative to an IgA antibody comprising a wild-type Fc polypeptide. In one embodiment, the present disclosure provides an IgA antibody comprising an amino acid modification at a position selected from the group consisting of: CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. In a preferred embodiment, the present disclosure provides an IgA antibody comprising an amino acid modification, wherein the amino acid modification is selected from the group consisting of: A_CH2.10_S, L_CH2.89_I, G_CH2.91_Q, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_H, N_CH2.97_Y, G_CH2.99_W, S_CH3.45_D, M_CH3.105_Y, E_CH3.109_D, Q_CH3.118_Y and L_CH3.124_F, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain.

In a further embodiment, the present disclosure provides an IgA antibody comprising an amino acid modification, wherein the amino acid modification is selected from the group consisting of: Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y, Q_CH2.94_E / S_CH3.45_D, Q_CH2.94_E / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D, N_CH2.97_Y / M_CH3.105_Y, S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y / Q_CH3.118_Y, A_CH2.10_S, L_CH2.89_I, G_CH2.91_V, N_CH2.97_H, G_CH2.99_W, E_CH3.109_D, L_CH3.124_F, L_CH2.89_I / G_CH2.91_V / Q_CH2.94_E / N_CH2.97_Y / G_CH2.99_W, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain.

In one embodiment, the present disclosure provides an IgA antibody comprising an amino acid modification at positions CH2.94, CH2.97, CH3.45, CH3.105 and CH3.118. In one embodiment, the IgA antibody comprises the amino acid substitutions Glu at position CH2.94, Tyr at position CH2.97, Asp at position CH3.45, Tyr at position CH3.105 or Tyr at position CH3.118. In a preferred embodiment, the IgA antibody comprises the amino acid substitutions Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q and CH3.118_Y.

In one embodiment, the present disclosure provides an IgA antibody comprising a variant Fc polypeptide, wherein the antibody is a human IgA1 or IgA2 antibody.

The present disclosure provides isolated nucleic acids encoding the Fc variants described herein. The present disclosure provides vectors comprising the nucleic acids, optionally, operably linked to control sequences. The present disclosure provides host cells containing the vectors, and methods for producing and optionally recovering the Fc variants. The present disclosure provides compositions comprising IgA antibodies that comprise the Fc variants described herein, and a physiologically or pharmaceutically acceptable carrier or diluent.

The present disclosure contemplates therapeutic and diagnostic uses for IgA antibodies that comprise the Fc variants disclosed herein. The Fc variants disclosed herein could also be used for the construction of other binding molecules such as bi-specific and multi-specific antibodies. The IgA antibodies described in the present disclosure may be used to treat a variety of indications, including but not limited to proliferative diseases such as cancers.

Brief Description of the Figures

Figure 1 shows PMN cytotoxicity of increasing concentrations of the Fc variants: SEQ ID NOs: 3 (■), 6 (▲), 32 (▼), 37 (◆) and 42 (●), and parental IgA2 (SEQ ID NO: 2 (●)) on SK-BR-3 cells, in an ADCC assay as described in Example 4. The efficacy (E_{max} %) for each Fc variant was as follows: SEQ ID NO: 2: 25%, SEQ ID NO: 3: 32%, SEQ ID NO: 6: 27%, SEQ ID NO: 32: 28%, SEQ ID NO: 37: 35% and SEQ ID NO: 42: 34%.

Figure 2 shows PMN cytotoxicity of increasing concentrations of the Fc variants: SEQ ID NOs: 3 (■), 6 (▲), 32 (▼), 37 (◆) and 42 (●), and parental IgA2 (SEQ ID NO: 2 (●)) on Calu-3 cells, in an ADCC assay as described in Example 4. The efficacy (E_{max} %) for each Fc variant was as follows: SEQ ID NO: 2: 42%, SEQ ID NO: 3: 44%, SEQ ID NO: 6: 41%, SEQ ID NO: 32: 71%, SEQ ID NO: 37: 76% and SEQ ID NO: 42: 81%.

Figure 3 shows PMN cytotoxicity of increasing concentrations of the Fc variant of SEQ ID NO: 42 and IgA2 (SEQ ID NO: 2) on MDA-MB-453 cells, in an ADCC assay as described in Example 4. The EC₅₀ value for the variant comprising SEQ ID NO: 2 was 2.45nM and the EC₅₀ value for the variant comprising SEQ ID NO: 42 was 0.36nM.

Figure 4 shows PMN cytotoxicity of increasing concentrations of the Fc variant of SEQ ID NO: 42 (●) and parental IgA2 (SEQ ID NO: 2 (●)) on MDA-MB-175 cells, in an ADCC assay as described in Example 4.

Figure 5 shows PMN and PBMC cytotoxicity of increasing concentrations of the heterodimeric Fc candidates on SK-BR-3 cells, in an ADCC assay as described in Example 4. Figures 5A and 5B show the Fc variants with SEQ ID NOs: 7-8 (■) and 80-8 (▲), compared to IgA2 (SEQ ID NO: 3 (●); Fig 5a) and IgG1 (SEQ ID NO: 1 (●); Fig 5b), respectively. Figures 5C and 5D

show the Fc variants with SEQ ID NOs: 7-9 (▼) and 80-9 (◆) compared to IgA2 (SEQ ID NO: 2 (●); Fig 5c) and IgG1 (SEQ ID NO: 1 (●); Fig 5d), respectively.

Figure 6 shows serum-time concentration profiles of IgG, IgA and engineered immunoglobulins in mice. Concentration in serum of (◆) SEQ ID NO: 1 immunoglobulin from HEK293T, (▲) SEQ ID NO: 2 immunoglobulin from HEK293T, (●) engineered immunoglobulin SEQ ID No: 7-8 from HEK293T, (x) engineered immunoglobulin SEQ ID NO: 8-80 from HEK293T.

Figure 7 shows serum-time concentration profiles of IgG, IgA and glyco-engineered immunoglobulins in mice. Concentration in serum of (◆) SEQ ID NO: 1 immunoglobulin from CHO-S, (▲) SEQ ID NO: 2 immunoglobulin from CHO-S, (x) engineered immunoglobulin SEQ ID No: 8-80 from CHO-S, (■) engineered immunoglobulin SEQ ID NO: 40 from CHO-S, (○) engineered immunoglobulin SEQ ID No: 82 from CHO-S, (□) engineered immunoglobulin SEQ ID NO: 83 from CHO-S, (●) engineered immunoglobulin SEQ ID NO: 84 from CHO-S.

Detailed Description

Disclosed herein are Fc variants of the IgA immunoglobulin having optimized properties, as well as antibodies comprising these Fc variants. These optimized properties include enhanced binding to FcαR and altered antibody-dependent cell-mediated cytotoxicity (ADCC), relative to a parent IgA Fc polypeptide.

Definitions

In order that the present disclosure may be more readily understood, certain terms are specifically defined throughout the detailed description. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by those of ordinary skill in the art to which this disclosure pertains.

In all cases where the term “comprise”, “comprises”, “comprising” or the like are used in reference to a sequence (e.g., an amino acid sequence), it shall be understood that said sequence may also be limited by the term “consist”, “consists”, “consisting” or the like. As used herein, the phrase “consisting essentially of” refers to the genera or species of active pharmaceutical agents included in a method or composition, as well as any excipients inactive for the intended purpose of the methods or compositions. In some aspects, the phrase “consisting essentially of” expressly excludes the inclusion of one or more additional active agents other than an Fc variant of the present disclosure. In some aspects, the phrase “consisting essentially of” expressly excludes the inclusion of one or more additional active agents other than an Fc variant of the present disclosure and a second co-administered agent.

As used herein, the term "antibody" refers to a polypeptide of the immunoglobulin family that is capable of binding a corresponding antigen non-covalently, reversibly, and in a specific manner. The basic functional unit of each antibody is an immunoglobulin monomer containing only one Ig unit, defined herein as an "Ig monomer". Secreted antibodies can also be dimeric with two Ig units (e.g. IgA), tetrameric with four Ig units or pentameric with five Ig units (e.g. mammalian IgM). The term "antibody" includes, for example, a monoclonal antibody (including a full length antibody which has an immunoglobulin Fc region). The Ig monomer is a Y-shaped molecule that consists of four polypeptide chains; two identical heavy chains and two identical light chains connected by disulfide bonds (Woof & Burton (2004) *Nature Reviews Immunology*, 4(2): 89–99). Each chain comprises a number of structural domains containing about 70–110 amino acids that are classified into two categories: variable or constant, according to their size and function. The heavy chain comprises one variable domain (abbreviated as VH) and three constant domains (abbreviated as CH1, CH2 and CH3). Each light chain comprises one variable domain (abbreviated as VL) and one constant domain (abbreviated as CL). Immunoglobulin domains have a characteristic immunoglobulin fold in which two beta sheets create a 'sandwich' shape, held together by interactions between conserved cysteine residues and other charged amino acids. The VH and VL regions can be further subdivided into regions of hypervariability, termed complementarity determining regions (CDR), interspersed with regions that are more conserved, termed framework regions (FR). Each VH and VL 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 and FR4. The variable regions of the heavy and light chains contain an antigen binding domain or antigen binding site that interacts with an antigen.

The term "antibody" includes, but is not limited to, monoclonal antibodies, human antibodies, humanized antibodies, camelid antibodies, chimeric antibodies, and anti-idiotypic (anti-Id) antibodies (including, e.g., anti-Id antibodies to antibodies of the present disclosure). The antibodies can be of any isotype/class (e.g., IgG, IgE, IgM, IgD, IgA and IgY), or subclass (e.g., IgG1, IgG2, IgG3, IgG4, IgA1 and IgA2).

The term "monospecific molecule," as used herein, refers to a molecule that binds to one epitope on a target antigen. In some embodiments, a mono-specific molecule of the present disclosure is a monospecific antibody-like molecule. In some embodiments, a mono-specific molecule of the present disclosure is a monospecific antibody. The term "bispecific molecule" refers to a multi-specific binding molecule that binds to two different antigens. In some embodiments, a bispecific molecule of the present disclosure is a bispecific antibody-like molecule. The term "multi-specific binding molecule" as used herein refers to a molecule that binds to two or more different

antigens. Recognition of each antigen is generally accomplished via an “antigen-binding domain” In some embodiments, a multi-specific binding molecule of the present disclosure is a multi-specific antibody-like molecule, such as a bispecific antibody-like molecule.

The term “antigen-binding site” refers to the part of an antibody that comprises determinants that form an interface that binds to the antigen, or an epitope thereof. The term “antigen binding site” may be used interchangeably with the term “antigen binding domain”. With respect to proteins (or protein mimetics), the antigen-binding site typically includes one or more loops (of at least four amino acids or amino acid mimics) that form an interface that binds to the antigen polypeptide. Typically, the antigen-binding site of an antibody molecule includes at least one or two CDRs and/or hypervariable loops, or more typically at least three, four, five or six CDRs and/or hypervariable loops.

“Complementarity-determining regions” (“CDRs”) as used herein, refer to the hypervariable regions of VL and VH. The CDRs are the target protein-binding site of the antibody chains that harbors specificity for such target protein. There are three CDRs (CDR1-3, numbered sequentially from the N-terminus) in each human VL or VH , constituting in total about 15-20% of the variable domains. CDRs can be referred to by their region and order. For example, “VHCDR1” or “HCDR1” both refer to the first CDR of the heavy chain variable region. The CDRs are structurally complementary to the epitope of the target protein and are thus directly responsible for the binding specificity. The remaining stretches of the VL or VH , the so-called framework regions, exhibit less variation in amino acid sequence (Kuby, (2000) Immunology, 4th ed., Chapter 4. W.H. Freeman & Co., New York). The positions of the CDRs and framework regions can be determined using various well-known definitions in the art, e.g., Kabat, Chothia, IMGT, AbM, and combined definitions (see, e.g., Johnson *et al.*, (2001) Nucleic Acids Res., 29:205-206; Chothia & Lesk, (1987) J. Mol. Biol., 196:901-917; Chothia *et al.*, (1989) Nature, 342:877-883; Chothia *et al.*, (1992) J. Mol. Biol., 227:799-817; Lefranc, M.P., (2001) Nucleic Acids Res., 29:207-209; Al-Lazikani *et al.*, (1997) J.Mol.Biol., 273:927-748 and Kabat *et al.*, (1991) Sequences of proteins of immunological interest. 5th Edition - US DHHS, NIH publication n° 91-3242, pp 662, 680, 689). Definitions of antigen combining sites are also described in the following: Ruiz *et al.*, (2000) Nucleic Acids Res., 28:219–221; MacCallum *et al.*, (1996) J. Mol. Biol., 262:732-745; and Martin *et al.*, (1989) Proc. Natl. Acad. Sci. USA, 86:9268–9272; Martin *et al.*, (1991) Methods Enzymol., 203:121–153; and Rees *et al.*, (1996) In Sternberg M.J.E. (ed.), Protein Structure Prediction, Oxford University Press, Oxford, 141–172. In a combined Kabat and Chothia numbering scheme, in some embodiments, the CDRs correspond to the amino acid residues that are part of a Kabat CDR, a Chothia CDR, or both. For instance, in some embodiments, the CDRs correspond to amino acid residues 26-35 (HCDR1), 50-

65 (HCDR2), and 95-102 (HCDR3) in a VH, e.g., a mammalian VH, e.g., a human VH; and amino acid residues 24-34 (LCDR1), 50-56 (LCDR2), and 89-97 (LCDR3) in a VL, e.g., a mammalian VL, e.g., a human VL. Under IMGT the CDR amino acid residues in the VH are numbered approximately 26-35 (CDR1), 51-57 (CDR2) and 93-102 (CDR3), and the CDR amino acid residues in the VL are numbered approximately 27-32 (CDR1), 50-52 (CDR2), and 89-97 (CDR3) (numbering according to "Kabat"). Under IMGT, the CDR regions of an antibody can be determined using the program IMGT/DomainGap Align. IMGT tools are available at world wide web (www.imgt.org).

In an embodiment, an antibody comprises an "antigen-binding fragment" of an antibody. Examples of such fragments include: (i) a Fab fragment, a monovalent fragment consisting of the VL, VH, CL and CH1 domains; (ii) a F(ab')₂ fragment, a bivalent fragment comprising two Fab fragments linked by a disulfide bridge at the hinge region; (iii) a Fd fragment consisting of the VH and CH1 domains; (iv) a Fv fragment consisting of the VL and VH domains of a single arm of an antibody, (v) a diabody (dAb) fragment, which consists of a VH domain; (vi) a camelid or camelized variable domain; (vii) a single chain Fv (scFv), see e.g., Bird *et al.*, (1988) Science 242:423-426; and Huston *et al.*, (1988) PNAS USA 85:5879-5883; (viii) a single domain antibody; (ix) diabodies (Dab) (bivalent and bispecific), and (x) chimeric (e.g., humanized) antibodies which may be produced by the modification of whole antibodies or those synthesized *de novo* using recombinant DNA technologies. These functional antibody fragments retain the ability to selectively bind with their respective antigen or receptor. These antibody fragments are obtained using conventional techniques known to those with skill in the art, and the fragments are screened for utility in the same manner as are intact antibodies.

In mammals there are two types of immunoglobulin light chain, which are called lambda (λ) and kappa (κ). Each antibody contains two light chains that are always identical; only one type of light chain, κ or λ , is present per antibody in mammals. The approximate length of a light chain is 211 to 217 amino acids and each light chain has two domains, one constant domain and one variable domain.

There are five types of mammalian Ig heavy chains denoted α , δ , ϵ , γ , and μ and the type of heavy chain present in the antibody defines the class or isotype of the antibody: IgM, IgG, IgA, IgD, IgE, respectively. The heavy chains vary in physiochemical, structural, and immunological properties but each heavy chain has two domains, a variable domain and a constant domain. The variable domain comprises a single Ig domain (approximately 110 amino acids long) and determines antibody binding specificity. The constant domain is identical in all antibodies of the same isotype, but differs in antibodies of different isotypes. Heavy chains γ , α and δ have a constant region composed of three tandem Ig domains, and a hinge region for added flexibility; heavy chains

μ and ϵ have a constant region composed of four immunoglobulin domains (Woof & Burton, *supra*). The term “immunoglobulin” (Ig) is used interchangeably with the term “antibody” herein.

IgG is the most abundant antibody isotype in the blood (plasma), accounting for 70-75% of human immunoglobulins. IgG detoxifies harmful substances and is important in the recognition of antigen-antibody complexes by leukocytes and macrophages. IgG is further divided into 4 subclasses in humans: IgG1, IgG2, IgG3 and IgG4. IgM usually circulates in the blood, accounting for about 10% of human immunoglobulins. IgM has a pentameric structure in which five basic Y-shaped molecules are linked together. B cells produce IgM first in response to microbial infection/antigen invasion. Although IgM has a lower affinity for antigens than IgG, it has higher avidity for antigens because of its pentameric/ hexameric structure. IgM, by binding to the cell surface receptor, also activates cell signaling pathways. IgA is abundant in serum, nasal mucus, saliva, breast milk, and intestinal fluid, accounting for 25% of human immunoglobulins. IgA forms dimers (i.e., two IgA monomers joined together). IgA in breast milk protects the gastrointestinal tract of neonates from pathogens. IgA is divided into 2 subclasses: IgA1 and IgA2. IgD accounts for less than 1% of human immunoglobulins and may be involved in the induction of antibody production in B cells, but its exact function remains unknown. IgE is present in minute amounts, accounting for no more than 0.001% of human immunoglobulins. Its original role is to protect against parasites. In regions where parasitic infection is rare, IgE is primarily involved in allergy.

Immune cell activity is modulated by a region of an antibody known as the fragment crystallisable region or “Fc region”. The Fc region is composed of two identical polypeptide chains (each referred to herein as an “Fc domain”), which in IgG and IgA comprises the CH2 and CH3 constant domains of the heavy chain. IgM and IgE Fc regions contain three heavy chain constant domains (CH domains 2–4) in each polypeptide chain. The amino acid residues in the CH2 and CH3 domains can be numbered according to the EU numbering system (Edelman *et al.*, (1969) PNAS. USA, 63, 78-85), “Kabat” numbering (Kabat *et al.*, *supra*) or alternatively using the IMGT numbering for C domains. IMGT tools are available at world wide web (www.imgt.org).

The Fc region binds to cell surface receptors, “Fc receptors” and complement proteins mediating physiological effects of antibodies. Fc receptors are found on many cells of the immune system including: B lymphocytes, follicular dendritic cells, natural killer cells, macrophages, neutrophils, eosinophils, basophils, human platelets and mast cells. Binding of antibody Fc region to Fc receptors stimulates phagocytic or cytotoxic cells to destroy microbes, or infected cells by the mechanism of antibody-dependent cell-mediated cytotoxicity (ADCC). There are several different types of Fc receptors (FcR), which are classified based on the type of antibody that they recognize. For example, those that bind IgG are called Fc-gamma receptors (Fc γ R), those that bind IgA are

called Fc-alpha receptors (FcαRI) and those that bind IgE are called Fc-epsilon receptors (FcεR). The classes of FcRs are also distinguished by the cells that express them (macrophages, granulocytes, natural killer cells, T and B cells) and the signaling properties of each receptor (Owen J *et al.*, (2009) Immunology (7th ed.). New York: W.H. Freeman and Company. p423). The FcαRI is also known as CD89 and its principal antibody ligand is IgA. This receptor has a low affinity for IgA ($K_d > 10^{-6}$ M) and is found on monocytes, macrophages, neutrophils and eosinophils. The binding of IgA to FcαRI primarily leads to phagocytosis and the induction of microbe killing.

In an embodiment, an antibody comprises a full-length antibody, or a full-length immunoglobulin chain. In an embodiment, an antibody comprises an antigen binding or functional fragment of a full-length antibody, or a full-length immunoglobulin chain. The preparation of an antibody can be monoclonal or polyclonal. An antibody can also be a human, humanized, CDR-grafted, or *in vitro* generated antibody.

In one embodiment, the antibody or immunoglobulin can be recombinantly produced, e.g., produced by phage display or by combinatorial methods. Phage display and combinatorial methods for generating antibodies are known in the art (as described in, e.g., Ladner *et al.*, US 5,223,409; Kang *et al.*, WO 92/18619; Dower *et al.*, WO 91/17271; Winter *et al.*, WO 92/20791; Markland *et al.*, WO 92/15679; Breitling *et al.*, WO 93/01288; McCafferty *et al.*, WO 92/01047; Garrard *et al.*, WO 92/09690; Ladner *et al.*, WO 90/02809; Fuchs *et al.*, (1991) Bio/Technology, 9:1370-1372; Hay *et al.*, (1992) Hum Antibody Hybridomas, 3:81-85; Huse *et al.*, (1989) Science 246:1275-1281; Griffiths *et al.*, (1993) EMBO J., 12:725-734; Hawkins *et al.*, (1992) J Mol Biol., 226:889-896; Clackson *et al.*, (1991) Nature, 352:624-628; Gram *et al.*, (1992) PNAS, 89:3576-3580; Garrard *et al.*, (1991) Bio/Technology, 9:1373-1377; Hoogenboom *et al.*, (1991) Nuc Acid Res., 19:4133-4137; and Barbas *et al.*, (1991) PNAS, 88:7978-7982; the contents of all of which are incorporated by reference herein).

In one embodiment, the antibody or immunoglobulin is a fully human antibody (e.g., an antibody made in a mouse which has been genetically engineered to produce an antibody from a human immunoglobulin sequence or an antibody isolated from a human), or a non-human antibody, e.g., a rodent (mouse or rat), goat, primate (e.g., monkey), camel antibody. Human monoclonal antibodies can be generated using transgenic mice carrying the human immunoglobulin genes rather than the mouse system. Splenocytes from these transgenic mice immunized with the antigen of interest are used to produce hybridomas that secrete human monoclonal antibodies with specific affinities for epitopes from a human protein (see, e.g., Wood *et al.*, WO 91/00906, Kucherlapati *et al.*, WO 91/10741; Lonberg *et al.*, WO 92/03918; Kay *et al.*, WO 92/03917; Lonberg *et al.*, (1994) Nature 368:856-859; Green *et al.*, (1994) Nature Genet. 7:13-21; Morrison *et al.*, (1994) PNAS USA

81:6851-6855; Bruggeman *et al.*, (1993) Year Immunol 7:33-40; Tuailon *et al.*, (1993) PNAS 90:3720-3724; Bruggeman *et al.*, (1991) Eur J Immunol 21:1323-1326).

An antibody or immunoglobulin can be one in which the variable region, or a portion thereof, e.g., the CDRs, are generated in a non-human organism, e.g., a rat or mouse. Chimeric, CDR-grafted, and humanized antibodies are within the invention. Antibodies generated in a non-human organism, e.g., a rat or mouse, and then modified, e.g., in the variable framework or constant region, to decrease antigenicity in a human are within the invention. Chimeric antibodies can be produced by recombinant DNA techniques known in the art (see Robinson *et al.*, WO 87/002671; Akira *et al.*, EP184187A1; Taniguchi, EP171496A1; Morrison *et al.*, EP173494A1; Neuberger *et al.*, WO 86/01533; Cabilly *et al.*, US 4,816,567; Cabilly *et al.*, EP125023A1; Better *et al.*, (1988) Science 240:1041-1043; Liu *et al.*, (1987) PNAS 84:3439-3443; Liu *et al.*, (1987), J. Immunol. 139:3521-3526; Sun *et al.*, (1987) PNAS 84:214-218; Nishimura *et al.*, (1987), Canc. Res. 47:999-1005; Wood *et al.*, (1985) Nature 314:446-449; and Shaw *et al.*, (1988), J. Natl Cancer Inst. 80:1553-1559).

A humanized or CDR-grafted antibody will have at least one or two but generally all three recipient CDRs (of heavy and or light immunoglobulin chains) replaced with a donor CDR. The antibody may be replaced with at least a portion of a non-human CDR or only some of the CDRs may be replaced with non-human CDRs. It is only necessary to replace the number of CDRs required for binding of the humanized antibody to the target antigen. Preferably, the donor will be a rodent antibody, e.g., a rat or mouse antibody, and the recipient will be a human framework or a human consensus framework. Typically, the immunoglobulin providing the CDRs is referred to as the 'donor' and the immunoglobulin providing the framework is referred to as the 'acceptor'. In one embodiment, the donor immunoglobulin is a non-human (e.g., rodent). The acceptor framework is a naturally-occurring (e.g., a human) framework or a consensus framework, or a sequence about 85% or higher, preferably 90%, 95%, 99% or higher identity thereto.

As used herein, the term "consensus sequence" refers to the sequence formed from the most frequently occurring amino acids (or nucleotides) in a family of related sequences (See e.g., Winnaker, From Genes to Clones (Verlagsgesellschaft, Weinheim, Germany 1987)). In a family of proteins, each position in the consensus sequence is occupied by the amino acid occurring most frequently at that position in the family. If two amino acids occur equally frequently, either can be included in the consensus sequence. A "consensus framework" refers to the framework region in the consensus immunoglobulin sequence.

An antibody can be humanized by methods known in the art (see e.g., Morrison, (1985), Science 229:1202-1207; Oi *et al.*, (1986), BioTechniques 4:214, and Queen *et al.*, US 5,585,089,

US 5,693,761 and US 5,693,762, the contents of all of which are hereby incorporated by reference). Humanized or CDR-grafted antibodies can be produced by CDR-grafting or CDR substitution, wherein one, two, or all CDRs of an immunoglobulin chain can be replaced. See, e.g., US 5,225,539; Jones *et al.*, (1986) Nature 321:552-525; Verhoeyan *et al.*, (1988) Science 239:1534; Beidler *et al.*, (1988) J. Immunol. 141:4053-4060 and Winter US 5,225,539, the contents of all of which are hereby expressly incorporated by reference. Also within the scope of the invention are humanized antibodies in which specific amino acids have been substituted, deleted or added. Criteria for selecting amino acids from the donor are described in US 5,585,089, e.g., columns 12-16 of US 5,585,089, the contents of which are hereby incorporated by reference. Other techniques for humanizing antibodies are described in Padlan *et al.*, EP 519596 A1.

Methods for altering an antibody constant region are known in the art. Antibodies with altered function, e.g. altered affinity for an effector ligand, such as FcR on a cell, or the C1 component of complement can be produced by replacing at least one amino acid residue in the constant portion of the antibody with a different residue (see e.g., EP388151A1, US 5,624,821 and US 5,648,260).

By "position" as used herein is meant a location of an amino acid in the sequence of a protein. Positions may be numbered sequentially, or according to an established format, for example the EU index as in Kabat or IMGT numbering (www.imgt.org). When using the IMGT numbering for example, glutamine 94 (also referred to as Gln94, also referred to as Q94) is also given a position location in the Fc region to denote if it is found in the CH2 or CH3 domain. For example, QCH2.94, SCH3.45 denotes a glutamine at position 94 in the CH2 domain and serine at position 45 in the CH3 domain, in the human antibody IgA1.

By "residue" as used herein is meant a position in a protein and its associated amino acid identity. For example, Glutamine 94 (also referred to as Gln94, also referred to as Q94) is a residue in the human antibody IgA1.

A "modification" or "mutation" of an amino acid residue(s)/position(s), as used herein, refers to a change of a primary amino acid sequence as compared to a starting amino acid sequence, wherein the change results from a sequence alteration involving said one or more amino acid residue/positions. For example, typical modifications include substitution of the one or more residue(s) (or at said position(s)) with another amino acid(s) (e.g., a conservative or non-conservative substitution), insertion of one or more amino acids adjacent to said one or more residue(s)/position(s), and deletion of said one or more residue(s)/position(s), inversion of said one or more residue(s)/position(s), and duplication of said one or more residue(s)/position(s). An amino acid 'substitution' or variation thereof, refers to the replacement of an one or more existing amino

acid residue(s) in a predetermined (starting) amino acid sequence with a one or more different amino acid residue(s). Generally and preferably, the modification results in alteration in at least one physicobiochemical activity of the variant polypeptide compared to a polypeptide comprising the starting or parental (or "wild-type") amino acid sequence. For example, in the case of an antibody or an Fc variant, a physicobiochemical activity that is altered can be binding affinity, binding capability and/or binding effect upon a target molecule.

By "variant polypeptide", "polypeptide variant", or "variant" as used herein is meant a polypeptide sequence that differs from that of a parent polypeptide sequence by virtue of at least one amino acid modification. The parent polypeptide may be a naturally occurring or wild-type (WT) polypeptide, or may be a modified version of a WT polypeptide. Variant polypeptide may refer to the polypeptide itself, a composition comprising the polypeptide, or the amino sequence that encodes it. Preferably, the variant polypeptide has at least one amino acid modification compared to the parent polypeptide, e.g., from about one to about ten amino acid modifications, and preferably from about one to about five amino acid modifications compared to the parent. The variant polypeptide sequence as described herein will possess at least about 80% homology with a parent polypeptide sequence, preferably at least about 90% homology, more preferably at least about 95% homology. In one embodiment, the variant polypeptide sequence as described herein will possess at least about 85% homology with a parent IgA CH2 polypeptide sequence, preferably at least about 90% homology, more preferably at least about 95% homology. In one embodiment, the variant polypeptide sequence as described herein will possess at least about 90% homology with a parent IgA CH3 polypeptide sequence, preferably at least about 95% homology, more preferably at least about 97% homology. In a preferred embodiment, the variant polypeptide sequence as described herein will possess at least about 85% homology, preferably at least about 90% homology, more preferably at least about 95% homology with a parent IgA CH2 polypeptide sequence, and possess at least about 90% homology, preferably at least about 95% homology, more preferably at least about 97% homology with a parent IgA CH3 polypeptide sequence. Accordingly, by "Fc variant" or "variant Fc" as used herein is meant an Fc sequence that differs from that of a parent Fc sequence by virtue of at least one amino acid modification. An Fc variant may only encompass an Fc region, or may exist in the context of an antibody, Fc fusion, isolated Fc, Fc fragment, or other polypeptide that is substantially encoded by Fc. Fc variant may refer to the Fc polypeptide itself, compositions comprising the Fc variant polypeptide, or the amino acid sequence that encodes it. By "Fc polypeptide variant" or "variant Fc polypeptide" as used herein is meant an Fc polypeptide that differs from a parent Fc polypeptide by virtue of at least one amino acid modification. The term "parent Fc polypeptide" as used herein means the starting Fc

polypeptide to which the amino acid modification(s) is made. The parent Fc polypeptide can be a wild-type Fc polypeptide or a Fc polypeptide which is an allelic variation of a wild-type Fc polypeptide. The parent Fc polypeptide can also be an Fc polypeptide to which amino acid modifications have already been made. By "protein variant" or "variant protein" as used herein is meant a protein that differs from a parent protein by virtue of at least one amino acid modification. By "antibody variant" or "variant antibody" as used herein is meant an antibody that differs from a parent antibody by virtue of at least one amino acid modification. By "IgA variant" or "variant IgA" as used herein is meant an antibody that differs from a parent IgA by virtue of at least one amino acid modification. The parent IgA can be of the isotype IgA1 or IgA2. By "immunoglobulin variant" or "variant immunoglobulin" as used herein is meant an immunoglobulin sequence that differs from that of a parent immunoglobulin sequence by virtue of at least one amino acid modification.

By "wild-type" or "WT" herein is meant an amino acid sequence or a nucleotide sequence that is found in nature, including allelic variations. A WT protein, polypeptide, antibody, immunoglobulin, IgA, etc. has an amino acid sequence or a nucleotide sequence that has not been intentionally modified.

A "conservative amino acid substitution" is one in which the amino acid residue is replaced with an amino acid residue having a similar side chain. Families of amino acid residues having similar side chains have been defined in the art. These families include amino acids with basic side chains (e.g., lysine (K), arginine (R), histidine (H)), acidic side chains (e.g., aspartic acid (D), glutamic acid (E)), uncharged polar side chains (e.g., glycine (G), asparagine (N), glutamine (Q), serine (S), threonine (T), tyrosine (Y), cysteine (C)), nonpolar side chains (e.g., alanine (A), valine (V), leucine (L), isoleucine (I), proline (P), phenylalanine (F), methionine (M), tryptophan (W)), beta-branched side chains (e.g., threonine (T), valine (V), isoleucine (I)) and aromatic side chains (e.g., tyrosine (Y), phenylalanine (F), tryptophan (W), histidine (H)).

The terms "percent identical" or "percent identity" in the context of two or more nucleic acids or polypeptide sequences, refers to two or more sequences or subsequences that are the same. Two sequences are "substantially identical" if two sequences have a specified percentage of amino acid residues or nucleotides that are the same (*i.e.*, 60% identity, optionally 65%, 70%, 75%, 80%, 85%, 90%, 95%, or 99% identity over a specified region, or, when not specified, over the entire sequence), when compared and aligned for maximum correspondence over a comparison window, or designated region as measured using one of the following sequence comparison algorithms or by manual alignment and visual inspection. Optionally, the identity exists over a region that is at least about 50 nucleotides (or 10 amino acids) in length, or more preferably over a region that is 100 to 500 or 1000 or more nucleotides (or 20, 50, 200 or more amino acids) in length. A

“percentage identity” or “percentage sequence identity” of the present disclosure can be calculated by (i) comparing two optimally aligned sequences (nucleotide or protein) over a window of comparison, (ii) determining the number of positions at which the identical nucleic acid base (for nucleotide sequences) or amino acid residue (for proteins) occurs in both sequences to yield the number of matched positions, (iii) dividing the number of matched positions by the total number of positions in the window of comparison, and then (iv) multiplying this quotient by 100% to yield the percent identity. If the “percent identity” is being calculated in relation to a reference sequence without a particular comparison window being specified, then the percent identity is determined by dividing the number of matched positions over the region of alignment by the total length of the reference sequence. Accordingly, for purposes of the present disclosure, when two sequences (query and subject) are optimally aligned (with allowance for gaps in their alignment), the “percent identity” for the query sequence is equal to the number of identical positions between the two sequences divided by the total number of positions in the query sequence over its length (or a comparison window), which is then multiplied by 100%.

For sequence comparison, typically one sequence acts as a reference sequence, to which test sequences are compared. When using a sequence comparison algorithm, test and reference sequences are entered into a computer, subsequence coordinates are designated, if necessary, and sequence algorithm program parameters are designated. Default program parameters can be used, or alternative parameters can be designated. The sequence comparison algorithm then calculates the percent sequence identities for the test sequences relative to the reference sequence, based on the program parameters.

The term “comparison window” as used herein includes reference to a segment of any one of the number of contiguous positions selected from the group consisting of from 20 to 600, usually about 50 to about 200, more usually about 100 to about 150 in which a sequence may be compared to a reference sequence of the same number of contiguous positions after the two sequences are optimally aligned. Methods of alignment of sequences for comparison are known in the art. Optimal alignment of sequences for comparison can be conducted, *e.g.*, by the local homology algorithm of Smith & Waterman (1970) *Adv. Appl. Math.* 2:482c, by the homology alignment algorithm of Needleman & Wunsch (1970) *J. Mol. Biol.*, 48: 443, by the search for similarity method of Pearson & Lipman (1988) *PNAS USA*, 85: 2444, by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group, 575 Science Dr., Madison, WI), or by manual alignment and visual inspection (see, *e.g.*, Brent *et al.*, (2003) *Current Protocols in Molecular Biology*).

Two examples of algorithms that are suitable for determining percent sequence identity and sequence similarity are the BLAST and BLAST 2.0 algorithms, which are described in Altschul *et al.*, (1977) *Nuc. Acids Res.*, 25: 3389-3402; and Altschul *et al.*, (1990) *J. Mol. Biol.*, 215: 403-410, respectively. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information. This algorithm involves first identifying high scoring sequence pairs (HSPs) by identifying short words of length W in the query sequence, which either match or satisfy some positive-valued threshold score T when aligned with a word of the same length in a database sequence. T is referred to as the neighbourhood word score threshold (Altschul *et al.*, (1990) *supra*). These initial neighbourhood word hits act as seeds for initiating searches to find longer HSPs containing them. The word hits are extended in both directions along each sequence for as far as the cumulative alignment score can be increased. Cumulative scores are calculated using, for nucleotide sequences, the parameters M (reward score for a pair of matching residues; always > 0) and N (penalty score for mismatching residues; always < 0). For amino acid sequences, a scoring matrix is used to calculate the cumulative score. Extension of the word hits in each direction are halted when: the cumulative alignment score falls off by the quantity X from its maximum achieved value; the cumulative score goes to zero or below, due to the accumulation of one or more negative-scoring residue alignments; or the end of either sequence is reached. The BLAST algorithm parameters W , T , and X determine the sensitivity and speed of the alignment. The BLASTN program (for nucleotide sequences) uses as defaults a word length (W) of 11, an expectation (E) or 10, $M=5$, $N=-4$ and a comparison of both strands. For amino acid sequences, the BLASTP program uses as defaults a word length of 3, and expectation (E) of 10, and the BLOSUM62 scoring matrix (see Henikoff & Henikoff, (1989) *PNAS. USA*, 89: 10915) alignments (B) of 50, expectation (E) of 10, $M=5$, $N=-4$, and a comparison of both strands.

The BLAST algorithm also performs a statistical analysis of the similarity between two sequences (see, *e.g.*, Karlin & Altschul (1993) *PNAS. USA*, 90: 5873-5787). One measure of similarity provided by the BLAST algorithm is the smallest sum probability ($P(N)$), which provides an indication of the probability by which a match between two nucleotide or amino acid sequences would occur by chance. For example, a nucleic acid is considered similar to a reference sequence if the smallest sum probability in a comparison of the test nucleic acid to the reference nucleic acid is less than about 0.2, more preferably less than about 0.01, and most preferably less than about 0.001.

The percent identity between two amino acid sequences can also be determined using the algorithm of E. Meyers and W. Miller (*Comput. Appl. Biosci.* 4:11-17 (1988)) which has been incorporated into the ALIGN program (version 2.0), using a PAM120 weight residue table, a gap

length penalty of 12 and a gap penalty of 4. In addition, the percent identity between two amino acid sequences can be determined using the Needleman & Wunsch *supra* algorithm which has been incorporated into the GAP program in the GCG software package (available at www.gcg.com), using either a Blossum 62 matrix or a PAM250 matrix, and a gap weight of 16, 14, 12, 10, 8, 6, or 4 and a length weight of 1, 2, 3, 4, 5, or 6.

Other than percentage of sequence identity noted above, another indication that two nucleic acid sequences or polypeptides are substantially identical is that the polypeptide encoded by the first nucleic acid is immunologically cross reactive with antibodies raised against the polypeptide encoded by the second nucleic acid, as described below. Thus, a polypeptide is typically substantially identical to a second polypeptide, for example, where the two peptides differ only by conservative substitutions. Another indication that two nucleic acid sequences are substantially identical is that the two molecules or their complements hybridize to each other under stringent conditions, as described below. Yet another indication that two nucleic acid sequences are substantially identical is that the same primers can be used to amplify the sequence.

The term "nucleic acid" is used herein interchangeably with the term "polynucleotide" and refers to deoxyribonucleotides or ribonucleotides and polymers thereof in either single- or double-stranded form. The term encompasses nucleic acids containing known nucleotide analogs or modified backbone residues or linkages, which are synthetic, naturally occurring, and non-naturally occurring, which have similar binding properties as the reference nucleic acid, and which are metabolized in a manner similar to the reference nucleotides. Examples of such analogs include, without limitation, phosphorothioates, phosphoramidates, methyl phosphonates, chiral-methyl phosphonates, 2-O-methyl ribonucleotides, peptide-nucleic acids (PNAs).

Unless otherwise indicated, a particular nucleic acid sequence also implicitly encompasses conservatively modified variants thereof (*e.g.*, degenerate codon substitutions) and complementary sequences, as well as the sequence explicitly indicated. Specifically, as detailed below, degenerate codon substitutions may be achieved by generating sequences in which the third position of one or more selected (or all) codons is substituted with mixed-base and/or deoxyinosine residues (Batzer *et al.*, (1991) *Nucleic Acid Res.*, 19: 5081; Ohtsuka *et al.*, (1985) *J Biol Chem.*, 260: 2605-2608; and Rossolini *et al.*, (1994) *Mol Cell Probes*, 8: 91-98). As used herein, the term, "optimized nucleotide sequence" means that the nucleotide sequence has been altered to encode an amino acid sequence using codons that are preferred in the production cell, in this case a Chinese Hamster Ovary cell (CHO). The optimized nucleotide sequence is engineered to retain completely the amino acid sequence originally encoded by the starting nucleotide sequence, which is also

known as the “parental” sequence. In particular embodiments, the optimized sequences herein have been engineered to have codons that are preferred in CHO mammalian cells.

As used herein, “C-terminus” refers to the carboxyl terminal amino acid of a polypeptide chain having a free carboxyl group (-COOH). As used herein, “N-terminus” refers to the amino terminal amino acid of a polypeptide chain having a free amine group (-NH₂).

The term “operably linked” or “functionally linked”, as used herein, refers to a functional relationship between two or more polynucleotide (*e.g.*, DNA) segments. Typically, it refers to the functional relationship of a transcriptional regulatory sequence to a transcribed sequence. For example, a promoter or enhancer sequence is operably linked to a coding sequence if it stimulates or modulates the transcription of the coding sequence in an appropriate host cell or other expression system. Generally, promoter transcriptional regulatory sequences that are operably linked to a transcribed sequence are physically contiguous to the transcribed sequence, *i.e.*, they are cis-acting. However, some transcriptional regulatory sequences, such as enhancers, need not be physically contiguous or located in close proximity to the coding sequences whose transcription they enhance.

The terms “polypeptide” and “protein” are used interchangeably herein to refer to a polymer of amino acid residues. The phrases also apply to amino acid polymers in which one or more amino acid residue is an artificial chemical mimetic of a corresponding naturally occurring amino acid, as well as to naturally occurring amino acid polymers and non-naturally occurring amino acid polymer. Unless otherwise indicated, a particular polypeptide sequence also implicitly encompasses conservatively modified variants thereof.

By “parent polypeptide”, “parent protein”, “precursor polypeptide”, or “precursor protein” as used herein is meant an unmodified polypeptide that is subsequently modified to generate a variant. The parent polypeptide may be a naturally occurring polypeptide, or a variant or engineered version of a naturally occurring polypeptide. Parent polypeptide may refer to the polypeptide itself, compositions that comprise the parent polypeptide, or the amino acid sequence that encodes it. Accordingly, by “parent Fc polypeptide” as used herein is meant an Fc polypeptide that is modified to generate a variant, and by “parent antibody” as used herein is meant an antibody that is modified to generate a variant antibody. In some embodiments, the “parent” is a wild-type protein.

The term “*in vivo* half-life”, as used herein, refers to the half-life of the molecule of interest or variants thereof circulating in the blood of a given mammal.

The term “subject” includes human and non-human animals. Non-human animals include all vertebrates, *e.g.*, mammals and non-mammals, such as non-human primates, sheep, dog, cow,

chickens, amphibians, and reptiles. In a preferred embodiment, the subject is human. Except when noted, the terms “patient” or “subject” are used herein interchangeably.

As used herein, phrases such as “a patient in need of treatment” or “a subject in need of treatment” includes subjects, such as mammalian subjects, that would benefit from administration of molecule or pharmaceutical composition of the present disclosure used, e.g., for detection, for a diagnostic procedure and/or for treatment.

As used herein, the terms term “treatment” or “treat” is herein defined as the application or administration of an Fc variant according to the disclosure, or a pharmaceutical composition comprising said Fc variant, to a subject or to an isolated tissue or cell line from a subject, where the subject has a particular disease (e.g., arthritis), a symptom associated with the disease, or a predisposition towards development of the disease (if applicable), where the purpose is to cure (if applicable), prevent (if applicable), delay the onset of, reduce the severity of, alleviate, ameliorate one or more symptoms of the disease, improve the disease, reduce or improve any associated symptoms of the disease or the predisposition toward the development of the disease. The term “treatment” or “treat” includes treating a patient suspected to have the disease as well as patients who are ill or who have been diagnosed as suffering from the disease or medical condition, and includes suppression of clinical relapse. The phrase “reducing the likelihood” refers to delaying the onset or development or progression of a disease, infection or disorder.

The term “therapeutically acceptable amount” or “therapeutically effective amount” or “therapeutically effective dose” interchangeably refer to an amount sufficient to effect the desired result (i.e., a reduction disease activity, reduction in disease progression, reduction in disease signs and/or symptoms, etc.). In some aspects, a therapeutically acceptable amount does not induce or cause undesirable side effects. A therapeutically acceptable amount can be determined by first administering a low dose, and then incrementally increasing that dose until the desired effect is achieved. A “prophylactically effective dosage” and a “therapeutically effective dosage” of the molecules of the present disclosure can prevent the onset of (if applicable), or result in a decrease in severity of, respectively, disease symptoms.

As used herein, “selecting” and “selected” in reference to a patient is used to mean that a particular patient is specifically chosen from a larger group of patients due to the particular patient having a predetermined criterion. Similarly, “selectively treating a patient” refers to providing treatment to a patient that is specifically chosen from a larger group of patients due to the particular patient having a predetermined criteria. Similarly, “selectively administering” refers to administering a drug to a patient that is specifically chosen from a larger group of patients due to the particular patient having a predetermined criterion.

Unless otherwise specifically stated or clear from context, as used herein, the term “about” in relation to a numerical value is understood as being within the normal tolerance in the art, e.g., within two standard deviations of the mean. Thus, “about” can be within $\pm 10\%$, 9%, 8%, 7%, 6%, 5%, 4%, 3%, 2%, 1%, 0.1%, 0.05%, or 0.01% of the stated value, preferably $\pm 10\%$ of the stated value. When used in front of a numerical range or list of numbers, the term “about” applies to each number in the series, e.g., the phrase “about 1-5” should be interpreted as “about 1- about 5”, or, e.g., the phrase “about 1, 2, 3, 4” should be interpreted as “about 1, about 2, about 3, about 4, etc.”

The word “substantially” does not exclude “completely,” e.g., a composition which is “substantially free” from Y may be completely free from Y. Where necessary, the word “substantially” may be omitted from the definition of the disclosure.

The term “co-administer” refers to the simultaneous presence of two active agents in the blood of an individual. Active agents (e.g., additional therapeutic agents) that are co-administered with the disclosed antibodies and antigen-binding fragments can be concurrently or sequentially delivered.

Various aspects of the disclosure are described in further detail in the following sections and subsections.

Fc variants of the Invention

Besides the ability of antibodies to bind antigen, an important feature of antibodies is their ability to recruit immune effector function. Engagement of the humoral immune response is mainly governed by interactions with C1q and the initiation of the complement cascade (Meyer *et al.*, (2014) MABS, 6(5):1133-44). The cellular immune response occurs mostly due to the interactions between the antibody and Fc gamma receptors (FcγRs). Intracellular signalling through the activating receptors is modulated through the phosphorylation of immunoreceptor tyrosine-based activation motifs (ITAMs), which leads to effector functions such as antibody-dependent cell-mediated cytotoxicity (ADCC), antibody-dependent cellular phagocytosis (ADCP), and inflammation via the induction of cytokine secretion.

Although many antibody-based therapies have clinical and commercial success, these therapeutics are often only effective in a subset of patients. To date, all commercial antibodies are of the IgG class, predominantly IgG1, that recruit immune effector function via FcγRIII (CD16). The typical reaction involves activation of natural killer (NK) cells that display FcγRIII on their cell surface by the Fc portion of an IgG antibody triggering ADCC. However NK cells are only one component of the innate immune system and activation of other forms of leukocytes could be used to enhance the ADCC response triggered by IgG. The IgA class of antibodies engage FcαRI, which is widely

expressed on neutrophils. Neutrophils comprise the highest percentage of innate effector cells found in the circulation and their activation triggers both ADCC and ADCP. In addition they have been shown to infiltrate many solid tumors (Gregory & Houghton (2011) *supra*). However, since IgG antibodies do not bind to the Fc α RI, most commercial antibody-based therapeutics cannot activate neutrophils. As of yet, IgA based therapeutic antibodies have not been developed commercially due to perceived drawbacks with this class of antibody, in comparison to IgG antibodies. However, the applicants have shown that by making modifications to the Fc region, IgA antibodies can be generated with improved binding to Fc α RI. This improved affinity of up to 1000-fold has been shown in cell based assays to directly translate to an increase in potency. Therefore, when used therapeutically, less antibody is required and the antibody can be dosed less often, which is preferential for patients.

In general, as outlined above, Fc variants include amino acid modifications in the CH2 domain and/or CH3 domain of the Fc region. An Fc variant comprises one or more amino acid modifications relative to a parent Fc polypeptide, wherein the amino acid modification(s) optionally provide one or more optimized properties, although in some cases, the variants exhibit substantially identical biological properties. Properties that may be optimized include but are not limited to enhanced or reduced affinity for an Fc α RI. In an embodiment, the Fc variants of the present invention are modified to possess enhanced affinity for a human Fc α RI. In a preferred embodiment, the Fc region of the Fc variant has been affinity matured, whereby amino acid modifications have been made in the CH2 and/or CH3 domains to enhance binding of the Fc region to its target Fc α RI. Such types of modifications may improve the association and/or the dissociation kinetics for binding to the target antigen. This optimized property is anticipated to provide Fc variants with enhanced therapeutic properties in humans, for example enhanced effector function and greater anti-cancer potency.

By "greater affinity" or "improved affinity" or "enhanced affinity" or "better affinity" than a parent Fc polypeptide, as used herein is meant that an Fc variant binds to an Fc receptor with a significantly higher equilibrium constant of association (K_A) or lower equilibrium constant of dissociation (K_D) than the parent Fc polypeptide when the amounts of variant and parent polypeptide in the binding assay are essentially the same. For example, the Fc variant with improved Fc receptor binding affinity may display from about 10 fold to about 100 fold, e.g. at least about 50-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance. For example, the Fc variant of a parent Fc polypeptide can have an increased affinity to human Fc α RI of at least about 50, about 100, about 150, about 200, about 250, about 300-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance.

The Fc receptor selectivity or specificity of a given Fc variant will provide different properties depending on whether it composes an antibody, Fc fusion, or Fc variant with a coupled fusion or conjugate partner.

Fc variants of the invention may comprise modifications that modulate interaction with Fc receptors other than Fc α RI, including but not limited to Fc γ Rs and/or FcRn.

An Fc variant of the present invention differs in amino acid sequence from its parent IgA Fc region by virtue of at least one amino acid modification. Thus, Fc variants of the present invention have at least one amino acid modification compared to the parent. Alternatively, the Fc variants of the present invention may have more than one amino acid modification as compared to the parent, for example from about one to ten amino acid modifications, preferably from one to five amino acid modifications, from one to four amino acid modifications, from one to three amino acid modifications, from one to two amino acid modifications compared to the parent. Thus the sequences of the Fc variants and those of the parent Fc polypeptide are substantially homologous or identical. For example, the variant Fc variant sequences herein will possess about 80% homology (including identity) with the parent Fc variant sequence, preferably at least about 90% homology, and most preferably at least about 95, 96, 97, 98 and 99% identity.

In one embodiment, one or more amino acid insertions, deletions or substitutions are made. All of these substitutions may be made in an IgA molecule, for example IgA1 or IgA2, particularly in IgA2. Preferably, in one embodiment, amino acid substitutions can be made at positions in the Fc region of CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and/or CH3.124, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. These amino acid substitutions include, but are not limited to: A_CH2.10_S, L_CH2.89_I, G_CH2.91_Q, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_H, N_CH2.97_Y, G_CH2.99_W, S_CH3.45_D, M_CH3.105_Y, E_CH3.109_D, Q_CH3.118_Y and/or L_CH3.124_F, again, as any possible combination of substitution(s), insertion(s) and deletion(s), wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. In a preferred embodiment, amino acid substitutions or combinations thereof can include, but are not limited to: Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y, Q_CH2.94_E / S_CH3.45_D, Q_CH2.94_E / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D, N_CH2.97_Y / M_CH3.105_Y, S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y /

Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y / Q_CH3.118_Y, A_CH2.10_S, L_CH2.89_I, G_CH2.91_V, N_CH2.97_H, G_CH2.99_W, E_CH3.109_D, L_CH3.124_F, L_CH2.89_I / G_CH2.91_V / Q_CH2.94_E / N_CH2.97_Y / G_CH2.99_W, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain.

In one embodiment, amino acid substitutions can be made at positions in the Fc region of CH2.94, CH2.97, CH3.45, CH3.105 and CH3.118. In one embodiment, amino acid substitutions can be made at positions in the Fc region of Glu at position CH2.94, Tyr at position CH2.97, Asp at position CH3.45, Tyr at position CH3.105 or Tyr at position CH3.118. In a preferred embodiment, amino acid substitutions can be made in the Fc region of Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y.

Functionally, variants that result in increased binding to Fc α RI find particular use in some embodiments. The Fc variants may comprise more than one protein chain. That is, the Fc variant may find use in an antibody or Fc fusion that is a monomer or an oligomer, including a homo- or hetero-oligomer.

Fc Fusions, Antibody fusions and Antibody Conjugates

Fc polypeptides and antibodies of the invention can be a variety of structures, including, but not limited antibody fragments, bispecific antibodies, minibodies, domain antibodies, synthetic antibodies (sometimes referred to herein as "antibody mimetics"), chimeric antibodies, humanized antibodies, antibody fusions (sometimes referred to as "antibody conjugates"), and fragments of each, respectively. The present invention includes variant Fc polypeptides and antibodies (e.g., antibodies or antibody-like molecules) or fragments thereof recombinantly fused or chemically conjugated (including both covalent and non-covalent conjugations) to a heterologous protein or polypeptide (or fragment thereof, preferably to a polypeptide of at least 10, at least 20, at least 30, at least 40, at least 50, at least 60, at least 70, at least 80, at least 90 or at least 100 amino acids) to generate fusion proteins. Methods for fusing or conjugating proteins, polypeptides, or peptides to an antibody or an antibody fragment are known in the art. See, e.g., US 5,336,603, US 5,622,929, US 5,359,046, US 5,349,053, US 5,447,851, and US 5,112,946; EP 307434 and EP 367166; WO 1996/04388 and WO 1991/06570; Ashkenazi *et al.*, (1991) PNAS. USA 88:10535-10539; Zheng *et al.*, (1995) J. Immunol. 154: 5590-5600; and Vil *et al.*, (1992) PNAS. USA 89:11337-11341.

Additional fusion proteins may be generated through the techniques of gene-shuffling, motif-shuffling, exon-shuffling, and/or codon-shuffling (collectively referred to as "DNA shuffling"). DNA shuffling may be employed to alter the activities of molecules of the disclosure or fragments thereof (e.g., molecules or fragments thereof with higher affinities and lower dissociation rates). See,

generally, US 5,605,793, US 5,811,238, US 5,830,721, US 5,834,252, and US 5,837,458; Patten *et al.*, (1997) *Curr. Opin. Biotechnol.* 8:724-33; Harayama (1998) *Trends Biotechnol.* 16(2):76-82; Hansson *et al.*, (1999) *J. Mol. Biol.* 287: 265-76; and Lorenzo & Blasco (1998) *Biotechniques*, 24(2):308- 313 (each of these patents and publications are hereby incorporated by reference in its entirety). The molecules described herein or fragments thereof may be altered by being subjected to random mutagenesis by error-prone PCR, random nucleotide insertion or other methods prior to recombination. A polynucleotide encoding a fragment of the present molecule may be recombined with one or more components, motifs, sections, parts, domains, fragments, etc. of one or more heterologous molecules.

Moreover, the variant Fc polypeptides and antibodies of the present disclosure can be fused to marker sequences, such as a peptide to facilitate purification. In preferred embodiments, the marker amino acid sequence is a hexa-histidine peptide (SEQ ID NO: 81), such as the tag provided in a pQE vector (QIAGEN, Inc., 9259 Eton Avenue, Chatsworth, CA, 91311), among others, many of which are commercially available. As described in Gentz *et al.*, (1989) *PNAS. USA* 86:821-824, for instance, hexa-histidine (SEQ ID NO: 81) provides for convenient purification of the fusion protein. Other peptide tags useful for purification include, but are not limited to, the hemagglutinin ("HA") tag, which corresponds to an epitope derived from the influenza hemagglutinin protein (Wilson *et al.*, (1984) *Cell* 37:767), and the "flag" tag.

In other embodiments, the variant Fc polypeptides and antibodies of the present disclosure are conjugated to a diagnostic or detectable agent. Such molecules can be useful for monitoring or prognosing the onset, development, progression and/or severity of a disease or disorder as part of a clinical testing procedure, such as determining the efficacy of a particular therapy. Such diagnosis and detection can be accomplished by coupling the molecules to detectable substances including, but not limited to, various enzymes, such as, but not limited to, horseradish peroxidase, alkaline phosphatase, beta-galactosidase, or acetylcholinesterase; prosthetic groups, such as, but not limited to, streptavidin/biotin and avidin/biotin; fluorescent materials, such as, but not limited to, umbelliferone, fluorescein, fluorescein isothiocyanate, rhodamine, dichlorotriazinylamine fluorescein, dansyl chloride or phycoerythrin; luminescent materials, such as, but not limited to, luminol; bioluminescent materials, such as but not limited to, luciferase, luciferin, and aequorin; radioactive materials, such as, but not limited to, iodine (131I, 125I, 123I, and 121I), carbon (14C), sulfur (35S), tritium (3H), indium (115In, 113In, 112In, and 111In), technetium (99Tc), thallium (201Tl), gallium (68Ga, 67Ga), palladium (103Pd), molybdenum (99Mo), xenon (133Xe), fluorine (18F), 153Sm, 177Lu, 159Gd, 149Pm, 140La, 175Yb, 166Ho, 90Y, 47Sc, 186Re, 188Re, 142Pr, 105Rh, 97Ru, 68Ge, 57Co, 65Zn, 85Sr, 32P, 153Gd, 169Yb, 51Cr, 54Mn, 75Se, 113Sn, and

¹¹⁷Ti; and positron emitting metals using various positron emission tomographies, and nonradioactive paramagnetic metal ions.

The present application further encompasses uses of the variant Fc polypeptides and antibodies of the present disclosure conjugated to a therapeutic moiety. For example, the therapeutic moiety may be a cytotoxin, e.g., a cytostatic or cytotoxic agent, a therapeutic agent or a radioactive metal ion, e.g., alpha-emitters. A cytotoxin or cytotoxic agent includes any agent that is detrimental to cells.

Furthermore, the variant Fc polypeptides and antibodies may be conjugated to a therapeutic moiety or drug moiety that modifies a given biological response. For example, the drug moiety may be a protein, peptide, or polypeptide possessing a desired biological activity. Such proteins may include, for example, a toxin such as abrin, ricin A, pseudomonas exotoxin, cholera toxin, or diphtheria toxin; a protein such as tumor necrosis factor, α -interferon, β -interferon, nerve growth factor, platelet derived growth factor, tissue plasminogen activator, an apoptotic agent, an anti-angiogenic agent; or, a biological response modifier such as, for example, a lymphokine.

For further discussion of types of cytotoxins, linkers and methods for conjugating therapeutic agents to the engineered immunoglobulin, see also Saito *et al.*, (2003) Adv. Drug Deliv. Rev. 55:199-215; Trail *et al.*, (2003) Cancer Immunol. Immunother. 52: 328-337; Payne (2003) Cancer Cell 3: 207-212; Allen (2002) Nat. Rev. Cancer, 2:750-763; Pastan & Kreitman (2002) Curr. Opin. Investig. Drugs, 3: 1089-1091; Senter & Springer (2001) Adv. Drug Deliv. Rev. 53: 247-264.

The variant Fc polypeptides and antibodies of the present disclosure also can be conjugated to a radioactive isotope to generate cytotoxic radiopharmaceuticals, also referred to as radioimmunoconjugates. Examples of radioactive isotopes that can be conjugated to engineered immunoglobulins for use diagnostically or therapeutically include, but are not limited to, iodine¹³¹, indium¹¹¹, yttrium⁹⁰, and lutetium¹⁷⁷. Method for preparing radioimmunoconjugates are established in the art. See, e.g., Denardo *et al.*, (1998) Clin Cancer Res. 4(10): 2483-90; Peterson *et al.*, (1999) Bioconjug. Chem. 10(4):553-7; and Zimmerman *et al.*, (1999) Nucl. Med. Biol. 26(8): 943-50, each incorporated by reference in their entireties.

Techniques for conjugating therapeutic moieties to variant Fc polypeptides such as antibodies or antibody-like molecules are known, see, e.g., Arnon *et al.*, "Monoclonal Antibodies for Immunotargeting of Drugs in Cancer Therapy", in Monoclonal Antibodies and Cancer Therapy, Reisfeld *et al.* (eds.), pp. 243-56 (Alan R. Liss, Inc. 1985); Hellstrom *et al.*, "Antibodies for Drug Delivery", in Controlled Drug Delivery (2nd Ed.), Robinson *et al.* (eds.), pp. 623-53 (Marcel Dekker, Inc. 1987); Thorpe, "Antibody Carriers of Cytotoxic Agents in Cancer Therapy: A Review", in Monoclonal Antibodies 84: Biological And Clinical Applications, Pinchera *et al.* (eds.), pp. 475-506

(1985); "Analysis, Results, and Future Prospective of the Therapeutic Use of Radiolabeled Antibody in Cancer Therapy", in *Monoclonal Antibodies For Cancer Detection and Therapy*, Baldwin *et al.* (eds.), pp. 303-16 (Academic Press 1985), and Thorpe *et al.*, (1982) *Immunol. Rev.* 62:119-58.

The variant Fc polypeptides and antibodies may also be attached to solid supports, which are particularly useful for immunoassays or purification of the target antigen. Such solid supports include, but are not limited to, glass, cellulose, polyacrylamide, nylon, polystyrene, polyvinyl chloride or polypropylene.

Fc variants of the invention may comprise one or more modifications that provide reduced or enhanced internalization of an Fc variant. In one embodiment, Fc variants of the present invention can be utilized or combined with additional modifications in order to reduce the cellular internalization of an Fc variant that occurs via interaction with one or more Fc ligands. This property might be expected to enhance effector function, and potentially reduce immunogenicity of the Fc variants of the invention. Alternatively, Fc variants of the present invention can be utilized directly or combined with additional modifications in order to enhance the cellular internalization of an Fc variant that occurs via interaction with one or more Fc ligands.

In a preferred embodiment, modifications are made to improve biophysical properties of the Fc variants of the present invention, including but not limited to stability, solubility, and oligomeric state. Modifications can include, for example, substitutions that provide more favorable intramolecular interactions in the Fc variant such as to provide greater stability, or substitution of exposed nonpolar amino acids with polar amino acids for higher solubility. A number of optimization goals and methods are described in US 10/379,392, incorporated herein by reference, that may find use for engineering additional modifications to further optimize the Fc variants of the present invention. The Fc variants of the present invention can also be combined with additional modifications that reduce oligomeric state or size, such that tumor penetration is enhanced, or *in vivo* clearance rates are increased as desired. Other modifications to the Fc variants of the present invention include those that enable the specific formation of homodimeric or homomultimeric molecules. Such modifications include but are not limited to engineered disulfides, as well as chemical modifications or aggregation methods which may provide a mechanism for generating covalent homodimeric or homomultimers. For example, methods of engineering and compositions of such molecules are described in Kan *et al.*, (2001) *J. Immunol.*, 166:1320-1326; Stevenson *et al.*, (2002) *Recent Results Cancer Res.* 159: 104-12; US 5,681,566; Caron *et al.*, (1992), *J. Exp. Med.* 176: 1191-1195, and Shaper (1992) *J. Immunol.* 148(9): 2918-22, all incorporated herein by reference. Additional modifications to the variants of the present invention include those that enable the specific formation of heterodimeric, heteromultimeric, bifunctional, and/or multifunctional

molecules. Such modifications include, but are not limited to, one or more amino acid substitutions in the CH3 domain, in which the substitutions reduce homodimer formation and increase heterodimer formation. For example, methods of engineering and compositions of such molecules are described in Atwell et al., 1997, J. Mol. Biol. 270(1):26-35, and Carter et al., 2001, J. Immunol. Methods 248:7-15, both incorporated herein by reference. Additional modifications include modifications in the hinge and CH3 domains, in which the modifications reduce the propensity to form dimers.

Preparing Fc variant polypeptides

Antibodies and fragments thereof comprising variant Fc polypeptides as disclosed herein, can be produced by a variety of techniques, including conventional monoclonal antibody methodology e.g., the standard somatic cell hybridization technique of Kohler & Milstein, (1975) Nature 256: 495.

An animal system for preparing hybridomas is the murine system. Hybridoma production in the mouse is a known procedure. Immunization protocols and techniques for isolation of immunized splenocytes for fusion are known in the art. Fusion partners (e.g., murine myeloma cells) and fusion procedures are also known.

Chimeric or humanized antibodies can be prepared based on the sequence of a murine monoclonal antibody prepared as described above. DNA encoding the heavy and light chain immunoglobulins can be obtained from the murine hybridoma of interest and engineered to contain non-murine (e.g., human) immunoglobulin sequences using standard molecular biology techniques. For example, to create a chimeric antibody, the murine variable regions can be linked to human constant regions using methods known in the art (see e.g., US 4,816,567 to Cabilly *et al.*). To create a humanized antibody, the murine CDR regions can be inserted into a human framework using methods known in the art. See e.g., US 5,225,539 to Winter, and US 5,530,101; US 5,585,089; US 5,693,762 and US 6,180,370 to Queen *et al.*

In a certain embodiment, antibodies or fragments thereof comprising Fc variants as described herein are human monoclonal antibodies. Such human monoclonal antibodies can be generated using transgenic or transchromosomal mice carrying parts of the human immune system rather than the mouse system. These transgenic and transchromosomal mice include mice referred to herein as HUMAB mice and KM mice, respectively, and are collectively referred to herein as "human Ig mice".

The HUMAB mouse (Medarex, Inc.) contains human immunoglobulin gene miniloci that encode un-rearranged human heavy (μ and γ) and κ light chain immunoglobulin sequences,

together with targeted mutations that inactivate the endogenous μ and κ chain loci (see e.g., Lonberg *et al.*, (1994) *Nature* 368(6474): 856-859). Accordingly, the mice exhibit reduced expression of mouse IgM or κ , and in response to immunization, the introduced human heavy and light chain transgenes undergo class switching and somatic mutation to generate high affinity human IgGk monoclonal (Lonberg *et al.*, (1994) *supra*; reviewed in Lonberg, (1994) *Handbook of Experimental Pharmacology* 113: 49-101; Lonberg & Huszar, (1995) *Intern. Rev. Immunol.* 13: 65-93, and Harding & Lonberg, (1995) *Ann. N. Y. Acad. Sci.* 764: 536-546). The preparation and use of HUMAB mice, and the genomic modifications carried by such mice, is further described in Taylor *et al.*, (1992) *Nucleic Acids Research* 20:6287-6295; Chen *et al.*, (1993) *International Immunology* 5: 647-656; Tuaillon *et al.*, (1993) *PNAS USA* 94:3720-3724; Choi *et al.*, (1993) *Nature Genetics* 4:117-123; Chen *et al.*, (1993) *EMBO J.* 12:821-830; Tuaillon *et al.*, (1994) *J. Immunol.* 152:2912-2920; Taylor *et al.*, (1994) *Int. Immun.*, 579-591; and Fishwild *et al.*, (1996) *Nature Biotech.*, 14: 845-851, the contents of all of which are hereby specifically incorporated by reference in their entirety. See further, US 5,545,806; US 5,569,825; US 5,625,126; US 5,633,425; US 5,789,650; US 5,877,397; US 5,661,016; US 5,814,318; US 5,874,299; and US 5,770,429; all to Lonberg & Kay; US 5,545,807 to Surani *et al.*; WO 92/103918, WO 93/12227, WO 94/25585, WO 97/113852, WO 98/24884 and WO 99/45962, all to Lonberg & Kay; and WO 01/14424 to Korman *et al.*

In another embodiment, human antibodies can be raised using a mouse that carries human immunoglobulin sequences on transgenes and transchromosomes such as a mouse that carries a human heavy chain transgene and a human light chain transchromosome. Such mice, referred to herein as "KM mice", are described in detail in WO 2002/43478 (Ishida *et al.*).

Still further, alternative transgenic animal systems expressing human immunoglobulin genes are available in the art and can be used to raise human antibodies. For example, an alternative transgenic system referred to as the Xenomouse (Abgenix, Inc.) can be used. Such mice are described in, e.g., US 5,939,598; US 6,075,181; US 6,114,598; US 6,150,584 and US 6,162,963 (Kucherlapati *et al.*).

Moreover, alternative transchromosomal animal systems expressing human immunoglobulin genes are available in the art and can be used to raise human antibodies. For example, mice carrying both a human heavy chain transchromosome and a human light chain transchromosome, referred to as "TC mice" can be used; such mice are described in Tomizuka *et al.*, (2000) *PNAS USA* 97:722-727. Furthermore, cows carrying human heavy and light chain transchromosomes have been described in the art (Kuroiwa *et al.*, (2002) *Nature Biotechnology* 20:889-894) and can be used to raise human antibodies useful in the present application.

Human monoclonal antibodies or fragments thereof can also be prepared using phage display methods for screening libraries of human immunoglobulin genes. Such phage display methods for isolating human antibodies are established in the art or described in the examples below. See for example: US 5,223,409; US 5,403,484; and US 5,571,698 (Ladner *et al*); US 5,427,908 and US 5,580,717 (Dower *et al*); US 5,969,108 and US 6,172,197 (McCafferty *et al*); and US 5,885,793; US 6,521,404; US 6,544,731; US 6,555,313; US 6,582,915 and US 6,593,081 (Griffiths *et al*).

Human monoclonal antibodies or fragments thereof useful in the disclosure can also be prepared using SCID mice into which human immune cells have been reconstituted such that a human antibody response can be generated upon immunization. Such mice are described in, for example, US 5,476,996 and US 5,698,767 (Wilson *et al*).

Human monoclonal antibodies or fragments thereof prepared according to methods described *infra* can be further modified to mutate amino acid residues within the VH, VL, CH1, CL, CH2, CH3 domains to thereby improve one or more binding properties (e.g., affinity) of the antibody or fragment thereof to a receptor of interest, a process known as "affinity maturation." Site-directed mutagenesis or PCR-mediated mutagenesis can be performed to introduce the mutation(s) and the effect on receptor binding, or other functional property of interest, can be evaluated in *in vitro* or *in vivo* assays as described herein and provided in the Examples. Therefore, in one embodiment, the disclosure relates to affinity matured antibodies or fragments thereof, in particular to affinity matured Fc regions. The mutations may be amino acid substitutions, additions or deletions. For example, an Fc variant of the disclosure is an affinity-matured Fc region wherein no more than one, two, three, four or five residues within the CH2 domain and/or CH3 domain have been modified. All of these substitutions may be made in an IgA molecule, for example IgA1 or IgA2, particularly in IgA2. In a preferred embodiment, amino acid substitutions can be made at positions in the Fc region at CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and/or CH3.124, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. These amino acid substitutions include, but are not limited to: A_CH2.10_S, L_CH2.89_I, G_CH2.91_Q, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_H, N_CH2.97_Y, G_CH2.99_W, S_CH3.45_D, M_CH3.105_Y, E_CH3.109_D, Q_CH3.118_Y and/or L_CH3.124_F, again, as any possible combination of substitution(s), insertion(s) and deletion(s), wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain. In a preferred embodiment, amino acid substitutions or combinations thereof in affinity matured Fc variants of the present invention can include, but are not limited to: Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y,

Q_CH2.94_E / S_CH3.45_D, Q_CH2.94_E / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D, N_CH2.97_Y / M_CH3.105_Y, S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y, N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / S_CH3.45_D / M_CH3.105_Y, M_CH3.105_Y / Q_CH3.118_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y, Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y / Q_CH3.118_Y, Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y / Q_CH3.118_Y, A_CH2.10_S, L_CH2.89_I, G_CH2.91_V, N_CH2.97_H, G_CH2.99_W, E_CH3.109_D, L_CH3.124_F, L_CH2.89_I / G_CH2.91_V / Q_CH2.94_E / N_CH2.97_Y / G_CH2.99_W, wherein the numbering of the amino acid modification is according to IMGT numbering for C-domain.

Nucleic acids and expression systems

The present invention also encompasses nucleic acids encoding the polypeptide chains of the Fc variants described herein. Nucleic acid molecules of the disclosure include DNA and RNA in both single-stranded and double-stranded form, as well as the corresponding complementary sequences. The nucleic acid molecules of the disclosure include full-length genes or cDNA molecules as well as a combination of fragments thereof. The nucleic acids of the disclosure are derived from human sources but can include those derived from non-human species.

An "isolated nucleic acid" is a nucleic acid that has been separated from adjacent genetic sequences present in the genome of the organism from which the nucleic acid was isolated, in the case of nucleic acids isolated from naturally-occurring sources. In the case of nucleic acids synthesized enzymatically from a template or chemically, such as PCR products, cDNA molecules, or oligonucleotides for example, it is understood that the nucleic acids resulting from such processes are isolated nucleic acids. An isolated nucleic acid molecule refers to a nucleic acid molecule in the form of a separate fragment or as a component of a larger nucleic acid construct. In one preferred embodiment, the nucleic acids are substantially free from contaminating endogenous material. The nucleic acid molecule has preferably been derived from DNA or RNA isolated at least once in substantially pure form and in a quantity or concentration enabling identification, manipulation, and recovery of its component nucleotide sequences by standard biochemical methods (such as those outlined in Sambrook et al., *Molecular Cloning: A Laboratory Manual*, 2nd ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, NY (1989)). Such sequences are preferably provided and/or constructed in the form of an open reading frame uninterrupted by internal non-translated sequences, or introns, that are typically present in eukaryotic genes.

Sequences of non-translated DNA can be present 5' or 3' from an open reading frame, where the same do not interfere with manipulation or expression of the coding region.

Variant sequences, for example a library of variant sequences can be prepared by site specific mutagenesis of nucleotides in the DNA encoding the polypeptide, using cassette or PCR mutagenesis or other techniques are known in the art, to produce DNA encoding the variant, and thereafter expressing the recombinant DNA in cell culture as outlined herein.

As "optimized nucleotide sequence" means a nucleotide sequence has been altered to encode an amino acid sequence using codons that are preferred in the production cell, for example, a Chinese Hamster Ovary cell (CHO). The optimized nucleotide sequence is engineered to retain completely the amino acid sequence originally encoded by the starting nucleotide sequence, which is also known as the "parental" sequence.

The present disclosure also provides expression systems and constructs in the form of plasmids, expression vectors, transcription or expression cassettes which comprise at least one polynucleotide as above. In addition, the disclosure provides host cells comprising such expression systems or constructs.

In one embodiment, the present invention provides a method of preparing an antibody or fragment thereof comprising a variant Fc region as described herein, the method comprising the steps of: (a) culturing a host cell comprising a nucleic acid encoding the variant heavy chain and light chain polypeptides, wherein the cultured host cell expresses the variant polypeptides; and (b) recovering the antibody or fragment thereof from the host cell culture.

Expression vectors of use in the present disclosure may be constructed from a starting vector such as a commercially available vector. After the vector has been constructed and a nucleic acid molecule encoding polypeptide chains of the engineered immunoglobulin has been inserted into the proper site of the vector, the completed vector may be inserted into a suitable host cell for amplification and/or polypeptide expression. The transformation of an expression vector into a selected host cell may be accomplished by known methods including transfection, infection, calcium phosphate co-precipitation, electroporation, microinjection, lipofection, DEAE-dextran mediated transfection, or other known techniques. The method selected will in part be a function of the type of host cell to be used. These methods and other suitable methods are known to the skilled artisan, and are set forth, for example, in Sambrook *et al.*, 2001, *supra*.

Typically, expression vectors used in the host cells will contain sequences for plasmid maintenance and for cloning and expression of exogenous nucleotide sequences. Such sequences, collectively referred to as 'flanking sequences', in certain embodiments will typically include one or more of the following nucleotide sequences: a promoter, one or more enhancer

sequences, an origin of replication, a transcriptional termination sequence, a complete intron sequence containing a donor and acceptor splice site, a sequence encoding a leader sequence for polypeptide secretion, a ribosome binding site, a polyadenylation sequence, a polylinker region for inserting the nucleic acid encoding the polypeptide to be expressed, and a selectable marker element.

A host cell, when cultured under appropriate conditions, can be used to express Fc variants that can subsequently be collected from the culture medium (if the host cell secretes it into the medium) or directly from the host cell producing it (if it is not secreted). The selection of an appropriate host cell will depend upon various factors, such as desired expression levels, polypeptide modifications that are desirable or necessary for activity (such as glycosylation or phosphorylation) and ease of folding into a biologically active molecule. A host cell may be eukaryotic or prokaryotic.

Mammalian cell lines available as hosts for expression are known in the art and include, but are not limited to, immortalized cell lines available from the American Type Culture Collection (ATCC) and any cell lines used in an expression system known in the art can be used to make polypeptides comprising the engineered immunoglobulins of the present disclosure. In general, host cells are transformed with a recombinant expression vector that comprises DNA encoding a desired engineered immunoglobulin. Among the host cells that may be employed are prokaryotes, yeast or higher eukaryotic cells. Prokaryotes include gram negative or gram positive organisms, for example *E. coli* or bacilli. Higher eukaryotic cells include insect cells and established cell lines of mammalian origin. Examples of suitable mammalian host cell lines include the COS-7 cells, L cells, C127 cells, 3T3 cells, Chinese hamster ovary (CHO) cells, or their derivatives and related cell lines which grow in serum free media, HeLa cells, BHK cell lines, the CVIIEBNA cell line, human embryonic kidney cells such as 293, 293 EBNA or MSR 293, human epidermal A431 cells, human Colo205 cells, other transformed primate cell lines, normal diploid cells, cell strains derived from in vitro culture of primary tissue, primary explants, HL-60, U937, HaK or Jurkat cells. Optionally, mammalian cell lines such as HepG2/3B, KB, NIH 3T3 or S49, for example, can be used for expression of the polypeptide when it is desirable to use the polypeptide in various signal transduction or reporter assays. Alternatively, it is possible to produce the polypeptide in lower eukaryotes such as yeast or in prokaryotes such as bacteria. Suitable yeasts include *S. cerevisiae*, *S. pombe*, *Kluyveromyces* strains, *Candida*, or any yeast strain capable of expressing heterologous polypeptides. Suitable bacterial strains include *E. coli*, *B. subtilis*, *S. typhimurium*, or any bacterial strain capable of expressing heterologous polypeptides. If the engineered immunoglobulin is made in yeast or bacteria, it may be desirable to modify the product produced therein, for example by

phosphorylation or glycosylation of the appropriate sites, in order to obtain a functional product. Such covalent attachments can be accomplished using known chemical or enzymatic methods.

In further embodiments, the Fc variants of the present invention comprise modifications that remove proteolytic degradation sites. These may include, for example, protease sites that reduce production yields, as well as protease sites that degrade the administered protein *in vivo*.

In a preferred embodiment, Fc variants are purified or isolated after expression. Proteins may be isolated or purified in a variety of ways known to those skilled in the art. Standard purification methods include chromatographic techniques, including ion exchange, hydrophobic interaction, affinity, sizing or gel filtration, and reversed-phase, carried out at atmospheric pressure or at high pressure using systems such as FPLC and HPLC. Purification methods also include electrophoretic, immunological, precipitation, dialysis, and chromatofocusing techniques. Ultrafiltration and diafiltration techniques, in conjunction with protein concentration, are also useful. As is known in the art, a variety of natural proteins bind Fc and antibodies, and these proteins can find use in the present invention for purification of Fc variants. For example, the bacterial proteins A and G bind to the Fc region. Likewise, the bacterial protein L binds to the Fab region of some antibodies, as of course does the antibody's target antigen. Purification can often be enabled by a particular fusion partner. For example, Fc variants may be purified using glutathione resin if a GST fusion is employed, Ni⁺² affinity chromatography if a His-tag is employed, or immobilized anti-flag antibody if a flag-tag is used. For general guidance in suitable purification techniques, see, e.g. incorporated entirely by reference Protein Purification: Principles and Practice, 3rd Ed., Scopes, Springer-Verlag, NY, 1994, incorporated entirely by reference.

Pharmaceutical Compositions and Dosing

Provided herein are pharmaceutical compositions comprising the Fc variants of the present disclosure. The Fc variant can be incorporated in an antibody format, for example as a monospecific, bispecific or multi-specific antibody, in combination with one or more pharmaceutically acceptable excipients, diluents or carriers.

To prepare pharmaceutical or sterile compositions comprising an Fc variant of the present disclosure, the molecule is mixed with a pharmaceutically acceptable carrier or excipient.

The phrase "pharmaceutically acceptable" means approved by a regulatory agency of a federal or a state government, or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly, in humans. The term "pharmaceutical composition" refers to a mixture of at least one active ingredient (e.g., an antibody comprising an

Fc variant of the disclosure) and at least one pharmaceutically-acceptable excipient, diluent or carrier. A "medicament" refers to a substance used for medical treatment.

Pharmaceutical compositions of therapeutic and diagnostic agents can be prepared by mixing with physiologically acceptable carriers, excipients, or stabilizers in the form of, e.g., lyophilized powders, slurries, aqueous solutions, lotions, or suspensions (see, e.g., Hardman *et al.* (2001) Goodman and Gilman's The Pharmacological Basis of Therapeutics, McGraw-Hill, New York, N.Y.; Gennaro (2000) Remington: The Science and Practice of Pharmacy, Lippincott, Williams and Wilkins, New York, N.Y.; Avis, *et al.* (eds.) (1993) Pharmaceutical Dosage Forms: Oral Medications, Marcel Dekker, NY; Lieberman, *et al.* (eds.) (1990) Pharmaceutical Dosage Forms: Tablets, Marcel Dekker, NY; Lieberman, *et al.* (eds.) (1990) Pharmaceutical Dosage Forms: Disperse Systems, Marcel Dekker, NY; Weiner & Kotkoskie (2000) Excipient Toxicity and Safety, Marcel Dekker, Inc., New York, N.Y.).

Selecting an administration regimen for a therapeutic depends on several factors, including the serum or tissue turnover rate of the entity, the level of symptoms, the immunogenicity of the entity, and the accessibility of the target cells in the biological matrix. In certain embodiments, an administration regimen maximizes the amount of therapeutic delivered to the patient consistent with an acceptable level of side effects. Accordingly, the amount of biologic delivered depends in part on the particular entity and the severity of the condition being treated. Guidance in selecting appropriate doses of antibodies, cytokines, and small molecules are available (see, e.g., Wawrzynczak (1996) Antibody Therapy, Bios Scientific Pub. Ltd, Oxfordshire, UK; Kresina (ed.) (1991) Monoclonal Antibodies, Cytokines and Arthritis, Marcel Dekker, New York, N.Y.; Bach (ed.) (1993) Monoclonal Antibodies and Peptide Therapy in Autoimmune Diseases, Marcel Dekker, New York, N.Y.; Baert, *et al.* (2003) New Engl. J. Med. 348:601-608; Milgrom, *et al.* (1999) New Engl. J. Med. 341:1966-1973; Slamon, *et al.* (2001) New Engl. J. Med. 344:783-792; Beniaminovitz, *et al.* (2000) New Engl. J. Med. 342:613-619; Ghosh, *et al.* (2003) New Engl. J. Med. 348:24-32; Lipsky, *et al.* (2000) New Engl. J. Med. 343:1594-1602).

Determination of the appropriate dose is made by the clinician, e.g., using parameters or factors known or suspected in the art to affect treatment or predicted to affect treatment. Generally, the dose begins with an amount somewhat less than the optimum dose and it is increased by small increments thereafter until the desired or optimum effect is achieved relative to any negative side effects. Important diagnostic measures include those of symptoms of, e.g., the inflammation or level of inflammatory cytokines produced.

Actual dosage levels of the active ingredients in the pharmaceutical compositions of the present disclosure may be varied so as to obtain an amount of the active ingredient which is

effective to achieve the desired therapeutic response for a particular patient, composition, and mode of administration, without being toxic to the patient. The selected dosage level will depend upon a variety of pharmacokinetic factors including the activity of the particular compositions of the present disclosure employed, or the ester, salt or amide thereof, the route of administration, the time of administration, the rate of excretion of the particular compound being employed, the duration of the treatment, other drugs, compounds and/or materials used in combination with the particular compositions employed, the age, sex, weight, condition, general health and prior medical history of the patient being treated, and like factors known in the medical arts.

Pharmaceutical compositions comprising the Fc variant of the present disclosure can be provided by continuous infusion, or by doses at intervals of, e.g., one day, one week, or 1-7 times per week. Doses may be provided intravenously, subcutaneously, topically, orally, nasally, rectally, intramuscular, intracerebrally, or by inhalation.

The desired dose of a therapeutic comprising the Fc variant of the present disclosure is about the same as for an antibody or polypeptide, on a moles/kg body weight basis. The doses administered to a subject may number at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12, or more.

For a therapeutic comprising the Fc variant of the present disclosure, the dosage administered to a patient may be about 0.0001 mg/kg to about 100 mg/kg of the patient's body weight. Where a series of doses are administered, these may, for example, be administered approximately every day, approximately every week, approximately every month. The doses may, for example, continue to be administered until disease progression, adverse event, or other time as determined by the physician.

An effective amount for a particular patient may vary depending on factors such as the condition being treated, the overall health of the patient, the method route and dose of administration and the severity of side effects (see, e.g., Maynard, *et al.* (1996) A Handbook of SOPs for Good Clinical Practice, Interpharm Press, Boca Raton, Fla.; Dent (2001) Good Laboratory and Good Clinical Practice, Urch Publ., London, UK).

Where necessary, the therapeutic comprising the Fc variant of the present disclosure may be incorporated into a composition that includes a solubilizing agent and a local anesthetic such as lidocaine to ease pain at the site of the injection. In addition, pulmonary administration can also be employed, e.g., by use of an inhaler or nebulizer, and formulation with an aerosolizing agent. See, e.g., US 6,019,968, US 5,985,320, US 5,985,309, US 5,934,272, US 5,874,064, US 5,855,913, US 5,290,540, and US 4,880,078; and WO 92/19244, WO 97/32572, WO 97/44013, WO 98/31346, and WO 99/66903, each of which is incorporated herein by reference their entirety.

A therapeutic comprising the Fc variant of the present disclosure can also be administered via one or more routes of administration using one or more of a variety of methods known in the art. As will be appreciated by the skilled artisan, the route and/or mode of administration will vary depending upon the desired results. Selected routes of administration for the antibodies include intravenous, intramuscular, intradermal, intraperitoneal, subcutaneous, spinal or other parenteral routes of administration, for example by injection or infusion. Parenteral administration can represent modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion. Alternatively, a composition of the present disclosure can be administered via a non-parenteral route, such as a topical, epidermal or mucosal route of administration, for example, intranasally, orally, vaginally, rectally, sublingually or topically.

The therapeutic comprising the Fc variant of the present disclosure may be administered via any of the above routes using, e.g., an injection device, an injection pen, a vial and syringe, pre-filled syringe, autoinjector, an infusion pump, a patch pump, an infusion bag and needle, etc. If the therapeutic comprising the Fc variant of the present disclosure is administered in a controlled release or sustained release system, a pump may be used to achieve controlled or sustained release (see Langer, *supra*; Sefton (1987) CRC Crit. Ref Biomed. Eng. 14:20; Buchwald *et al.*, (1980) Surgery 88:507; Saudek *et al.*, (1989) N. Engl. J. Med. 321:574). Polymeric materials can be used to achieve controlled or sustained release of the therapies of the disclosure (see e.g., Medical Applications of Controlled Release, Langer and Wise (eds.), CRC Pres., Boca Raton, Fla. (1974); Controlled Drug Bioavailability, Drug Product Design and Performance, Smolen & Ball (eds.), Wiley, New York (1984); Ranger & Peppas (1983) J. Macromol. Sci. Rev. Macromol. Chem. 23:61; see also Levy *et al.*, (1985) Science 228:190; During *et al.*, (1989) Ann. Neurol. 25:351; Howard *et al.*, (1989) J. Neurosurg., 7(1):105; US 5,679,377; US 5,916,597; US 5,912,015; US 5,989,463; US 5,128,326; WO 99/15154; and WO 99/20253. Examples of polymers used in sustained release formulations include, but are not limited to, poly(2-hydroxy ethyl methacrylate), poly(methyl methacrylate), poly(acrylic acid), poly(ethylene-co-vinyl acetate), poly(methacrylic acid), polyglycolides (PLG), polyanhydrides, poly(N-vinyl pyrrolidone), poly(vinyl alcohol), polyacrylamide, poly(ethylene glycol), polylactides (PLA), poly(lactide-co-glycolides) (PLGA), and polyorthoesters. In one embodiment, the polymer used in a sustained release formulation is inert, free of leachable impurities, stable on storage, sterile, and biodegradable. A controlled or sustained release system can be placed in proximity of the prophylactic or therapeutic target, thus requiring

only a fraction of the systemic dose (see, e.g., Goodson, in *Medical Applications of Controlled Release*, *supra*, vol. 2, pp. 115-138 (1984)).

Controlled release systems are discussed in the review by Langer (*Science* (1990) 249:1527-1533). Any technique known to one of skill in the art can be used to produce sustained release formulations comprising one or more Fc variants of the present application. See, e.g., US 4,526,938, WO 91/05548, WO 96/20698, Ning *et al.*, (1996) *Radiotherapy & Oncology* 39: 179-189; Song *et al.*, (1995) *PDA Journal of Pharm Sci & Tech.*, 50: 372-397; Cleek *et al.*, (1997) *Pro. Int'l. Symp. Control. Rel. Bioact. Mater.* 24: 853-854; Lam *et al.*, (1997) *Proc. Int'l. Symp. Control Rel. Bioact. Mater.*, 24: 759-760, each of which is incorporated herein by reference in their entirety.

If a pharmaceutical composition comprising the Fc variant of the present disclosure is administered topically, it can be formulated in the form of an ointment, cream, transdermal patch, lotion, gel, shampoo, spray, aerosol, solution, emulsion, or other forms known to one of skill in the art. See, e.g., *Remington's Pharmaceutical Sciences and Introduction to Pharmaceutical Dosage Forms*, 19th ed., Mack Pub. Co., Easton, Pa. (1995). For non-sprayable topical dosage forms, viscous to semi-solid or solid forms comprising a carrier or one or more excipients compatible with topical application and having a dynamic viscosity, in some instances, greater than water are typically employed. Suitable formulations include, without limitation, solutions, suspensions, emulsions, creams, ointments, powders, liniments, salves, and the like, which are, if desired, sterilized or mixed with auxiliary agents (e.g., preservatives, stabilizers, wetting agents, buffers, or salts) for influencing various properties, such as, for example, osmotic pressure. Other suitable topical dosage forms include sprayable aerosol preparations wherein the active ingredient, in some instances, in combination with a solid or liquid inert carrier, is packaged in a mixture with a pressurized volatile (e.g., a gaseous propellant, such as Freon) or in a squeeze bottle. Moisturizers or humectants can also be added to pharmaceutical compositions and dosage forms if desired. Examples of such additional ingredients are known in the art.

If a pharmaceutical composition comprising the Fc variant of the present disclosure is administered intranasally, it can be formulated in an aerosol form, spray, mist or in the form of drops. In particular, prophylactic or therapeutic agents for use according to the present disclosure can be conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebulizer, with the use of a suitable propellant (e.g., dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide or other suitable gas). In the case of a pressurized aerosol the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges (composed of, e.g., gelatin) for use in an inhaler or

insufflator may be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

A pharmaceutical composition comprising the Fc variant of the present disclosure can also be cyclically administered to a patient.

In certain embodiments, pharmaceutical compositions comprising an Fc variant of the present disclosure can be formulated to ensure proper distribution *in vivo*. For example, the blood-brain barrier (BBB) excludes many highly hydrophilic compounds. To ensure that the therapeutic compounds of the disclosure cross the BBB (if desired), they can be formulated, for example, in liposomes. For methods of manufacturing liposomes, see, e.g., US 4,522,811; US 5,374,548; and US 5,399,331. The liposomes may comprise one or more moieties which are selectively transported into specific cells or organs, thus enhance targeted drug delivery (see, e.g., Ranade, (1989) J. Clin. Pharmacol. 29:685). Exemplary targeting moieties include folate or biotin (see, e.g., US 5,416,016 to Low *et al*); mannosides (Umezawa *et al.*, (1988) Biochem. Biophys. Res. Commun. 153:1038); antibodies (Bloeman *et al.*, (1995) FEBS Lett., 357: 140; Owais *et al.*, (1995) Antimicrob. Agents Chemother., 39: 180); surfactant protein A receptor (Briscoe *et al.*, (1995) Am. J. Physiol. 1233:134); p 120 (Schreier *et al* (1994) J. Biol. Chem. 269:9090); see also Keinänen & Laukkanen (1994) FEBS Lett., 346:123-6; Killion & Fidler (1994) Immunomethods, 4: 273.

The present application also provides protocols for the co-administration or treatment of patients using a pharmaceutical composition comprising Fc variants of the present disclosure in combination with other therapies or therapeutic agent(s). Methods for co-administration or treatment with an additional therapeutic agent, e.g., a cytokine, steroid, chemotherapeutic agent, antibiotic, or radiation, are known in the art (see, e.g., Hardman *et al.*, (eds.) (2001) Goodman and Gilman's The Pharmacological Basis of Therapeutics, 10.sup.th ed., McGraw-Hill, New York, N.Y.; Poole and Peterson (eds.) (2001) Pharmacotherapeutics for Advanced Practice: A Practical Approach, Lippincott, Williams & Wilkins, Phila., Pa.; Chabner and Longo (eds.) (2001) Cancer Chemotherapy and Biotherapy, Lippincott, Williams & Wilkins, Phila., Pa.). An effective amount of therapeutic may decrease the symptoms by at least 10%, by at least 20%, at least about 30%, at least 40%, or at least 50%.

In some embodiments, a pharmaceutical composition of the disclosure further comprises one or more additional therapeutic agents.

In addition to the above therapeutic regimens, the patient may be subjected to surgery and other forms of physical therapy.

Therapeutic Application

Therapeutic or pharmaceutical compositions comprising Fc variants of the present disclosure, whilst not being limited to, are useful for the treatment, prevention, or amelioration of disorders or conditions in which there is an abnormal proliferation of cells, termed herein as "cell proliferative disorders or conditions". In one aspect, the disclosure provides methods for treating a cell proliferative disorder or condition. In one aspect, the subject of treatment is a human.

Examples of cell proliferative disorders or conditions that may be treated, prevented, or ameliorated using therapeutic or pharmaceutical compositions comprising Fc variants of the present disclosure include but are not limited to cancer. As used herein, the term "cancer" is meant to include all types of cancerous growths or oncogenic processes, metastatic tissues or malignantly transformed cells, tissues, or organs, irrespective of histopathologic type or stage of invasiveness.

In specific embodiments, the administration of a therapeutic or pharmaceutical composition comprising a Fc variant of the present disclosure to a subject in accordance with the methods described herein achieves one, two, or three or more results: (1) a reduction in the growth of a tumor or neoplasm; (2) a reduction in the formation of a tumor; (3) an eradication, removal, or control of primary, regional and/or metastatic cancer; (4) a reduction in metastatic spread; (5) a reduction in mortality; (6) an increase in survival rate; (7) an increase in length of survival; (8) an increase in the number of patients in remission; (9) a decrease in hospitalization rate; (10) a decrease in hospitalization lengths; and (11) the maintenance in the size of the tumor so that it does not increase by more than 10%, or by more than 8%, or by more than 6%, or by more than 4%; preferably the size of the tumor does not increase by more than 2%.

In a specific embodiment, the administration of a therapeutic or pharmaceutical composition comprising a Fc variant of the present disclosure to a subject with cancer (in some embodiments, an animal model for cancer) in accordance with the methods described herein inhibits or reduces the growth of a tumor by at least about 2 fold, preferably at least about 2.5 fold, at least about 3 fold, at least about 4 fold, at least about 5 fold, at least about 7 fold, or at least about 10 fold relative to the growth of a tumor in a subject with cancer (in some embodiments, in the same animal model for cancer) administered a negative control as measured using assays known in the art. In another embodiment, the administration of a therapeutic or pharmaceutical composition comprising a Fc variant of the present disclosure to a subject with cancer (in some embodiments, an animal model for cancer) in accordance with the methods described herein inhibits or reduces the growth of a tumor by at least about 25%, at least about 30%, at least about 35%, at least about 40%, at least about 45%, at least about 50%, at least about 55%, at least about 60%, at least about 65%, at least 70%, at least 75%, at least about 80%, at least about 85%, at least about 90%, or at least about

95% relative to the growth of a tumor in a subject with cancer (in some embodiments, in the same animal model for cancer) administered a negative control, as measured using assays known in the art.

Examples of cancerous disorders include, but are not limited to, solid tumors, hematological cancers, soft tissue tumors, and metastatic lesions. Examples of solid tumors include malignancies, e.g., sarcomas, and carcinomas (including adenocarcinomas and squamous cell carcinomas), of the various organ systems, such as those affecting liver, lung, breast, lymphoid, gastrointestinal (e.g., colon), genitourinary tract (e.g., renal, urothelial cells), prostate and pharynx. Adenocarcinomas include malignancies such as most colon cancers, rectal cancer, renal-cell carcinoma, liver cancer, non-small cell carcinoma of the lung, cancer of the small intestine and cancer of the esophagus. Squamous cell carcinomas include malignancies, e.g., in the lung, esophagus, skin, head and neck region, oral cavity, anus, and cervix. In one embodiment, the cancer is a melanoma, e.g., an advanced stage melanoma. Metastatic lesions of the aforementioned cancers can also be treated or prevented using the methods and compositions of the disclosure.

Exemplary cancers whose growth can be inhibited using a therapeutic or pharmaceutical composition comprising a Fc variant of the present disclosure include cancers typically responsive to immunotherapy. Non-limiting examples of preferred cancers for treatment include melanoma (e.g., metastatic malignant melanoma), renal cancer (e.g., clear cell carcinoma), prostate cancer (e.g., hormone refractory prostate adenocarcinoma), breast cancer, colon cancer and lung cancer (e.g., non-small cell lung cancer), epithelial cancer. Additionally, refractory or recurrent malignancies can be treated using the combination therapy described herein.

Examples of other cancers that can be treated include bone cancer, pancreatic cancer, skin cancer, cancer of the head or neck, cutaneous or intraocular malignant melanoma, uterine cancer, ovarian cancer, rectal cancer, anal cancer, gastro-esophageal, stomach cancer, testicular cancer, uterine cancer, carcinoma of the fallopian tubes, carcinoma of the endometrium, carcinoma of the cervix, carcinoma of the vagina, carcinoma of the vulva, Merkel cell cancer, Hodgkin lymphoma, non-Hodgkin lymphoma, cancer of the esophagus, cancer of the small intestine, cancer of the endocrine system, cancer of the thyroid gland, cancer of the parathyroid gland, cancer of the adrenal gland, sarcoma of soft tissue, cancer of the urethra, cancer of the penis, chronic or acute leukemias including acute myeloid leukemia, chronic myeloid leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia, solid tumors of childhood, lymphocytic lymphoma, cancer of the bladder, multiple myeloma, myelodysplastic syndromes, cancer of the kidney or ureter, carcinoma of the renal pelvis, neoplasm of the central nervous system (CNS), primary CNS

lymphoma, neuroblastoma, tumor angiogenesis, spinal axis tumor, brain stem glioma, pituitary adenoma, Kaposi's sarcoma, epidermoid cancer, squamous cell cancer, T-cell lymphoma, environmentally induced cancers including those induced by asbestos (e.g., mesothelioma), and combinations of said cancers.

In a specific embodiment, the cancer is breast cancer, neuroblastoma, lymphoma, colon cancers, pancreatic ductal adenocarcinoma, melanoma, renal cell carcinoma, bladder cancer, colorectal cancer, non-small cell lung cancer, non-Hodgkins lymphoma, multiple myeloma.

Combination Therapies

Administered "in combination", in reference to an additional therapeutic agent, means that two (or more) different treatments are delivered to the subject during the course of the subject's affliction with the disorder. In some embodiments, the delivery of one treatment is still occurring when the delivery of the second begins, so that there is overlap in terms of administration. This is referred to as "simultaneous" or "concurrent delivery". In other embodiments, the delivery of one treatment ends before the delivery of the other treatment begins. This is referred to as "sequential delivery". In some embodiments of either case, the treatment is more effective because of combined administration. The additional therapeutic agent(s) of the combination therapies of the present disclosure can also be cyclically administered. Combination cycling therapy involves the administration of a first therapy for a period of time, followed by the administration of a second for a period of time and repeating this sequential administration.

A therapeutic or pharmaceutical composition comprising an engineered immunoglobulin as described herein can be administered together with one or more other therapies, e.g., anti-cancer agents, cytokines or anti-hormonal agents, to treat and/or manage cancer. Other therapies that can be used in combination with a therapeutic or pharmaceutical composition comprising an engineered immunoglobulin as described herein, include, but are not limited to, small molecules, synthetic drugs, peptides (including cyclic peptides), polypeptides, proteins, nucleic acids (e.g., DNA and RNA nucleotides including, but not limited to, antisense nucleotide sequences, triple helices, RNAi, and nucleotide sequences encoding biologically active proteins, polypeptides or peptides), antibodies, synthetic or natural inorganic molecules, mimetic agents, and synthetic or natural organic molecules.

Non-limiting examples of one or more other therapies that can be used in addition to a therapeutic or pharmaceutical composition comprising an engineered immunoglobulin as described herein include, but not limited to, chemotherapy, radiotherapy, cytotoxic agents, chemotherapeutic agents, cytokines, kinase inhibitors, low dose gemcitabine, 5-fluorouracil and cytokine modulators.

In particular, one or more other therapies that can be used in addition to a therapeutic or pharmaceutical composition comprising an engineered immunoglobulin of the present disclosure include in particular immune oncology approaches that would perturb the tumor microenvironment, for example, recombinant IL-2, recombinant IL-15, recombinant IL-12, recombinant IL-21, anti-IL1 β , anti-TGF β , anti-CD39, anti-CD73, anti-CTLA4, anti-PD(L)1, anti-TIM3, HDAC inhibitors, HIF1a inhibitors and anti-angiogenics such as anti-VEGF.

Kits

The disclosure also encompasses kits for treating a patient having a cell proliferative disorder. Such kits comprise a therapeutically effective amount of a therapeutic or pharmaceutical composition comprising a Fc variant as described herein. Additionally, such kits may comprise means for administering the therapeutic or pharmaceutical composition comprising a Fc variant as described herein (e.g., an autoinjector, a syringe and vial, a prefilled syringe, a prefilled pen) and instructions for use. These kits may contain additional therapeutic agents (described *infra*) for treating a cell proliferative disorder. Such kits may also comprise instructions for administration of the therapeutic or pharmaceutical composition comprising a Fc variant as described herein, to treat the patient. Such instructions can provide the dose, route of administration, regimen, and total treatment duration for use with the therapeutic or pharmaceutical composition comprising a Fc variant as described herein.

The phrase “means for administering” is used to indicate any available implement for systemically administering a drug to a patient, including, but not limited to, a pre-filled syringe, a vial and syringe, an injection pen, an auto-injector, an IV drip and bag, an infusion pump, a patch, an infusion bag and needle, etc. With such items, a patient may self-administer the drug (i.e., administer the drug without the assistance of a physician) or a medical practitioner may administer the drug.

Examples

The following examples are provided to further illustrate the disclosure but not to limit its scope. Other variants of the disclosure will be readily apparent to one of ordinary skill in the art and are encompassed by the appended claims.

All constructs derived from amino acid sequences generated according to Example 1 and were expressed in mammalian systems and purified (Example 2) to be assessed for binding to human Fc α RI and rat Fc α R using surface plasmon resonance (SPR) (Example 3). Finally, functionality of the engineered immunoglobulins was assessed by a cell-based assay using human

freshly isolated PMN (Example 4). All Examples were performed using the Fc variants in an antibody format comprising VH and VL domains recognizing the antigen HER2 and engineered hinge and Fc regions based on IgA2. SEQ ID NO: 1 is a full length heavy chain sequence of an anti-HER2 binding antibody having a VH domain that binds HER2 and a hinge and constant domains from IgG1. SEQ ID NO: 2 is a full length heavy chain sequence of an anti-HER2 binding antibody having a VH domain that binds HER2 and a hinge and constant domains from the m2 allotype of IgA2 (Lombana *et al.*, (2019) MABS, 11: 1122-38). SEQ ID NO: 4 is the light chain sequence of an anti-HER2-binding antibody having a VL domain that binds HER2 and a constant domain (CL) from IgA2.

Example 1: IgA2 Fc Affinity maturation for hFc α RI

1.1 IgA2 Fc library design

In-silico analysis was performed on the IgA1 Fc/hFc α RI complex using the crystal structure PDB 1OW0, since IgA1 has a similar structure to IgA2, differing only in the hinge region. All residues located in proximity to hFc α RI were considered to be potentially involved in the IgA1 Fc/hFc α RI interaction and were classified into two categories: (i) residues from the “core” interface region (LCH2.15, LCH2.15.1, MCH3.105, ECH3.109, PCH3.113, LCH3.114, ACH3.115, FCH3.116, QCH3.118, wherein the residues are numbered according to the IMGT numbering for C-domain) and (ii) residues from the “shell” region surrounding the core (QCH2.94, NCH2.97, HCH2.98, RCH3.1, ECH3.3, RCH3.40, LCH3.42, SCH3.45, ECH3.45.2, wherein the residues are numbered according to the IMGT numbering for C-domain). Both groups of residues were diversified using a trinucleotide-directed mutagenesis (TRIM) based approach (Virnekäs *et al.*, (1994) Nucleic Acids Res., 22: 5600-5607; Knappik *et al.*, (2000) J Mol Biol., 296: 57-86) to generate two libraries L1 and L2, corresponding to the ‘shell’ region and the ‘core’ region, respectively.

A third library was generated using error prone PCR of the IgA2 Fc domain (EP library) (Gram *et al.*, (1992) PNAS USA, 89: 3576-3580).

1.2 Library screening by yeast display

All three IgA2 Fc libraries were screened using yeast display technology (Boder *et al.*, (1997) Nature Biot., 15: 553-557). Briefly, IgA Fcs were displayed on yeast cell membranes via the α -agglutinin (Aga1/Aga2) protein heterodimer, with IgA2 Fc fused to the N-terminus of the Aga2 protein. Four rounds of sorting were performed:

(i) During the first round of sorting, all three libraries were grown for two days at 20°C with shaking in selective medium containing 1% raffinose and 2% galactose to induce IgA2 Fc

expression on yeast cell surface. Each culture was pelleted, the supernatant removed, and the pellet washed once with PBSM (PBS (Gibco, Waltham, MA) with 1% BSA (bovine serum albumin) and 2 mM EDTA. After resuspension of pellets in 20 ml PBSM, 100 μ l each streptavidin and anti-biotin microbeads (Miltenyi Biotec, Bergisch Gladbach, Germany) were added. Cells were incubated for 1 hr at room temperature with rotation. The beads were then removed using a MACS LS column (Miltenyi). The libraries were then pelleted and resuspended in 20 ml PBSM + 50 nM biotinylated Fc α RI (CD89) (SEQ ID NO: 5) and incubated for 1 hr at room temperature with rotation. The cells were then pelleted, the supernatant removed, washed once in PBSM, then resuspended in 20 ml PBSM + 100 μ l streptavidin microspheres (Miltenyi). The libraries were incubated for 5 min on ice with occasional shaking, then the cells were pelleted, the supernatant removed, resuspended in 20 ml PBSM, then separated on MACS LS columns (Miltenyi). The columns were washed once with 5ml PBSM, then the bound cells were eluted with selective medium, brought to 10 ml final in selective medium, and grown at 30°C with shaking overnight.

(ii) For the second round of sorting, the first round output from each of the three libraries was grown 24 hrs at 20°C in selective medium containing 1% raffinose and 2% galactose to induce IgA expression. The libraries were pelleted, washed once in PBSF (PBS (Gibco) + 0.1% bovine serum albumin), and resuspended in PBSF. Each library was divided into two samples; the first sample was brought to 25 nM biotinylated Fc α RI in PBSF, and the second sample was brought to 10 nM biotinylated Fc α RI in PBSF. To each, rabbit anti myc-tag Dylight 488 (Rockland, Limerick, PA) was added at a 1:100 final dilution, and the samples were incubated for 1.5 hrs at room temperature with rotation. The samples were pelleted, washed once with PBSF, then incubated with PBSF + 1:100 final streptavidin Dylight 633 (Invitrogen, Waltham, MA) for 5 min with rotation. The samples were then pelleted, washed once, resuspended in PBSF, filtered through a 40 μ m strainer, then analyzed and sorted using flow cytometry on a FACS Aria cell sorter (Becton Dickinson Biosciences, San Jose, CA). For the L1 and L2 libraries, the 10 nM Fc α RI sample was sorted, and for the EP library, the 25 nM Fc α RI sample was sorted. In each case, the yeast showing the top 1-2% of signal were gated, collected, and grown overnight at 30°C in selective medium.

(iii) For the third round of sorting, the cultures from the second round of sorting were inoculated into selective medium + 1% raffinose + 2% galactose, and grown overnight at 20° to induce IgA expression. Cells from each of the three libraries were prepared and sorted as was done in the second round, except with the use of chicken anti myc tag FITC (Genetex, Irvine, CA) and Neutravidin Dylight 633 (Invitrogen), as detection reagents. Biotinylated Fc α RI was used at 5 nM for the EP library, 2 nM for the L1 library, and 1 nM for the L2 library. In each case, the yeast

showing the top 1-2% of signal were gated, collected, and grown overnight at 30°C in selective medium.

(iv) The fourth round of sorting was completed on the EP and L1 libraries only. The cultures from the third round of sorting were inoculated into selective medium + 1% raffinose + 2% galactose, and grown overnight at 20° to induce IgA expression. Cells from each of the libraries were prepared and sorted as was done in the second round, except with the use of mouse anti c myc Dylight 488 (Invitrogen) and Streptavidin cy5 (Invitrogen), as detection reagents. Biotinylated FcαRI was used at 2 nM for the EP library, and 1 nM for the L1 library. In each case, the yeast showing the top 1-2% of signal were gated, collected, and grown overnight at 30°C in selective medium.

1.3 Hot spot identification, translation in full-length immunoglobulins and SPR validation towards hFcαRI

Plasmids were purified from the third (L2 library) and fourth (EP and L1 libraries) round cultures, transformed in to *E. coli*, plated on selective agar plates, grown overnight at 37°, and submitted to Genewiz (South Plainfield, NJ) for Sanger sequencing (Sanger *et al* (1975) J Mol Biol., 94(3): 441-8; Sanger *et al* (1977) PNAS USA., 74(12): 5463-7). The top clones were selected based on their frequency of appearance and were used to identify mutations enhancing the IgA2/hFcαRI interaction. The IgA2 residue positions are presented Table 1.

Table 1: Mutations identified by yeast display for enhancing IgA2 affinity towards hFcαRI.

IgA2 sequence position (IMGT numbering for C-domain)	Initial residue in IgA2	Mutation
CH2.10	A	S
CH2.89	L	I
CH2.91	G	V
CH2.94	Q	E
CH2.97	N	Y, H
CH2.99	G	W
CH3.105	M	Y
CH3.109	E	D
CH3.118	Q	Y
CH3.124	L	F

Identified mutations were incorporated into the full-length IgA2 immunoglobulin having SEQ ID NO: 2, as single point mutation or in combination, and expressed transiently in HEK293 cells as described in Example 2. The same mutations were also incorporated into IgG1 isotype immunoglobulins having SEQ ID NOs: 3 and 6 and containing an engineered IgG1 Fc that was capable of binding to hFcαRI. The tested mutation sets are presented in Table 2 (based on SEQ ID NO: 2), Table 4 (based on SEQ ID NO: 3) and Table 6 (based on SEQ ID NO: 6).

The Fc variants were purified and assessed using surface plasmon resonance (SPR), measured against hFcαRI, to evaluate the effect of specific mutations on immunoglobulin affinity to hFcαRI. Interestingly, all mutations had a limited effect or no real effect on expression yield and aggregation propensity of the respective immunoglobulin. SPR data and aggregation content after capture are shown in Table 3, Table 5 and Table 7.

Finally, lead candidates were selected based on SPR and aggregation data and SPR experiments were repeated using a broader range of hFcαRI concentrations. The use of the adapted concentration range enabled a more precise measurement of the interaction between engineered immunoglobulin and hFcαRI. Results are shown in Table 8, Table 9 and Table 10.

Table 2: Tested mutation sets, based on parental IgA2 immunoglobulin SEQ ID 2.

SEQ ID NO	Ref number	Mutation set
2	2737	-
10	3240	Q_CH2.94_E
11	3241	N_CH2.97_Y
12	3242	S_CH3.45_D
13	3243	M_CH3.105_Y
14	3244	Q_CH3.118_Y
15	3245	Q_CH2.94_E, N_CH2.97_Y
53	3309	Q_CH2.94_E, S_CH3.45_D
54	3310	Q_CH2.94_E, M_CH3.105_Y
55	3311	N_CH2.97_Y, S_CH3.45_D
56	3312	N_CH2.97_Y, M_CH3.105_Y
57	3313	S_CH3.45_D, M_CH3.105_Y
28	3258	M_CH3.105_Y, Q_CH3.118_Y
58	3314	Q_CH2.94_E, N_CH2.97_Y, M_CH3.105_Y
59	3315	N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
60	3316	Q_CH2.94_E, S_CH3.45_D, M_CH3.105_Y
29	3259	M_CH3.105_Y, Q_CH3.118_Y, S_CH3.45_D
30	3260	Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D
61	3317	Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
31	3261	Q_CH2.94_E, N_CH2.97_Y, M_CH3.105_Y, Q_CH3.118_Y
32	3262	Q_CH2.94_E, N_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y

43	3273	A_CH2.10_S
44	3274	L_CH2.89_I
45	3275	G_CH2.91_V
50	3280	N_CH2.97_H
46	3276	G_CH2.99_W
47	3277	E_CH3.109_D
48	3278	L_CH3.124_F
49	3279	L_CH2.89_I, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_Y, G_CH2.99_W

Table 3: Biophysical characterization of the Fc variants based on parental IgA2 SEQ ID No: 2.

SEQ ID NO	Ref number	KD (1:1) (M) ¹	Maximum response ¹ at 1000nM hFcαRI (RU)	Aggregation ² (%)
2	2737	5.20E-07	168	11.5
10	3240	1.26E-07	253	12.40
11	3241	8.69E-08	235	10.60
12	3242	6.67E-08	261	9.93
13	3243	2.63E-08	278	11.30
14	3244	1.46E-07	194	8.60
15	3245	6.73E-08	250	14.00
53	3309	5.20E-08	242	8.30
54	3310	1.70E-08	213	8.10
55	3311	1.94E-08	246	9.60
56	3312	6.77E-09	251	7.50
57	3313	9.81E-09	194	8.90
28	3258	1.30E-08	278	10.20
58	3314	5.65E-09	247	8.40
59	3315	3.96E-09	223	9.90
60	3316	9.80E-09	226	7.40
29	3259	7.43E-09	289	10.40
30	3260	4.10E-08	306	13.10
61	3317	3.81E-09	244	11.90
31	3261	5.66E-09	289	13.60
32	3262	5.99E-09	294	16.70
43	3273	1.09E-07	244	13.50
44	3274	1.24E-07	189	11.00
45	3275	1.38E-07	247	10.30
50	3280	1.00E-07	188	nd
46	3276	1.43E-07	225	9.90
47	3277	9.20E-08	220	11.40
48	3278	1.60E-07	231	12.80
49	3279	nd	nd	nd

¹ Affinity and maximum response of engineered immunoglobulins towards hFcαRI were determined by SPR experiments, following the procedure described in Example 3.

² Aggregation propensity was measured following the procedure described in Example 2.

nd: not determined

Table 4: Tested mutation sets, based on parental IgG1 engineered immunoglobulin SEQ ID 3

SEQ ID NO	Ref number	Mutation set
3	2771	-
16	3246	Q_CH2.94_E
17	3247	L_CH2.97_Y
18	3248	S_CH3.45_D
19	3249	M_CH3.105_Y
20	3250	Q_CH3.118_Y
21	3251	Q_CH2.94_E, L_CH2.97_Y
62	3318	Q_CH2.94_E, S_CH3.45_D
63	3319	Q_CH2.94_E, M_CH3.105_Y
64	3320	L_CH2.97_Y, S_CH3.45_D
65	3321	L_CH2.97_Y, M_CH3.105_Y
66	3322	S_CH3.45_D, M_CH3.105_Y
33	3263	M_CH3.105_Y, Q_CH3.118_Y
67	3323	Q_CH2.94_E, L_CH2.97_Y, M_CH3.105_Y
68	3324	L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
69	3325	Q_CH2.94_E, S_CH3.45_D, M_CH3.105_Y
34	3264	M_CH3.105_Y, Q_CH3.118_Y, S_CH3.45_D
35	3265	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D
70	3326	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
36	3266	Q_CH2.94_E, L_CH2.97_Y, M_CH3.105_Y, Q_CH3.118_Y
37	3267	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y
51	3281	L_CH2.89_I, V_CH2.91, Q_CH2.94_E, L_CH2.97_Y, G_CH2.99_W

Table 5: Biophysical characterization of Fc variants based on parental SEQ ID NO: 3

SEQ ID NO	Ref number	KD (1:1) (M) ¹	Maximum response ¹ at 1000nM hFcαRI (RU)	Aggregation ² (%)
2	2737	5.20E-07	168	11.5
3	2771	2.70E-07	197	9.20
16	3246	8.72E-08	267	14.80
17	3247	1.45E-08	372	12.00
18	3248	5.75E-08	344	9.80
19	3249	2.06E-08	339	6.80
20	3250	1.04E-07	240	10.00
21	3251	1.22E-08	344	9.00
62	3318	4.38E-08	342	10.10
63	3319	1.51E-08	352	9.40
64	3320	4.81E-09	326	7.90

65	3321	1.64E-09	289	8.30
66	3322	1.00E-08	327	8.70
33	3263	9.56E-09	322	12.70
67	3323	9.56E-10	319	9.00
68	3324	7.81E-10	304	7.50
69	3325	8.47E-09	325	7.80
34	3264	3.81E-09	289	11.40
35	3265	5.02E-09	278	13.90
70	3326	5.84E-10	307	8.50
36	3266	5.57E-10	333	12.05
37	3267	3.84E-10	305	13.70
51	3281	1.87E-08	228	nd

¹ Affinity and maximum response of engineered immunoglobulins toward hFcαRI were determined by SPR experiment, following the procedure described in Example 3.

² Aggregation propensity was measured following the procedure described in Example 2.

nd: not determined

Table 6: Tested mutation sets, based on parental IgG1 engineered immunoglobulin SEQ ID 6

SEQ ID NO	Ref number	Mutation set
6	3084	-
22	3252	Q_CH2.94_E
23	3253	L_CH2.97_Y
24	3254	S_CH3.45_D
25	3255	M_CH3.105_Y
26	3256	Q_CH3.118_Y
27	3257	Q_CH2.94_E, L_CH2.97_Y
71	3327	Q_CH2.94_E, S_CH3.45_D
72	3328	Q_CH2.94_E, M_CH3.105_Y
73	3329	L_CH2.97_Y, S_CH3.45_D
74	3330	L_CH2.97_Y, M_CH3.105_Y
75	3331	S_CH3.45_D, M_CH3.105_Y
38	3268	M_CH3.105_Y, Q_CH3.118_Y
76	3332	Q_CH2.94_E, L_CH2.97_Y, M_CH3.105_Y
77	3333	L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
78	3334	Q_CH2.94_E, S_CH3.45_D, M_CH3.105_Y
39	3269	M_CH3.105_Y, Q_CH3.118_Y, S_CH3.45_D
40	3270	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D
79	3335	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y
41	3271	Q_CH2.94_E, L_CH2.97_Y, M_CH3.105_Y, Q_CH3.118_Y
42	3272	Q_CH2.94_E, L_CH2.97_Y, S_CH3.45_D, M_CH3.105_Y, Q_CH3.118_Y
52	3282	L_CH2.89_I, V_CH2.91, Q_CH2.94_E, L_CH2.97_Y, G_CH2.99_W

Table 7: Biophysical characterization of Fc variants based on parental SEQ ID NO: 6

SEQ ID NO	Ref number	KD (1:1) (M) ¹	Maximum response ¹ at 1000nM hFcαRI (RU)	Aggregation ² (%)
2	2737	5.20E-07	168	11.5
6	3084	5.09E-07	146	10.30
22	3252	1.15E-07	212	9.20
23	3253	3.52E-08	359	11.30
24	3254	1.32E-07	276	12.00
25	3255	5.38E-08	300	13.90
26	3256	1.33E-07	194	11.70
27	3257	2.77E-08	376	9.80
71	3327	7.53E-08	303	9.30
72	3328	3.88E-08	342	8.70
73	3329	1.12E-08	369	12.70
74	3330	4.32E-09	275	13.80
75	3331	2.80E-08	342	14.60
38	3268	2.29E-08	341	13.60
76	3332	2.39E-09	294	11.70
77	3333	1.96E-09	238	9.10
78	3334	2.23E-08	353	7.50
39	3269	1.05E-08	353	12.00
40	3270	1.04E-08	365	11.70
79	3335	1.27E-09	282	8.30
41	3271	1.13E-09	371	15.20
42	3272	4.86E-10	371	14.70
52	3282	4.71E-08	235	nd

¹ Affinity and maximum response of engineered immunoglobulins toward hFcαRI were determined by SPR experiment, following the procedure described in Example 3.

² Aggregation propensity was measured following the procedure described in Example 2.

nd: not determined

Table 8: Affinity and maximum response of Fc variants, based on parental IgA2 (SEQ ID NO: 2), towards hFcαRI as determined by SPR experiment described in Example 3.

SEQ ID NO	Ref number	KD (1:1) (M)	Max response at 31.25nM hFcαRI (RU)
13	3243	8.45E-09	157
28	3258	4.02E-09	179
59	3315	1.45E-09	190
30	3260	8.34E-09	185
61	3317	1.06E-09	201
32	3262	1.13E-09	191

Table 9: Affinity and maximum response of Fc variants, based on parental IgG1 engineered immunoglobulin (SEQ ID NO: 3), towards hFcαRI as determined by SPR experiment described in Example 3.

SEQ ID NO	Ref number	KD (1:1) (M)	Max response at 31.25nM hFcαRI (RU)
17	3247	9.34E-09	259
64	3320	2.56E-09	252
66	3322	5.40E-09	220
68	3324	3.24E-10	249
70	3326	2.95E-10	248
37	3267	2.19E-10	268

Table 10: Affinity and maximum response of Fc variants, based on parental IgG1 engineered immunoglobulin (SEQ ID NO: 6), towards hFcαRI as determined by SPR experiment described in Example 3.

SEQ ID NO	Ref number	KD (1:1) (M)	Max response at 31.25nM hFcαRI (RU)
23	3253	2.25E-08	187
25	3255	2.92E-08	139
27	3257	1.49E-08	239
73	3329	9.11E-09	229
76	3332	1.20E-09	237
77	3333	8.80E-10	189
40	3270	5.17E-09	290
79	3335	6.51E-10	240
41	3271	3.82E-10	322
42	3272	1.96E-10	313

1.4 Translation of affinity maturation to enhancement of alpha effector function in *in vitro* assays

Lead candidates having a homodimeric Fc (SEQ ID NOs: 32, 37 and 42) were selected for their improved binding capacities towards hFcαRI. They were next tested in a PMN killing assay following the procedure described in Example 4. Potency (EC₅₀; concentration of the immunoglobulin required to produce 50% of its maximal effect) and efficacy (E_{max}; maximum effect expected of the immunoglobulin) results are shown in Figures 1 to Figure 4.

All tested candidates were active and were shown to have an improved efficacy compared to the parental IgA2 in a SK-BR-3 PMN killing assay (Figure 1).

In addition, a substantial improvement in efficacy of up to 2-fold was shown in a PMN killing assay using Calu-3 cells (Figure 2) where HER2 receptor density is known to be lower than SK-BR-3 cells (described in Example 4). Moreover, a substantial improvement in potency was shown

for the variant having SEQ ID NO: 42 in a PMN killing assay on MDA-MB-453 cells, also known to express a lower level of HER2 receptors (Figure 3). This improvement in potency was approximately 7-fold.

Finally, the affinity matured variant having SEQ ID NO: 42 was tested in a PMN killing assay using MDA-MB-175 cells, known as the lowest HER2 expressing cell line, and showed no killing, even at very high concentrations (Figure 4). This observation highlights the safe profile of the tested candidates.

The mutation set was applied to a heterodimeric Fc resulting in candidates comprising SEQ ID NOs: 7-8, SEQ ID NOs: 80-8, SEQ ID NOs: 7-9 or SEQ ID NOs: 80-9 (Figure 5). Tested candidates SEQ ID NOs: 80-8 and SEQ ID NOs: 80-9 were shown to have better killing properties on SK-BR-3 cells in PMN killing assays, compared to their parental immunoglobulins and IgA2 (Fig 5A and 5C) but showed no effect in a PBMC killing assay to mediate gamma response (Fig 5B and 5D).

Example 2: Expression and purification of engineered proteins

Nucleic acid sequences coding for heavy and light chains were synthesized at Geneart (LifeTechnologies) and cloned into a mammalian expression vector using restriction enzyme-ligation based cloning techniques. The resulting plasmids were co-transfected into HEK293T cells. In brief, for transient expression of immunoglobulins (IgG, IgA and engineered immunoglobulins), equal quantities of light chain and each engineered heavy chain vectors were co-transfected into suspension-adapted HEK293T cells using Polyethylenimine ((PEI) Ref. cat# 24765 Polysciences, Inc.). Typically, 100 ml of cells in suspension at a density of 1-2 Mio cells per ml was transfected with DNA containing 50 µg of expression vector encoding the engineered heavy chain and 50 µg expression vectors encoding the light chain. The recombinant expression vectors were then introduced into the host cells and the construct produced by further culturing of the cells for a period of 7 days to allow for secretion into the culture medium (HEK, serum-free medium) supplemented with 0.1% pluronic acid, 4mM glutamine, and 0.25 µg/ml antibiotic.

The produced constructs were then purified from cell-free supernatant using immuno-affinity chromatography. Anti-Kappa LC resin (KappaSelect, GE Healthcare Life Sciences), equilibrated with PBS buffer pH 7.4 was incubated with filtered conditioned media using liquid chromatography system (Aekta pure chromatography system, GE Healthcare Life Sciences). The resin was washed with PBS pH 7.4 before the constructs were eluted with elution buffer (50mM citrate, 90mM NaCl, pH 2.7).

After capture, eluted proteins were pH neutralized using 1M TRIS pH 10.0 solution and polished using size exclusion chromatography technique (HiPrep Superdex 200 16/60, GE Healthcare Life Sciences). Purified proteins were finally formulated in PBS buffer pH 7.4.

Aggregation propensity was measured after capture and pH neutralization step using analytical size exclusion chromatography technique (Superdex 200 Increase 3.2/300 GL, GE Healthcare Life Sciences).

Example 3: SPR measurement against human Fc alpha receptor (hFcαRI) or rat Fc alpha receptor (rFcαR)

A direct binding assay was performed to characterize the binding of the Fc variants (in antibody format with light chain of SEQ ID NO: 4 against human FcαRI or rat FcαR.

Kinetic binding affinity constants (KD) were measured on a BIAcore® T200 instrument (GE Healthcare, Glattbrugg, Switzerland) at room temperature, with proteins diluted in running buffer 10mM NaP, 150mM NaCl, 0.05% Tween 20, pH7.6. A streptavidin sensor chip (Sensor Chip SA, GE Healthcare Life Sciences) immobilized with a biotinylated anti-kappa light chain scFv was used to capture engineered immunoglobulins, and recombinant human hFcαRI or recombinant rat FcαR was used as the analyte.

To serve as a reference, one flow cell did not capture any immunoglobulin. Binding data were acquired by subsequent injection of analyte dilution series on the reference and measuring flow cells. Zero concentration samples (running buffer only) were included to allow double referencing during data evaluation. For data evaluation, doubled referenced sensorgrams were analyzed by applying a 1:1 binding model analysis to generate the equilibrium dissociation constant (KD). The results related to rFcαR are summarized in Table 11.

This experiment showed that the candidate Fc variants were cross-reactive with human/rat FcαRI, which is a desired property for testing the candidates in *in vivo* disease models.

Table 11: SPR measurement and affinity for rFcαR

SEQ ID NO	Ref number	KD (1:1) (M)	Maximum response at 250nM rFcαR (RU)
2	2737	1.87E-08	97
3	2771	2.37E-08	196
6	3084	5.78E-08	127
21	3251	4.43E-08	183
30	3260	1.43E-07	124
32	3262	3.19E-08	133
37	3267	2.39E-08	212
40	3270	7.72E-08	101

42	3272	4.57E-08	197
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Example 4: Antibody-dependent cell cytotoxicity (ADCC) assay method

Blood samples from healthy donors were collected from freshly drawn peripheral blood, according to the Swiss human research act (Basel tissue donor program - Prevomed). After lysis of red blood cells with ACK lysis buffer, Polymorphonuclear cells and Peripheral blood mononuclear cells (PMN and PBMC) were isolated by ficoll-paque gradient. PMN were used to characterize Alpha effector function of engineered immunoglobulin, whereas PBMC were used to characterize Gamma effector function.

Effector cells (freshly isolated PMN or PBMC cells) were added to HER2 expressing target cells (SK-BR-3, Calu-3, MDA-MB-453 or MDA-MB-175 cells, purchased at the American Type Culture Collection, Rockville MD) at an effector to target ratio of 20:1. SK-BR-3 is a breast cancer cell line overexpressing HER2. Calu-3 and MDA-MB-453 are lung and breast cancer cell lines respectively, overexpressing HER2 at a lower level compared to SK-BR-3 (Cheung *et al.*, 2019). MDA-MB-175 is a breast cancer cell line expressing the lowest amount of HER2 (Crocker *et al.*, 2005). PMN cell killing was not observed with any of the candidate Fc variants indicating a good safety profile towards a lower HER2 expressing cell line.

The immunoglobulin construct was added at the concentration indicated and the combination was mixed gently and then centrifuged at 260xg for 4 minutes without a break to encourage co-localization of target and effector cells. The assay was then incubated for 18 hours at 37°C in 5% CO₂ in a standard tissue culture incubator. After 18 hours, the supernatant was used for LDH release measurements using Cytotox96 reagent (Promega) according to the manufacturer instructions. Absorbance at 490nm was read on a Biotek Synergy HT plate reader. Data were analyzed and graphed using GraphPad Prism 6.0.

Example 5: Improvement of engineered immunoglobulins pharmacokinetic (PK) properties compare to IgA

5.1 Engineered immunoglobulin material production

Nucleic acids coding for anti-HER2 engineered immunoglobulin heavy chain variants having sequence SEQ ID NO: 1, 2, 7, 8, 40, 80, 82, 83, 84 were synthesized at Geneart (LifeTechnologies) and cloned into a mammalian expression vector using restriction enzyme-ligation based cloning techniques. Selected N-glycosylation sites were removed by substitution of specific Asp residues by Ala residues. The resulting plasmids coding for the heavy chain were co-transfected with a

plasmid coding for the light chain (SEQ ID NO: 4) into a mammalian expression system. For the HEK293T expression cell line, expression was performed according to procedure described Example 2. For the CHO-S expression cell line (Thermo), the following procedure was used. In brief, for protein transient expression, the expression vector was transfected into suspension-adapted CHO-S cells using ExpifectamineCHO transfecting agent (Thermo). Typically, 400 ml of cells in suspension at a density of 6 Mio cells per ml were transfected with DNA containing 400 µg of expression vector encoding the engineered protein. The recombinant expression vector was then introduced into the host cells for further secretion for seven days in culture medium (ExpiCHO expression media, supplemented with ExpiCHO feed and enhancer reagent (Thermo)). The expressed constructs were then purified from cell-free supernatant according to procedure described Example 2. Measured immunoglobulin concentrations in serum were plotted as a function of time and presented in Figure 6 and Figure 7. The material generated is described Tables 12 and 13.

Table 12: Description of immunoglobulins produced in HEK293T mammalian system

SEQ ID	Description, with numbering is according to IMGT numbering for C-domain
1	IgG1
2	IgA2
7-8	Heterodimer engineered IgG1 - recruits CD89 via first half-Fc, - recruits FcγRs and FcRn via second half-Fc
8-80	Heterodimer engineered IgG1 - recruits CD89 via first half Fc (affinity matured), - recruits FcγRs and FcRn via second half-Fc

Table 13: Description of immunoglobulins produced in CHO mammalian system

SEQ ID	Description, with numbering is according to IMGT numbering for C-domain
1	IgG1
2	IgA2
8-80	Heterodimer engineered IgG1 - recruits CD89 via first half Fc (affinity matured), - recruits FCγRs and FcRn via second half-Fc.
40	Homodimer engineered IgG1
82	Homodimer engineered IgG1 N_CH2.20_A

83	Homodimer engineered IgG1 N_CH2.84.4_A
84	Homodimer engineered IgG1 N_CH2.20_A N_CH2.84.4_A

In line with the construct design, engineered immunoglobulins having sequence SEQ ID NO: 7-8 and SEQ ID NO: 8-80 bound to CD89 while retaining binding to FcRn and showed improved PK properties and an improved half-life compare to IgA immunoglobulin, as shown in Figure 6. Moreover, as shown in Figure 6, the affinity matured variant with SEQ ID 8-80 exhibits an identical PK profile as the parental construct with SEQ ID NO: 7-8. This shows that affinity maturation towards CD89 does impair engineered immunoglobulin PK properties.

Data presented in Figure 7 show how the N-glycosylation pattern affects immunoglobulin PK. The PK properties of engineered immunoglobulins were improved compared to IgA and improved when individual the N-glycosylation site CH2.84.4 was removed (SEQ ID NO: 83).

5.1 Mouse studies

Male CD1 mice were obtained by Charles River laboratories. Following arrival, all mice were maintained in a pathogen-free animal facility under a standard 12h light/12h dark cycle at 21°C room temperature with access to food and water ad libitum. All mice received a single intravenous (IV) injection of IgG or IgA or engineered immunoglobulin (3mg/kg) produced and purified as described above. Each compound was injected into three mice. Blood samples were collected into serum separator tubes via saphenous vein at various times post injection. The blood was allowed to clot at ambient temperature for at least 20 min. Clotted samples were maintained at room temperature until centrifuged, commencing within 1 h of the collection time. Each sample was centrifuged at a relative centrifugal force of 1500–2000 x g for 5 min at 2–8°C. The serum was separated from the blood sample within 20 min after centrifugation and transferred into labeled 2.0-mL polypropylene, conical-bottom microcentrifuge tubes. Only animals that appeared to be healthy and that were free of obvious abnormalities were used for the study. All animal work performed was reviewed and approved by Novartis' Institutional Animal Care and Use Committee.

5.2 Immunoglobulin ELISA for pharmacokinetic studies

Immunoglobulin levels were measured by sequential sandwich ELISA. For IgA dosing, wells of Nunc Maxisorp microtiter plates were coated overnight at 4°C with goat anti-human IgA (Southern Biotech, Cat# 2053–01). For IgG and engineered immunoglobulins dosing, wells of Roche

StreptaWell microtiter plates were coated 1h at room temperature with biotinylated SB goat anti-human IgG (Southern Biotech, Cat# 2049-08). After 1h incubation with blocking buffer (PBS, 0.5% bovine serum albumin (BSA)), samples diluted in same blocking buffer were added to the blocked plates and incubated for 2 h at room temperature. After incubation, horseradish peroxidase-conjugated goat anti-human IgA (SouthernBiotech, Cat# 2053-05) or horseradish peroxidase-conjugated goat anti-human IgG (SouthernBiotech, Cat# 2049-05) were added and incubated for 1 h at room temperature. The plates were then incubated with substrate solution (BM Blue POD Substrate TMB, Roche, Cat# 11484281001), and the reaction was stopped with 0.5M sulfuric acid. Absorbance was measured at 450 nm with a reduction at 650 nm using a plate reader. Between steps, plates were washed 3 times with washing buffer (0.05% Tween-20 in PBS).

Sequence Information

Table 14 describes the amino acid sequences (SEQ ID NOs) of the full length heavy chains comprising the variant Fc regions as described in the examples as well as the light chain used to generate complete antibodies. The Fc variants, full length heavy chains, light chains or complete antibodies as described herein can be produced using conventional recombinant protein production and purification processes.

All the sequences referred to in this specification (SEQ ID NOs) are found in Table 14. Ref No refers to an internal sequence reference number. Throughout the text of this application, should there be a discrepancy between the text of the specification (e.g., Table 14) and the sequence listing, the text of the specification shall prevail.

Table 14: Amino acid sequences

SEQ ID NO:	AMINO ACID SEQUENCES	Ref No
1	Evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsrlraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgclvkdylfpepvtvswnsgaltsgvhtfpavlgssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtppcpapellggpsvflfppkpkdtlmisrtpevtcvvvdvshedpevkfnwyvdg vevhnaktkpreeqynstyrsvltvlhqdwlngkeyckvsnkalpapietkiskakgqprepqvylp psrdeltknqvsltcclvkgfypsdiavewesngqpennykttppvldsdgsfflyskltvdkrswqggnvf scsvmhealhnhytqkslsisp	2257
2	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsrlraedtavyycsrwggdgyamdywgqgtltvtssasptspkvfplslldstpqdgnv vvaclvqgffpqpelstwsesgqnvtnarnfppsqsasgdyttssqltlpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavqgpper dlcgcyssvslpgcqpwnhgetftctaahpelktpltanitksgntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgtfscmvghea lplaftgktidrla	2737
3	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsrlraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgclvkdylfpepvtvswnsgaltsgvhtfpavlgssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtppcpccchprvflfrpaledlllgseanvtcvvtglrdedpevkfnwyvdgvevhn	2771

	aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvylppsrdel tknqvsltlclakgfypkdvlvrwlqgsqelprenykttasvldsdsqsfvyskltvaaedwkkgd fscmv ghealplaftqksisrsp	
4	diqmtqspsslsasvqdrvtitcrasqdvntavawyyqkpgkapklliysasflysgvpsrfsgrsgtdf tlitisslqpedfatyyccqhytppptfgqgtkveikrtvaapsvfifppsdeqlksgtasvvcllnnfypr eakvqkwvdnalqsgnsqesvteqdskdstyslssltltskadyekhkvyacevthqgllsspvtksfnrge c	2156
5	qegdfpmpfisaksspvipldgsvkiqccaireayltqlmiiknstyreigrllkfwnetdpefvidhmda nkagryqcqyrighyrfrysdtlelvvtglygkpfilsadrglvmpgenislcssahipfdrfslakege lsllpqhsggehpansflgpvdlnvsgiyrcygywnrspyfswfnsalelvvtdsihqdyttqnhhhhhhg lndifeagkiewhe	2922
6	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssastkgpsvfplapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavllqssgylslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvylppsr rdeltknqvsltlclakgfypkdvlvrwlqgsqelprenykttasvldsdsqsfvyskltvaaedwkkgd f scmv ghealplaftqksisrsp	3084
7	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssastkgpsvfplapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavllqssgylslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvcllpps rdeltknqvslscaakgfypkdvlvrwlqgsqelprenykttasvldsdsqsfvyskltvaaedwkkgd f scmv ghealplaftqksisrsp	3097
8	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssastkgpsvfplapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavllqssgylslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpapellggpsvflfppkpkdtlmisrtpvtcvvvdvshedpevkfnwyvdgv vevhnaktkpreeqynstyrvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvyltpp crdeltknqvslwclvkgfypsdiawesngqpennyktppvldsdsqsflyskltvdkswqqgnv f scvmhealhnhytqkslslsp	3099
9	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssastkgpsvfplapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavllqssgylslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpapellggpdvflfppkpkdtlmisrtpvtcvvvdvshedpevkfnwyvdgv vevhnaktkpreeqynstyrvsvltvlhqdwlngkeykckvsnkalpapeektiskagqprepqvyltpp crdeltknqvslwclvkgfypsdiawesngqpennyktppvldsdsqsflyskltvdkswqqgnv f scvmhealhnhytqkslslsp	3101
10	Evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssasptspkvfplslldstpqdgnv vvaclvqgffpqpelplsvtwesegqnvtnarnfppsqqdasgdlyttssqlt lpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavagppper dlcgcyssvsvlpgcaepwnhgetftctaahpelktpltanitksqntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgd fscmv ghea lplaftqktidrla	3240
11	Evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssasptspkvfplslldstpqdgnv vvaclvqgffpqpelplsvtwesegqnvtnarnfppsqqdasgdlyttssqlt lpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavagppper dlcgcyssvsvlpgcaqpwyhgetftctaahpelktpltanitksqntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgd fscmv ghea lplaftqktidrla	3241
12	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssasptspkvfplslldstpqdgnv vvaclvqgffpqpelplsvtwesegqnvtnarnfppsqqdasgdlyttssqlt lpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavagppper dlcgcyssvsvlpgcaqpwnhgetftctaahpelktpltanitksqntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgdqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgd fscmv ghea lplaftqktidrla	3242
13	evqlvesggglvqpqgsrlrlscaasgfnikdtyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyfamydgqgtltvtvssasptspkvfplslldstpqdgnv vvaclvqgffpqpelplsvtwesegqnvtnarnfppsqqdasgdlyttssqlt lpatqcpdgksvtchvkhytnp	3243

	sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavqgpper dlcgcyssvssvlpgcaqpwnhgetftctaahpelktpltanitksngntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgdtfscyvgha lplaftqktidrla	
14	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssasptspkvfplsldstpqdgnv vvaclvqgffpqeplsvtwesgqnvartarnfppsqqdasgdlyttssqtltpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavqgpper dlcgcyssvssvlpgcaqpwnhgetftctaahpelktpltanitksngntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgdtfscmvgha lplaftyktidrla	3244
15	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssasptspkvfplsldstpqdgnv vvaclvqgffpqeplsvtwesgqnvartarnfppsqqdasgdlyttssqtltpatqcpdgksvtchvkhytnp sqdvtvpcrvpppppcchprlslhrpaledlllgseanltctltglrdasgatftwtpssgksavqgpper dlcgcyssvssvlpgcaepwyhgetftctaahpelktpltanitksngntfrpevhllpppseelalnelvtl tclargfspkdvlvrwlqgsqelprekyltwasrqepsqgtttfavtsilrvaaedwkkgdtfscmvgha lplaftqktidrla	3245
16	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscmv ghealplaftqksisrsp	3246
17	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscmv ghealplaftqksisrsp	3247
18	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgdqelprenykttasvldsdsffvyskltvaaedwkkgdtfscmv ghealplaftqksisrsp	3248
19	Evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscyv ghealplaftqksisrsp	3249
20	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscmv ghealplaftyksisrsp	3250
21	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcpcchprvflfrpaledlllgseanvtcvvtglrddedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwlngkeykckvsnkalpapiektiskagqprepqvllppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscmv ghealplaftqksisrsp	3251
22	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdylfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk	3252

	vdkkvepkscdkthtppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvvsvltvlhedwlngkeykckvsnkalpapiektiskagqpprepqvyllpps rdeltknqvsltlclakgfypkdvlvrwlqgsqelprenykttasvldsdgsffvyskltvaaedwkkgd f scmvghealplaftqksisrsp	
23	evqlvesggglvqppgslrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtvssastkgpsvflapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavqlqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdkkvepkscdkthtppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvvsvltvlhqdwlngkeykckvsnkalpapiektiskagqpprepqvyllpps rdeltknqvsltlclakgfypkdvlvrwlqgsqelprenykttasvldsdgsffvyskltvaaedwkkgd f scmvghealplaftqksisrsp	3253
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25	evqlvesggglvqppgslrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtvssastkgpsvflapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavqlqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdkkvepkscdkthtppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvvsvltvlhqdwlngkeykckvsnkalpapiektiskagqpprepqvyllpps rdeltknqvsltlclakgfypkdvlvrwlqgsqelprenykttasvldsdgsffvyskltvaaedwkkgd f scvyghealplaftqksisrsp	3255
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65	Evqlvesggglvqppgslrlscaasgfnikdyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalglclvkdypfepvtvswngaltsgvhtfpavqlqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdckvepkscdkthtccppcchprvflfrpaledlllgseanvtcvvtglrdedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhqdwngkeykckvsnkalpapiektiskagqprepqvylppsrdel tknqvsltclakgfypkdvlvrwlqgsqelprenykttasvldsdsffvyskltvaaedwkkgdtfscyv ghealplaftqksisrps	3321
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67	evqlvesggglvqppgslrlscaasgfnikdyihwvrqapkgglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalglclvkdypfepvtvswngaltsgvhtfpavqlqssglyslssvvtvpssslgtqtyicnvnhkpsntk	3323

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69	evqlvesggglvqppgslrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdyfpepvtvswngaltsgvhtfpavllqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdkkvepkscdkthtpppcpcchprvflfrpaledlllgseanvtcvvtglrdedpevkfnwyvdgvevhn aktkpreeqycgcysvsvltvlhedwlngkeykckvsnkalpapiektiskagqprepqvylppsrdel tknqvsltlclakgfypkdvlvrwlqgdqelprenykttasvldsdgsffvyskltvaaedwkkgdtfscyv ghealplaftqksisrsp	3325
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81	hhhhh	
82	evqlvesggglvqppggsrlscaasgfnikdtyihwvrqapgkglewariyptngytryadsvkgrftis adtskntaylqmnsraedtavyycsrwggdgyamdywgqgtltvtssastkgpsvfplapsskstsggt aalgcclvkdypfepvtvswngaltsgvhtfpavqlqssglyslssvvtvpssslgtqtyicnvnhkpsntk vdkkvepkscdkthtppcpapellggpsvflfrpaledlllgseanvtcvvvdvshedpevkfnwyvdgv evhnaktkpreeqynstyrvvsvltvlhedwyngkeykckvsnkalpapiektiskagqprepqvylpps rdeltknqvsiltclakgfypkdvlvrwlqgdqelprenykttasvldsdsffvyskltvaaedwkkgdtf scmvghealplaftqksisrsp	3400
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Claims

1. An Fc variant of a parent Fc polypeptide, wherein the Fc variant exhibits altered binding to a Fc α R or altered antibody dependent cell-mediated cytotoxicity (ADCC) as compared to the parent Fc polypeptide, wherein the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide, wherein the amino acid modification is at a position selected from the group consisting of: CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.

2. The Fc variant according to claim 1, wherein the at least one amino acid modification is selected from the group consisting of: A_CH2.10_S, L_CH2.89_I, G_CH2.91_Q, G_CH2.91_V, Q_CH2.94_E, N_CH2.97_H, N_CH2.97_Y, G_CH2.99_W, S_CH3.45_D, M_CH3.105_Y, E_CH3.109_D, Q_CH3.118_Y and L_CH3.124_F, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.

3. The Fc variant according to claim 1 or claim 2, wherein the at least one amino acid modification is selected from the group consisting of:

Q_CH2.94_E,

N_CH2.97_Y,

S_CH3.45_D,

M_CH3.105_Y,

Q_CH3.118_Y,

Q_CH2.94_E / N_CH2.97_Y,

Q_CH2.94_E / S_CH3.45_D,

Q_CH2.94_E / M_CH3.105_Y,

N_CH2.97_Y / S_CH3.45_D,

N_CH2.97_Y / M_CH3.105_Y,

S_CH3.45_D / M_CH3.105_Y,

M_CH3.105_Y / Q_CH3.118_Y,

Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y,

N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y,
 Q_CH2.94_E / S_CH3.45_D / M_CH3.105_Y,
 M_CH3.105_Y / Q_CH3.118_Y / S_CH3.45_D,
 Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D,
 Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y,
 Q_CH2.94_E / N_CH2.97_Y / M_CH3.105_Y / Q_CH3.118_Y,
 Q_CH2.94_E / N_CH2.97_Y / S_CH3.45_D / M_CH3.105_Y / Q_CH3.118_Y,
 A_CH2.10_S,
 L_CH2.89_I,
 G_CH2.91_V,
 N_CH2.97_H,
 G_CH2.99_W,
 E_CH3.109_D,
 L_CH3.124_F, and
 L_CH2.89_I / G_CH2.91_V / Q_CH2.94_E / N_CH2.97_Y / G_CH2.99_W,

wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.

4. The Fc variant according to any one of the preceding claims, wherein the parent Fc polypeptide is comprised within a human IgA.
5. The Fc variant according to any one of the preceding claims, wherein the parent Fc polypeptide is comprised within a human IgA2.
6. The Fc variant according to any one of the preceding claims, wherein the Fc variant has an increased affinity to human Fc α RI of at least about 50-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance.
7. The Fc variant according to any one of claims 1-3, wherein the parent Fc polypeptide comprises human IgG1.

8. The Fc variant according to claim 7, wherein the Fc variant has an increased affinity to human Fc α RI of at least about 300-fold relative to the parent Fc polypeptide as measured by surface plasmon resonance.
9. The Fc variant according to any one of the preceding claims, wherein the Fc variant increases antibody-dependent cell-mediated cytotoxicity by at least about 5-fold relative to the parent Fc polypeptide as measured in a MDA-MB-453 cell killing assay.
10. The Fc variant according to any one of the preceding claims, wherein the Fc variant has an increased efficacy of at least about 2-fold in a Calu-3 cell killing assay relative to the parent Fc polypeptide.
11. An IgA antibody comprising an Fc variant, wherein the antibody has increased Fc α R affinity, or increased antibody dependent cell-mediated cytotoxicity, relative to an IgA antibody comprising a parent Fc polypeptide.
12. The IgA antibody according to claim 11, wherein the antibody comprises an amino acid modification at a position selected from the group consisting of: CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.
13. The IgA antibody according to claim 12, wherein the antibody is a human IgA1 or IgA2 antibody.
14. The IgA antibody according to any one of claims 11-13, wherein the antibody binds to a tumor antigen.
15. A pharmaceutical composition comprising an Fc variant according to any one of claims 1-10 or an antibody according to any one of claims 11-14, in combination with one or more pharmaceutically acceptable excipient, diluent or carrier.
16. The pharmaceutical composition according to claim 15, further comprising one or more additional active agents.
17. The Fc variant according to any one of claims 1-10 or the antibody according to any one of claims 11-14, for use in the treatment of a cell proliferative disorder or condition.

18. The Fc variant or antibody for use according to claim 17 wherein the cell proliferative disorder or condition is selected from the group comprising: breast cancer, neuroblastoma, lymphoma, pancreatic ductal adenocarcinoma, melanoma, renal cell carcinoma, bladder cancer, colorectal cancer, non-small cell lung cancer, non-Hodgkins lymphoma and multiple myeloma.
19. An isolated nucleic acid molecule encoding the Fc variant according to any one of claims 1-10 or the antibody according to any one of claims 11-14.
20. A cloning or expression vector comprising one or more nucleic acid sequences according to claim 19, wherein the vector is suitable for the recombinant production of the Fc variant according to any one of claims 1-10 or the antibody according to any one of claims 11-14.
21. A host cell comprising one or more cloning or expression vectors according to claim 20.
22. A method of preparing the Fc variant according to any one of claims 1-10 or the antibody according to any one of claims 11-13, the method comprising culturing a host cell according to claim 21, purifying the Fc variant or antibody from the host cell culture, and recovering the Fc variant or antibody from the host cell culture.

Figure 1

SK-BR-3

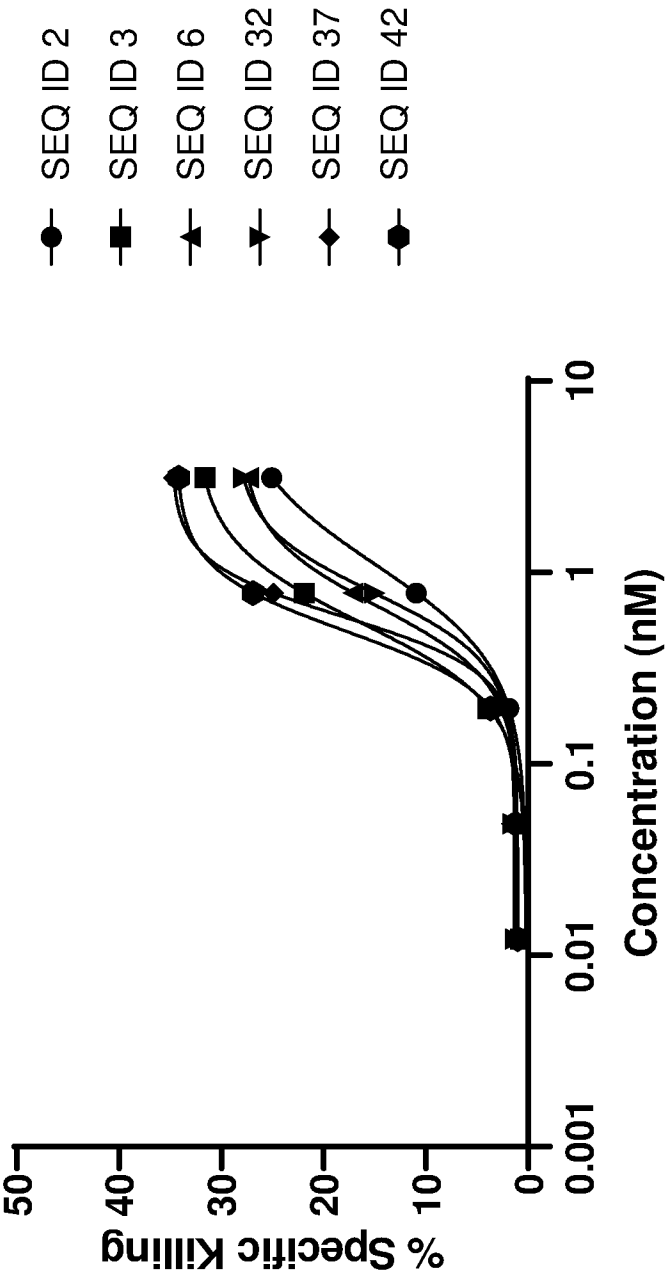


Figure 2

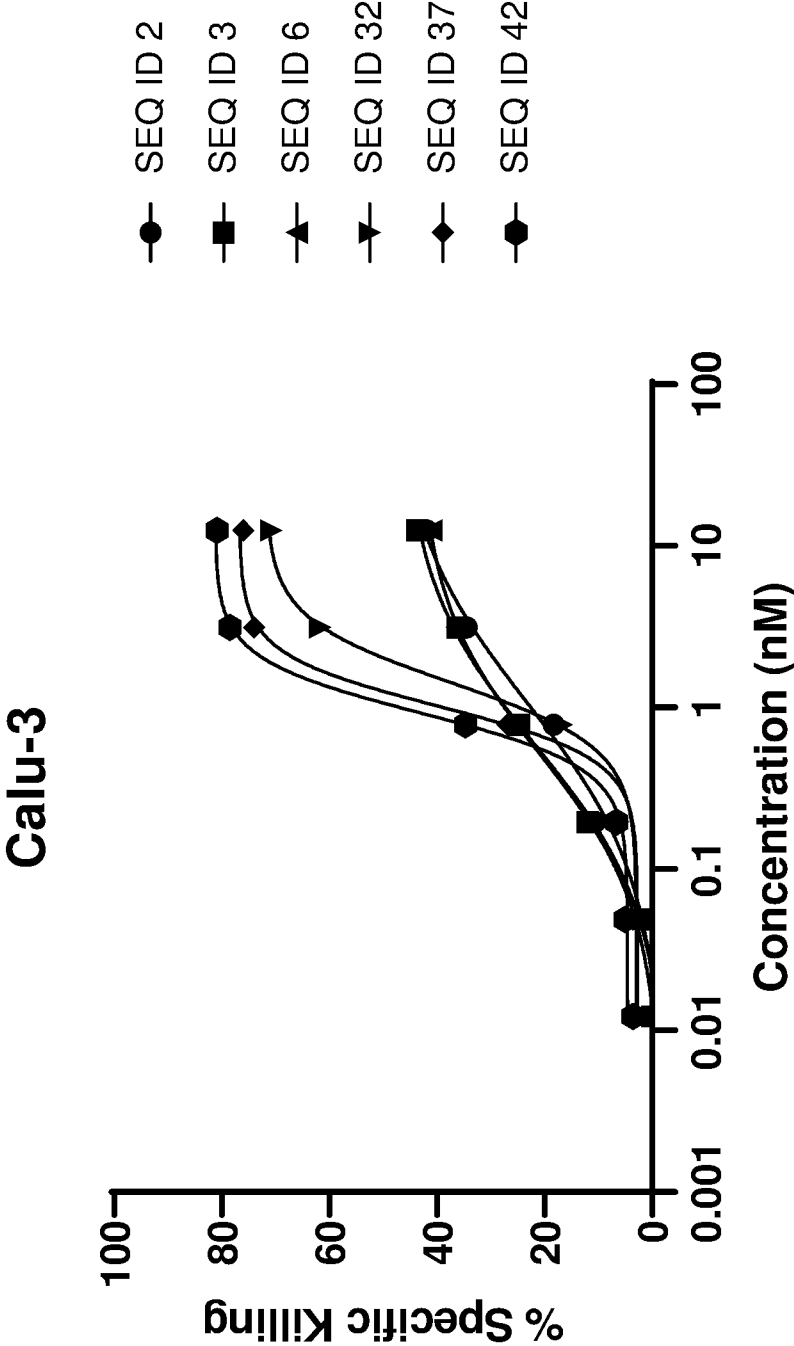


Figure 3

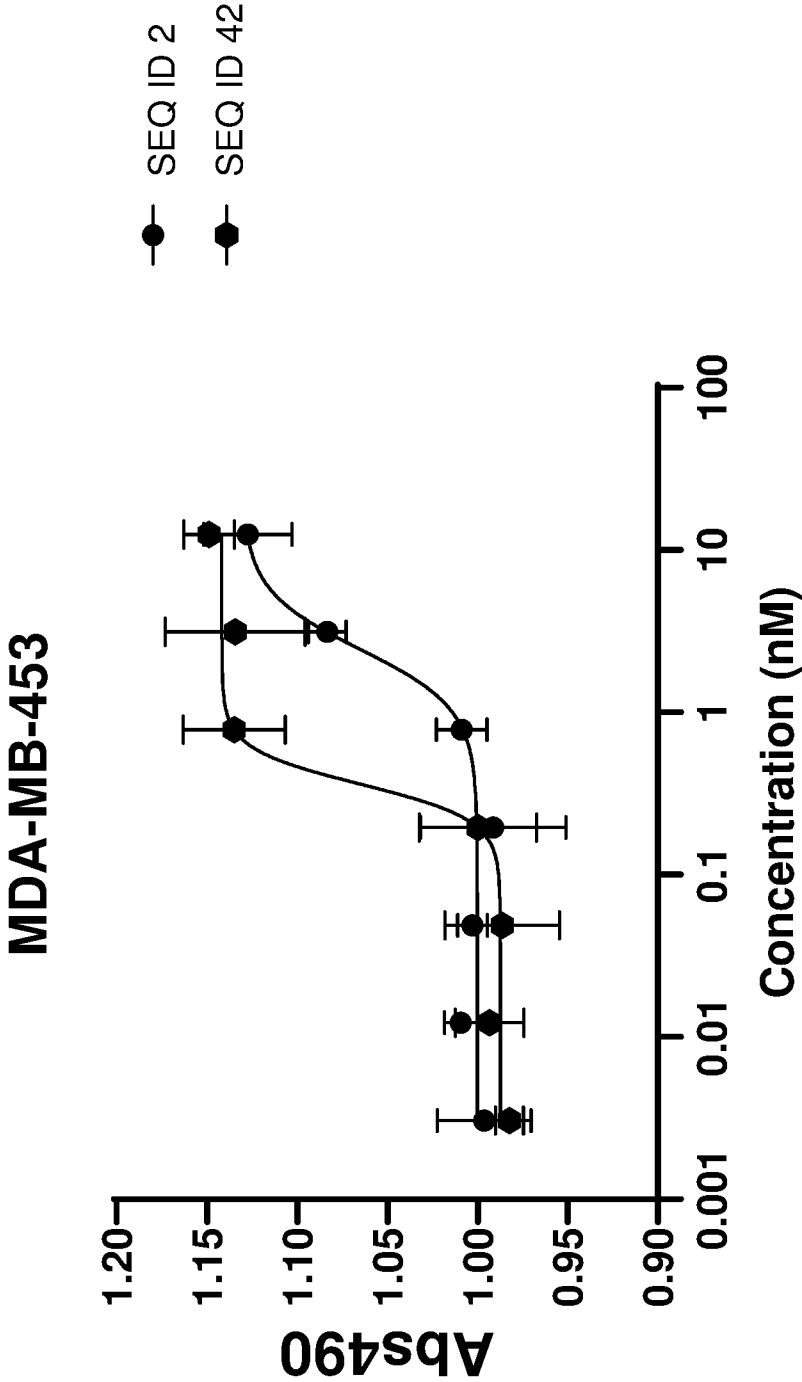


Figure 4

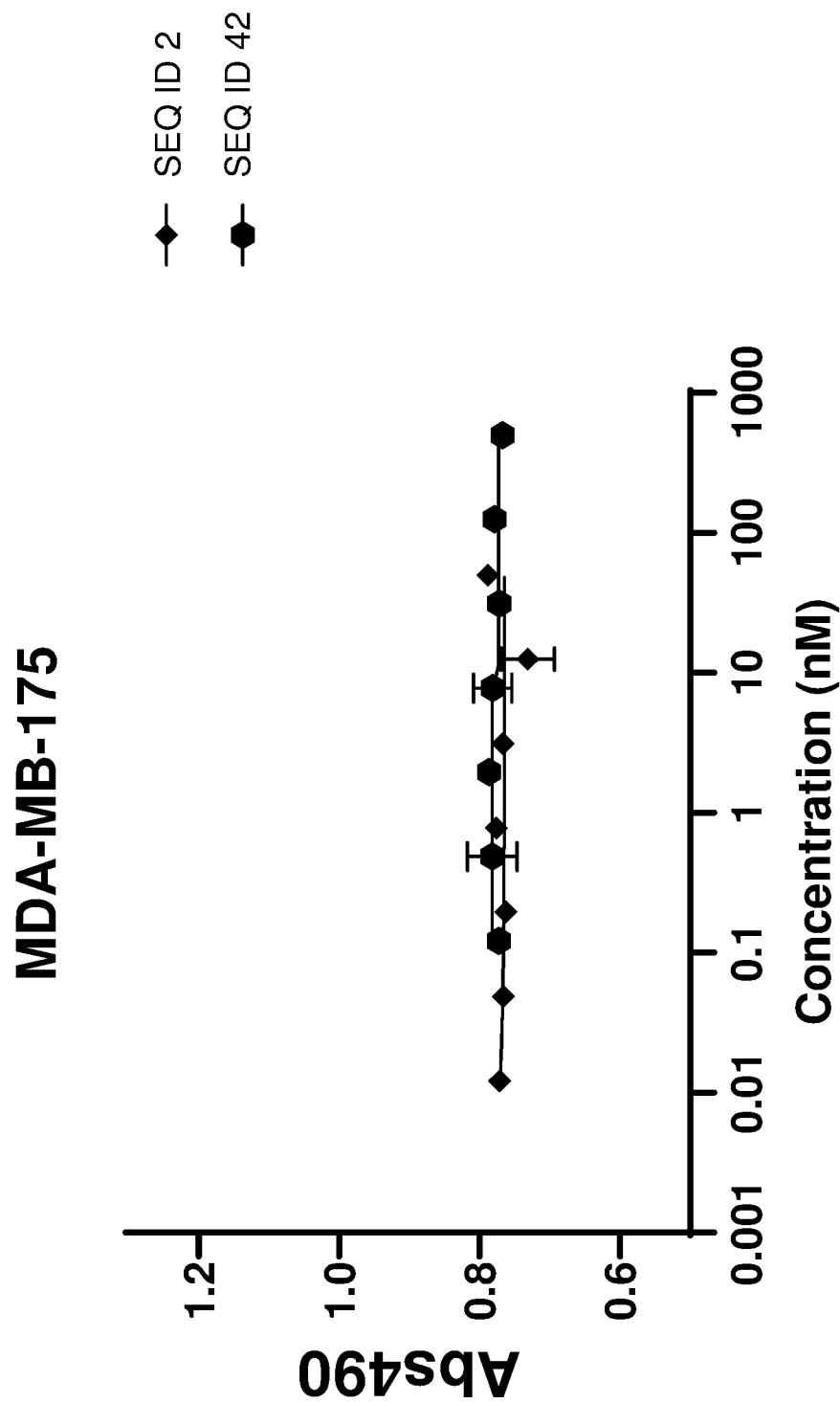


Figure 5

Fig 5A

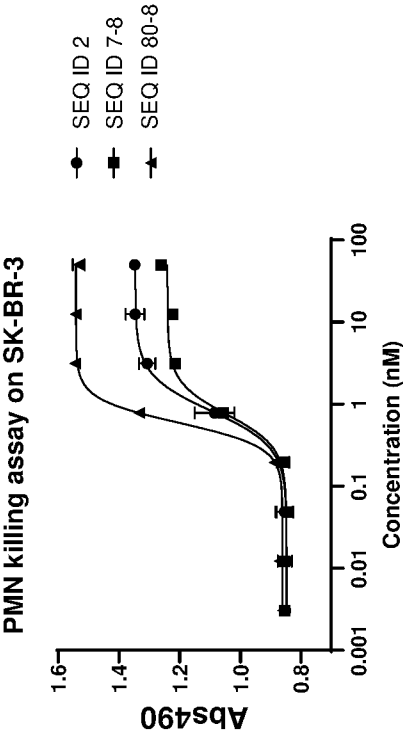


Fig 5B

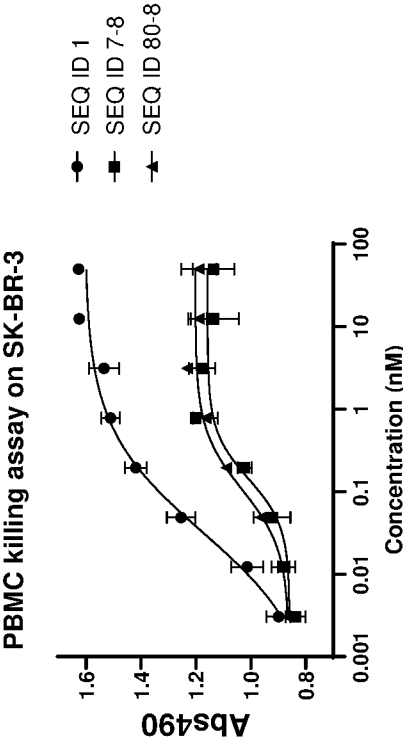


Fig 5C

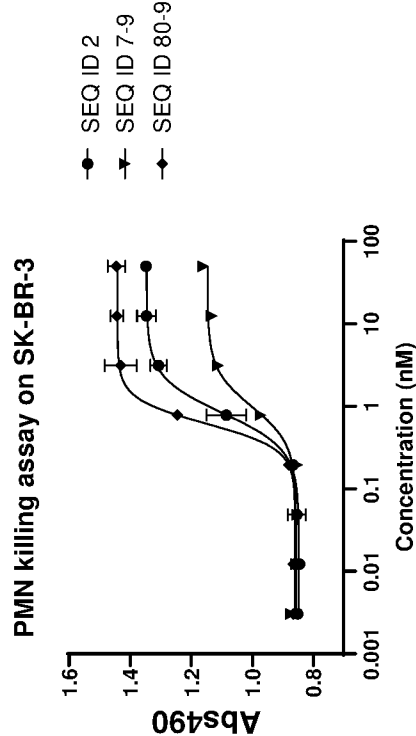


Fig 5D

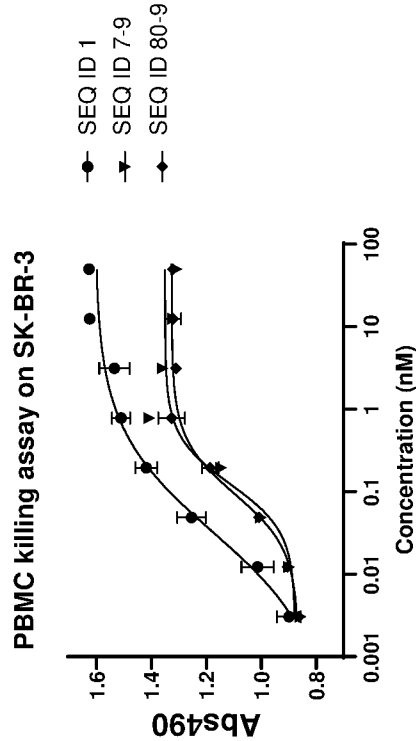


Figure 6

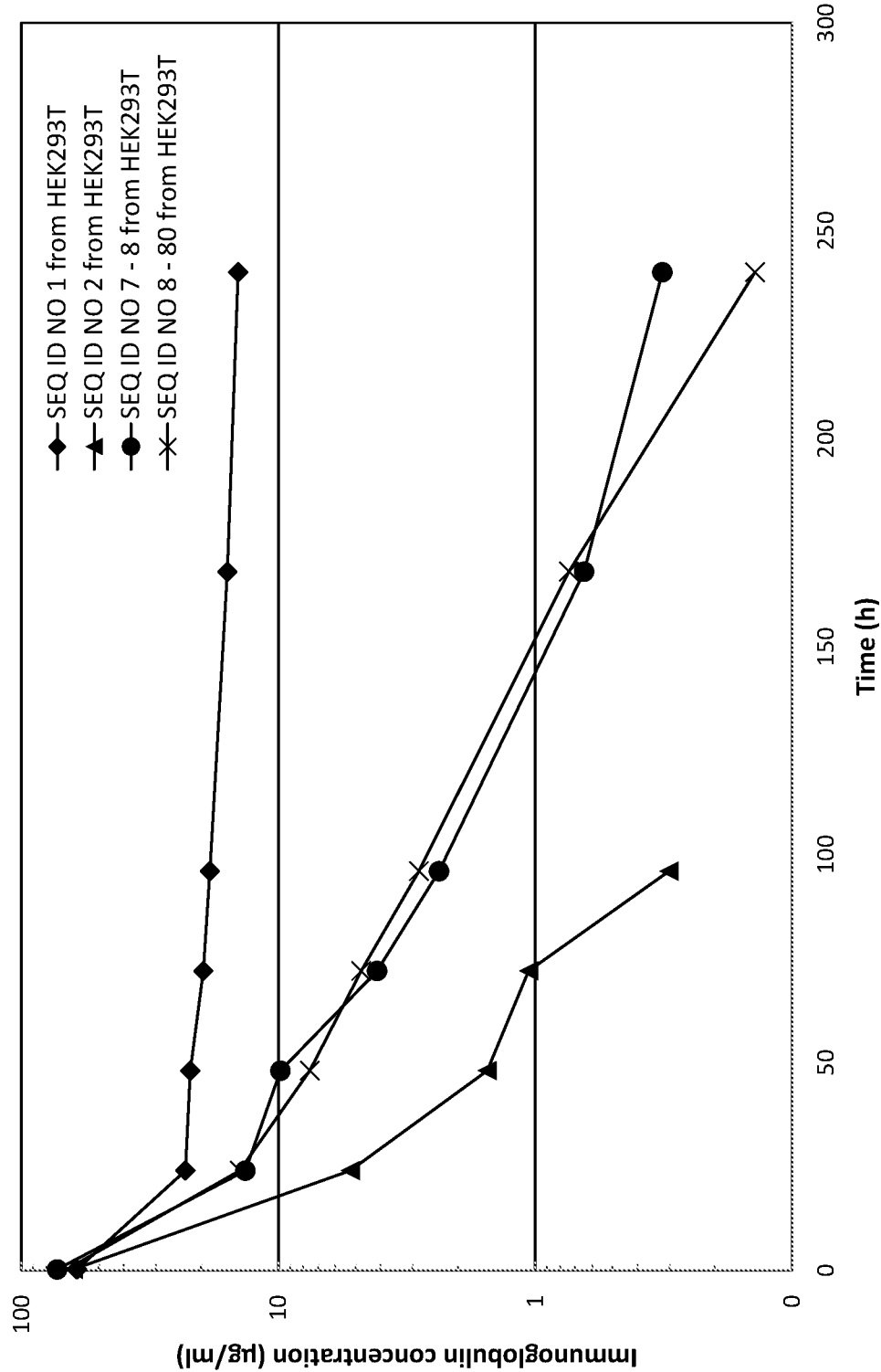
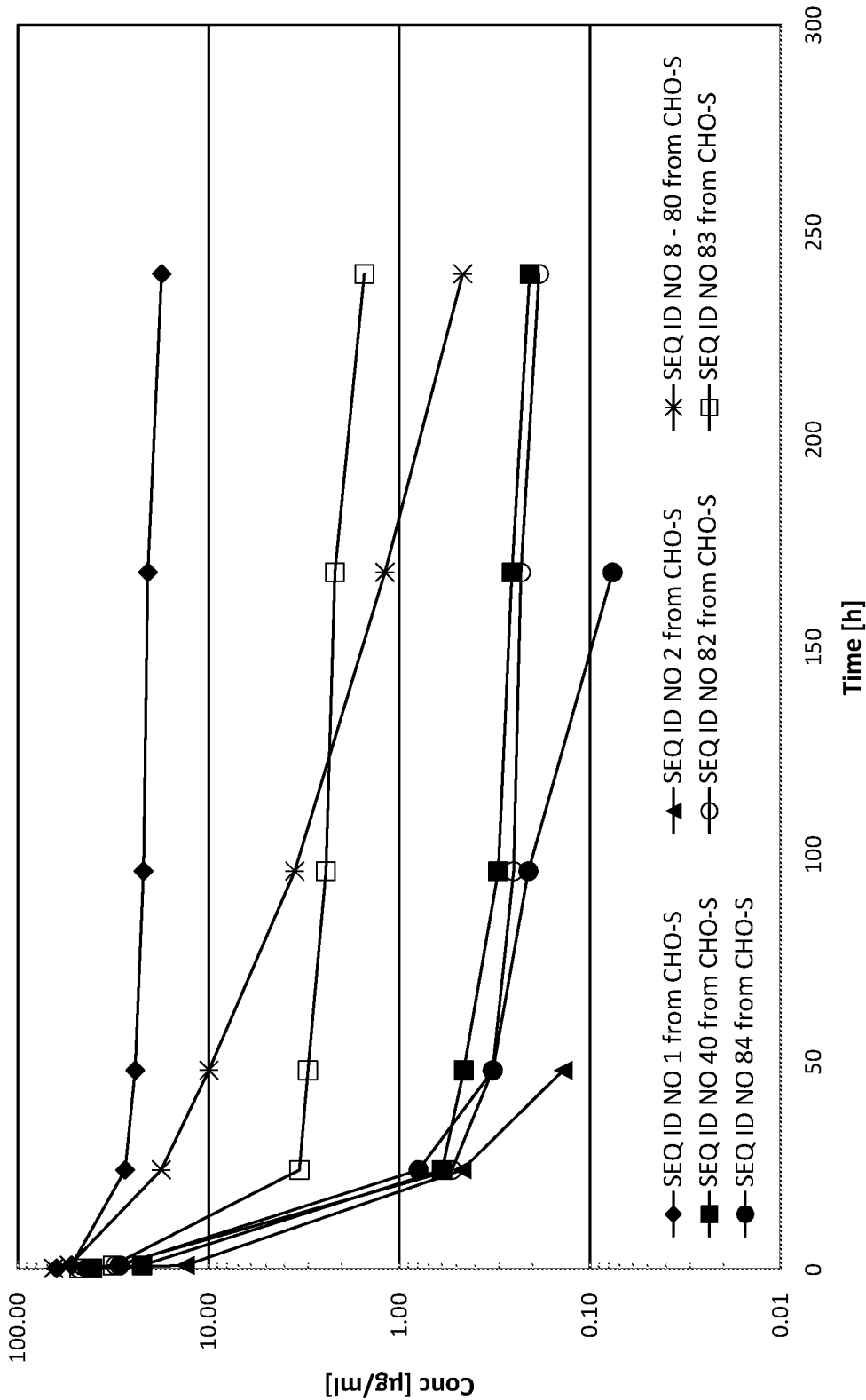


Figure 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/053585

A. CLASSIFICATION OF SUBJECT MATTER

INV. C07K16/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07K A61K

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

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

EPO-Internal, BIOSIS, EMBASE, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LOHSE STEFAN ET AL: "An Anti-EGFR IgA That Displays Improved Pharmacokinetics and Myeloid Effector Cell Engagement In Vivo", CANCER RESEARCH, vol. 76, no. 2, 15 January 2016 (2016-01-15), pages 403-417, XP055831026, ISSN: 0008-5472, DOI: 10.1158/0008-5472.CAN-15-1232 Retrieved from the Internet: URL:https://cancerres.aacrjournals.org/content/76/2/403.full-text.pdf> figures 1,5D-5F; table 1 -----	1-22
X	US 2019/309085 A1 (MONNET CÉLINE [FR]) 10 October 2019 (2019-10-10) paragraphs [0017], [0036]; tables 1,2 ----- -/--	1,6-22

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

☒ See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

10 August 2021

Date of mailing of the international search report

14/10/2021

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Cilensek, Zoran

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2021/053585

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KEVIN O. SAUNDERS ET AL: "Conceptual Approaches to Modulating Antibody Effector Functions and Circulation Half-Life", FRONTIERS IN IMMUNOLOGY, vol. 10, 17 June 2019 (2019-06-17), page 1296, XP055654839, DOI: 10.3389/fimmu.2019.01296 figure 2; table 1 -----	1-22
A	BRANDSMA ARIANNE M. ET AL: "Potent Fc Receptor Signaling by IgA Leads to Superior Killing of Cancer Cells by Neutrophils Compared to IgG", FRONTIERS IN IMMUNOLOGY, vol. 10, 1 April 2019 (2019-04-01), XP055831055, ISSN: 1664-3224, DOI: 10.3389/fimmu.2019.00704 the whole document -----	1-22
T	VAN GOOL MELISSA MARIA JOHANNA ET AL: "IgA and Fc[alpha]RI: Versatile Players in Homeostasis, Infection, and Autoimmunity", IMMUNOTARGETS AND THERAPY, vol. Volume 9, 17 December 2020 (2020-12-17), pages 351-372, XP055830972, DOI: 10.2147/ITT.S266242 Retrieved from the Internet: URL:https://www.dovepress.com/getfile.php?fileID=65336> the whole document -----	1-22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2021/053585

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:
 - a. ☒ forming part of the international application as filed:
 - ☒ in the form of an Annex C/ST.25 text file.
 - ☐ on paper or in the form of an image file.
 - b. ☐ furnished together with the international application under PCT Rule 13~~ter~~.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
 - c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
 - ☐ in the form of an Annex C/ST.25 text file (Rule 13~~ter~~.1(a)).
 - ☐ on paper or in the form of an image file (Rule 13~~ter~~.1(b) and Administrative Instructions, Section 713).
2. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
3. Additional comments:

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2021/053585

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 1-22(partially)
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-22(partially)

Remark on Protest

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

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

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

1. claims: 1-22(partially)

An Fc variant of a parent Fc polypeptide, wherein the Fc variant exhibits altered binding to a FcγR or altered antibody dependent cell-mediated cytotoxicity (ADCC) as compared to the parent Fc polypeptide, wherein the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide, wherein the amino acid modification is at position CH2.10, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.
Subject-matter related thereto.

2-10. claims: 1-22(partially)

Idem as item 1, wherein the modification is at position CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.2

Claims Nos.: 1-22(partially)

The International Searching Authority invited the Applicant on 20 July 2021 to provide informal clarification.

Independent claim 1 is directed to an Fc variant of a parent Fc polypeptide, wherein the Fc variant exhibits altered binding to an Fc alpha receptor or altered antibody dependent cell-mediated cytotoxicity (ADCC) as compared to the parent Fc polypeptide, wherein the Fc variant comprises at least one amino acid modification in the Fc region of the parent Fc polypeptide, wherein the amino acid modification is at a position selected from the group consisting of: CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.

If the parent variant is not disclosed, as in the present case, the ability to mediate ADCC or to bind Fc alpha receptor cannot be determined for this parent variant or any further variant thereof.

Furthermore, it is not unambiguously clear how the residues at the recited positions should be changed.

It is neither clear what is meant by the terms "altered" and "amino acid modification", as this latter term also encompasses post-translational modifications.

Finally yet importantly, the claim encompasses a huge number of possible modifications and combinations thereof. Even if possible, the search for all such modifications would make little sense, as the resulting combinations may, or may not exhibit the desired properties. It should also be noted for the sake of good order that this searching authority is not in the position to verify that the given sequences exhibit the one or another alleged or desired property.

The subject-matter of claim 1 is thus considered to lack clarity and support to such an extent that a meaningful search does not appear possible.

At least some of the aforementioned defects are not remedied by claims 2 and 3, since these claims merely recite the amino acid residues present at the above positions.

Turning to claims 4, 5 and 7, it should be noted that there are different native sequences for IgAs and IgGs. In addition, taking account of the fact that the application is from the field of engineered immunoglobulins, such parent variants may be also non-native, and also cover entirely new hybrid sequences which may not be classified as IgA or IgG.

Claims 6 and 8-10 do not overcome these deficiencies as they merely attempt to define the meaning of the term "altered" in claim 1.

Claim 11 is yet another independent claim, which presence itself contravenes the requirements of conciseness.

This claim also fails to define the sequence of an "IgA antibody comprising a parent

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Fc polypeptide", and in the absence of this sequence, it cannot be determined which subject-matter falls under the scope of this claim. Most importantly, claim 11 does not define which modifications have been done to the parent IgA to give rise to said "variant".

In the same vein as discussed above, this claim is therefore regarded to lack clarity and support.

At least some of the foregoing objections also apply to claims 12-22.

In their reply dated 28 July 2021, the applicant indicates that for search purposes, sequences of the parent Fc polypeptide referred to in claim 1 and claims dependent thereon, are comprised in SEQ ID NO: 2, SEQ ID NO: 3 and SEQ ID NO: 6 in the application as filed. For the antibody related claims 11-14 and claims dependent thereon, the parent Fc polypeptide referred to has the sequence comprised in SEQ ID NO: 2. Reference to the parent Fc polypeptide of SEQ ID NO: 2, SEQ ID NO: 3 and SEQ ID NO: 6 can be found in Example 1 and Tables 2, 4 and 6.

In view of the above, the claimed subject-matter can be searched for the general concept of introducing modifications into the CH2 or the CH3 domain, at positions CH2.10, CH2.89, CH2.91, CH2.94, CH2.97, CH2.99, CH3.45, CH3.105, CH3.109, CH3.118 and CH3.124, in particular to SEQ ID NO: 2, SEQ ID NO: 3 and SEQ ID NO: 6, wherein numbering of the amino acid modification is according to IMGT numbering for C-domain.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) PCT declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2021/053585

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2019309085	A1	10-10-2019	CA 3029971 A1 11-01-2018
			EP 3481865 A1 15-05-2019
			FR 3053688 A1 12-01-2018
			US 2019309085 A1 10-10-2019
			WO 2018007453 A1 11-01-2018
