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(57) Abstract: The present application relates to a variant Fc region comprising at least one modification relative to a wild-type human Fc region, where the modification selected from the group consisting of 434S, 252Y/428L, 252Y/434S, and 428L/434S, and the numbering is according to the EU index.



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### **Fc VARIANTS WITH ALTERED BINDING TO FcRn**

[1] This application claims benefit under 35 U.S.C. §119(e) to USSN 61/016,793, filed December 26, 2007; USSN 61/ 031,353, filed February 25, 2008; USSN 61/046,353, filed April 18, 2008; USSN 61/050,172, filed May 2, 2008; USSN 61/079,779, filed July 10, 2008; and USSN 61/099,178, filed September 22, 2008.

### **FIELD OF THE INVENTION**

[2] The present application relates to optimized IgG immunoglobulin variants, engineering methods for their generation, and their application, particularly for therapeutic purposes.

### **BACKGROUND OF THE INVENTION**

[3] Antibodies are immunological proteins that each binds a specific antigen. In most mammals, including humans and mice, antibodies are constructed from paired heavy and light polypeptide chains. Each chain is made up of individual immunoglobulin (Ig) domains, and thus the generic term immunoglobulin is used for such proteins. Each chain is made up of two distinct regions, referred to as the variable and constant regions. The light and heavy chain variable regions show significant sequence diversity between antibodies, and are responsible for binding the target antigen. The constant regions show less sequence diversity, and are responsible for binding a number of natural proteins to elicit important biochemical events. In humans there are five different classes of antibodies including IgA (which includes subclasses IgA1 and IgA2), IgD, IgE, IgG (which includes subclasses IgG1, IgG2, IgG3, and IgG4), and IgM. The distinguishing feature between these antibody classes is their constant regions, although subtler differences may exist in the V region. IgG antibodies are tetrameric proteins composed of two heavy chains and two light chains. The IgG heavy chain is composed of four immunoglobulin domains linked from N- to C-terminus in the order VH-CH1-CH2-CH3, referring to the heavy chain variable domain, heavy chain constant domain 1, heavy chain constant domain 2, and heavy chain constant domain 3 respectively (also referred to as VH-C $\gamma$ 1-C $\gamma$ 2-C $\gamma$ 3, referring to the heavy chain variable domain, constant gamma 1 domain, constant gamma 2 domain, and constant gamma 3 domain respectively). The IgG light chain is composed of two immunoglobulin domains linked from N- to C-terminus in the order VL-CL, referring to the light chain variable domain and the light chain constant domain respectively.

[4] In IgG, a site on Fc between the C $\gamma$ 2 and C $\gamma$ 3 domains mediates interaction with the neonatal receptor FcRn. Binding to FcRn recycles endocytosed antibody from the endosome back to the bloodstream (Raghavan et al., 1996, Annu Rev Cell Dev Biol 12:181-220; Ghetie et al., 2000, Annu Rev Immunol 18:739-766, both entirely incorporated by reference). This process, coupled with preclusion of kidney filtration due to the large size of the full-length molecule, results in favorable antibody serum half-lives ranging from one to three weeks. Binding of Fc to FcRn also plays a key role in antibody transport. The binding site on Fc for FcRn is also the site at which the

bacterial proteins A and G bind. The tight binding by these proteins is typically exploited as a means to purify antibodies by employing protein A or protein G affinity chromatography during protein purification. Thus the fidelity of this region on Fc is important for both the clinical properties of antibodies and their purification. Available structures of the rat Fc/FcRn complex (Burmeister et al., 1994, *Nature*, 372:379-383; Martin et al., 2001, *Mol Cell* 7:867-877, both entirely incorporated by reference), and of the complexes of Fc with proteins A and G (Deisenhofer, 1981, *Biochemistry* 20:2361-2370; Sauer-Eriksson et al., 1995, *Structure* 3:265-278; Tashiro et al., 1995, *Curr Opin Struct Biol* 5:471-481, all entirely incorporated by reference), provide insight into the interaction of Fc with these proteins. The FcRn receptor is also responsible for the transfer of IgG to the neonatal gut and to the lumen of the intestinal epithelia in adults (Ghetie and Ward, *Annu. Rev. Immunol.*, 2000, 18:739-766; Yoshida et al., *Immunity*, 2004, 20(6):769-783, both entirely incorporated by reference).

**[5]** Studies of rat and human Fc domains have demonstrated the importance of some Fc residues to the binding of FcRn. The rat and human sequences have about 64% sequence identity in the Fc regions (residues 237-443 in the numbering of EU index). See figures 3, 4, and 5 for the rat/human alignments of Fc, FcRn heavy chain, and FcRn light chain (beta-2-microglobulin). A model of the human Fc/FcRn complex has been built from the existing structure of the rat Fc/FcRn complex (Martin et al., 2001, *Mol Cell* 7:867-877, entirely incorporated by reference). The rat and human sequences share some residues that are critical for FcRn binding, such as H310 and H435 (Medesan et al., 1997 *J. Immunol.* 158(5):221-7; Shields et al., 2001, *J. Biol. Chem.* 276(9):6591-6604, both entirely incorporated by reference). In many positions, however, the human and rat proteins have different amino acids, giving the residues in the human sequence different environments, and possibly a different identities, than in the rat sequence. This variability limits the ability to transfer characteristics from one homolog to the other homolog.

**[6]** In the murine Fc, random mutation and phage display selection at the sites, T252, T254, and T256 lead to a triple mutant, T252L/T254S/T256F, that has a 3.5-fold increase in FcRn affinity and a 1.5-fold increase in serum half-life (Ghetie et al., 1997, *Nat. Biotech.* 15(7): 637-640, entirely incorporated by reference). Disruption of the Fc/FcRn interaction by mutations at positions 253, 310 and 435 also lead to decreased *in vivo* half-life (Medesan et al *J. Immunol.* 1997 158(5):2211-7, entirely incorporated by reference).

**[7]** Mutational studies in human Fc $\gamma$  have been done on some of the residues that are important for binding to FcRn and have demonstrated an increased serum half-life. In human Fc $\gamma$ 1, Hinton et al. mutated three residues individually to the other 19 common amino acids. Hinton et al., found that some point mutants a double mutant increased the FcRn binding affinity (Hinton et al., 2004, *J. Biol. Chem.* 279(8): 6213-6216; Hinton et al. *Journal of Immunology* 2006, 176:346-356, both entirely incorporated by reference). Two mutations had increased half-lives in monkeys. Shields et al. mutated residues, almost exclusively to Ala, and studied their binding to FcRn and

the Fc $\gamma$ R's (Shields et al., 2001, *J. Biol. Chem.*, 276(9):6591-6604, entirely incorporated by reference).

**[8]** Dall'Acqua et al. used phage display to select for Fc mutations that bound FcRn with increased affinity (Dall'Acqua et al. 2002, *J. Immunol.* 169:5171-5180, entirely incorporated by reference). The DNA sequences selected for were primarily double and triple mutants. The reference expressed the proteins encoded by many of their selected sequences and found some that bound to FcRn more tightly than the wild-type Fc.

**[9]** The administration of antibodies and Fc fusion proteins as therapeutics requires injections with a prescribed frequency relating to the clearance and half-life characteristics of the protein. Longer *in vivo* half-lives allow more seldom injections or lower dosing, which is clearly advantageous. Although the past mutations in the Fc domain have lead to some proteins with increased FcRn binding affinity and *in vivo* half-lives, these mutations have not identified the optimal mutations and enhanced *in vivo* half-life.

**[10]** One feature of the Fc region is the conserved N-linked glycosylation that occurs at N297. This carbohydrate, or oligosaccharide as it is sometimes called, plays a critical structural and functional role for the antibody, and is one of the principle reasons that antibodies must be produced using mammalian expression systems. Umaña et al., 1999, *Nat Biotechnol* 17:176-180; Davies et al., 2001, *Biotechnol Bioeng* 74:288-294; Mimura et al., 2001, *J Biol Chem* 276:45539-45547.; Radaev et al., 2001, *J Biol Chem* 276:16478-16483; Shields et al., 2001, *J Biol Chem* 276:6591-6604; Shields et al., 2002, *J Biol Chem* 277:26733-26740; Simmons et al., 2002, *J Immunol Methods* 263:133-147; Radaev et al., 2001, *J Biol Chem* 276:16469-16477; and Krapp et al., 2003, *J Mol Biol* 325:979-989, all entirely incorporated by reference).

**[11]** Antibodies have been developed for therapeutic use. Representative publications related to such therapies include Chamow et al., 1996, *Trends Biotechnol* 14:52-60; Ashkenazi et al., 1997, *Curr Opin Immunol* 9:195-200, Cragg et al., 1999, *Curr Opin Immunol* 11:541-547; Glennie et al., 2000, *Immunol Today* 21:403-410, McLaughlin et al., 1998, *J Clin Oncol* 16:2825-2833, and Cobleigh et al., 1999, *J Clin Oncol* 17:2639-2648, all entirely incorporated by reference. Currently for anticancer therapy, any small improvement in mortality rate defines success. Certain IgG variants disclosed herein enhance the capacity of antibodies to limit further growth or destroy at least partially, targeted cancer cells.

**[12]** Anti-tumor potency of antibodies is via enhancement of their ability to mediate cytotoxic effector functions such as ADCC, ADCP, and CDC. Examples include Clynes et al., 1998, *Proc Natl Acad Sci U S A* 95:652-656; Clynes et al., 2000, *Nat Med* 6:443-446 and Cartron et al., 2002, *Blood* 99:754-758, both entirely incorporated by reference.

**[13]** Human IgG1 is the most commonly used antibody for therapeutic purposes, and the majority of engineering studies have been constructed in this context. The different isotypes of the IgG class however, including IgG1, IgG2, IgG3, and IgG4, have unique physical, biological, and

clinical properties. There is a need in the art to design improved IgG1, IgG2, IgG3, and IgG4 variants. There is a further need to design such variants to improve binding to FcRn and/or increase *in vivo* half-life as compared to native IgG polypeptides. Additionally, there is a need to combine variants with improved pharmacokinetic properties with variants comprising modifications to improve efficacy through altered FcγR binding. The present application meets these and other needs.

### SUMMARY OF THE INVENTION

**[14]** The present application is directed to Fc variants of a parent polypeptide including at least one modification in the Fc region of the polypeptide. In various embodiments, the variant polypeptides exhibit altered binding to FcRn as compared to a parent polypeptide. In certain variations, the modification can be selected from the group consisting of: 428L, 434M and 434S, where the numbering is according to the EU Index in Kabat et al.

**[15]** In another embodiment, the Fc variant includes at least two modifications selected from the group consisting of: 252Y/428L, 428L/434H, 428L/434F, 428L/434Y, 428L/434A, 428L/434M, and 428L/434S.

**[16]** In another embodiment, the Fc variant includes at least one modification selected from the group consisting of: M428L/N434S, V308F/M428L/N434S.

**[17]** In another embodiment, the Fc variant includes at least one modification selected from the group consisting of: 259I/434S, 308F/434S, 308F/428L/434S, 259I/308F/434S, 307Q/308F/434S, 250I/308F/434S, and 308F/319L/434S.

**[18]** In another embodiment, the Fc variant includes at least one modification selected from the group consisting of:

**[19]** In another embodiment, the invention includes a method of treating a patient in need of said treatment comprising administering an effective amount of an Fc variant described herein.

**[20]** In another embodiment, the invention includes a method of increasing the half-life of an antibody or immunoadhesin by modifying an Fc according to the modifications described herein.

**[21]** In another variant, the invention includes Fc variant with enhanced FcRn binding with additional Fc variants that modulate effector function.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[22]** Figure 1. Sequence alignments of human IgG constant heavy chains. Gray indicates differences from IgG1, and boxed residues indicate common allotypic variations in the human population.

**[23]** Figure 2. (SEQ ID NO: 1-6) Amino acid sequences of constant regions used in the invention.

**[24]** Figure 3. (SEQ ID NO: 7-12) Amino acid sequences of exemplary variant constant regions.

**[25]** Figure 4. (SEQ ID NO: 13-22) Amino acid sequences of VH and VL variable regions used in the invention.

- [26]** Figure 5. (SEQ ID NO: 23-29) Amino acid sequences of exemplary variant antibodies.
- [27]** Figure 6. Relative VEGF binding by WT and select variant IgG1 anti-VEGF antibodies. The plot shows the Biacore response units (RU) at the end of the association phase for binding of antibody analyte to immobilized VEGF antigen. Anti-Her2 IgG1 antibody was used as a negative control.
- [28]** Figure 7. Biacore sensorgrams of WT and variant IgG1 antibodies to immobilized human FcRn at low (6.0) and high (7.4) pH.
- [29]** Figure 8. FcRn binding affinities of WT and select variant IgG1 antibodies to human FcRn at pH 6.0 as determined by Biacore. The graph shows a plot of the pseudo-affinity constant ( $K_a^*$ ), on a log scale.
- [30]** Figure 9. Relative binding of variant IgG1 anti-VEGF antibodies to human FcRn as determined by Biacore. The table shows the fold of the  $K_a^*$  of each variant relative to human WT (native) IgG1. n indicates the number of time each variant was tested, and Mean and SD indicate the average and standard deviation respectively for each variant over n binding experiments. Fold FcRn was calculated for all variants relative to WT IgG1 within each respective binding experiment. NB indicates no binding was detected. ND indicates that binding was not determined for that particular variant. NF indicates no fit was possible from the binding data.
- [31]** Figure 10. Relative binding of variant IgG2 and IgG1/2 anti-VEGF antibodies to human FcRn as determined by Biacore. The table is as described in Figure 9.
- [32]** Figure 11. Analysis of additive and synergistic substitution combinations. Figure 11a shows a plot of the experimentally determined fold binding to human FcRn by each variant versus the predicted fold FcRn binding as determined by the product of the single variants. Variant data points are labeled, and the line represents perfect additivity. Figure 11b shows the difference between experimental and predicted fold for each combination variant. Figure 11c shows the synergy of each variant combination. % synergy is calculated as the  $100 \times [(\text{experimental fold} / \text{predicted fold}) - 1]$ .
- [33]** Figure 12. Relative binding of variant anti-TNF, -CD25, -EGFR, and -IgE antibodies to human FcRn as determined by Biacore. The table is as described in Figure 9.
- [34]** Figure 13. In vivo pharmacokinetics of WT and variant antibodies in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice. The graphs plot the serum concentration of antibody versus time after a single intravenous dose. Figure 13a shows data from one of the 4 studies carried out with IgG1 antibodies (Study 3), and Figure 13b shows data from a study carried out with IgG2 antibodies (Study 5).
- [35]** Figure 14. Fitted PK parameters from all in vivo PK studies carried out in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice with variant and WT antibodies. n represents the number of mice per group, with Mean and standard deviation (SD) data provided for PK parameters. Half-Life represents the beta phase that characterizes elimination of antibody from serum. C<sub>max</sub> is the maximal observed serum concentration, AUC is the area under the concentration time curve, and clearance is the clearance

of antibody from serum. Fold half-life is calculated as the half-life of variant antibody over that of the WT IgG1 or IgG2 parent within each study.

[36] Figure 15. Correlation between half-life of IgG1 (Figure 15a) and IgG2 (Figure 15b) variant antibodies in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice and fold FcRn binding relative to WT IgG1. Data on the y-axis are from Figure 14, and data on the x-axis are from Figures 9 and 10. Select variants are labeled, and variant data from repeat experiments are circled. Figure 15c shows both IgG1 and IgG2 correlation data, with the black and gray lines representing fits of the IgG1 and IgG2 data respectively.

[37] Figure 16. (SEQ ID NO: 30-35) Amino acid sequences of variant and parent anti-TNF Fc immunoadhesins used in the invention.

[38] Figure 17. Binding of anti-TNF immunoadhesins to TNF antigen as determined by Biacore.

[39] Figure 18. Relative binding of variant Fc immunoadhesins to human FcRn as determined by Biacore. The table shows the fold of the  $K_a^*$  of each variant relative to human WT (native) IgG1. n indicates the number of time each variant was tested, and Mean and SD indicate the average and standard deviation respectively for each variant over n binding experiments. Fold FcRn was calculated for all variants relative to the respective IgG parent within each respective binding experiment.

[40] Figure 19. In vivo pharmacokinetics of parent and variant Fc immunoadhesins in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice. The graphs plot the serum concentration of Fc fusion versus time after a single intravenous dose.

[41] Figure 20. Fitted PK parameters from the Fc fusion in vivo PK study in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice. Parameters are as described in Figure 14. % increase in half-life is calculated as 100 times the half-life of variant Fc fusion over that of the WT IgG1 or IgG2 parent.

[42] Figure 21. Relative binding of variant IgG1 anti-VEGF antibodies to cynomolgus monkey and human FcRn as determined by Biacore. Figure 21a shows the data in tabular form. Description of the figure is as in Figure 9, and data for binding to human FcRn are taken from Figure 9. Figure 21b shows a plot of the data.

[43] Figure 22. In vivo pharmacokinetics of WT and variant antibodies in cynomolgus monkeys. The graphs plot the serum concentration of antibody versus time after a single intravenous dose.

[44] Figure 23. Fitted PK parameters from the in vivo PK study in cynomolgus monkeys with variant and WT antibodies. Parameters are as described in Figure 14.

#### DETAILED DESCRIPTION OF THE INVENTION

[45] The present invention discloses the generation of novel variants of Fc domains, including those found in antibodies, Fc fusions, and immuno-adhesions, which have an increased binding to the FcRn receptor. As noted herein, binding to FcRn results in longer serum retention *in vivo*.

[46] In order to increase the retention of the Fc proteins *in vivo*, the increase in binding affinity must be at around pH 6 while maintaining lower affinity at around pH 7.4. Although still under

examination, Fc regions are believed to have longer half-lives *in vivo*, because binding to FcRn at pH 6 in an endosome sequesters the Fc (Ghetie and Ward, 1997 Immunol Today. 18(12): 592-598, entirely incorporated by reference). The endosomal compartment then recycles the Fc to the cell surface. Once the compartment opens to the extracellular space, the higher pH, ~7.4, induces the release of Fc back into the blood. In mice, Dall'Acqua et al. showed that Fc mutants with increased FcRn binding at pH 6 and pH 7.4 actually had reduced serum concentrations and the same half life as wild-type Fc (Dall'Acqua et al. 2002, J. Immunol. 169:5171-5180, entirely incorporated by reference). The increased affinity of Fc for FcRn at pH 7.4 is thought to forbid the release of the Fc back into the blood. Therefore, the Fc mutations that will increase Fc's half-life *in vivo* will ideally increase FcRn binding at the lower pH while still allowing release of Fc at higher pH. The amino acid histidine changes its charge state in the pH range of 6.0 to 7.4. Therefore, it is not surprising to find His residues at important positions in the Fc/FcRn complex (Figure 6.)

**[47]** An additional aspect of the invention is the increase in FcRn binding over wild type specifically at lower pH, about pH 6.0, to facilitate Fc/FcRn binding in the endosome. Also disclosed are Fc variants with altered FcRn binding and altered binding to another class of Fc receptors, the FcγR's (sometimes written FcγR's) as differential binding to FcγRs, particularly increased binding to FcγRIIIb and decreased binding to FcγRIIb, has been shown to result in increased efficacy.

**[48]** *Definitions*

**[49]** In order that the application may be more completely understood, several definitions are set forth below. Such definitions are meant to encompass grammatical equivalents.

**[50]** By "ADCC" or "antibody dependent cell-mediated cytotoxicity" as used herein is meant the cell-mediated reaction wherein nonspecific cytotoxic cells that express FcγRs recognize bound antibody on a target cell and subsequently cause lysis of the target cell.

**[51]** By "ADCP" or "antibody dependent cell-mediated phagocytosis" as used herein is meant the cell-mediated reaction wherein nonspecific cytotoxic cells that express FcγRs recognize bound antibody on a target cell and subsequently cause phagocytosis of the target cell.

**[52]** By "modification" herein is meant an amino acid substitution, insertion, and/or deletion in a polypeptide sequence or an alteration to a moiety chemically linked to a protein. For example, a modification may be an altered carbohydrate or PEG structure attached to a protein. By "amino acid modification" herein is meant an amino acid substitution, insertion, and/or deletion in a polypeptide sequence.

**[53]** By "amino acid substitution" or "substitution" herein is meant the replacement of an amino acid at a particular position in a parent polypeptide sequence with another amino acid. For example, the substitution E272Y refers to a variant polypeptide, in this case an Fc variant, in which the glutamic acid at position 272 is replaced with tyrosine.



**[54]** By “amino acid insertion” or “insertion” as used herein is meant the addition of an amino acid sequence at a particular position in a parent polypeptide sequence. For example, -233E or ^233E designates an insertion of glutamic acid after position 233 and before position 234. Additionally, -233ADE or ^233ADE designates an insertion of AlaAspGlu after position 233 and before position 234.

**[55]** By “amino acid deletion” or “deletion” as used herein is meant the removal of an amino acid sequence at a particular position in a parent polypeptide sequence. For example, E233- or E233# designates a deletion of glutamic acid at position 233. Additionally, EDA233- or EDA233# designates a deletion of the sequence GluAspAla that begins at position 233.

**[56]** By “variant protein” or “protein variant”, or “variant” as used herein is meant a protein that differs from that of a parent protein by virtue of at least one amino acid modification. Protein variant may refer to the protein itself, a composition comprising the protein, or the amino sequence that encodes it. Preferably, the protein variant has at least one amino acid modification compared to the parent protein, e.g. from about one to about seventy amino acid modifications, and preferably from about one to about five amino acid modifications compared to the parent. The protein variant sequence herein will preferably possess at least about 80% homology with a parent protein sequence, and most preferably at least about 90% homology, more preferably at least about 95% homology. Variant protein can refer to the variant protein itself, compositions comprising the protein variant, or the DNA sequence that encodes it. Accordingly, 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, “IgG variant” or “variant IgG” as used herein is meant an antibody that differs from a parent IgG by virtue of at least one amino acid modification, and “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. “Fc variant” or “variant Fc” as used herein is meant a protein comprising a modification in an Fc domain. The Fc variants of the present invention are defined according to the amino acid modifications that compose them. Thus, for example, N434S or 434S is an Fc variant with the substitution serine at position 434 relative to the parent Fc polypeptide, wherein the numbering is according to the EU index. Likewise, M428L/N434S defines an Fc variant with the substitutions M428L and N434S. A relative to the parent Fc polypeptide. The identity of the WT amino acid may be unspecified, in which case the aforementioned variant is referred to as 428L/434S. It is noted that the order in which substitutions are provided is arbitrary, that is to say that, for example, 428L/434S is the same Fc variant as M428L/N434S, and so on. For all positions discussed in the present invention, numbering is according to the EU index. The EU index or EU index as in Kabat or EU numbering scheme refers to the numbering of the EU antibody (Edelman et al., 1969, Proc Natl Acad Sci USA 63:78-85, hereby entirely incorporated by reference.) The modification can be an addition, deletion, or substitution. Substitutions can include

naturally occurring amino acids and non-naturally occurring amino acids. Variants may comprise non-natural amino acids. Examples include US 6,586,207; WO 98/48032; WO 03/073238; US2004-0214988A1; WO 05/35727A2; WO 05/74524A2; J. W. Chin et al., (2002), Journal of the American Chemical Society 124:9026-9027; J. W. Chin, & P. G. Schultz, (2002), ChemBioChem 11:1135-1137; J. W. Chin, et al., (2002), PICAS United States of America 99:11020-11024; and, L. Wang, & P. G. Schultz, (2002), Chem. 1-10, all entirely incorporated by reference.

**[57]** As used herein, "protein" herein is meant at least two covalently attached amino acids, which includes proteins, polypeptides, oligopeptides and peptides. The peptidyl group may comprise naturally occurring amino acids and peptide bonds, or synthetic peptidomimetic structures, i.e. "analogs", such as peptoids (see Simon et al., PNAS USA 89(20):9367 (1992), entirely incorporated by reference). The amino acids may either be naturally occurring or non-naturally occurring; as will be appreciated by those in the art. For example, homo-phenylalanine, citrulline, and noreleucine are considered amino acids for the purposes of the invention, and both D- and L- (R or S) configured amino acids may be utilized. The variants of the present invention may comprise modifications that include the use of unnatural amino acids incorporated using, for example, the technologies developed by Schultz and colleagues, including but not limited to methods described by Cropp & Shultz, 2004, Trends Genet. 20(12):625-30, Anderson et al., 2004, Proc Natl Acad Sci USA 101(2):7566-71, Zhang et al., 2003, 303(5656):371-3, and Chin et al., 2003, Science 301(5635):964-7, all entirely incorporated by reference. In addition, polypeptides may include synthetic derivatization of one or more side chains or termini, glycosylation, PEGylation, circular permutation, cyclization, linkers to other molecules, fusion to proteins or protein domains, and addition of peptide tags or labels.

**[58]** By "residue" as used herein is meant a position in a protein and its associated amino acid identity. For example, Asparagine 297 (also referred to as Asn297 or N297) is a residue at position 297 in the human antibody IgG1.

**[59]** By "Fab" or "Fab region" as used herein is meant the polypeptide that comprises the VH, CH1, VL, and CL immunoglobulin domains. Fab may refer to this region in isolation, or this region in the context of a full length antibody, antibody fragment or Fab fusion protein. By "Fv" or "Fv fragment" or "Fv region" as used herein is meant a polypeptide that comprises the VL and VH domains of a single antibody.

**[60]** By "IgG subclass modification" as used herein is meant an amino acid modification that converts one amino acid of one IgG isotype to the corresponding amino acid in a different, aligned IgG isotype. For example, because IgG1 comprises a tyrosine and IgG2 a phenylalanine at EU position 296, a F296Y substitution in IgG2 is considered an IgG subclass modification.

**[61]** By "non-naturally occurring modification" as used herein is meant an amino acid modification that is not isotypic. For example, because none of the IgGs comprise a serine at

position 434, the substitution 434S in IgG1, IgG2, IgG3, or IgG4 is considered a non-naturally occurring modification.

**[62]** By “amino acid” and “amino acid identity” as used herein is meant one of the 20 naturally occurring amino acids or any non-natural analogues that may be present at a specific, defined position.

**[63]** By “effector function” as used herein is meant a biochemical event that results from the interaction of an antibody Fc region with an Fc receptor or ligand. Effector functions include but are not limited to ADCC, ADCP, and CDC.

**[64]** By “IgG Fc ligand” as used herein is meant a molecule, preferably a polypeptide, from any organism that binds to the Fc region of an IgG antibody to form an Fc / Fc ligand complex. Fc ligands include but are not limited to FcγRs, FcγRs, FcγRs, FcRn, C1q, C3, mannan binding lectin, mannose receptor, *staphylococcal* protein A, *streptococcal* protein G, and viral FcγR. Fc ligands also include Fc receptor homologs (FcRH), which are a family of Fc receptors that are homologous to the FcγRs (Davis *et al.*, 2002, *Immunological Reviews* 190:123-136, entirely incorporated by reference). Fc ligands may include undiscovered molecules that bind Fc. Particular IgG Fc ligands are FcRn and Fc gamma receptors. By “Fc ligand” as used herein is meant a molecule, preferably a polypeptide, from any organism that binds to the Fc region of an antibody to form an Fc / Fc ligand complex.

**[65]** By “Fc gamma receptor”, “FcγR” or “FcγgammaR” as used herein is meant any member of the family of proteins that bind the IgG antibody Fc region and is encoded by an FcγR gene. In humans this family includes but is not limited to FcγRI (CD64), including isoforms FcγRIa, FcγRIb, and FcγRIc; FcγRII (CD32), including isoforms FcγRIIa (including allotypes H131 and R131), FcγRIIb (including FcγRIIb-1 and FcγRIIb-2), and FcγRIIc; and FcγRIII (CD16), including isoforms FcγRIIIa (including allotypes V158 and F158) and FcγRIIIb (including allotypes FcγRIIIb-NA1 and FcγRIIIb-NA2) (Jefferis *et al.*, 2002, *Immunol Lett* 82:57-65, entirely incorporated by reference), as well as any undiscovered human FcγRs or FcγR isoforms or allotypes. An FcγR may be from any organism, including but not limited to humans, mice, rats, rabbits, and monkeys. Mouse FcγRs include but are not limited to FcγRI (CD64), FcγRII (CD32), FcγRIII (CD16), and FcγRIII-2 (CD16-2), as well as any undiscovered mouse FcγRs or FcγR isoforms or allotypes.

**[66]** By “FcRn” or “neonatal Fc Receptor” as used herein is meant a protein that binds the IgG antibody Fc region and is encoded at least in part by an FcRn gene. The FcRn may be from any organism, including but not limited to humans, mice, rats, rabbits, and monkeys. As is known in the art, the functional FcRn protein comprises two polypeptides, often referred to as the heavy chain and light chain. The light chain is beta-2-microglobulin and the heavy chain is encoded by the FcRn gene. Unless other wise noted herein, FcRn or an FcRn protein refers to the complex of

FcRn heavy chain with beta-2-microglobulin. Sequences of particular interest of FcRn are shown in the Figures, particularly the human species.

[67] By "parent polypeptide" 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 immunoglobulin" as used herein is meant an unmodified immunoglobulin polypeptide that is modified to generate a variant, and by "parent antibody" as used herein is meant an unmodified antibody that is modified to generate a variant antibody. It should be noted that "parent antibody" includes known commercial, recombinantly produced antibodies as outlined below.

[68] By "position" as used herein is meant a location in the sequence of a protein. Positions may be numbered sequentially, or according to an established format, for example the EU index for antibody numbering.

[69] By "target antigen" as used herein is meant the molecule that is bound specifically by the variable region of a given antibody. A target antigen may be a protein, carbohydrate, lipid, or other chemical compound.

[70] By "target cell" as used herein is meant a cell that expresses a target antigen.

[71] By "variable region" as used herein is meant the region of an immunoglobulin that comprises one or more Ig domains substantially encoded by any of the V $\kappa$ , V $\lambda$ , and/or V $H$  genes that make up the kappa, lambda, and heavy chain immunoglobulin genetic loci respectively.

[72] 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 has an amino acid sequence or a nucleotide sequence that has not been intentionally modified.

[73] The present invention is directed to antibodies that exhibit increased binding to FcRn relative to a wild-type antibody. For example, in some instances, increased binding results in cellular recycling of the antibody and hence increased half-life. In addition, antibodies exhibiting increased binding to FcRn and altered binding to other Fc receptors, eg. Fc $\gamma$ Rs, find use in the present invention.

#### *Antibodies*

[74] The present application is directed to antibodies that include amino acid modifications that modulate binding to FcRn. Of particular interest are antibodies that minimally comprise an Fc region, or functional variant thereof, that displays increased binding affinity to FcRn at lowered pH, and do not exhibit substantially altered binding at higher pH.

[75] Traditional antibody structural units typically comprise a tetramer. Each tetramer is typically composed of two identical pairs of polypeptide chains, each pair having one "light" (typically having a molecular weight of about 25 kDa) and one "heavy" chain (typically having a molecular

weight of about 50-70 kDa). Human light chains are classified as kappa and lambda light chains. Heavy chains are classified as mu, delta, gamma, alpha, or epsilon, and define the antibody's isotype as IgM, IgD, IgG, IgA, and IgE, respectively. IgG has several subclasses, including, but not limited to IgG1, IgG2, IgG3, and IgG4. IgM has subclasses, including, but not limited to, IgM1 and IgM2. Thus, "isotype" as used herein is meant any of the subclasses of immunoglobulins defined by the chemical and antigenic characteristics of their constant regions. The known human immunoglobulin isotypes are IgG1, IgG2, IgG3, IgG4, IgA1, IgA2, IgM1, IgM2, IgD, and IgE.

**[76]** The amino-terminal portion of each chain includes a variable region of about 100 to 110 or more amino acids primarily responsible for antigen recognition. In the variable region, three loops are gathered for each of the V domains of the heavy chain and light chain to form an antigen-binding site. Each of the loops is referred to as a complementarity-determining region (hereinafter referred to as a "CDR"), in which the variation in the amino acid sequence is most significant.

**[77]** The carboxy-terminal portion of each chain defines a constant region primarily responsible for effector function. Kabat et al. collected numerous primary sequences of the variable regions of heavy chains and light chains. Based on the degree of conservation of the sequences, they classified individual primary sequences into the CDR and the framework and made a list thereof (see SEQUENCES OF IMMUNOLOGICAL INTEREST, 5th edition, NIH publication, No. 91-3242, E.A. Kabat et al., entirely incorporated by reference).

**[78]** In the IgG subclass of immunoglobulins, there are several immunoglobulin domains in the heavy chain. By "immunoglobulin (Ig) domain" herein is meant a region of an immunoglobulin having a distinct tertiary structure. Of interest in the present invention are the heavy chain domains, including, the constant heavy (CH) domains and the hinge domains. In the context of IgG antibodies, the IgG isotypes each have three CH regions. Accordingly, "CH" domains in the context of IgG are as follows: "CH1" refers to positions 118-220 according to the EU index as in Kabat. "CH2" refers to positions 237-340 according to the EU index as in Kabat, and "CH3" refers to positions 341-447 according to the EU index as in Kabat.

**[79]** Another type of Ig domain of the heavy chain is the hinge region. By "hinge" or "hinge region" or "antibody hinge region" or "immunoglobulin hinge region" herein is meant the flexible polypeptide comprising the amino acids between the first and second constant domains of an antibody. Structurally, the IgG CH1 domain ends at EU position 220, and the IgG CH2 domain begins at residue EU position 237. Thus for IgG the antibody hinge is herein defined to include positions 221 (D221 in IgG1) to 236 (G236 in IgG1), wherein the numbering is according to the EU index as in Kabat. In some embodiments, for example in the context of an Fc region, the lower hinge is included, with the "lower hinge" generally referring to positions 226 or 230.

**[80]** Of particular interest in the present invention are the Fc regions. By "Fc" or "Fc region", as used herein is meant the polypeptide comprising the constant region of an antibody excluding the first constant region immunoglobulin domain and in some cases, part of the hinge. Thus Fc refers

to the last two constant region immunoglobulin domains of IgA, IgD, and IgG, the last three constant region immunoglobulin domains of IgE and IgM, and the flexible hinge N-terminal to these domains. For IgA and IgM, Fc may include the J chain. For IgG, as illustrated in Figure 1, Fc comprises immunoglobulin domains Cgamma2 and Cgamma3 (Cg2 and Cg3) and the lower hinge region between Cgamma1 (Cg1) and Cgamma2 (Cg2). Although the boundaries of the Fc region may vary, the human IgG heavy chain Fc region is usually defined to include residues C226 or P230 to its carboxyl-terminus, wherein the numbering is according to the EU index as in Kabat. Fc may refer to this region in isolation, or this region in the context of an Fc polypeptide, as described below. By "Fc polypeptide" as used herein is meant a polypeptide that comprises all or part of an Fc region. Fc polypeptides include antibodies, Fc fusions, isolated Fcs, and Fc fragments.

**[81]** In some embodiments, the antibodies are full length. By "full length antibody" herein is meant the structure that constitutes the natural biological form of an antibody, including variable and constant regions, including one or more modifications as outlined herein.

**[82]** Alternatively, the antibodies can be a variety of structures, including, but not limited to, antibody fragments, monoclonal antibodies, 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.

**[83]** *Antibody Fragments*

**[84]** In one embodiment, the antibody is an antibody fragment. Of particular interest are antibodies that comprise Fc regions, Fc fusions, and the constant region of the heavy chain (CH1-hinge-CH2-CH3), again also including constant heavy region fusions.

**[85]** Specific antibody fragments include, but are not limited to, (i) the Fab fragment consisting of VL, VH, CL and CH1 domains, (ii) the Fd fragment consisting of the VH and CH1 domains, (iii) the Fv fragment consisting of the VL and VH domains of a single antibody; (iv) the dAb fragment (Ward et al., 1989, Nature 341:544-546, entirely incorporated by reference) which consists of a single variable, (v) isolated CDR regions, (vi) F(ab')<sub>2</sub> fragments, a bivalent fragment comprising two linked Fab fragments (vii) single chain Fv molecules (scFv), wherein a VH domain and a VL domain are linked by a peptide linker which allows the two domains to associate to form an antigen binding site (Bird et al., 1988, Science 242:423-426, Huston et al., 1988, Proc. Natl. Acad. Sci. U.S.A. 85:5879-5883, entirely incorporated by reference), (viii) bispecific single chain Fv (WO 03/11161, hereby incorporated by reference) and (ix) "diabodies" or "triabodies", multivalent or multispecific fragments constructed by gene fusion (Tomlinson et. al., 2000, Methods Enzymol. 326:461-479; WO94/13804; Holliger et al., 1993, Proc. Natl. Acad. Sci. U.S.A. 90:6444-6448, all entirely incorporated by reference). The antibody fragments may be modified. For example, the molecules may be stabilized by the incorporation of disulphide bridges linking the VH and VL domains (Reiter et al., 1996, Nature Biotech. 14:1239-1245, entirely incorporated by reference).

**[86]** *Chimeric and Humanized Antibodies*

**[87]** In some embodiments, the scaffold components can be a mixture from different species. As such, if the protein is an antibody, such antibody may be a chimeric antibody and/or a humanized antibody. In general, both "chimeric antibodies" and "humanized antibodies" refer to antibodies that combine regions from more than one species. For example, "chimeric antibodies" traditionally comprise variable region(s) from a mouse (or rat, in some cases) and the constant region(s) from a human. "Humanized antibodies" generally refer to non-human antibodies that have had the variable-domain framework regions swapped for sequences found in human antibodies. Generally, in a humanized antibody, the entire antibody, except the CDRs, is encoded by a polynucleotide of human origin or is identical to such an antibody except within its CDRs. The CDRs, some or all of which are encoded by nucleic acids originating in a non-human organism, are grafted into the beta-sheet framework of a human antibody variable region to create an antibody, the specificity of which is determined by the engrafted CDRs. The creation of such antibodies is described in, e.g., WO 92/11018, Jones, 1986, *Nature* 321:522-525, Verhoeyen et al., 1988, *Science* 239:1534-1536, all entirely incorporated by reference. "Backmutation" of selected acceptor framework residues to the corresponding donor residues is often required to regain affinity that is lost in the initial grafted construct (US 5530101; US 5585089; US 5693761; US 5693762; US 6180370; US 5859205; US 5821337; US 6054297; US 6407213, all entirely incorporated by reference). The humanized antibody optimally also will comprise at least a portion of an immunoglobulin constant region, typically that of a human immunoglobulin, and thus will typically comprise a human Fc region. Humanized antibodies can also be generated using mice with a genetically engineered immune system. Roque et al., 2004, *Biotechnol. Prog.* 20:639-654, entirely incorporated by reference. A variety of techniques and methods for humanizing and reshaping non-human antibodies are well known in the art (See Tsurushita & Vasquez, 2004, *Humanization of Monoclonal Antibodies*, *Molecular Biology of B Cells*, 533-545, Elsevier Science (USA), and references cited therein, all entirely incorporated by reference). Humanization methods include but are not limited to methods described in Jones et al., 1986, *Nature* 321:522-525; Riechmann et al., 1988, *Nature* 332:323-329; Verhoeyen et al., 1988, *Science*, 239:1534-1536; Queen et al., 1989, *Proc Natl Acad Sci USA* 86:10029-33; He et al., 1998, *J. Immunol.* 160: 1029-1035; Carter et al., 1992, *Proc Natl Acad Sci USA* 89:4285-9; Presta et al., 1997, *Cancer Res.* 57(20):4593-9; Gorman et al., 1991, *Proc. Natl. Acad. Sci. USA* 88:4181-4185; O'Connor et al., 1998, *Protein Eng* 11:321-8, all entirely incorporated by reference. Humanization or other methods of reducing the immunogenicity of nonhuman antibody variable regions may include resurfacing methods, as described for example in Roguska et al., 1994, *Proc. Natl. Acad. Sci. USA* 91:969-973, entirely incorporated by reference. In one embodiment, the parent antibody has been affinity matured, as is known in the art. Structure-based methods may be employed for humanization and affinity maturation, for example as described in USSN 11/004,590. Selection

based methods may be employed to humanize and/or affinity mature antibody variable regions, including but not limited to methods described in Wu et al., 1999, J. Mol. Biol. 294:151-162; Baca et al., 1997, J. Biol. Chem. 272(16):10678-10684; Rosok et al., 1996, J. Biol. Chem. 271(37): 22611-22618; Rader et al., 1998, Proc. Natl. Acad. Sci. USA 95: 8910-8915; Krauss et al., 2003, Protein Engineering 16(10):753-759, all entirely incorporated by reference. Other humanization methods may involve the grafting of only parts of the CDRs, including but not limited to methods described in USSN 09/810,510; Tan et al., 2002, J. Immunol. 169:1119-1125; De Pascalis et al., 2002, J. Immunol. 169:3076-3084, all entirely incorporated by reference.

**[88]** *Bispecific Antibodies*

**[89]** In one embodiment, the antibodies of the invention multispecific antibody, and notably a bispecific antibody, also sometimes referred to as “diabodies”. These are antibodies that bind to two (or more) different antigens. Diabodies can be manufactured in a variety of ways known in the art (Holliger and Winter, 1993, Current Opinion Biotechnol. 4:446-449, entirely incorporated by reference), e.g., prepared chemically or from hybrid hybridomas.

**[90]** *Minibodies*

**[91]** In one embodiment, the antibody is a minibody. Minibodies are minimized antibody-like proteins comprising a scFv joined to a CH3 domain. Hu et al., 1996, Cancer Res. 56:3055-3061, entirely incorporated by reference. In some cases, the scFv can be joined to the Fc region, and may include some or the entire hinge region.

**[92]** *Antibody Fusions*

**[93]** In one embodiment, the antibodies of the invention are antibody fusion proteins (sometimes referred to herein as an “antibody conjugate”). One type of antibody fusions comprises Fc fusions, which join the Fc region with a conjugate partner. By “Fc fusion” as used herein is meant a protein wherein one or more polypeptides is operably linked to an Fc region. Fc fusion is herein meant to be synonymous with the terms “immunoadhesin”, “Ig fusion”, “Ig chimera”, and “receptor globulin” (sometimes with dashes) as used in the prior art (Chamow et al., 1996, Trends Biotechnol 14:52-60; Ashkenazi et al., 1997, Curr Opin Immunol 9:195-200, both entirely incorporated by reference). An Fc fusion combines the Fc region of an immunoglobulin with a fusion partner, which in general can be any protein or small molecule. Virtually any protein or small molecule may be linked to Fc to generate an Fc fusion. Protein fusion partners may include, but are not limited to, the variable region of any antibody, the target-binding region of a receptor, an adhesion molecule, a ligand, an enzyme, a cytokine, a chemokine, or some other protein or protein domain. Small molecule fusion partners may include any therapeutic agent that directs the Fc fusion to a therapeutic target. Such targets may be any molecule, preferably an extracellular receptor, which is implicated in disease. Thus, the IgG variants can be linked to one or more fusion partners. In one alternate embodiment, the IgG variant is conjugated or operably linked to another therapeutic compound. The therapeutic compound may be a cytotoxic agent, a chemotherapeutic



agent, a toxin, a radioisotope, a cytokine, or other therapeutically active agent. The IgG may be linked to one of a variety of nonproteinaceous polymers, e.g., polyethylene glycol, polypropylene glycol, polyoxyalkylenes, or copolymers of polyethylene glycol and polypropylene glycol.

**[94]** In addition to Fc fusions, antibody fusions include the fusion of the constant region of the heavy chain with one or more fusion partners (again including the variable region of any antibody), while other antibody fusions are substantially or completely full length antibodies with fusion partners. In one embodiment, a role of the fusion partner is to mediate target binding, and thus it is functionally analogous to the variable regions of an antibody (and in fact can be). Virtually any protein or small molecule may be linked to Fc to generate an Fc fusion (or antibody fusion). Protein fusion partners may include, but are not limited to, the target-binding region of a receptor, an adhesion molecule, a ligand, an enzyme, a cytokine, a chemokine, or some other protein or protein domain. Small molecule fusion partners may include any therapeutic agent that directs the Fc fusion to a therapeutic target. Such targets may be any molecule, preferably an extracellular receptor, which is implicated in disease.

**[95]** The conjugate partner can be proteinaceous or non-proteinaceous; the latter generally being generated using functional groups on the antibody and on the conjugate partner. For example linkers are known in the art; for example, homo-or hetero-bifunctional linkers as are well known (see, 1994 Pierce Chemical Company catalog, technical section on cross-linkers, pages 155-200, incorporated herein by reference).

**[96]** Suitable conjugates include, but are not limited to, labels as described below, drugs and cytotoxic agents including, but not limited to, cytotoxic drugs (e.g., chemotherapeutic agents) or toxins or active fragments of such toxins. Suitable toxins and their corresponding fragments include diphtheria A chain, exotoxin A chain, ricin A chain, abrin A chain, curcin, crotin, phenomycin, enomycin and the like. Cytotoxic agents also include radiochemicals made by conjugating radioisotopes to antibodies, or binding of a radionuclide to a chelating agent that has been covalently attached to the antibody. Additional embodiments utilize calicheamicin, auristatins, geldanamycin, maytansine, and duocarmycins and analogs; for the latter, see U.S. 2003/0050331A1, entirely incorporated by reference.

**[97]** *Covalent modifications of Antibodies*

**[98]** Covalent modifications of antibodies are included within the scope of this invention, and are generally, but not always, done post-translationally. For example, several types of covalent modifications of the antibody are introduced into the molecule by reacting specific amino acid residues of the antibody with an organic derivatizing agent that is capable of reacting with selected side chains or the N- or C-terminal residues.

**[99]** Cysteinyl residues most commonly are reacted with  $\alpha$ -haloacetates (and corresponding amines), such as chloroacetic acid or chloroacetamide, to give carboxymethyl or carboxyamidomethyl derivatives. Cysteinyl residues may also be derivatized by reaction with

bromotrifluoroacetone,  $\alpha$ -bromo- $\beta$ -(5-imidazolyl)propionic acid, chloroacetyl phosphate, N-alkylmaleimides, 3-nitro-2-pyridyl disulfide, methyl 2-pyridyl disulfide, p-chloromercuribenzoate, 2-chloromercuri-4-nitrophenol, or chloro-7-nitrobenzo-2-oxa-1,3-diazole and the like.

**[100]** Histidyl residues are derivatized by reaction with diethylpyrocarbonate at pH 5.5-7.0 because this agent is relatively specific for the histidyl side chain. Para-bromophenacyl bromide also is useful; the reaction is preferably performed in 0.1M sodium cacodylate at pH 6.0.

**[101]** Lysinyl and amino terminal residues are reacted with succinic or other carboxylic acid anhydrides. Derivatization with these agents has the effect of reversing the charge of the lysinyl residues. Other suitable reagents for derivatizing alpha-amino-containing residues include imidoesters such as methyl picolinimate; pyridoxal phosphate; pyridoxal; chloroborohydride; trinitrobenzenesulfonic acid; O-methylisourea; 2,4-pentanedione; and transaminase-catalyzed reaction with glyoxylate.

**[102]** Arginyl residues are modified by reaction with one or several conventional reagents, among them phenylglyoxal, 2,3-butanedione, 1,2-cyclohexanedione, and ninhydrin. Derivatization of arginine residues requires that the reaction be performed in alkaline conditions because of the high pKa of the guanidine functional group. Furthermore, these reagents may react with the groups of lysine as well as the arginine epsilon-amino group.

**[103]** The specific modification of tyrosyl residues may be made, with particular interest in introducing spectral labels into tyrosyl residues by reaction with aromatic diazonium compounds or tetranitromethane. Most commonly, N-acetylimidazole and tetranitromethane are used to form O-acetyl tyrosyl species and 3-nitro derivatives, respectively. Tyrosyl residues are iodinated using  $^{125}\text{I}$  or  $^{131}\text{I}$  to prepare labeled proteins for use in radioimmunoassay, the chloramine T method described above being suitable.

**[104]** Carboxyl side groups (aspartyl or glutamyl) are selectively modified by reaction with carbodiimides ( $\text{R}'\text{—N}=\text{C}=\text{N—R}'$ ), where R and R' are optionally different alkyl groups, such as 1-cyclohexyl-3-(2-morpholinyl-4-ethyl) carbodiimide or 1-ethyl-3-(4-azonia-4,4-dimethylpentyl) carbodiimide. Furthermore, aspartyl and glutamyl residues are converted to asparaginy and glutaminy residues by reaction with ammonium ions.

**[105]** Derivatization with bifunctional agents is useful for crosslinking antibodies to a water-insoluble support matrix or surface for use in a variety of methods, in addition to methods described below. Commonly used crosslinking agents include, e.g., 1,1-bis(diazoacetyl)-2-phenylethane, glutaraldehyde, N-hydroxysuccinimide esters, for example, esters with 4-azidosalicylic acid, homobifunctional imidoesters, including disuccinimidyl esters such as 3,3'-dithiobis (succinimidylpropionate), and bifunctional maleimides such as bis-N-maleimido-1,8-octane. Derivatizing agents such as methyl-3-[(p-azidophenyl)dithio]propioimide yield photoactivatable intermediates that are capable of forming crosslinks in the presence of light. Alternatively, reactive water-insoluble matrices such as cyanogen bromide-activated

carbohydrates and the reactive substrates described in U.S. Pat. Nos. 3,969,287; 3,691,016; 4,195,128; 4,247,642; 4,229,537; and 4,330,440, all entirely incorporated by reference, are employed for protein immobilization.

**[106]** Glutaminyl and asparaginyl residues are frequently deamidated to the corresponding glutamyl and aspartyl residues, respectively. Alternatively, these residues are deamidated under mildly acidic conditions. Either form of these residues falls within the scope of this invention. Other modifications include hydroxylation of proline and lysine, phosphorylation of hydroxyl groups of seryl or threonyl residues, methylation of the  $\alpha$ -amino groups of lysine, arginine, and histidine side chains (T. E. Creighton, *Proteins: Structure and Molecular Properties*, W. H. Freeman & Co., San Francisco, pp. 79-86 [1983], entirely incorporated by reference), acetylation of the N-terminal amine, and amidation of any C-terminal carboxyl group.

**[107]** *Glycosylation*

**[108]** Another type of covalent modification is glycosylation. In another embodiment, the IgG variants disclosed herein can be modified to include one or more engineered glycoforms. By “engineered glycoform” as used herein is meant a carbohydrate composition that is covalently attached to an IgG, wherein said carbohydrate composition differs chemically from that of a parent IgG. Engineered glycoforms may be useful for a variety of purposes, including but not limited to enhancing or reducing effector function. Engineered glycoforms may be generated by a variety of methods known in the art (Umaña et al., 1999, *Nat Biotechnol* 17:176-180; Davies et al., 2001, *Biotechnol Bioeng* 74:288-294; Shields et al., 2002, *J Biol Chem* 277:26733-26740; Shinkawa et al., 2003, *J Biol Chem* 278:3466-3473; US 6,602,684; USSN 10/277,370; USSN 10/113,929; PCT WO 00/61739A1; PCT WO 01/29246A1; PCT WO 02/31140A1; PCT WO 02/30954A1, all entirely incorporated by reference; (Potelligent® technology [Biowa, Inc., Princeton, NJ]; GlycoMAb® glycosylation engineering technology [Glycart Biotechnology AG, Zürich, Switzerland]). Many of these techniques are based on controlling the level of fucosylated and/or bisecting oligosaccharides that are covalently attached to the Fc region, for example by expressing an IgG in various organisms or cell lines, engineered or otherwise (for example Lec-13 CHO cells or rat hybridoma YB2/0 cells), by regulating enzymes involved in the glycosylation pathway (for example FUT8 [ $\alpha$ 1,6-fucosyltransferase] and/or  $\beta$ 1-4- N-acetylglucosaminyltransferase III [GnTIII]), or by modifying carbohydrate(s) after the IgG has been expressed. Engineered glycoform typically refers to the different carbohydrate or oligosaccharide; thus an IgG variant, for example an antibody or Fc fusion, can include an engineered glycoform. Alternatively, engineered glycoform may refer to the IgG variant that comprises the different carbohydrate or oligosaccharide. As is known in the art, glycosylation patterns can depend on both the sequence of the protein (e.g., the presence or absence of particular glycosylation amino acid residues, discussed below), or the host cell or organism in which the protein is produced. Particular expression systems are discussed below.

**[109]** Glycosylation of polypeptides is typically either N-linked or O-linked. N-linked refers to the attachment of the carbohydrate moiety to the side chain of an asparagine residue. The tri-peptide sequences asparagine-X-serine and asparagine-X-threonine, where X is any amino acid except proline, are the recognition sequences for enzymatic attachment of the carbohydrate moiety to the asparagine side chain. Thus, the presence of either of these tri-peptide sequences in a polypeptide creates a potential glycosylation site. O-linked glycosylation refers to the attachment of one of the sugars N-acetylgalactosamine, galactose, or xylose, to a hydroxyamino acid, most commonly serine or threonine, although 5-hydroxyproline or 5-hydroxylysine may also be used.

**[110]** Addition of glycosylation sites to the antibody is conveniently accomplished by altering the amino acid sequence such that it contains one or more of the above-described tri-peptide sequences (for N-linked glycosylation sites). The alteration may also be made by the addition of, or substitution by, one or more serine or threonine residues to the starting sequence (for O-linked glycosylation sites). For ease, the antibody amino acid sequence is preferably altered through changes at the DNA level, particularly by mutating the DNA encoding the target polypeptide at preselected bases such that codons are generated that will translate into the desired amino acids.

**[111]** Another means of increasing the number of carbohydrate moieties on the antibody is by chemical or enzymatic coupling of glycosides to the protein. These procedures are advantageous in that they do not require production of the protein in a host cell that has glycosylation capabilities for N- and O-linked glycosylation. Depending on the coupling mode used, the sugar(s) may be attached to (a) arginine and histidine, (b) free carboxyl groups, (c) free sulfhydryl groups such as those of cysteine, (d) free hydroxyl groups such as those of serine, threonine, or hydroxyproline, (e) aromatic residues such as those of phenylalanine, tyrosine, or tryptophan, or (f) the amide group of glutamine. These methods are described in WO 87/05330 and in Aplin and Wriston, 1981, CRC Crit. Rev. Biochem., pp. 259-306, both entirely incorporated by reference.

**[112]** Removal of carbohydrate moieties present on the starting antibody may be accomplished chemically or enzymatically. Chemical deglycosylation requires exposure of the protein to the compound trifluoromethanesulfonic acid, or an equivalent compound. This treatment results in the cleavage of most or all sugars except the linking sugar (N-acetylglucosamine or N-acetylgalactosamine), while leaving the polypeptide intact. Chemical deglycosylation is described by Hakimuddin et al., 1987, Arch. Biochem. Biophys. 259:52 and by Edge et al., 1981, Anal. Biochem. 118:131, both entirely incorporated by reference. Enzymatic cleavage of carbohydrate moieties on polypeptides can be achieved by the use of a variety of endo- and exo-glycosidases as described by Thotakura et al., 1987, Meth. Enzymol. 138:350, entirely incorporated by reference. Glycosylation at potential glycosylation sites may be prevented by the use of the compound tunicamycin as described by Duskin et al., 1982, J. Biol. Chem. 257:3105, entirely incorporated by reference. Tunicamycin blocks the formation of protein-N-glycoside linkages.

**[113]** Another type of covalent modification of the antibody comprises linking the antibody to various nonproteinaceous polymers, including, but not limited to, various polyols such as polyethylene glycol, polypropylene glycol or polyoxyalkylenes, in the manner set forth in, for example, 2005-2006 PEG Catalog from Nektar Therapeutics (available at the Nektar website) US Patents 4,640,835; 4,496,689; 4,301,144; 4,670,417; 4,791,192 or 4,179,337, all entirely incorporated by reference. In addition, as is known in the art, amino acid substitutions may be made in various positions within the antibody to facilitate the addition of polymers such as PEG. See for example, U.S. Publication No. 2005/0114037A1, entirely incorporated by reference.

**[114]** *Labeled Antibodies*

**[115]** In some embodiments, the covalent modification of the antibodies of the invention comprises the addition of one or more labels. In some cases, these are considered antibody fusions. The term "labelling group" means any detectable label. In some embodiments, the labelling group is coupled to the antibody via spacer arms of various lengths to reduce potential steric hindrance. Various methods for labelling proteins are known in the art and may be used in performing the present invention.

**[116]** In general, labels fall into a variety of classes, depending on the assay in which they are to be detected: a) isotopic labels, which may be radioactive or heavy isotopes; b) magnetic labels (e.g., magnetic particles); c) redox active moieties; d) optical dyes; enzymatic groups (e.g. horseradish peroxidase,  $\beta$ -galactosidase, luciferase, alkaline phosphatase); e) biotinylated groups; and f) predetermined polypeptide epitopes recognized by a secondary reporter (e.g., leucine zipper pair sequences, binding sites for secondary antibodies, metal binding domains, epitope tags, etc.). In some embodiments, the labelling group is coupled to the antibody via spacer arms of various lengths to reduce potential steric hindrance. Various methods for labelling proteins are known in the art and may be used in performing the present invention.

**[117]** Specific labels include optical dyes, including, but not limited to, chromophores, phosphors and fluorophores, with the latter being specific in many instances. Fluorophores can be either "small molecule" fluors, or proteinaceous fluors.

**[118]** By "fluorescent label" is meant any molecule that may be detected via its inherent fluorescent properties. Suitable fluorescent labels include, but are not limited to, fluorescein, rhodamine, tetramethylrhodamine, eosin, erythrosin, coumarin, methyl-coumarins, pyrene, Malacite green, stilbene, Lucifer Yellow, Cascade BlueJ, Texas Red, IAEDANS, EDANS, BODIPY FL, LC Red 640, Cy 5, Cy 5.5, LC Red 705, Oregon green, the Alexa-Fluor dyes (Alexa Fluor 350, Alexa Fluor 430, Alexa Fluor 488, Alexa Fluor 546, Alexa Fluor 568, Alexa Fluor 594, Alexa Fluor 633, Alexa Fluor 660, Alexa Fluor 680), Cascade Blue, Cascade Yellow and R-phycoerythrin (PE) (Molecular Probes, Eugene, OR), FITC, Rhodamine, and Texas Red (Pierce, Rockford, IL), Cy5, Cy5.5, Cy7 (Amersham Life Science, Pittsburgh, PA). Suitable optical dyes, including

fluorophores, are described in Molecular Probes Handbook by Richard P. Haugland, entirely incorporated by reference.

**[119]** Suitable proteinaceous fluorescent labels also include, but are not limited to, green fluorescent protein, including a Renilla, Ptilosarcus, or Aequorea species of GFP (Chalfie et al., 1994, Science 263:802-805), EGFP (Clontech Laboratories, Inc., Genbank Accession Number U55762), blue fluorescent protein (BFP, Quantum Biotechnologies, Inc. 1801 de Maisonneuve Blvd. West, 8th Floor, Montreal, Quebec, Canada H3H 1J9; Stauber, 1998, Biotechniques 24:462-471; Heim et al., 1996, Curr. Biol. 6:178-182), enhanced yellow fluorescent protein (EYFP, Clontech Laboratories, Inc.), luciferase (Ichiki et al., 1993, J. Immunol. 150:5408-5417),  $\beta$  galactosidase (Nolan et al., 1988, Proc. Natl. Acad. Sci. U.S.A. 85:2603-2607) and Renilla (WO92/15673, WO95/07463, WO98/14605, WO98/26277, WO99/49019, U.S. Patent Nos. 5292658, 5418155, 5683888, 5741668, 5777079, 5804387, 5874304, 5876995, 5925558). All of the above-cited references in this paragraph are expressly incorporated herein by reference.

**[120]** *IgG Variants*

**[121]** In one embodiment, the invention provides variant IgG proteins. At a minimum, IgG variants comprise an antibody fragment comprising the CH2-CH3 region of the heavy chain. In addition, suitable IgG variants comprise Fc domains (e.g. including the lower hinge region), as well as IgG variants comprising the constant region of the heavy chain (CH1-hinge-CH2-CH3) also being useful in the present invention, all of which can be fused to fusion partners.

**[122]** An IgG variant includes one or more amino acid modifications relative to a parent IgG polypeptide, in some cases relative to the wild type IgG. The IgG variant can have one or more optimized properties. An IgG variant differs in amino acid sequence from its parent IgG by virtue of at least one amino acid modification. Thus IgG variants have at least one amino acid modification compared to the parent. Alternatively, the IgG variants may have more than one amino acid modification as compared to the parent, for example from about one to fifty amino acid modifications, preferably from about one to ten amino acid modifications, and most preferably from about one to about five amino acid modifications compared to the parent.

**[123]** Thus the sequences of the IgG variants and those of the parent Fc polypeptide are substantially homologous. For example, the variant IgG variant sequences herein will possess about 80% homology with the parent IgG variant sequence, preferably at least about 90% homology, and most preferably at least about 95% homology. Modifications may be made genetically using molecular biology, or may be made enzymatically or chemically.

**[124]** *Target Antigens for Antibodies*

**[125]** Virtually any antigen may be targeted by the IgG variants, including but not limited to proteins, subunits, domains, motifs, and/or epitopes belonging to the following list of target antigens, which includes both soluble factors such as cytokines and membrane-bound factors, including transmembrane receptors: 17-IA, 4-1BB, 4Dc, 6-keto-PGF1a, 8-iso-PGF2a, 8-oxo-dG,

A1 Adenosine Receptor, A33, ACE, ACE-2, Activin, Activin A, Activin AB, Activin B, Activin C, Activin RIA, Activin RIA ALK-2, Activin RIB ALK-4, Activin RIIA, Activin RIIB, ADAM, ADAM10, ADAM12, ADAM15, ADAM17/TACE, ADAM8, ADAM9, ADAMTS, ADAMTS4, ADAMTS5, Addressins, aFGF, ALCAM, ALK, ALK-1, ALK-7, alpha-1-antitrypsin, alpha-V/beta-1 antagonist, ANG, Ang, APAF-1, APE, APJ, APP, APRIL, AR, ARC, ART, Artemin, anti-Id, ASPARTIC, Atrial natriuretic factor, av/b3 integrin, Axl, b2M, B7-1, B7-2, B7-H, B-lymphocyte Stimulator (BlyS), BACE, BACE-1, Bad, BAFF, BAFF-R, Bag-1, BAK, Bax, BCA-1, BCAM, Bcl, BCMA, BDNF, b-ECGF, bFGF, BID, Bik, BIM, BLC, BL-CAM, BLK, BMP, BMP-2 BMP-2a, BMP-3 Osteogenin, BMP-4 BMP-2b, BMP-5, BMP-6 Vgr-1, BMP-7 (OP-1), BMP-8 (BMP-8a, OP-2), BMPR, BMPR-IA (ALK-3), BMPR-IB (ALK-6), BRK-2, RPK-1, BMPR-II (BRK-3), BMPs, b-NGF, BOK, Bombesin, Bone-derived neurotrophic factor, BPDE, BPDE-DNA, BTC, complement factor 3 (C3), C3a, C4, C5, C5a, C10, CA125, CAD-8, Calcitonin, cAMP, carcinoembryonic antigen (CEA), carcinoma-associated antigen, Cathepsin A, Cathepsin B, Cathepsin C/DPPI, Cathepsin D, Cathepsin E, Cathepsin H, Cathepsin L, Cathepsin O, Cathepsin S, Cathepsin V, Cathepsin X/Z/P, CBL, CCL, CCK2, CCL, CCL1, CCL11, CCL12, CCL13, CCL14, CCL15, CCL16, CCL17, CCL18, CCL19, CCL2, CCL20, CCL21, CCL22, CCL23, CCL24, CCL25, CCL26, CCL27, CCL28, CCL3, CCL4, CCL5, CCL6, CCL7, CCL8, CCL9/10, CCR, CCR1, CCR10, CCR10, CCR2, CCR3, CCR4, CCR5, CCR6, CCR7, CCR8, CCR9, CD1, CD2, CD3, CD3E, CD4, CD5, CD6, CD7, CD8, CD10, CD11a, CD11b, CD11c, CD13, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD27L, CD28, CD29, CD30, CD30L, CD32, CD33 (p67 proteins), CD34, CD38, CD40, CD40L, CD44, CD45, CD46, CD49a, CD52, CD54, CD55, CD56, CD61, CD64, CD66e, CD74, CD80 (B7-1), CD89, CD95, CD123, CD137, CD138, CD140a, CD146, CD147, CD148, CD152, CD164, CEACAM5, CFTR, cGMP, CINC, *Clostridium botulinum* toxin, *Clostridium perfringens* toxin, Ckb8-1, CLC, CMV, CMV UL, CNTF, CNTN-1, COX, C-Ret, CRG-2, CT-1, CTACK, CTGF, CTLA-4, CX3CL1, CX3CR1, CXCL, CXCL1, CXCL2, CXCL3, CXCL4, CXCL5, CXCL6, CXCL7, CXCL8, CXCL9, CXCL10, CXCL11, CXCL12, CXCL13, CXCL14, CXCL15, CXCL16, CXCR, CXCR1, CXCR2, CXCR3, CXCR4, CXCR5, CXCR6, cytokeratin tumor-associated antigen, DAN, DCC, DcR3, DC-SIGN, Decay accelerating factor, des(1-3)-IGF-I (brain IGF-1), Dhh, digoxin, DNAM-1, Dnase, Dpp, DPPIV/CD26, Dtk, ECAD, EDA, EDA-A1, EDA-A2, EDAR, EGF, EGFR (ErbB-1), EMA, EMMPRIN, ENA, endothelin receptor, Enkephalinase, eNOS, Eot, eotaxin1, EpCAM, Ephrin B2/ EphB4, EPO, ERCC, E-selectin, ET-1, Factor IIa, Factor VII, Factor VIIIc, Factor IX, fibroblast activation protein (FAP), Fas, FcR1, FEN-1, Ferritin, FGF, FGF-19, FGF-2, FGF3, FGF-8, FGFR, FGFR-3, Fibrin, FL, FLIP, Flt-3, Flt-4, Follicle stimulating hormone, Fractalkine, FZD1, FZD2, FZD3, FZD4, FZD5, FZD6, FZD7, FZD8, FZD9, FZD10, G250, Gas 6, GCP-2, GCSF, GD2, GD3, GDF, GDF-1, GDF-3 (Vgr-2), GDF-5 (BMP-14, CDMP-1), GDF-6 (BMP-13, CDMP-2), GDF-7 (BMP-12, CDMP-3), GDF-8 (Myostatin), GDF-9, GDF-15 (MIC-1), GDNF, GDNF, GFAP, GFRa-1, GFR-alpha1, GFR-alpha2, GFR-alpha3, GTR, Glucagon, Glut 4, glycoprotein IIb/IIIa (GP IIb/IIIa),

GM-CSF, gp130, gp72, GRO, Growth hormone releasing factor, Hapten (NP-cap or NIP-cap), HB-EGF, HCC, HCMV gB envelope glycoprotein, HCMV gH envelope glycoprotein, HCMV UL, Hemopoietic growth factor (HGF), Hep B gp120, heparanase, Her2, Her2/neu (ErbB-2), Her3 (ErbB-3), Her4 (ErbB-4), herpes simplex virus (HSV) gB glycoprotein, HSV gD glycoprotein, HGFA, High molecular weight melanoma-associated antigen (HMW-MAA), HIV gp120, HIV IIIB gp 120 V3 loop, HLA, HLA-DR, HM1.24, HMFG PEM, HRG, Hrk, human cardiac myosin, human cytomegalovirus (HCMV), human growth hormone (HGH), HVEM, I-309, IAP, ICAM, ICAM-1, ICAM-3, ICE, ICOS, IFNg, Ig, IgA receptor, IgE, IGF, IGF binding proteins, IGF-1R, IGFBP, IGF-I, IGF-II, IL, IL-1, IL-1R, IL-2, IL-2R, IL-4, IL-4R, IL-5, IL-5R, IL-6, IL-6R, IL-8, IL-9, IL-10, IL-12, IL-13, IL-15, IL-18, IL-18R, IL-23, interferon (INF)-alpha, INF-beta, INF-gamma, Inhibin, iNOS, Insulin A-chain, Insulin B-chain, Insulin-like growth factor 1, integrin alpha2, integrin alpha3, integrin alpha4, integrin alpha4/beta1, integrin alpha4/beta7, integrin alpha5 (alphaV), integrin alpha5/beta1, integrin alpha5/beta3, integrin alpha6, integrin beta1, integrin beta2, interferon gamma, IP-10, I-TAC, JE, Kallikrein 2, Kallikrein 5, Kallikrein 6, , Kallikrein 11, Kallikrein 12, Kallikrein 14, Kallikrein 15, Kallikrein L1, Kallikrein L2, Kallikrein L3, Kallikrein L4, KC, KDR, Keratinocyte Growth Factor (KGF), laminin 5, LAMP, LAP, LAP (TGF- 1), Latent TGF-1, Latent TGF-1 bp1, LBP, LDGF, LECT2, Lefty, Lewis-Y antigen, Lewis-Y related antigen, LFA-1, LFA-3, Lfo, LIF, LIGHT, lipoproteins, LIX, LKN, Lptn, L-Selectin, LT-a, LT-b, LTB4, LTBP-1, Lung surfactant, Luteinizing hormone, Lymphotoxin Beta Receptor, Mac-1, MAdCAM, MAG, MAP2, MARC, MCAM, MCAM, MCK-2, MCP, M-CSF, MDC, Mer, METALLOPROTEASES, MGDF receptor, MGMT, MHC (HLA-DR), MIF, MIG, MIP, MIP-1-alpha, MK, MMAC1, MMP, MMP-1, MMP-10, MMP-11, MMP-12, MMP-13, MMP-14, MMP-15, MMP-2, MMP-24, MMP-3, MMP-7, MMP-8, MMP-9, MPIF, Mpo, MSK, MSP, mucin (Muc1), MUC18, Muellerian-inhibitin substance, Mug, MuSK, NAIP, NAP, NCAD, N-Cadherin, NCA 90, NCAM, NCAM, Neprilysin, Neurotrophin-3,-4, or -6, Neurturin, Neuronal growth factor (NGF), NGFR, NGF-beta, nNOS, NO, NOS, Npn, NRG-3, NT, NTN, OB, OGG1, OPG, OPN, OSM, OX40L, OX40R, p150, p95, PADPr, Parathyroid hormone, PARC, PARP, PBR, PBSF, PCAD, P-Cadherin, PCNA, PDGF, PDGF, PDK-1, PECAM, PEM, PF4, PGE, PGF, PGI2, PGJ2, PIN, PLA2, placental alkaline phosphatase (PLAP), PIGF, PLP, PP14, Proinsulin, Prorelaxin, Protein C, PS, PSA, PSCA, prostate specific membrane antigen (PSMA), PTEN, PTHrp, Ptk, PTN, R51, RANK, RANKL, RANTES, RANTES, Relaxin A-chain, Relaxin B-chain, renin, respiratory syncytial virus (RSV) F, RSV Fgp, Ret, Rheumatoid factors, RLIP76, RPA2, RSK, S100, SCF/KL, SDF-1, SERINE, Serum albumin, sFRP-3, Shh, SIGIRR, SK-1, SLAM, SLPI, SMAC, SMDF, SMOH, SOD, SPARC, Stat, STEAP, STEAP-II, TACE, TACI, TAG-72 (tumor-associated glycoprotein-72), TARC, TCA-3, T-cell receptors (e.g., T-cell receptor alpha/beta), TdT, TECK, TEM1, TEM5, TEM7, TEM8, TERT, testicular PLAP-like alkaline phosphatase, TfR, TGF, TGF-alpha, TGF-beta, TGF-beta Pan Specific, TGF-beta RI (ALK-5), TGF-beta RII, TGF-beta RIIB, TGF-beta RIII, TGF-beta1, TGF-beta2, TGF-beta3, TGF-



beta4, TGF-beta5, Thrombin, Thymus Ck-1, Thyroid stimulating hormone, Tie, TIMP, TIQ, Tissue Factor, TMEFF2, Tmpo, TMPRSS2, TNF, TNF-alpha, TNF-alpha beta, TNF-beta2, TNFc, TNF-RI, TNF-RII, TNFRSF10A (TRAIL R1 Apo-2, DR4), TNFRSF10B (TRAIL R2 DR5, KILLER, TRICK-2A, TRICK-B), TNFRSF10C (TRAIL R3 DcR1, LIT, TRID), TNFRSF10D (TRAIL R4 DcR2, TRUNDD), TNFRSF11A (RANK ODF R, TRANCE R), TNFRSF11B (OPG OCIF, TR1), TNFRSF12 (TWEAK R FN14), TNFRSF13B (TACI), TNFRSF13C (BAFF R), TNFRSF14 (HVEM ATAR, HveA, LIGHT R, TR2), TNFRSF16 (NGFR p75NTR), TNFRSF17 (BCMA), TNFRSF18 (GITR AITR), TNFRSF19 (TROY TAJ, TRADE), TNFRSF19L (RELT), TNFRSF1A (TNF RI CD120a, p55-60), TNFRSF1B (TNF RII CD120b, p75-80), TNFRSF26 (TNFRH3), TNFRSF3 (LTbR TNF RIII, TNFC R), TNFRSF4 (OX40 ACT35, TXGP1 R), TNFRSF5 (CD40 p50), TNFRSF6 (Fas Apo-1, APT1, CD95), TNFRSF6B (DcR3 M68, TR6), TNFRSF7 (CD27), TNFRSF8 (CD30), TNFRSF9 (4-1BB CD137, ILA), TNFRSF21 (DR6), TNFRSF22 (DcTRAIL R2 TNFRH2), TNFRST23 (DcTRAIL R1 TNFRH1), TNFRSF25 (DR3 Apo-3, LARD, TR-3, TRAMP, WSL-1), TNFSF10 (TRAIL Apo-2 Ligand, TL2), TNFSF11 (TRANCE/RANK Ligand ODF, OPG Ligand), TNFSF12 (TWEAK Apo-3 Ligand, DR3 Ligand), TNFSF13 (APRIL TALL2), TNFSF13B (BAFF BLYS, TALL1, THANK, TNFSF20), TNFSF14 (LIGHT HVEM Ligand, LTg), TNFSF15 (TL1A/VEGI), TNFSF18 (GITR Ligand AITR Ligand, TL6), TNFSF1A (TNF-a Conectin, DIF, TNFSF2), TNFSF1B (TNF-b LTa, TNFSF1), TNFSF3 (LTb TNFC, p33), TNFSF4 (OX40 Ligand gp34, TXGP1), TNFSF5 (CD40 Ligand CD154, gp39, HIGM1, IMD3, TRAP), TNFSF6 (Fas Ligand Apo-1 Ligand, APT1 Ligand), TNFSF7 (CD27 Ligand CD70), TNFSF8 (CD30 Ligand CD153), TNFSF9 (4-1BB Ligand CD137 Ligand), TP-1, t-PA, Tpo, TRAIL, TRAIL R, TRAIL-R1, TRAIL-R2, TRANCE, transferring receptor, TRF, Trk, TROP-2, TSG, TSLP, tumor-associated antigen CA 125, tumor-associated antigen expressing Lewis Y related carbohydrate, TWEAK, TXB2, Ung, uPAR, uPAR-1, Urokinase, VCAM, VCAM-1, VECAD, VE-Cadherin, VE-cadherin-2, VEGFR-1 (flt-1), VEGF, VEGFR, VEGFR-3 (flt-4), VEGI, VIM, Viral antigens, VLA, VLA-1, VLA-4, VNR integrin, von Willebrands factor, WIF-1, WNT1, WNT2, WNT2B/13, WNT3, WNT3A, WNT4, WNT5A, WNT5B, WNT6, WNT7A, WNT7B, WNT8A, WNT8B, WNT9A, WNT9A, WNT9B, WNT10A, WNT10B, WNT11, WNT16, XCL1, XCL2, XCR1, XCR1, XEDAR, XIAP, XPD, and receptors for hormones and growth factors.

**[126]** One skilled in the art will appreciate that the aforementioned list of targets refers not only to specific proteins and biomolecules, but the biochemical pathway or pathways that comprise them. For example, reference to CTLA-4 as a target antigen implies that the ligands and receptors that make up the T cell co-stimulatory pathway, including CTLA-4, B7-1, B7-2, CD28, and any other undiscovered ligands or receptors that bind these proteins, are also targets. Thus target as used herein refers not only to a specific biomolecule, but the set of proteins that interact with said target and the members of the biochemical pathway to which said target belongs. One skilled in the art will further appreciate that any of the aforementioned target antigens, the ligands or receptors that bind them, or other members of their corresponding biochemical pathway, may be operably linked

to the Fc variants of the present invention in order to generate an Fc fusion. Thus for example, an Fc fusion that targets EGFR could be constructed by operably linking an Fc variant to EGF, TGF- $\beta$ , or any other ligand, discovered or undiscovered, that binds EGFR. Accordingly, an Fc variant of the present invention could be operably linked to EGFR in order to generate an Fc fusion that binds EGF, TGF- $\beta$ , or any other ligand, discovered or undiscovered, that binds EGFR. Thus virtually any polypeptide, whether a ligand, receptor, or some other protein or protein domain, including but not limited to the aforementioned targets and the proteins that compose their corresponding biochemical pathways, may be operably linked to the Fc variants of the present invention to develop an Fc fusion.

**[127]** The choice of suitable antigen depends on the desired application. For anti-cancer treatment it is desirable to have a target whose expression is restricted to the cancerous cells. Some targets that have proven especially amenable to antibody therapy are those with signaling functions. Other therapeutic antibodies exert their effects by blocking signaling of the receptor by inhibiting the binding between a receptor and its cognate ligand. Another mechanism of action of therapeutic antibodies is to cause receptor down regulation. Other antibodies do not work by signaling through their target antigen. In some cases, antibodies directed against infectious disease agents are used.

**[128]** In one embodiment, the Fc variants of the present invention are incorporated into an antibody against a cytokine. Alternatively, the Fc variants are fused or conjugated to a cytokine. By "cytokine" as used herein is meant a generic term for proteins released by one cell population that act on another cell as intercellular mediators. For example, as described in Penichet et al., 2001, J Immunol Methods 248:91-101, expressly incorporated by reference, cytokines may be fused to antibody to provide an array of desirable properties. Examples of such cytokines are lymphokines, monokines, and traditional polypeptide hormones. Included among the cytokines are growth hormone such as human growth hormone, N-methionyl human growth hormone, and bovine growth hormone; parathyroid hormone; thyroxine; insulin; proinsulin; relaxin; prorelaxin; glycoprotein hormones such as follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), and luteinizing hormone (LH); hepatic growth factor; fibroblast growth factor; prolactin; placental lactogen; tumor necrosis factor- $\alpha$  and - $\beta$ ; mullerian-inhibiting substance; mouse gonadotropin-associated peptide; inhibin; activin; vascular endothelial growth factor; integrin; thrombopoietin (TPO); nerve growth factors such as NGF- $\beta$ ; platelet-growth factor; transforming growth factors (TGFs) such as TGF- $\alpha$  and TGF- $\beta$ ; insulin-like growth factor-I and -II; erythropoietin (EPO); osteoinductive factors; interferons such as interferon- $\alpha$ ,  $\beta$ , and - $\gamma$ ; colony stimulating factors (CSFs) such as macrophage-CSF (M-CSF); granulocyte-macrophage-CSF (GM-CSF); and granulocyte-CSF (G-CSF); interleukins (ILs) such as IL-1, IL-1 $\alpha$ , IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12; IL-15, a tumor necrosis factor such as TNF- $\alpha$  or TNF- $\beta$ ; C5a; and other polypeptide factors including LIF and kit ligand

(KL). As used herein, the term cytokine includes proteins from natural sources or from recombinant cell culture, and biologically active equivalents of the native sequence cytokines.

**[129]** Cytokines and soluble targets, such as TNF superfamily members, are preferred targets for use with the variants of the present invention. For example, anti-VEGF, anti-CTLA-4, and anti-TNF antibodies, or fragments thereof, are particularly good antibodies for the use of Fc variants that increase the FcRn binding. Therapeutics against these targets are frequently involved in the treatment of autoimmune diseases and require multiple injections over long time periods. Therefore, longer serum half-lives and less frequent treatments, brought about from the variants of the present invention, are particularly preferred.

**[130]** A number of antibodies and Fc fusions that are approved for use, in clinical trials, or in development may benefit from the Fc variants of the present invention. These antibodies and Fc fusions are herein referred to as “clinical products and candidates”. Thus in a preferred embodiment, the Fc polypeptides of the present invention may find use in a range of clinical products and candidates. For example, a number of antibodies that target CD20 may benefit from the Fc polypeptides of the present invention. For example the Fc polypeptides of the present invention may find use in an antibody that is substantially similar to rituximab (Rituxan®, IDEC/Genentech/Roche) (see for example US 5,736,137), a chimeric anti-CD20 antibody approved to treat Non-Hodgkin’s lymphoma; HuMax-CD20, an anti-CD20 currently being developed by Genmab, an anti-CD20 antibody described in US 5,500,362, AME-133 (Applied Molecular Evolution), hA20 (Immunomedics, Inc.), HumaLYM (Intracel), and PRO70769 (PCT/US2003/040426, entitled “Immunoglobulin Variants and Uses Thereof”). A number of antibodies that target members of the family of epidermal growth factor receptors, including EGFR (ErbB-1), Her2/neu (ErbB-2), Her3 (ErbB-3), Her4 (ErbB-4), may benefit from the Fc polypeptides of the present invention. For example the Fc polypeptides of the present invention may find use in an antibody that is substantially similar to trastuzumab (Herceptin®, Genentech) (see for example US 5,677,171), a humanized anti-Her2/neu antibody approved to treat breast cancer; pertuzumab (rhuMab-2C4, Omnitarg™), currently being developed by Genentech; an anti-Her2 antibody described in US 4,753,894; cetuximab (Erbix®, Imclone) (US 4,943,533; PCT WO 96/40210), a chimeric anti-EGFR antibody in clinical trials for a variety of cancers; ABX-EGF (US 6,235,883), currently being developed by Abgenix-Immunex-Amgen; HuMax-EGFr (USSN 10/172,317), currently being developed by Genmab; 425, EMD55900, EMD62000, and EMD72000 (Merck KGaA) (US 5,558,864; Murthy et al. 1987, Arch Biochem Biophys. 252(2):549-60; Rodeck et al., 1987, J Cell Biochem. 35(4):315-20; Kettleborough et al., 1991, Protein Eng. 4(7):773-83); ICR62 (Institute of Cancer Research) (PCT WO 95/20045; Modjtahedi et al., 1993, J. Cell Biophys. 1993, 22(1-3):129-46; Modjtahedi et al., 1993, Br J Cancer. 1993, 67(2):247-53; Modjtahedi et al, 1996, Br J Cancer, 73(2):228-35; Modjtahedi et al, 2003, Int J Cancer, 105(2):273-80); TheraCIM hR3 (YM Biosciences, Canada and Centro de Immunologia Molecular, Cuba (US 5,891,996; US 6,

506,883; Mateo et al, 1997, Immunotechnology, 3(1):71-81); mAb-806 (Ludwig Institute for Cancer Research, Memorial Sloan-Kettering) (Jungbluth et al. 2003, Proc Natl Acad Sci U S A. 100(2):639-44); KSB-102 (KS Biomedix); MR1-1 (IVAX, National Cancer Institute) (PCT WO 0162931A2); and SC100 (Scancell) (PCT WO 01/88138). In another preferred embodiment, the Fc polypeptides of the present invention may find use in alemtuzumab (Campath®, Millenium), a humanized monoclonal antibody currently approved for treatment of B-cell chronic lymphocytic leukemia. The Fc polypeptides of the present invention may find use in a variety of antibodies or Fc fusions that are substantially similar to other clinical products and candidates, including but not limited to muromonab-CD3 (Orthoclone OKT3®), an anti-CD3 antibody developed by Ortho Biotech/Johnson & Johnson, ibritumomab tiuxetan (Zevalin®), an anti-CD20 antibody developed by IDEC/Schering AG, gemtuzumab ozogamicin (Mylotarg®), an anti-CD33 (p67 protein) antibody developed by Celltech/Wyeth, alefacept (Amevive®), an anti-LFA-3 Fc fusion developed by Biogen), abciximab (ReoPro®), developed by Centocor/Lilly, basiliximab (Simulect®), developed by Novartis, palivizumab (Synagis®), developed by MedImmune, infliximab (Remicade®), an anti-TNFalpha antibody developed by Centocor, adalimumab (Humira®), an anti-TNFalpha antibody developed by Abbott, Humicade™, an anti-TNFalpha antibody developed by Celltech, etanercept (Enbrel®), an anti-TNFalpha Fc fusion developed by Immunex/Amgen, ABX-CBL, an anti-CD147 antibody being developed by Abgenix, ABX-IL8, an anti-IL8 antibody being developed by Abgenix, ABX-MA1, an anti-MUC18 antibody being developed by Abgenix, Pentumomab (R1549, 90Y-muHMFG1), an anti-MUC1 In development by Antisoma, Therex (R1550), an anti-MUC1 antibody being developed by Antisoma, AngioMab (AS1405), being developed by Antisoma, HuBC-1, being developed by Antisoma, Thioplatin (AS1407) being developed by Antisoma, Antegren® (natalizumab), an anti-alpha-4-beta-1 (VLA-4) and alpha-4-beta-7 antibody being developed by Biogen, VLA-1 mAb, an anti-VLA-1 integrin antibody being developed by Biogen, LTBR mAb, an anti-lymphotoxin beta receptor (LTBR) antibody being developed by Biogen, CAT-152, an anti-TGF-β2 antibody being developed by Cambridge Antibody Technology, J695, an anti-IL-12 antibody being developed by Cambridge Antibody Technology and Abbott, CAT-192, an anti-TGFβ1 antibody being developed by Cambridge Antibody Technology and Genzyme, CAT-213, an anti-Eotaxin1 antibody being developed by Cambridge Antibody Technology, LymphoStat-B™ an anti-Blys antibody being developed by Cambridge Antibody Technology and Human Genome Sciences Inc., TRAIL-R1mAb, an anti-TRAIL-R1 antibody being developed by Cambridge Antibody Technology and Human Genome Sciences, Inc., Avastin™ (bevacizumab, rhuMab-VEGF), an anti-VEGF antibody being developed by Genentech, an anti-HER receptor family antibody being developed by Genentech, Anti-Tissue Factor (ATF), an anti-Tissue Factor antibody being developed by Genentech, Xolair™ (Omalizumab), an anti-IgE antibody being developed by Genentech, Raptiva™ (Efalizumab), an anti-CD11a antibody being developed by Genentech and Xoma, MLN-02 Antibody (formerly LDP-02), being developed by Genentech and Millenium

Pharmaceuticals, HuMax CD4, an anti-CD4 antibody being developed by Genmab, HuMax-IL15, an anti-IL15 antibody being developed by Genmab and Amgen, HuMax-Inflam, being developed by Genmab and Medarex, HuMax-Cancer, an anti-Heparanase I antibody being developed by Genmab and Medarex and Oxford GcoSciences, HuMax-Lymphoma, being developed by Genmab and Amgen, HuMax-TAC, being developed by Genmab, IDEC-131, and anti-CD40L antibody being developed by IDEC Pharmaceuticals, IDEC-151 (Clenoliximab), an anti-CD4 antibody being developed by IDEC Pharmaceuticals, IDEC-114, an anti-CD80 antibody being developed by IDEC Pharmaceuticals, IDEC-152, an anti-CD23 being developed by IDEC Pharmaceuticals, anti-macrophage migration factor (MIF) antibodies being developed by IDEC Pharmaceuticals, BEC2, an anti-idiotypic antibody being developed by Imclone, IMC-1C11, an anti-KDR antibody being developed by Imclone, DC101, an anti-flk-1 antibody being developed by Imclone, anti-VE cadherin antibodies being developed by Imclone, CEA-Cide™ (labetuzumab), an anti-carcinoembryonic antigen (CEA) antibody being developed by Immunomedics, LymphoCide™ (Epratuzumab), an anti-CD22 antibody being developed by Immunomedics, AFP-Cide, being developed by Immunomedics, MyelomaCide, being developed by Immunomedics, LkoCide, being developed by Immunomedics, ProstaCide, being developed by Immunomedics, MDX-010, an anti-CTLA4 antibody being developed by Medarex, MDX-060, an anti-CD30 antibody being developed by Medarex, MDX-070 being developed by Medarex, MDX-018 being developed by Medarex, Osidem™ (IDM-1), and anti-Her2 antibody being developed by Medarex and Immuno-Designed Molecules, HuMax™-CD4, an anti-CD4 antibody being developed by Medarex and Genmab, HuMax-IL15, an anti-IL15 antibody being developed by Medarex and Genmab, CNTO 148, an anti-TNF $\alpha$  antibody being developed by Medarex and Centocor/J&J, CNTO 1275, an anti-cytokine antibody being developed by Centocor/J&J, MOR101 and MOR102, anti-intercellular adhesion molecule-1 (ICAM-1) (CD54) antibodies being developed by MorphoSys, MOR201, an anti-fibroblast growth factor receptor 3 (FGFR-3) antibody being developed by MorphoSys, Nuvion® (visilizumab), an anti-CD3 antibody being developed by Protein Design Labs, HuZAF™, an anti-gamma interferon antibody being developed by Protein Design Labs, Anti- $\alpha 5\beta 1$  Integrin, being developed by Protein Design Labs, anti-IL-12, being developed by Protein Design Labs, ING-1, an anti-Ep-CAM antibody being developed by Xoma, and MLN01, an anti-Beta2 integrin antibody being developed by Xoma, all of the above-cited references in this paragraph are expressly incorporated herein by reference.

**[131]** The Fc polypeptides of the present invention may be incorporated into the aforementioned clinical candidates and products, or into antibodies and Fc fusions that are substantially similar to them. The Fc polypeptides of the present invention may be incorporated into versions of the aforementioned clinical candidates and products that are humanized, affinity matured, engineered, or modified in some other way.

**[132]** In one embodiment, the Fc polypeptides of the present invention are used for the treatment of autoimmune, inflammatory, or transplant indications. Target antigens and clinical products and candidates that are relevant for such diseases include but are not limited to anti- $\alpha 4\beta 7$  integrin antibodies such as LDP-02, anti-beta2 integrin antibodies such as LDP-01, anti-complement (C5) antibodies such as 5G1.1, anti-CD2 antibodies such as BTI-322, MEDI-507, anti-CD3 antibodies such as OKT3, SMART anti-CD3, anti-CD4 antibodies such as IDEC-151, MDX-CD4, OKT4A, anti-CD11a antibodies, anti-CD14 antibodies such as IC14, anti-CD18 antibodies, anti-CD23 antibodies such as IDEC 152, anti-CD25 antibodies such as Zenapax, anti-CD40L antibodies such as 5c8, Antova, IDEC-131, anti-CD64 antibodies such as MDX-33, anti-CD80 antibodies such as IDEC-114, anti-CD147 antibodies such as ABX-CBL, anti-E-selectin antibodies such as CDP850, anti-gpIIb/IIIa antibodies such as ReoPro/Abcixima, anti-ICAM-3 antibodies such as ICM3, anti-ICE antibodies such as VX-740, anti-FcR1 antibodies such as MDX-33, anti-IgE antibodies such as rhuMab-E25, anti-IL-4 antibodies such as SB-240683, anti-IL-5 antibodies such as SB-240563, SCH55700, anti-IL-8 antibodies such as ABX-IL8, anti-interferon gamma antibodies, anti-TNF (TNF, TNFa, TNFa, TNF-alpha) antibodies such as CDP571, CDP870, D2E7, Infliximab, MAK-195F, and anti-VLA-4 antibodies such as Antegren.

**[133]** Fc variants of the present invention such as those with increased binding to FcRn may be utilized in TNF inhibitor molecules to provide enhanced properties. Useful TNF inhibitor molecules include any molecule that inhibits the action of TNF-alpha in a mammal. Suitable examples include the Fc fusion Enbrel® (etanercept) and the antibodies Humira® (adalimumab) and Remicade® (infliximab). Monoclonal antibodies (such as Remicade and Humira) engineered using the Fc variants of the present invention to increase FcFn binding, may translate to better efficacy through an increased half-life.

**[134]** In some embodiments, antibodies against infectious diseases are used. Antibodies against eukaryotic cells include antibodies targeting yeast cells, including but not limited to *Saccharomyces cerevisiae*, *Hansenula polymorpha*, *Kluyveromyces fragilis* and *K. lactis*, *Pichia guillermondii* and *P. pastoris*, *Schizosaccharomyces pombe*, *plasmodium falciparum*, and *Yarrowia lipolytica*.

**[135]** Antibodies against additional fungal cells are also useful, including target antigens associated with *Candida* strains including *Candida glabrata*, *Candida albicans*, *C. krusei*, *C. lusitanae* and *C. maltosa*, as well as species of *Aspergillus*, *Cryptococcus*, *Histoplasma*, *Coccidioides*, *Blastomyces*, and *Penicillium*, among others

**[136]** Antibodies directed against target antigens associated with protozoa include, but are not limited to, antibodies associated with *Trypanosoma*, *Leishmania* species including *Leishmania donovani*; , *Plasmodium* spp., *Pneumocystis carinii*, *Cryptosporidium parvum*, *Giardia lamblia*, *Entamoeba histolytica*, and *Cyclospora cayetanensis*.

**[137]** Antibodies against prokaryotic antigens are also useful, including antibodies against suitable bacteria such as pathogenic and non-pathogenic prokaryotes including but not limited to Bacillus, including *Bacillus anthracis*; Vibrio, e.g. *V. cholerae*; Escherichia, e.g. Enterotoxigenic *E. coli*, Shigella, e.g. *S. dysenteriae*; Salmonella, e.g. *S. typhi*; Mycobacterium e.g. *M. tuberculosis*, *M. leprae*; Clostridium, e.g. *C. botulinum*, *C. tetani*, *C. difficile*, *C. perfringens*; Corynebacterium, e.g. *C. diphtheriae*; Streptococcus, *S. pyogenes*, *S. pneumoniae*; Staphylococcus, e.g. *S. aureus*; Haemophilus, e.g. *H. influenzae*; Neisseria, e.g. *N. meningitidis*, *N. gonorrhoeae*; Yersinia, e.g. *Y. lambia*, *Y. pestis*, Pseudomonas, e.g. *P. aeruginosa*, *P. putida*; Chlamydia, e.g. *C. trachomatis*; Bordetella, e.g. *B. pertussis*; Treponema, e.g. *T. palladium*; *B. anthracis*, *Y. pestis*, *Brucella spp.*, *F. tularensis*, *B. mallei*, *B. pseudomallei*, *B. mallei*, *B. pseudomallei*, *C. botulinum*, *Salmonella spp.*, *SEB V. cholerae toxin B*, *E. coli O157:H7*, *Listeria spp.*, *Trichosporon beigeli*, *Rhodotorula species*, *Hansenula anomala*, *Enterobacter sp.*, *Klebsiella sp.*, *Listeria sp.*, *Mycoplasma sp.* and the like.

**[138]** In some aspects, the antibodies are directed against viral infections; these viruses include, but are not limited to, including orthomyxoviruses, (e.g. influenza virus), paramyxoviruses (e.g. respiratory syncytial virus, mumps virus, measles virus), adenoviruses, rhinoviruses, coronaviruses, reoviruses, togaviruses (e.g. rubella virus), parvoviruses, poxviruses (e.g. variola virus, vaccinia virus), enteroviruses (e.g. poliovirus, coxsackievirus), hepatitis viruses (including A, B and C), herpesviruses (e.g. Herpes simplex virus, varicella-zoster virus, cytomegalovirus, Epstein-Barr virus), rotaviruses, Norwalk viruses, hantavirus, arenavirus, rhabdovirus (e.g. rabies virus), retroviruses (including HIV, HTLV-I and -II), papovaviruses (e.g. papillomavirus), polyomaviruses, and picornaviruses, and the like.

**[139]** *Optimized IgG Variant Properties*

**[140]** The present application also provides IgG variants that are optimized for a variety of therapeutically relevant properties. An IgG variant that is engineered or predicted to display one or more optimized properties is herein referred to as an “optimized IgG variant”. The most preferred properties that may be optimized include but are not limited to enhanced or reduced affinity for FcRn and increased or decreased *in vivo* half-life. Suitable embodiments include antibodies that exhibit increased binding affinity to FcRn at lowered pH, such as the pH associated with endosomes, e.g. pH 6.0, while maintaining the reduced affinity at higher pH, such as 7.4., to allow increased uptake into endosomes but normal release rates. Similarly, these antibodies with modulated FcRn binding may optionally have other desirable properties, such as modulated FcγR binding, such as outlined in U.S.S.N.s U.S.S.N.s 11/174,287, 11/124,640, 10/822,231, 10/672,280, 10/379,392, and the patent application entitled IgG Immunoglobulin variants with optimized effector function filed on October 21, 2005 having application no. 11/256,060. That is, optimized properties also include but are not limited to enhanced or reduced affinity for an FcγR. In one optional embodiment, the IgG variants are optimized to possess enhanced affinity for a human

activating FcγR, preferably FcγRIIIa in addition to the FcRn binding profile. In yet another optional alternate embodiment, the IgG variants are optimized to possess reduced affinity for the human inhibitory receptor FcγRIIb. That is, particular embodiments embrace the use of antibodies that show increased binding to FcRn, and increased binding to FcγRIIIa. Other embodiments utilize use of antibodies that show increased binding to FcRn, and increased binding to FcγRIIIa. These embodiments are anticipated to provide IgG polypeptides with enhanced therapeutic properties in humans, for example enhanced effector function and greater anti-cancer potency. In an alternate embodiment, the IgG variants are optimized to have increased or reduced affinity for FcRn and increased or decreased affinity for a human FcγR, including but not limited to FcγRI, FcγRIIa, FcγRIIb, FcγRIIc, FcγRIIIa, and FcγRIIIb including their allelic variations. These embodiments are anticipated to provide IgG polypeptides with enhanced therapeutic properties in humans, for example increased serum half-life and reduced effector function. In other embodiments, IgG variants provide enhanced affinity for FcRn and enhanced affinity for one or more FcγRs, yet reduced affinity for one or more other FcγRs. For example, an IgG variant may have enhanced binding to FcRn and FcγRIIIa, yet reduced binding to FcγRIIb. Alternately, an IgG variant may have reduced binding to FcRn and to FcγR's. In another embodiment, an IgG variant may have reduced affinity for FcRn and enhanced affinity for FcγRIIb, yet reduced affinity to one or more activating FcγRs. In yet another embodiment, an IgG variant may have increased serum half-life and reduced effector functions.

**[141]** Preferred embodiments comprise optimization of binding to a human FcRn and FcγR, however in alternate embodiments the IgG variants possess enhanced or reduced affinity for FcRn and FcγR from nonhuman organisms, including but not limited to rodents and non-human primates. IgG variants that are optimized for binding to a nonhuman FcRn may find use in experimentation. For example, mouse models are available for a variety of diseases that enable testing of properties such as efficacy, toxicity, and pharmacokinetics for a given drug candidate. As is known in the art, cancer cells can be grafted or injected into mice to mimic a human cancer, a process referred to as xenografting. Testing of IgG variants that comprise IgG variants that are optimized for FcRn may provide valuable information with regard to the clearance characteristics of the protein, its mechanism of clearance, and the like. The IgG variants may also be optimized for enhanced functionality and/or solution properties in aglycosylated form. The Fc ligands include but are not limited to FcRn, FcγRs, C1q, and proteins A and G, and may be from any source including but not limited to human, mouse, rat, rabbit, or monkey, preferably human. In an alternately preferred embodiment, the IgG variants are optimized to be more stable and/or more soluble than the aglycosylated form of the parent IgG variant.

**[142]** IgG variants can include modifications that modulate interaction with Fc ligands other than FcRn and FcγRs, including but not limited to complement proteins, and Fc receptor homologs



(FcRHs). FcRHs include but are not limited to FcRH1, FcRH2, FcRH3, FcRH4, FcRH5, and FcRH6 (Davis et al., 2002, *Immunol. Reviews* 190:123-136, entirely incorporated by reference).

**[143]** Preferably, the Fc ligand specificity of the IgG variant will determine its therapeutic utility. The utility of a given IgG variant for therapeutic purposes will depend on the epitope or form of the target antigen and the disease or indication being treated. For most targets and indications, enhanced FcRn binding may be preferable as the enhanced FcRn binding may result in an increase in serum half-life. Longer serum half-lives allow less frequent dosing or lower dosing of the therapeutic. This is particularly preferable when the therapeutic agent is given in response to an indication that requires repeated administration. For some targets and indications, decreased FcRn affinity may be preferable. This may be particularly preferable when a variant Fc with increased clearance or decreased serum half-life is desired, for example in Fc polypeptides used as imaging agents or radio-therapeutics.

**[144]** IgG variants may be used that comprise IgG variants that provide enhanced affinity for FcRn with enhanced activating FcγRs and/or reduced affinity for inhibitory FcγRs. For some targets and indications, it may be further beneficial to utilize IgG variants that provide differential selectivity for different activating FcγRs; for example, in some cases enhanced binding to FcγRIIa and FcγRIIIa may be desired, but not FcγRI, whereas in other cases, enhanced binding only to FcγRIIa may be preferred. For certain targets and indications, it may be preferable to utilize IgG variants that alter FcRn binding and enhance both FcγR-mediated and complement-mediated effector functions, whereas for other cases it may be advantageous to utilize IgG variants that enhance FcRn binding, or serum half-life, and either FcγR-mediated or complement-mediated effector functions. For some targets or cancer indications, it may be advantageous to reduce or ablate one or more effector functions, for example by knocking out binding to C1q, one or more FcγR's, FcRn, or one or more other Fc ligands. For other targets and indications, it may be preferable to utilize IgG variants that provide enhanced binding to the inhibitory FcγRIIb, yet WT level, reduced, or ablated binding to activating FcγRs. This may be particularly useful, for example, when the goal of an IgG variant is to inhibit inflammation or auto-immune disease, or modulate the immune system in some way. Because auto-immune diseases are generally long-lasting and treatment is given in repeated dosing, their treatment with Fc variants with increased half-life from increased FcRn is particularly preferred.

**[145]** Modification may be made to improve the IgG stability, solubility, function, or clinical use. In a preferred embodiment, the IgG variants can include modifications to reduce immunogenicity in humans. In a most preferred embodiment, the immunogenicity of an IgG variant is reduced using a method described in USSN 11/004,590, entirely incorporated by reference. In alternate embodiments, the IgG variants are humanized (Clark, 2000, *Immunol Today* 21:397-402, entirely incorporated by reference).

**[146]** The IgG variants can include modifications that reduce immunogenicity. Modifications to reduce immunogenicity can include modifications that reduce binding of processed peptides derived from the parent sequence to MHC proteins. For example, amino acid modifications would be engineered such that there are no or a minimal number of immune epitopes that are predicted to bind, with high affinity, to any prevalent MHC alleles. Several methods of identifying MHC-binding epitopes in protein sequences are known in the art and may be used to score epitopes in an IgG variant. See for example WO 98/52976; WO 02/079232; WO 00/3317; USSN 09/903,378; USSN 10/039,170; USSN 60/222,697; USSN 10/754,296; PCT WO 01/21823; and PCT WO 02/00165; Mallios, 1999, *Bioinformatics* 15: 432-439; Mallios, 2001, *Bioinformatics* 17: 942-948; Sturniolo *et al.*, 1999, *Nature Biotech.* 17: 555-561; WO 98/59244; WO 02/069232; WO 02/77187; Marshall *et al.*, 1995, *J. Immunol.* 154: 5927-5933; and Hammer *et al.*, 1994, *J. Exp. Med.* 180: 2353-2358, all entirely incorporated by reference. Sequence-based information can be used to determine a binding score for a given peptide – MHC interaction (see for example Mallios, 1999, *Bioinformatics* 15: 432-439; Mallios, 2001, *Bioinformatics* 17: p942-948; Sturniolo *et. al.*, 1999, *Nature Biotech.* 17: 555-561, all entirely incorporated by reference).

**[147]** *Engineering IgG Variants*

**[148]** Variants of the present invention may be designed by various means. The variants, as described herein, may be insertions, deletions, substitutions, other modifications, or combinations of these and other changes. A particularly novel embodiment of the present invention is the design of insertions and deletions that either improve or reduce the binding of an Fc polypeptide to an Fc ligand. As disclosed herein, insertions or deletions may be made that increase or decrease the affinity of the Fc polypeptide for FcRn. Insertions and deletions may be designed by rational approaches or by approaches that include the use of random components, such as random or semi-random library creation or screening. In an alternative embodiment, substitutions are disclosed that increase or decrease the affinity of the Fc polypeptide for FcRn.

**[149]** *Backbone Modifications: Insertions and deletions*

**[150]** Variant Fc polypeptides may be created by substituting a variant amino acid in place of the parent amino acid at a position in the Fc polypeptide. By substituting one or more amino acids for variant amino acids in the Fc polypeptide, the side chains at those positions are altered. Most useful substitutions modify the Fc properties by altering the Fc side chains. The substituted side chains may interact directly or indirectly with an Fc binding partner that is associated with an Fc function or property. The at least one substitution alters the covalent structure of one or more side chains of the parent Fc polypeptide.

**[151]** Alternatively, variant Fc polypeptides may be created that change the covalent structure of the backbone of the parent Fc polypeptide. The backbone atoms in proteins are the peptide nitrogen, the alpha carbon, the carbonyl or peptide carbon and the carbonyl oxygen. Changing the covalent structure of the backbone provides additional methods of altering the properties of the Fc

polypeptides. The covalent structure of the Fc backbone may be altered by the addition of atoms into the backbone, e.g. by inserting one or more amino acids, or the subtraction of atoms from the backbone, e.g. by deleting one or more amino acids. The covalent structure of the backbone may also be altered by changing individual atoms of the backbone to other atoms (Deechongkit et al., J Am Chem Soc. 2004. 126(51):16762-71, entirely incorporated by reference). As is known in the art and is illustrated herein, insertions or deletions of amino acids in Fc polypeptides may be done by inserting or deleting the corresponding nucleotides in the DNA encoding the Fc polypeptide. Alternatively, as is known in the art, insertions or deletions of amino acids may be done during synthesis of Fc polypeptides.

**[152]** The design of insertions or deletions of amino acids that alter the interaction of the Fc polypeptide with one or more binding partners (e.g. FcγR's, FcRn, C1q) may be done by considering the structure of the complex of the Fc polypeptide and its binding partner. In a less preferred embodiment, the design may be done by considering the structure of the Fc polypeptide and information about the Fc region involved in binding the binding partner. This information may be obtained by mutagenesis experiments, phage display experiments, homology comparisons, computer modeling or other means.

**[153]** Preferred positions in the amino acid sequence for insertions or deletions that affect the Fc binding interactions, but do not affect the overall structure, stability, expression or use of the Fc polypeptide, are in loops that are involved in the Fc/Fc-binding partner interactions. To alter FcRn binding to the Fc polypeptide, positions 244-257, 279-284, 307-317, 383-390, and 428-435 are preferred loop locations for insertions or deletions (numbering from EU index of Kabat et al., Burmeister et al., 1994, Nature, 372:379-383; Martin et al., 2001, Mol Cell 7:867-877, all entirely incorporated by reference). To alter the Fcγ receptor binding to the Fc polypeptide, positions 229-239, 266-273, 294-299, and 324-331 are preferred loop locations for insertions or deletions (numbering from EU index of Kabat et al., PDB code 1E4K.pdb Sondermann et al. Nature. 2000 406:267, all entirely incorporated by reference). Loops are regions of the polypeptide not involved in alpha helical or beta sheet structure. Loop positions are positions that are not in either alpha helical or beta sheet structures (van Holde, Johnson and Ho. Principles of Physical Biochemistry. Prentice Hall, New Jersey 1998, Chapter 1 pp2-67, entirely incorporated by reference). Loop positions are preferred because the backbone atoms are typically more flexible and less likely involved in hydrogen bonds compared to the backbone atoms of alpha helices and beta sheets. Therefore, the lengthening or shortening of a loop due to an insertion or deletion of one or more amino acids is less likely to lead to large, disruptive changes to the Fc polypeptide, including stability, expression or other problems.

**[154]** Insertions and deletions may be used to alter the length of the polypeptide. For example, in loop regions, altering the loop length results in altered flexibility and conformational entropy of the loop. Insertions in a loop will generally increase the conformational entropy of the loop, which may

be defined as Boltzman's constant multiplied by the natural logarithm of the number of possible conformations (van Holde, Johnson and Ho. Principles of Physical Biochemistry. Prentice Hall, New Jersey 1998, pp78, entirely incorporated by reference). By inserting at least one amino acid into a polypeptide, the total number of conformations available to the polypeptide increases. These additional conformations may be beneficial for forming favorable Fc/Fc-binding partner interactions because the Fc polypeptide may use one of the additional conformations in binding the Fc-binding protein. In this case, the insertion may lead to stronger Fc/Fc-binding partner interactions. If the additional conformations are not used in the binding interface, then the insertion may lead to weaker Fc/Fc-binding partner interactions, because the additional conformations would compete with the binding-competent conformation. Similarly, deletion of a polypeptide segment may also lead to either stronger or weaker Fc/Fc binding-partner interactions. If deletion of a segment, which reduces the possible number of backbone conformations, removes the binding-competent conformation, then the deletion may lead to weaker Fc/Fc-binding partner interactions. If the deletion does not remove the binding-competent conformation, then the deletion may lead to stronger Fc/Fc-binding partner interactions because the deletion may remove conformations that compete with the binding-competent conformation.

**[155]** Insertions and deletions may be used to alter the positions and orientations of the amino acids in the Fc polypeptide. Because insertions and deletions cause a change in the covalent structure of the backbone, they necessarily cause a change in the positions of the backbone atoms. Figure 7 compares the backbone positions at some loop segments, marked L1 to L4, in three different backbones. The reference backbone structure contains four loop segments, whereas the deletion backbone lacks segment L1 and the insertion segment comprises an additional segment before, ie, N-terminal to, segment L1. Deletions and insertions cause the largest change in the backbone structure near the site of the insertion or deletion. By deleting a segment near the N-terminal end of the loop, e.g. segment L1, the loop shortens and the remaining segments shift their position closer to the loop N-terminus. This has the effect of moving the L2 segment toward the prior location of the L1 segment and toward the loop N-terminus. This change in position of the L2 segment toward the L1 segment may strengthen the binding of the Fc/Fc-binding partner complex and is preferred when there is prior information suggesting that the amino acid or amino acids located in L2 make favorable interactions with the Fc-binding partner, when located in L1. For example, if L2 contains alanine and tyrosine and substitution of two L1 amino acids for alanine and tyrosine previously lead to an Fc variant with increased binding, then deletion of L1 may create an Fc variant with increased affinity for the Fc-binding partner.

**[156]** Similarly, an insertion of a polypeptide segment into an Fc polypeptide at the N-terminal side of a loop causes the positions of the loop segments to be shifted toward the C-terminal side of the loop. In Figure 7, an insertion of one or more amino acids before, i.e. N-terminally to, segment L1 alters the backbone conformation including a shift of the L1 segment toward the C-terminal end

of the loop. This type of insertion is preferred when the amino acids located in segment L1 are known to make favorable interactions when located in the L2 positions, as the insertion may lead to stronger Fc/Fc-binding partner interactions. If weaker Fc/Fc-binding partner interactions are desired, then the insertion may be used to shift unfavorable amino acid into a new position. The inserted, deleted and reference segments (L1 to L4 in Figure 7) may be one or more than one amino acid in the Fc polypeptide.

**[157]** Alternatively, insertions or deletions may be used at the C-terminal end of loops in a manner analogous to the insertions or deletions at the N-terminal end of loops. Insertions at the loop C-terminus may lead to a movement of the positions N-terminal of the insertion toward the loop N-terminus. Deletions at the loop C-terminus may lead to a movement of the positions N-terminal of the deletion toward the loop C-terminus. The choice of using an insertion or deletion at the N-terminal or C-terminal end of the loop is based on the amino acids located in the loop, the desire for increased or decreased Fc/Fc-binding partner affinity, and the positional shift desired.

**[158]** Insertions or deletions may be used in any region of an Fc polypeptide, including the loops, the alpha helical, and the beta sheet regions. Preferred locations for insertions and deletions include loop regions, which are those that are not alpha helical or beta sheet regions. Loops are preferred because they generally accept alterations in the backbone better than alpha helices or beta sheets. The particularly preferred locations for insertions or deletions that result in stronger protein/protein interactions are at the N-terminal or C-terminal edges of a loop. If the loop side chains are involved in the Fc/Fc-binding partner interactions, then insertions or deletion at the edges are less likely to lead to strongly detrimental changes in the binding interactions. Deletions within the exact center of the loop are more likely to remove important residues in the Fc/Fc-binding partner interface and insertions within the exact center of the loop are more likely to create unfavorable interactions in the Fc/Fc-binding partner interface. The number of residues deleted or inserted may be determined by the size of the backbone change desired with insertions or deletions of 15 or less residues being preferred, insertions or deletions of 10 or less residues being more preferred, and insertions or deletions of 5 or less residues being most preferred.

**[159]** Once the position and size of an Fc deletion variant is designed, the entire polypeptide sequence is completely determined and the polypeptide may be constructed by methods known in the art.

**[160]** Fc insertion variants, however, have the additional step of designing the sequence of the at least one amino acid to be inserted. Insertions of polar residues, including Ser, Thr, Asn, Gln, Ala, Gly, His, are preferred at positions expected to be exposed in the Fc polypeptide. The smaller amino acids, including Ser, Thr, and Ala, are particularly preferred as the small size is less likely to sterically interfere with the Fc/Fc-binding partner interactions. Ser and Thr also have the capability to hydrogen bond with atoms on the Fc-binding partner.

**[161]** Insertions also have the added flexibility that the inserted polypeptide may be designed to make favorable interactions with the Fc-binding partner as would be desired when stronger Fc/Fc-binding partner binding is desired. The length of the backbone insertion may be determined by modeling the variant backbone with a simple, generic sequence to be inserted. For example, polyserine, polyglycine or polyalanine insertions of different lengths may be constructed and modeled. Modeling may be done by a variety of methods, including homology modeling based on known three-dimensional structures of homologues comprising the insertion, and by computer modeling including MODELLER (M.A. Marti-Renom et al. Annu. Rev. Biophys. Biomol. Struct. 29, 291-325, 2000) and ROSETTA (Kuhlman et al. (2003). Science 302, 1364-8), both entirely incorporated by reference. Typically, various backbone conformations are initially generated and the final backbone structure may be determined after the identities of the side chain are established. The side chains may be designed by PDA® algorithms (US 6,188,965; 6,269,312; 6,403,312; 6,801,861; 6,804,611; 6,792,356, 6,950,754, and USSN 09/782,004; 09/927,790; 10/101,499; 10/666,307; 10/666,311; 10/218,102, all entirely incorporated by reference).

**[162]** Insertions and deletions may be made to alter the binding of Fc polypeptides to FcγRIIIa in an analogous manner to the described method to alter FcRn-binding properties. Fc domains bind to the FcγRIIIa at the position indicated in Figure 1. Structures of the Fc/FcγRIIIa complex, including PDB codes 1T89 and 1IIS (Radaev S et al. J. Biol. Chem. v276, p.16469-16477 entirely incorporated by reference), demonstrate the interacting residues and loops between the two structures. Mutagenesis results such as those found in US11/124620 and US6737056, both entirely incorporated by reference) all have utility in determining appropriate shifts of backbone positioning.

**[163]** Insertions and deletions may be designed in any polypeptide besides Fc polypeptides by the methods described herein. For example, insertions or deletions in the TNF superfamily member, APRIL, may be designed with the aid of its three-dimensional structure (PDB code 1XU1.pdb, Hymowitz, et al. (2005) J. Biol. Chem. 280:7218, entirely incorporated by reference). Insertions or deletions may be designed to increase APRIL binding to its receptor, TACI. The loop residues preferred as insertion or deletion sites are residues Ser118-Val124, Asp164-Phe167, Pro192-Ala198, Pro221-Lys226. These loops interact with TACI in the APRIL/TACI complex and mediate binding.

**[164]** *Polypeptides incorporating variants*

**[165]** The IgG variants can be based on human IgG sequences, and thus human IgG sequences are used as the “base” sequences against which other sequences are compared, including but not limited to sequences from other organisms, for example rodent and primate sequences. IgG variants may also comprise sequences from other immunoglobulin classes such as IgA, IgE, IgD, IgM, and the like. It is contemplated that, although the IgG variants are engineered in the context of one parent IgG, the variants may be engineered in or “transferred” to the context of another,

second parent IgG. This is done by determining the “equivalent” or “corresponding” residues and substitutions between the first and second IgG, typically based on sequence or structural homology between the sequences of the IgGs. In order to establish homology, the amino acid sequence of a first IgG outlined herein is directly compared to the sequence of a second IgG. After aligning the sequences, using one or more of the homology alignment programs known in the art (for example using conserved residues as between species), allowing for necessary insertions and deletions in order to maintain alignment (i.e., avoiding the elimination of conserved residues through arbitrary deletion and insertion), the residues equivalent to particular amino acids in the primary sequence of the first IgG variant are defined. Alignment of conserved residues preferably should conserve 100% of such residues. However, alignment of greater than 75% or as little as 50% of conserved residues is also adequate to define equivalent residues. Equivalent residues may also be defined by determining structural homology between a first and second IgG that is at the level of tertiary structure for IgGs whose structures have been determined. In this case, equivalent residues are defined as those for which the atomic coordinates of two or more of the main chain atoms of a particular amino acid residue of the parent or precursor (N on N, CA on CA, C on C and O on O) are within 0.13 nm and preferably 0.1 nm after alignment. Alignment is achieved after the best model has been oriented and positioned to give the maximum overlap of atomic coordinates of non-hydrogen protein atoms of the proteins. Regardless of how equivalent or corresponding residues are determined, and regardless of the identity of the parent IgG in which the IgGs are made, what is meant to be conveyed is that the IgG variants discovered by can be engineered into any second parent IgG that has significant sequence or structural homology with the IgG variant. Thus for example, if a variant antibody is generated wherein the parent antibody is human IgG1, by using the methods described above or other methods for determining equivalent residues, the variant antibody may be engineered in another IgG1 parent antibody that binds a different antigen, a human IgG2 parent antibody, a human IgA parent antibody, a mouse IgG2a or IgG2b parent antibody, and the like. Again, as described above, the context of the parent IgG variant does not affect the ability to transfer the IgG variants to other parent IgGs.

**[166]** Methods for engineering, producing, and screening IgG variants are provided. The described methods are not meant to constrain to any particular application or theory of operation. Rather, the provided methods are meant to illustrate generally that one or more IgG variants may be engineered, produced, and screened experimentally to obtain IgG variants with optimized effector function. A variety of methods are described for designing, producing, and testing antibody and protein variants in USSN 10/754,296, and USSN 10/672,280, both entirely incorporated by reference.

**[167]** A variety of protein engineering methods may be used to design IgG variants with optimized effector function. In one embodiment, a structure-based engineering method may be used, wherein available structural information is used to guide substitutions, insertions or

deletions. In a preferred embodiment, a computational screening method may be used, wherein substitutions are designed based on their energetic fitness in computational calculations. See for example USSN 10/754,296 and USSN 10/672,280, and references cited therein, all entirely incorporated by reference.

**[168]** An alignment of sequences may be used to guide substitutions at the identified positions. One skilled in the art will appreciate that the use of sequence information may curb the introduction of substitutions that are potentially deleterious to protein structure. The source of the sequences may vary widely, and include one or more of the known databases, including but not limited to the Kabat database (Northwestern University); Johnson & Wu, 2001, *Nucleic Acids Res.* 29:205-206; Johnson & Wu, 2000, *Nucleic Acids Res.* 28:214-218), the IMGT database (IMGT, the international ImMunoGeneTics information system®; ; Lefranc *et al.*, 1999, *Nucleic Acids Res.* 27:209-212; Ruiz *et al.*, 2000 *Nucleic Acids Res.* 28:219-221; Lefranc *et al.*, 2001, *Nucleic Acids Res.* 29:207-209; Lefranc *et al.*, 2003, *Nucleic Acids Res.* 31:307-310), and VBASE, all entirely incorporated by reference. Antibody sequence information can be obtained, compiled, and/or generated from sequence alignments of germline sequences or sequences of naturally occurring antibodies from any organism, including but not limited to mammals. One skilled in the art will appreciate that the use of sequences that are human or substantially human may further have the advantage of being less immunogenic when administered to a human. Other databases which are more general nucleic acid or protein databases, i.e. not particular to antibodies, include but are not limited to SwissProt, GenBank Entrez, and EMBL Nucleotide Sequence Database. Aligned sequences can include VH, VL, CH, and/or CL sequences. There are numerous sequence-based alignment programs and methods known in the art, and all of these find use in the generation of sequence alignments.

**[169]** Alternatively, random or semi-random mutagenesis methods may be used to make amino acid modifications at the desired positions. In these cases positions are chosen randomly, or amino acid changes are made using simplistic rules. For example all residues may be mutated to alanine, referred to as alanine scanning. Such methods may be coupled with more sophisticated engineering approaches that employ selection methods to screen higher levels of sequence diversity. As is well known in the art, there are a variety of selection technologies that may be used for such approaches, including, for example, display technologies such as phage display, ribosome display, cell surface display, and the like, as described below.

**[170]** Methods for production and screening of IgG variants are well known in the art. General methods for antibody molecular biology, expression, purification, and screening are described in Antibody Engineering, edited by Duebel & Kontermann, Springer-Verlag, Heidelberg, 2001; and Hayhurst & Georgiou, 2001, *Curr Opin Chem Biol* 5:683-689; Maynard & Georgiou, 2000, *Annu Rev Biomed Eng* 2:339-76. Also see the methods described in USSN 10/754,296; USSN 10/672,280; and USSN 10/822,231; and 11/124,620, all entirely incorporated by reference.



Preferred variants of the present invention include those found in Figure 8. Alternatively preferred variants of the present invention include those found in Figure 9. Additionally alternatively preferred variants of the present invention include those found in Figure 10. These variants have shown increased binding to the Fc receptor, FcRn, as illustrated in the examples.

**[171]** *Making IgG Variants*

**[172]** The IgG variants can be made by any method known in the art. In one embodiment, the IgG variant sequences are used to create nucleic acids that encode the member sequences, and that may then be cloned into host cells, expressed and assayed, if desired. These practices are carried out using well-known procedures, and a variety of methods that may find use in are described in *Molecular Cloning - A Laboratory Manual*, 3<sup>rd</sup> Ed. (Maniatis, Cold Spring Harbor Laboratory Press, New York, 2001), and *Current Protocols in Molecular Biology* (John Wiley & Sons), both entirely incorporated by reference. The nucleic acids that encode the IgG variants may be incorporated into an expression vector in order to express the protein. Expression vectors typically include a protein operably linked, that is, placed in a functional relationship, with control or regulatory sequences, selectable markers, any fusion partners, and/or additional elements. The IgG variants may be produced by culturing a host cell transformed with nucleic acid, preferably an expression vector, containing nucleic acid encoding the IgG variants, under the appropriate conditions to induce or cause expression of the protein. A wide variety of appropriate host cells may be used, including but not limited to mammalian cells, bacteria, insect cells, and yeast. For example, a variety of cell lines that may find use are described in the ATCC cell line catalog, available from the American Type Culture Collection, entirely incorporated by reference. The methods of introducing exogenous nucleic acid into host cells are well known in the art, and will vary with the host cell used.

**[173]** In a preferred embodiment, IgG variants are purified or isolated after expression. Antibodies may be isolated or purified in a variety of ways known to those skilled in the art. Standard purification methods include chromatographic techniques, electrophoretic, immunological, precipitation, dialysis, filtration, concentration, and chromatofocusing techniques. As is well known in the art, a variety of natural proteins bind antibodies, for example bacterial proteins A, G, and L, and these proteins may find use in purification. Often, purification may be enabled by a particular fusion partner. For example, proteins may be purified using glutathione resin if a GST fusion is employed, Ni<sup>2+</sup> 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 *Antibody Purification: Principles and Practice*, 3<sup>rd</sup> Ed., Scopes, Springer-Verlag, NY, 1994, entirely incorporated by reference.

**[174]** *Screening IgG Variants*

**[175]** Fc variants may be screened using a variety of methods, including but not limited to those that use *in vitro* assays, *in vivo* and cell-based assays, and selection technologies. Automation and

high-throughput screening technologies may be utilized in the screening procedures. Screening may employ the use of a fusion partner or label, for example an immune label, isotopic label, or small molecule label such as a fluorescent or colorimetric dye.

**[176]** In a preferred embodiment, the functional and/or biophysical properties of Fc variants are screened in an *in vitro* assay. In a preferred embodiment, the protein is screened for functionality, for example its ability to catalyze a reaction or its binding affinity to its target.

**[177]** As is known in the art, subsets of screening methods are those that select for favorable members of a library. The methods are herein referred to as “selection methods”, and these methods find use in the present invention for screening Fc variants. When protein libraries are screened using a selection method, only those members of a library that are favorable, that is which meet some selection criteria, are propagated, isolated, and/or observed. A variety of selection methods are known in the art that may find use in the present invention for screening protein libraries. Other selection methods that may find use in the present invention include methods that do not rely on display, such as *in vivo* methods. A subset of selection methods referred to as “directed evolution” methods are those that include the mating or breeding of favorable sequences during selection, sometimes with the incorporation of new mutations.

**[178]** In a preferred embodiment, Fc variants are screened using one or more cell-based or *in vivo* assays. For such assays, purified or unpurified proteins are typically added exogenously such that cells are exposed to individual variants or pools of variants belonging to a library. These assays are typically, but not always, based on the function of the Fc polypeptide; that is, the ability of the Fc polypeptide to bind to its target and mediate some biochemical event, for example effector function, ligand/receptor binding inhibition, apoptosis, and the like. Such assays often involve monitoring the response of cells to the IgG, for example cell survival, cell death, change in cellular morphology, or transcriptional activation such as cellular expression of a natural gene or reporter gene. For example, such assays may measure the ability of Fc variants to elicit ADCC, ADCP, or CDC. For some assays additional cells or components, that is in addition to the target cells, may need to be added, for example example serum complement, or effector cells such as peripheral blood monocytes (PBMCs), NK cells, macrophages, and the like. Such additional cells may be from any organism, preferably humans, mice, rat, rabbit, and monkey. Antibodies may cause apoptosis of certain cell lines expressing the target, or they may mediate attack on target cells by immune cells which have been added to the assay. Methods for monitoring cell death or viability are known in the art, and include the use of dyes, immunochemical, cytochemical, and radioactive reagents. Transcriptional activation may also serve as a method for assaying function in cell-based assays. Alternatively, cell-based screens are performed using cells that have been transformed or transfected with nucleic acids encoding the variants. That is, Fc variants are not added exogenously to the cells.

**[179]** The biological properties of the IgG variants may be characterized in cell, tissue, and whole organism experiments. As is known in the art, drugs are often tested in animals, including but not limited to mice, rats, rabbits, dogs, cats, pigs, and monkeys, in order to measure a drug's efficacy for treatment against a disease or disease model, or to measure a drug's pharmacokinetics, toxicity, and other properties. The animals may be referred to as disease models. Therapeutics are often tested in mice, including but not limited to nude mice, SCID mice, xenograft mice, and transgenic mice (including knockins and knockouts). Such experimentation may provide meaningful data for determination of the potential of the protein to be used as a therapeutic. Any organism, preferably mammals, may be used for testing. For example because of their genetic similarity to humans, monkeys can be suitable therapeutic models, and thus may be used to test the efficacy, toxicity, pharmacokinetics, or other property of the IgGs. Tests of the in humans are ultimately required for approval as drugs, and thus of course these experiments are contemplated. Thus the IgGs may be tested in humans to determine their therapeutic efficacy, toxicity, immunogenicity, pharmacokinetics, and/or other clinical properties.

**[180]** *Methods of Using IgG Variants*

**[181]** The IgG variants may find use in a wide range of products. In one embodiment the IgG variant is a therapeutic, a diagnostic, or a research reagent, preferably a therapeutic. The IgG variant may find use in an antibody composition that is monoclonal or polyclonal. In a preferred embodiment, the IgG variants are used to kill target cells that bear the target antigen, for example cancer cells. In an alternate embodiment, the IgG variants are used to block, antagonize or agonize the target antigen, for example for antagonizing a cytokine or cytokine receptor. In an alternately preferred embodiment, the IgG variants are used to block, antagonize or agonize the target antigen and kill the target cells that bear the target antigen.

**[182]** The IgG variants may be used for various therapeutic purposes. In a preferred embodiment, an antibody comprising the IgG variant is administered to a patient to treat an antibody-related disorder. A "patient" for the purposes includes humans and other animals, preferably mammals and most preferably humans. By "antibody related disorder" or "antibody responsive disorder" or "condition" or "disease" herein are meant a disorder that may be ameliorated by the administration of a pharmaceutical composition comprising an IgG variant. Antibody related disorders include but are not limited to autoimmune diseases, immunological diseases, infectious diseases, inflammatory diseases, neurological diseases, and oncological and neoplastic diseases including cancer. By "cancer" and "cancerous" herein refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth. Examples of cancer include but are not limited to carcinoma, lymphoma, blastoma, sarcoma (including liposarcoma), neuroendocrine tumors, mesothelioma, schwannoma, meningioma, adenocarcinoma, melanoma, and leukemia and lymphoid malignancies.

**[183]** In one embodiment, an IgG variant is the only therapeutically active agent administered to a patient. Alternatively, the IgG variant is administered in combination with one or more other therapeutic agents, including but not limited to cytotoxic agents, chemotherapeutic agents, cytokines, growth inhibitory agents, anti-hormonal agents, kinase inhibitors, anti-angiogenic agents, cardioprotectants, or other therapeutic agents. The IgG variants may be administered concomitantly with one or more other therapeutic regimens. For example, an IgG variant may be administered to the patient along with chemotherapy, radiation therapy, or both chemotherapy and radiation therapy. In one embodiment, the IgG variant may be administered in conjunction with one or more antibodies, which may or may not be an IgG variant. In accordance with another embodiment, the IgG variant and one or more other anti-cancer therapies are employed to treat cancer cells *ex vivo*. It is contemplated that such *ex vivo* treatment may be useful in bone marrow transplantation and particularly, autologous bone marrow transplantation. It is of course contemplated that the IgG variants can be employed in combination with still other therapeutic techniques such as surgery.

**[184]** A variety of other therapeutic agents may find use for administration with the IgG variants. In one embodiment, the IgG is administered with an anti-angiogenic agent. By "anti-angiogenic agent" as used herein is meant a compound that blocks, or interferes to some degree, the development of blood vessels. The anti-angiogenic factor may, for instance, be a small molecule or a protein, for example an antibody, Fc fusion, or cytokine, that binds to a growth factor or growth factor receptor involved in promoting angiogenesis. The preferred anti-angiogenic factor herein is an antibody that binds to Vascular Endothelial Growth Factor (VEGF). In an alternate embodiment, the IgG is administered with a therapeutic agent that induces or enhances adaptive immune response, for example an antibody that targets CTLA-4. In an alternate embodiment, the IgG is administered with a tyrosine kinase inhibitor. By "tyrosine kinase inhibitor" as used herein is meant a molecule that inhibits to some extent tyrosine kinase activity of a tyrosine kinase. In an alternate embodiment, the IgG variants are administered with a cytokine.

**[185]** Pharmaceutical compositions are contemplated wherein an IgG variant and one or more therapeutically active agents are formulated. Formulations of the IgG variants are prepared for storage by mixing the IgG having the desired degree of purity with optional pharmaceutically acceptable carriers, excipients or stabilizers (Remington's Pharmaceutical Sciences 16th edition, Osol, A. Ed., 1980, entirely incorporated by reference), in the form of lyophilized formulations or aqueous solutions. The formulations to be used for *in vivo* administration are preferably sterile. This is readily accomplished by filtration through sterile filtration membranes or other methods. The IgG variants and other therapeutically active agents disclosed herein may also be formulated as immunoliposomes, and/or entrapped in microcapsules.

**[186]** The concentration of the therapeutically active IgG variant in the formulation may vary from about 0.1 to 100% by weight. In a preferred embodiment, the concentration of the IgG is in the

range of 0.003 to 1.0 molar. In order to treat a patient, a therapeutically effective dose of the IgG variant may be administered. By "therapeutically effective dose" herein is meant a dose that produces the effects for which it is administered. The exact dose will depend on the purpose of the treatment, and will be ascertainable by one skilled in the art using known techniques. Dosages may range from 0.01 to 100 mg/kg of body weight or greater, for example 0.01, 0.1, 1.0, 10, or 50 mg/kg of body weight, with 1 to 10mg/kg being preferred. As is known in the art, adjustments for protein degradation, systemic versus localized delivery, and rate of new protease synthesis, as well as the age, body weight, general health, sex, diet, time of administration, drug interaction and the severity of the condition may be necessary, and will be ascertainable with routine experimentation by those skilled in the art.

**[187]** Administration of the pharmaceutical composition comprising an IgG variant, preferably in the form of a sterile aqueous solution, may be done in a variety of ways, including, but not limited to, orally, subcutaneously, intravenously, parenterally, intranasally, intraotically, intraocularly, rectally, vaginally, transdermally, topically (e.g., gels, salves, lotions, creams, etc.), intraperitoneally, intramuscularly, intrapulmonary (e.g., AERx® inhalable technology commercially available from Aradigm, or Inhance® pulmonary delivery system commercially available from Nektar Therapeutics, etc.). Therapeutic described herein may be administered with other therapeutics concomitantly, i.e., the therapeutics described herein may be co-administered with other therapies or therapeutics, including for example, small molecules, other biologicals, radiation therapy, surgery, etc.

### EXAMPLES

**[188]** Examples are provided below to illustrate the present invention. These examples are not meant to constrain the present invention to any particular application or theory of operation. For all positions discussed in the present invention, numbering is according to the EU index as in Kabat (Kabat *et al.*, 1991, *Sequences of Proteins of Immunological Interest*, 5th Ed., United States Public Health Service, National Institutes of Health, Bethesda, entirely incorporated by reference). Those skilled in the art of antibodies will appreciate that this convention consists of nonsequential numbering in specific regions of an immunoglobulin sequence, enabling a normalized reference to conserved positions in immunoglobulin families. Accordingly, the positions of any given immunoglobulin as defined by the EU index will not necessarily correspond to its sequential sequence.

#### EXAMPLE 1: DNA construction, expression, and purification of Fc variants

**[189]** Amino acid modifications were engineered in the Fc region of IgG antibodies to improve their affinity for the neonatal Fc receptor FcRn. Variants were screened in the context of a number of different human IgG constant chains (Figure 2), including IgG1, IgG2, and a hybrid IgG sequences that contains the CH1 and upper hinge of IgG1 and the Fc region of IgG2. It will be appreciated by those skilled in the art that because of the different interactions of the IgG1 and

IgG2 Fc region with Fc $\gamma$ Rs and complement, these different parent Fc regions will have different Fc $\gamma$ R- and complement-mediated effector function properties. Exemplary sequences of Fc variants in the context of these parent IgG constant chains are shown in Figure 3.

**[190]** Fc variants were engineered in the context of an antibody targeting vascular endothelial factor (VEGF). The heavy and light chain variable regions (VH and VL) are those of a humanized version of the antibody A4.6.1, also referred to as bevacizumab (Avastin®), which is approved for the treatment of a variety of cancers. The amino acid sequences of the VH and VL regions of this antibody are shown in Figure 4.

**[191]** Genes encoding the heavy and light chains of the anti-VEGF antibodies were constructed in the mammalian expression vector pTT5. Human IgG1 and IgG2 constant chain genes were obtained from IMAGE clones and subcloned into the pTT5 vector. The IgG1/2 gene was constructed using PCR mutagenesis. VH and VL genes encoding the anti-VEGF antibodies were synthesized commercially (Blue Heron Biotechnologies, Bothell WA), and subcloned into the vectors encoding the appropriate CL, IgG1, IgG2, and IgG1/2 constant chains. Amino acid modifications were constructed using site-directed mutagenesis using the QuikChange® site-directed mutagenesis methods (Stratagene, La Jolla CA). All DNA was sequenced to confirm the fidelity of the sequences.

**[192]** Plasmids containing heavy chain gene (VH-C $\gamma$ 1-C $\gamma$ 2-C $\gamma$ 3) were co-transfected with plasmid containing light chain gene (VL-C $\kappa$ ) into 293E cells using Ilipofectamine (Invitrogen, Carlsbad CA) and grown in FreeStyle 293 media (Invitrogen, Carlsbad CA). After 5 days of growth, the antibodies were purified from the culture supernatant by protein A affinity using the MabSelect resin (GE Healthcare). Antibody concentrations were determined by bicinchoninic acid (BCA) assay (Pierce).

#### EXAMPLE 2. Fc variant antibodies maintain binding to antigen

**[193]** The fidelity of the expressed variant antibodies was confirmed by demonstrating that they maintained specificity for antigen. VEGF binding was monitored using surface plasmon resonance (SPR, Biacore), performed using a Biacore 3000 instrument. Recombinant VEGF (VEGF-165, PeproTech, Rocky Hill, NJ) was adhered to a CM5 chip surface by coupling with N-hydroxysuccinimide/N-ethyl-N'-(-3-dimethylamino-propyl) carbodiimide (NHS/EDC) using standard methods. WT and variant antibodies were injected as analytes, and response, measured in resonance units (RU), was acquired. The dissociation phase was too slow to measure true equilibrium constants, and so relative binding was determined by measuring RU's at the end of the association phase, which should be proportional to the protein concentration (which is held constant in the experiment) and the association rate constant. The data (Figure 6) show that the variant anti-VEGF antibodies maintain binding to antigen, in contrast to the negative control anti-Her2 antibody which does not bind VEGF.

#### EXAMPLE 3. Measurement of binding to human FcRn

**[194]** Binding of variant antibodies to human FcRn was measured at pH 6.0, the pH at which it is naturally bound in endosomes. Vectors encoding beta 2 microglobulin and His-tagged alpha chain genes of FcRn were constructed, co-transfected into 293T cells, and purified using nickel chromatography. Antibody affinity for human FcRn (hFcRn) at pH 6.0 was measured on a Biacore 3000 instrument by coupling human FcRn to a CM5 chip surface using standard NHS/EDC chemistry. WT and variant antibodies were used in the mobile phase at 25-100 nM concentration and response was measured in resonance units. Association and dissociation phases at pH 6.0 were acquired, followed by an injection of pH 7.4 buffer to measure release of antibody from receptor at the higher pH. A cycle with antibody and buffer only provided baseline response, which was subtracted from each sample sensorgram.

**[195]** Figure 7 shows Biacore sensorgrams for binding of native IgG1 and select Fc variant antibodies to human FcRn at the two relevant pH's. The data show that wild-type and variant antibodies bind readily to FcRn chip at pH 6.0 and dissociate slowly at that pH, as they would in the endosome, yet release rapidly at pH7.4, as they would upon recycling of endosome to the membrane and exposure to the higher pH of serum.

**[196]** The FcRn association/dissociation curves did not fit to a simple Langmuir model, possibly due to the antibody and receptor multi-valency or chip heterogeneity. Pseudo-Ka values (referred to as Ka\*) were determined by fitting to a conformational change model with the change in refractive index (RI) fixed at 0 RU. These values for select variant antibodies are plotted in Figure 8. The relative affinity of each variant as compared to its parent IgG was calculated according to the equation  $\text{Fold} = (\text{WT Ka}^* / \text{Variant Ka}^*)$ . The relative binding data for all Fc variants in an IgG1 Fc region are presented in Figure 9, and binding data for variants in antibodies with an IgG2 Fc region (constant chains IgG1 and IgG1/2) are presented in Figure 10. For many variants, the binding experiment was repeated multiple times (n), for which folds were calculated with reference to the WT IgG parent within each particular binding experiment. Averaging of these data provided a mean and standard deviation, as presented in Figures 9 and 10.

**[197]** Figures 9 and 10 show that a number of engineered variants bind with greater affinity to human FcRn binding at pH 6.0 relative to WT IgG1. Improvements were heavily dependent on the identity of the substitution at a given position. For example, using 2-fold as a criteria for improved binding, a number of mutations at position 434 in IgG2 increased affinity (A, S, Y, F, and W), some were neutral (within 2-fold of WT IgG2) (G, H, M, and T), and a number of substitutions reduced affinity (< 0.5 fold) (D, E, K, P, R, and V). Greater binding in the context of IgG1 did not necessarily translate to greater binding in IgG2 (for example 434T was improved in binding in IgG1 but not IgG2). Moreover, improvements provided by single variants were not always additive upon combination. Figure 11a demonstrates this graphically by plotting the experimental fold FcRn binding by select double substitution variants versus the product of the fold FcRn binding by the individual single variants that compose them. The straight line represents perfect additivity, i.e. the

value that would be expected or predicted from the product of the single substitutions. A number of double variants fall on or close to this line (259I/319I, 259I/428L, 319I/428L, and 308F/428L). Several variants are less than additive (319I/308F, 252Y/428L, and 428L/434M). For these variants, particularly in the case of the latter two (252Y/428L and 428L/434M), the affinity improvements of the single substitutions would seem to be incompatible with each other when combined. Surprisingly, the FcRn affinity improvements of variants 259I/308F and 428L/434S were greater than would be expected from the affinities of their respective single substitutions. These particular single substitutions had unexpected synergistic improvements when combined. The difference between experimental affinities and those predicted from the affinities of the single variants are plotted in Figure 11b, with variants grouped according to their composite single variants (259I, 308F, and 319I on the left, and combinations with 428L on the right). Synergy can be quantitated by calculating the fold of the experimental value relative to the predicted value, followed by normalization to 1 and conversion to a percentage (% synergy =  $100 \times [(\text{experimental fold/predicted fold}) - 1]$ ). This analysis is plotted in Figure 11b, with variants grouped according to their composite single variants. This graph highlights again the synergy of some of the variants, particularly 259I/308F and 428L/434S. Figures 11b and 11c also emphasize the nonpredictive nature of combining many of the best single substitutions from the screen. For example, whereas combination of 428L with 434S and 259I provided synergistic binding improvements, 252Y or 434M had a negative impact when combined with 428L. The dramatic difference between combining 428L with 434S versus 434M further highlights the importance of the particular amino acid identity of the substitution at a given position.

#### EXAMPLE 4. Testing of variants in other antibody contexts

**[198]** Select variants were constructed in the context of antibodies targeting other antigens, including TNF (TNF $\alpha$ ), CD25 (TAC), EGFR, and IgE. Figure 4 provides the amino acid sequences of the VH and VL regions of antibodies targeting these antigens that were used in the invention. The WT and Fc variant anti-TNF antibodies contain the variable region of the fully human antibody adalimumab (Humira®), currently approved for the treatment of rheumatoid arthritis (RA), juvenile idiopathic arthritis (JIA), psoriatic arthritis (PsA), ankylosing spondylitis (AS), and Crohn's disease (CD). The WT and Fc variant anti-CD25 antibodies are humanized versions of the antibody anti-TAC (Junghans et al., 1990, Cancer Research 50:1495-1502), referred to as H1.8/L1 anti-TAC. The WT and Fc variant anti-EGFR antibodies are humanized versions of the murine antibody C225, referred to as H4.42/L3.32 C225. Finally, the WT and Fc variant anti-IgE antibodies contain the variable region of the humanized antibody omalizumab (Xolair®), which is approved for the treatment of allergic asthma.

**[199]** WT and variant antibodies were constructed, expressed, and purified as described above. Antibodies were tested for binding to human FcRn at pH 6.0 by Biacore as described above. The relative binding data of the variant anti-TNF, -CD25, -EGFR, and -IgE antibodies to human FcRn



are provided in Figure 12. As can be seen, the variants improve FcRn affinity in the context of antibodies targeting a variety of antigens.

EXAMPLE 5. Pharmacokinetic experiments in human FcRn knock-in mice

**[200]** To test the ability of select variants to improve half-life in vivo, pharmacokinetic experiments were performed in B6 mice that are homozygous knock-outs for murine FcRn and heterozygous knock-ins of human FcRn (mFcRn<sup>-/-</sup>, hFcRn<sup>+</sup>) (Petkova et al., 2006, Int Immunol 18(12):1759-69, entirely incorporated by reference), herein referred to as hFcRn or hFcRn<sup>+</sup> mice. A single, intravenous tail vein injection of anti-VEGF antibody (2 mg/kg) was given to groups of 4-7 female mice randomized by body weight (20-30g range). Blood (~50ul) was drawn from the orbital plexus at each time point, processed to serum, and stored at -80°C until analysis. Study durations were 28 or 49 days. Animals were not harmed during these studies.

**[201]** Antibody concentrations were determined using two ELISA assays. In the first two studies (referred to as Study 1 and Study 2), goat anti-human Fc antibody (Jackson Immuno research) was adhered to the plate, wells were washed with PBST (phosphate buffered saline with 0.05% Tween) and blocked with 3% BSA in PBST. Serum or calibration standards were then added, followed by PBST washing, addition of europium labeled anti-human IgG (Perkin Elmer), and further PBST washing. The time resolved fluorescence signal was collected. For Studies 3-5, serum concentration was detected using a similar ELISA, but recombinant VEGF (VEGF-165, PeproTech, Rocky Hill, NJ) was used as capture reagent and detection was carried out with biotinylated anti-human kappa antibody and europium-labeled streptavidin. PK parameters were determined for individual mice with a non-compartmental model using WinNonLin (Pharsight Inc, Mountain View CA). Nominal times and dose were used with uniform weighing of points. The time points used (lambda Z ranges) were from 4 days to the end of the study, although all time points were used for the faster clearing mutants, P257N and P257L.

**[202]** Five antibody PK studies in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice were carried out. Figure 13 shows serum concentration data for WT and variant IgG1 (Study 3) and IgG2 (Study 5) antibodies respectively. Fitted PK parameters from all in vivo PK studies carried out in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice are provided in Figure 14. PK data include half-life, which represents the beta phase that characterizes elimination of antibody from serum, C<sub>max</sub>, which represents the maximal observed serum concentration, AUC, which represents the area under the concentration time curve, and clearance, which represents the clearance of antibody from serum. Also provided for each variant is the calculated fold improvement or reduction in half-life relative to the IgG1 or IgG2 parent antibody [Fold half-life = half-life(variant) / half-life (WT)].

**[203]** The data show that a number of the engineered Fc variant antibodies with enhanced FcRn affinity at pH 6.0 extend half-life in vivo. Figure 15a shows a plot of the in vivo half-life versus the fold FcRn binding for the IgG1 antibodies, with select variants labeled. Results from repeat experiments (circled in the figure) indicate that data from the in vivo model are reproducible. The

best single variants include 308F and 434S, the best double variants include 259I/308F, 308F/428L, 308F/434S, and 428L/434S, and the best triple variant is 259I/308F/428L. There is a general correlation between affinity for FcRn and in vivo half-life, but it is not completely predictive. Notably, variants 257L and 257N, which improved FcRn binding by 3.4 and 3.5 –fold respectively, reduced in vivo half-life by 0.6 and 0.3 respectively. The plot also highlights again the importance of the amino acid identity of substitution at a given position – whereas 308F/434S provided substantial half-life improvement, 308F/434M was barely better than WT IgG1.

**[204]** Figure 15b shows a plot of the in vivo half-life versus fold FcRn binding for the IgG2 variant antibodies with the variants labeled. When the IgG2 in vivo data were compared with the IgG1 in vivo data (Figure 15c), a surprising result was observed. The variants provided a substantially greater improvement to in vivo half-life in the context of an IgG2 Fc region than they do an IgG1 Fc region. The longest single variant and double variant half-lives from all antibodies in all 5 studies were 12.2 and 16.5, provided by 434S IgG2 and 428L/434S IgG2 respectively. The dramatic improvement in half-lives for the IgG2 variants relative to IgG1 were despite the fact that fold-improvements by the variants in IgG2 were comparable or even lower than they were in IgG1 (434S IgG1 fold = 3.8, 434S IgG2 fold = 4.9, 428L/434S IgG1 fold = 17.3, 428L/434S IgG2 fold = 14.8). Thus unexpectedly, the IgG2 antibody may be the best application for the Fc variants for improving in vivo half-life in mammals.

#### EXAMPLE 6. Variant immunoadhesins

**[205]** The Fc variants of the invention were also evaluated for their capacity to improve the half-life of immunoadhesins (also referred to as Fc fusions). Select Fc variants were engineered into the anti-TNF immunoadhesion etanercept (Enbrel®). Etanercept is a fusion of human TNF receptor 2 (TNF RII) and the Fc region of human IgG1, and is clinically approved for the treatment of rheumatoid arthritis, juvenile idiopathic arthritis, ankylosing spondylitis, psoriatic arthritis, and psoriasis. An IgG2 Fc region version of this Fc fusion was also constructed, and select Fc variants were constructed in this context as well. The amino acid sequences of the anti-TNF immunoadhesins characterized in the invention are provided in Figure 16. Genes were constructed using recursive PCR and subcloned into the pTT5 vector, and Fc variants were constructed using QuikChange® mutagenesis methods. Immunoadhesins were expressed in 293E cells and purified as described above.

**[206]** The binding specificity of the purified immunoadhesins was confirmed by testing binding to recombinant TNF by Biacore. Immunoadhesins were captured onto an immobilized Protein A/G (Pierce) CM5 biosensor chip (Biacore), generated using standard primary amine coupling. Immunoadhesins were immobilized on the Protein A/G surface, and recombinant TNF in serial dilutions was injected over antibody bound surface, followed by a dissociation phase. After each cycle, the surface was regenerated with buffer. Data were processed by zeroing time and response before the injection of receptor and by subtracting from a reference channel to account

for changes due to injections. Kinetic data were fit to a 1:1 binding model (Langmuir). Equilibrium association constants ( $K_a$ 's) obtained from these fits are provided in Figure 17. The results show that the variant immunoadhesins retained affinity for TNF, comparable to commercial enbrel.

**[207]** Variant immunoadhesins were tested for binding to human FcRn at pH 6.0 using Biacore as described above. The results (Figure 18) indicate that, similar as in the context of antibodies, the variants improve binding to FcRn relative to their IgG1 and IgG2 parent immunoadhesin proteins.

**[208]** The half-lives of the variant immunoadhesins were tested in the mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice as described above. 12 mice per group were injected at 2 mg/kg of variant and parent IgG1 immunoadhesin. Serum concentration was detected using an ELISA similar to that described above, except that goat anti-human TNF RII antibody was used as capture reagent; detection was carried out with biotinylated anti-human kappa antibody and europium-labeled streptavidin. Figure 19 shows serum concentration data for WT IgG1 Fc and variant Fc immunoadhesins. Fitted PK parameters, as described above, from the PK study are provided in Figure 20. Also provided for each variant is the calculated % increase in half-life, calculated as 100 times the half-life of variant Fc fusion over that of the WT IgG1 Fc parent. The results indicate that the variants extend in vivo half-life in the context of the immunoadhesin.

#### EXAMPLE 7. Pharmacokinetic experiment in nonhuman primates

**[209]** The PK properties of biologics in non-human primates are well-established to be predictive of their properties in humans. A PK study was carried out in cynomolgus monkeys (*macaca fascicularis*) in order to evaluate the capacity of the variant anti-VEGF antibodies to improve serum half-life in non-human primates.

**[210]** In preparation for a PK study in cynomolgus monkeys, binding of the variant antibodies to cynomolgus (cyno) FcRn (cFcRn) at pH 6.0 was measured. cFcRn was constructed, expressed, and purified as described above for human FcRn. Binding of variant anti-VEGF antibodies to cFcRn was measured using Biacore as described above. The data are provided in Figure 21. The results show that the variants improve affinity for cyno FcRn similarly as they do for human FcRn. Dissociation at the higher pH (7.4) was also very rapid (data not shown), similar to as was observed for binding to human FcRn. These results are not surprising given the high sequence homology of the human and cyno receptors (FcRn alpha chain 96%, beta-2-microglobulin 91%).

**[211]** The PK of the variants were studied in vivo in non-human primates. Male cynomolgus monkeys (*macaca fascicularis*, also called crab-eating Macaque) weighing 2.3-5.1kg were randomized by weight and divided into 5 groups with 3 monkeys per group. The monkeys were given a single, 1 hour peripheral vein infusion of 4 mg/kg antibody. Blood samples (1 ml) were drawn from a separate vein from 5 minutes to 90 days after completion of the infusion, processed to serum and stored at -70C. Animals were not harmed during these studies.

**[212]** Antibody concentrations were determined using the VEGF capture method as described above. PK parameters were determined by fitting the concentrations versus time to a non-compartmental model as was done in the mouse PK studies. However, time points from day 10 to day 90 were used for PK parameter determinations. The PK results are plotted in Figure 22, and the fitted parameters are provided in Figure 23. The results show that the variants enhanced the in vivo half-life of antibody up to 3.2-fold. In the best case (the 428L/434S variant) half-life was extended from 9.7 days to 31.1 days. The PK results obtained in cynomolgus monkeys are consistent with those obtained in mFcRn<sup>-/-</sup> hFcRn<sup>+</sup> mice, validating the hFcRn mouse model as a system for assessing the in vivo PK properties of the variants, and supporting the conclusions from those studies.

**[213]** Whereas particular embodiments of the invention have been described above for purposes of illustration, it will be appreciated by those skilled in the art that numerous variations of the details may be made without departing from the invention as described in the appended claims. All references cited herein are incorporated in their entirety.

**CLAIMS**

We claim:

1. A variant Fc region comprising at least one modification relative to a wild-type human Fc region, wherein said modification selected from the group consisting of: 252Y/428L, 252Y/434S, and 428L/434S, wherein numbering is according to the EU index.
2. A variant according to claim 1, wherein said modification is 428L/434S.
3. A variant according to claim 1, wherein said modification is 252Y/428L.
4. A variant according to claim 1, wherein said modification is 252Y/434S.
5. A variant according to claim 1, wherein said variant comprises an antibody or immunoadhesin, and wherein said Fc region is selected from the group consisting of: IgG1, IgG2, IgG3, and IgG4.
6. A variant according to claim 5, wherein said variant comprises an IgG1 Fc region.
7. A variant according to claim 5, wherein said variant comprises an IgG2 Fc region.
8. A variant according to claim 5, wherein said variant has longer serum half-life in a mammal relative to said antibody or immunoadhesin with said wild-type Fc region.
9. A variant according to claim 8, wherein said mammal is a mouse expressing human FcRn or a non-human primate.
10. A variant according to claim 8, wherein said mammal is human.
11. A variant according to claim 5, wherein said antibody or immunoadhesin has specificity for an antigen selected from the group consisting of: vascular endothelial growth factor (VEGF), tumor necrosis factor  $\alpha$  (TNF- $\alpha$ ), CD25, epidermal growth factor receptor (EGFR) and IgE.
12. A variant antibody or variant immunoadhesin comprising a variant of an IgG2 Fc region, wherein said variant antibody or immunoglobulin comprises between one and five modifications relative to the wild-type IgG2 Fc region, wherein at least one of said modifications is at position 434, wherein numbering is according to the EU index, and wherein said variant antibody or variant immunoadhesin has longer serum half-life in a mammal relative to said antibody or immunoadhesin with said wild-type IgG2 Fc region.
13. A variant according to claim 12, wherein said variant comprises at least one modification at 434S and one modification at a position selected from the group consisting of: 252 and 428.
14. A variant according to claim 12, wherein said mammal is a mouse expressing human FcRn or a non-human primate.
15. A variant according to claim 12, wherein said mammal is human.
16. A variant Fc region comprising at least two modifications relative to a wild-type human Fc region, wherein at least one modification is 428L, and at least one modification is at position 252 or 434, wherein numbering is according to the EU index,
17. A variant according to claim 16, wherein said Fc region comprises an antibody or immunoadhesin, and wherein said antibody or immunoadhesin comprises an IgG1 or IgG2 Fc region, and wherein said variant has longer serum half-life in a mammal relative to said antibody or

immunoadhesin with said wild-type human Fc region, wherein said mammal is a mouse expressing human FcRn, a non-human primate, or in humans.

Figure 1

<b>CH1</b>	
<b>EU Index</b>	118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138
<b>IgG1</b>	A S T K G P S V F P L A P S S K S T S G G
<b>IgG2</b>	A S T K G P S V F P L A P <span>C</span> S <span>R</span> S T S <span>E</span> <span>S</span>
<b>IgG3</b>	A S T K G P S V F P L A P <span>C</span> S <span>R</span> S T S G G
<b>IgG4</b>	A S T K G P S V F P L A P <span>C</span> S <span>R</span> S T S <span>E</span> <span>S</span>
<b>EU Index</b>	139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159
<b>IgG1</b>	T A A L G C L V K D Y F P E P V T V S W N
<b>IgG2</b>	T A A L G C L V K D Y F P E P V T V S W N
<b>IgG3</b>	T A A L G C L V K D Y F P E P V T V S W N
<b>IgG4</b>	T A A L G C L V K D Y F P E P V T V S W N
<b>EU Index</b>	160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180
<b>IgG1</b>	S G A L T S G V H T F P A V L Q S S G L Y
<b>IgG2</b>	S G A L T S G V H T F P A V L Q S S G L Y
<b>IgG3</b>	S G A L T S G V H T F P A V L Q S S G L Y
<b>IgG4</b>	S G A L T S G V H T F P A V L Q S S G L Y
<b>EU Index</b>	181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201
<b>IgG1</b>	S L S S V V T V P S S S L G T Q T Y I C N
<b>IgG2</b>	S L S S V V T V P S S <span>N</span> <span>F</span> G T Q T Y <span>T</span> C N
<b>IgG3</b>	S L S S V V T V P S S S L G T Q T Y <span>T</span> C N
<b>IgG4</b>	S L S S V V T V P S S S L G T <span>K</span> T Y <span>T</span> C N
<b>EU Index</b>	202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220
<b>IgG1</b>	V N H K P S N T K V D K <span>K/R</span> V E P K S C
<b>IgG2</b>	V <span>D</span> H K P S N T K V D K <span>T</span> V E <span>R</span> K <span>C</span> C
<b>IgG3</b>	V N H K P S N T K V D K <span>R</span> V E <span>L</span> K <span>T</span> <span>P</span>
<b>IgG4</b>	V <span>D</span> H K P S N T K V D K <span>R</span> V E <span>S</span> K <span>Y</span> <span>G</span>
<b>Hinge</b>	
<b>EU Index</b>	221 222 223 224 225 226 227 228
<b>IgG1</b>	D K T H T C P P
<b>IgG2</b>	<span></span> <span>V</span> <span></span> <span>E</span> <span></span> C P P
<b>IgG3</b>	<span>L</span> <span>G</span> <span>D</span> <span>T</span> <span>T</span> <span>H</span> <span>T</span> C P <span>R</span> <span>C</span> <span>P</span> <span>E</span> <span>P</span> <span>K</span> <span>S</span> <span>C</span> <span>D</span> <span>T</span> <span>P</span> <span>P</span>
<b>IgG4</b>	<span></span> <span></span> <span></span> <span></span> <span>P</span> <span>P</span> C P <span>S</span>
<b>EU Index</b>	
<b>IgG1</b>	
<b>IgG2</b>	
<b>IgG3</b>	<span>P</span> <span>C</span> <span>P</span> <span>R</span> <span>C</span> <span>P</span> <span>E</span> <span>P</span> <span>K</span> <span>S</span> <span>C</span> <span>D</span> <span>T</span> <span>P</span> <span>P</span> <span>P</span> <span>C</span> <span>P</span> <span>R</span> <span>C</span> <span>P</span>
<b>IgG4</b>	
<b>EU Index</b>	229 230 231 232 233 234 235 236
<b>IgG1</b>	C P A P E L L G
<b>IgG2</b>	C P A P <span>P</span> <span>V</span> <span>A</span> <span></span>
<b>IgG3</b>	<span>E</span> <span>P</span> <span>K</span> <span>S</span> <span>C</span> <span>D</span> <span>T</span> <span>P</span> <span>P</span> <span>P</span> <span>C</span> <span>P</span> <span>R</span> C P A P E L L G
<b>IgG4</b>	C P A P E <span>F</span> L G

Figure 1 (continued)

CH2																																							
EU Index	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257																		
IgG1	G	P	S	V	F	L	F	P	P	K	P	K	D	T	L	M	I	S	R	T	P																		
IgG2	G	P	S	V	F	L	F	P	P	K	P	K	D	T	L	M	I	S	R	T	P																		
IgG3	G	P	S	V	F	L	F	P	P	K	P	K	D	T	L	M	I	S	R	T	P																		
IgG4	G	P	S	V	F	L	F	P	P	K	P	K	D	T	L	M	I	S	R	T	P																		
EU Index	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278																		
IgG1	E	V	T	C	V	V	V	D	V	S	H	E	D	P	E	V	K	F	N	W	Y																		
IgG2	E	V	T	C	V	V	V	D	V	S	H	E	D	P	E	V	Q	F	N	W	Y																		
IgG3	E	V	T	C	V	V	V	D	V	S	H	E	D	P	E	V	Q	F	K	W	Y																		
IgG4	E	V	T	C	V	V	V	D	V	S	Q	E	D	P	E	V	Q	F	N	W	Y																		
EU Index	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299																		
IgG1	V	D	G	V	E	V	H	N	A	K	T	K	P	R	E	E	Q	Y	N	S	T																		
IgG2	V	D	G	VM	E	V	H	N	A	K	T	K	P	R	E	E	Q	F	N	S	T																		
IgG3	V	D	G	V	E	V	H	N	A	K	T	K	P	R	E	E	Q	Y	N	S	T																		
IgG4	V	D	G	V	E	V	H	N	A	K	T	K	P	R	E	E	Q	F	N	S	T																		
EU Index	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320																		
IgG1	Y	R	V	V	S	V	L	T	V	L	H	Q	D	W	L	N	G	K	E	Y	K																		
IgG2	F	R	V	V	S	V	L	T	V	V	H	Q	D	W	L	N	G	K	E	Y	K																		
IgG3	F	R	V	V	S	V	L	T	V	L	H	Q	D	W	L	N	G	K	E	Y	K																		
IgG4	Y	R	V	V	S	V	L	T	V	L	H	Q	D	W	L	N	G	K	E	Y	K																		
EU Index	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340																			
IgG1	C	K	V	S	N	K	A	L	P	A	P	I	E	K	T	I	S	K	A	K																			
IgG2	C	K	V	S	N	K	Q	L	P	A	P	I	E	K	T	I	S	K	T	K																			
IgG3	C	K	V	S	N	K	A	L	P	A	P	I	E	K	T	I	S	K	T	K																			
IgG4	C	K	V	S	N	K	Q	L	P	S	S	I	E	K	T	I	S	K	A	K																			
CH3																																							
EU Index	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361																		
IgG1	G	Q	P	R	E	P	Q	V	Y	T	L	P	P	S	R	D/E	E	LM	T	K	N																		
IgG2	G	Q	P	R	E	P	Q	V	Y	T	L	P	P	S	R	E	E	M	T	K	N																		
IgG3	G	Q	P	R	E	P	Q	V	Y	T	L	P	P	S	R	E	E	M	T	K	N																		
IgG4	G	Q	P	R	E	P	Q	V	Y	T	L	P	P	S	Q	E	E	M	T	K	N																		
EU Index	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382																		
IgG1	Q	V	S	L	T	C	L	V	K	G	F	Y	P	S	D	I	A	V	E	W	E																		
IgG2	Q	V	S	L	T	C	L	V	K	G	F	Y	P	S	D	I	A	V	E	W	E																		
IgG3	Q	V	S	L	T	C	L	V	K	G	F	Y	P	S	D	I	A	V	E	W	E																		
IgG4	Q	V	S	L	T	C	L	V	K	G	F	Y	P	S	D	I	A	V	E	W	E																		
EU Index	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403																		
IgG1	S	N	G	Q	P	E	N	N	Y	K	T	T	P	P	V	L	D	S	D	G	S																		
IgG2	S	N	G	Q	P	E	N	N	Y	K	T	T	P	P	M	L	D	S	D	G	S																		
IgG3	S	S	G	Q	P	E	N	N	Y	N	T	T	P	P	M	L	D	S	D	G	S																		
IgG4	S	N	G	Q	P	E	N	N	Y	K	T	T	P	P	V	L	D	S	D	G	S																		
EU Index	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424																		
IgG1	F	F	L	Y	S	K	L	T	V	D	K	S	R	W	Q	Q	G	N	V	F	S																		
IgG2	F	F	L	Y	S	K	L	T	V	D	K	S	R	W	Q	Q	G	N	V	F	S																		
IgG3	F	F	L	Y	S	K	L	T	V	D	K	S	R	W	Q	Q	G	N	I	F	S																		
IgG4	F	F	L	Y	S	R	L	T	V	D	K	S	R	W	Q	E	G	N	V	F	S																		
EU Index	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445																		
IgG1	C	S	V	M	H	E	AVG	L	H	N	H	Y	T	Q	K	S	L	S	L	S	P																		
IgG2	C	S	V	M	H	E	A	L	H	N	H	Y	T	Q	K	S	L	S	L	S	P																		
IgG3	C	S	V	M	H	E	A	L	H	N	R	F	T	Q	K	S	L	S	L	S	P																		
IgG4	C	S	V	M	H	E	A	L	H	N	H	Y	T	Q	K	S	L	S	L	S	L																		
EU Index	446	447																																					
IgG1	G	K																																					
IgG2	G	K																																					
IgG3	G	K																																					
IgG4	G	K																																					



Figure 2

**Kappa constant light chain (C $\kappa$ ) (SEQ ID NO:1)**

RTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDS  
 TYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

**IgG1 constant heavy chain (CH1-hinge-CH2-CH3) (SEQ ID NO:2)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCPCPAPELLGGPSVFLFPPKPK  
 KDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQ  
 DWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDI  
 AVEWESNGQPENNYKTTTPVLDSGDSFFLYSKLTVDKSRWQQGNVFCFSVMHEALHNHYTQKS  
 LSLSPGK

**IgG2 constant heavy chain (CH1-hinge-CH2-CH3) (SEQ ID NO:3)**

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSNFGTQTYTCNVDHKPSNTKVDKTKVERKCCVECPPCAPPVAGPSVFLFPPKPKDTL  
 MISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLN  
 GKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVE  
 WESNGQPENNYKTTTPMLDSGDSFFLYSKLTVDKSRWQQGNVFCFSVMHEALHNHYTQKSLSL  
 SPGK

**IgG3 constant heavy chain (CH1-hinge-CH2-CH3) (SEQ ID NO:4)**

ASTKGPSVFPLAPCSRSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSSLGTQTYTCNVNHKPSNTKVDKRVELKTPLGDTTHTCPRCPEPKSCDTPPPCPRC  
 PEKSCDTPPPCPRCPEPKSCDTPPPCPRCPEPELLGGPSVFLFPPKPKDTLMISRTPEVTCVV  
 DVSHEDPEVQFKWYVDGVEVHNAKTKPREEQYNSTFRVSVLTVLHQDWLNGKEYKCKVSNKA  
 LPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESSGQPENNYN  
 TTPMLDSGDSFFLYSKLTVDKSRWQQGNIFCFSVMHEALHNRFQKSLSLSPGK

**IgG4 constant heavy chain (CH1-hinge-CH2-CH3) (SEQ ID NO:5)**

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSSLGKTYTCNVDHKPSNTKVDKRVESKYGPPCPSCPAPEFLGGPSVFLFPPKPKDT  
 LMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWL  
 NGKEYKCKVSNKGLPSSIEKTISKAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVE  
 WESNGQPENNYKTTTPVLDSGDSFFLYSRLTVDKSRWQEGNVFSCFSVMHEALHNHYTQKSLSL  
 SLGK

**IgG1/2 constant heavy chain (CH1-hinge-CH2-CH3)) (SEQ ID NO:6)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCPCPAAPPVAGPSVFLFPPKPK  
 DTLMISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQD  
 WLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIA  
 VEWESNGQPENNYKTTTPMLDSGDSFFLYSKLTVDKSRWQQGNVFCFSVMHEALHNHYTQKS  
 LSLSPGK

**Figure 3****IgG1 259I/308F (SEQ ID NO:7)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPVSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCTPPCPAPELLGGPSVFLFPPKP  
 KDTLMISRTPEITCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTLFQH  
 WLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIA  
 VEWESNGQPENNYKTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSL  
 SLSPGK

**IgG1 434S/428L (SEQ ID NO:8)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPVSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCTPPCPAPELLGGPSVFLFPPKP  
 KDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQ  
 DWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDI  
 AVEWESNGQPENNYKTPPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSL  
 SLSPGK

**IgG2 434S (SEQ ID NO:9)**

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSNFGTQTYTCNVNHHKPSNTKVDKTKVERKCCVECPPCAPPVAGPSVFLFPPKPKDTL  
 MISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLN  
 GKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVE  
 WESNGQPENNYKTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHSHYTQKSLSL  
 SPGK

**IgG2 434S/428L (SEQ ID NO:10)**

ASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPSSNFGTQTYTCNVNHHKPSNTKVDKTKVERKCCVECPPCAPPVAGPSVFLFPPKPKDTL  
 MISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLN  
 GKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVE  
 WESNGQPENNYKTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSL  
 SPGK

**IgG1/2 434S (SEQ ID NO:11)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPVSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCTPPCPAPPVAGPSVFLFPPKPK  
 DTLMISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQD  
 WLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIA  
 VEWESNGQPENNYKTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHSHYTQKSL  
 SLSPGK

**IgG1/2 434S/428L (SEQ ID NO:12)**

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSL  
 SSVVTPVSSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCTPPCPAPPVAGPSVFLFPPKPK  
 DTLMISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQD  
 WLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIA  
 VEWESNGQPENNYKTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSL  
 SLSPGK

Figure 4

**Anti-VEGF VH (SEQ ID NO:13)**

EVQLVESGGGLVQPGGSLRLSCAASGYTFTNYGMNWRQAPGKGLEWVGWINTYTGEPTYAA  
DFKRRFTFSLDTSKSTAYLQMNSLRAEDTAVYYCAKYPHYYGSSHWYFDVWGQGTLLTVSS

**Anti-VEGF VL (SEQ ID NO:14)**

DIQMTQSPSSLSASVGDRVTITCSASQDISNYLNWYQQKPGKAPKVLIIYFTSSLHSGVPSRFSGS  
SGSDFTLTISLQPEDFATYYCQQYSTVPWTFGQGTKVEIK

**Anti-TNF VH (SEQ ID NO:15)**

EVQLVESGGGLVQPGSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
VEGRFTISRDNKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTLLTVSS

**Anti-TNF VL (SEQ ID NO:16)**

DIQMTQSPSSLSASVGDRVTITCRASQGIRNYLAWYQQKPGKAPKLLIYAASLTQSGVPSRFSGS  
SGSDFTLTISLQPEDVATYYCQRYNRAPYTFGQGTKVEIK

**Anti-CD25 VH (SEQ ID NO:17)**

QVQLVQSGAEVKKPGASVKVSCKASGYTFTSYRMHWVRQAPGQGLEWMGWINPSTGYTEYNQ  
KFQGRVTITADKSISTAYMELSRLRSDDTAVYYCARGGGVFDYWGQGTLLTVSS

**Anti-CD25 VL (SEQ ID NO:18)**

QIVLTQSPATLSLSPGERATLSCRASSSISYMHWFQQKPGQSPQLLIYTTSNLASGVPARFSGSG  
SGTDYTLTISLQPEDFAVYYCHQRSTYPLTFGSGTKLEIK

**Anti-EGFR VH (SEQ ID NO:19)**

QVQLQQSGPGLVKPSQTLSTCTVSGFSLSNYGVHWVRQAPGKGLEWMGIWSSGSTDYSTSL  
KSRLTISKDTSKSQVLTMTNMDPVDATYYCARALTYDYEFAYWGQGTLLTVSS

**Anti-EGFR VL (SEQ ID NO:20)**

DIQLTQSPSSLSASVGDRVTITCRASQSISSNLHWYQQKPDQSPKLLIKYASESISGVPSRFSGSG  
SGTDFTLTISLQAEDVAVYYCQQNNNWPTTFGQGTKLEIK

**Anti-IgE VH (SEQ ID NO:21)**

EVQLVESGGGLVQPGGSLRLSCAVSGYSITSGYSWNWIRQAPGKGLEWVASITYDGSTNYPNSV  
KGRITISRDDSKNTFYLMNSLRAEDTAVYYCARGSHYFGHWHFAVWGQGTLLTVSS

**Anti-IgE VL (SEQ ID NO:22)**

DIQLTQSPSSLSASVGDRVTITCRASQSVDDYDGDSYMNWYQQKPGKAPKLLIYAASYLESGVPSR  
FSGSGSGTDFTLTISLQPEDFATYYCQSHEDPYTFGQGTKVEIK

Figure 5

**Anti-TNF light chain (SEQ ID NO:23)**

DIQMTQSPSSLSASVGDRTITCRASQGIRNYLAWYQQKPGKAPKLLIYAASLTQSGVPSRFSGS  
 GSGTDFLTITSLQPEDVATYYCQRYNRPYTFGGGTKVEIKRTVAAPSVFIFPPSDEQLKSGTAS  
 VVCLLNFPYFREAKVQWKVDNALQSGNSQESVTEQDSKSTYLSSTLTLSKADYEKHKVYACE  
 VTHQGLSSPVTKSFNRGEC

**Anti-TNF heavy chain IgG1 259I/308F (SEQ ID NO:24)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRTISRDNNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTTLTVSSASTKGPS  
 VFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTP  
 SSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCPPCPAPELLGGPSVFLFPPKPKDTLMISR  
 TPEITCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTLHQQDWLNGKEY  
 KCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESN  
 GQPENNYKTTTPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

**Anti-TNF heavy chain IgG1 434S/428L (SEQ ID NO:25)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRTISRDNNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTTLTVSSASTKGPS  
 VFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTP  
 SSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCPPCPAPELLGGPSVFLFPPKPKDTLMISR  
 TPEVTCVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKE  
 YKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESN  
 GQPENNYKTTTPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSLSPGK

**Anti-TNF heavy chain IgG2 434S (SEQ ID NO:26)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRTISRDNNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTTLTVSSASTKGPS  
 VFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTP  
 SSNFGTQTYTCNVDHKPSNTKVDKTVKCCVECPPCPAPPVAGPSVFLFPPKPKDTLMISRTP  
 VTCVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEYKC  
 KVSNGKLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQ  
 PENNYKTTTPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSLSPGK

**Anti-TNF heavy chain IgG2 434S/428L (SEQ ID NO:27)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRTISRDNNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTTLTVSSASTKGPS  
 VFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTP  
 SSNFGTQTYTCNVDHKPSNTKVDKTVKCCVECPPCPAPPVAGPSVFLFPPKPKDTLMISRTP  
 VTCVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEYKC  
 KVSNGKLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQ  
 PENNYKTTTPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSLSPGK

**Anti-TNF heavy chain IgG1/2 434S (SEQ ID NO:28)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRTISRDNNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTTLTVSSASTKGPS  
 VFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTP  
 SSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTCPPCPAPPVAGPSVFLFPPKPKDTLMISRT  
 PEVTCVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEY  
 KCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESN  
 GQPENNYKTTTPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSLSPGK

Figure 5 (continued)

**Anti-TNF heavy chain IgG1/2 434S/428L (SEQ ID NO:29)**

EVQLVESGGGLVQPGRSLRLSCAASGFTFDDYAMHWVRQAPGKGLEWWSAITWNSGHIDYADS  
 VEGRFTISRDNAKNSLYLQMNSLRAEDTAVYYCAKVSYLSTASSLDYWGQGTLLVTVSSASTKGPS  
 VFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVP  
 SSSLGTQTYICNVNHKPSNTKVDKKVEPKSCDKHTHTCPPCPAPPVAGPSVFLFPPKPKDTLMISRT  
 PEVTCVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVVSVLTVVHQDWLNGKEY  
 KCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESN  
 GQPENNYKTPPMLDSGSFFLYSKLTVDKSRWQQGNVFSCSVLHEALHSHYTQKSLSLSPGK

Figure 6

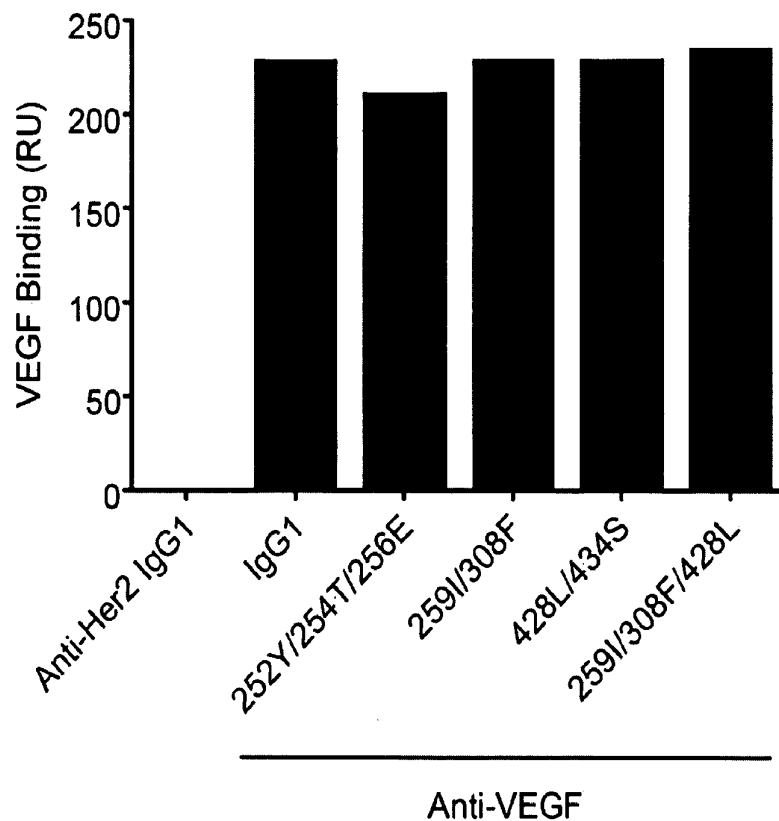


Figure 7

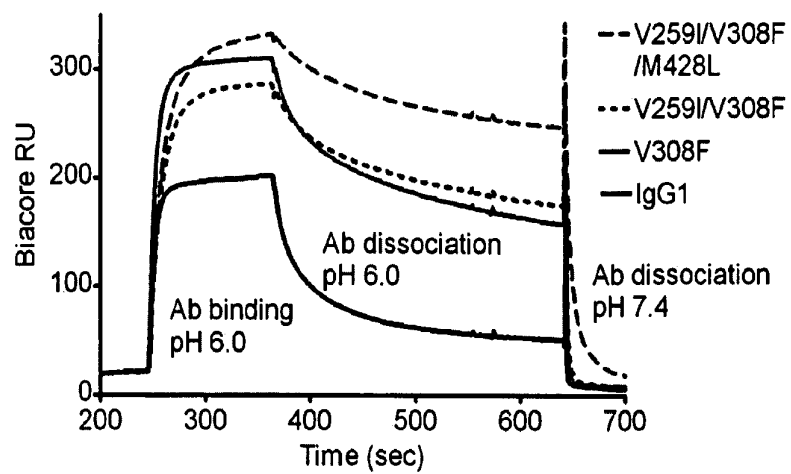


Figure 8

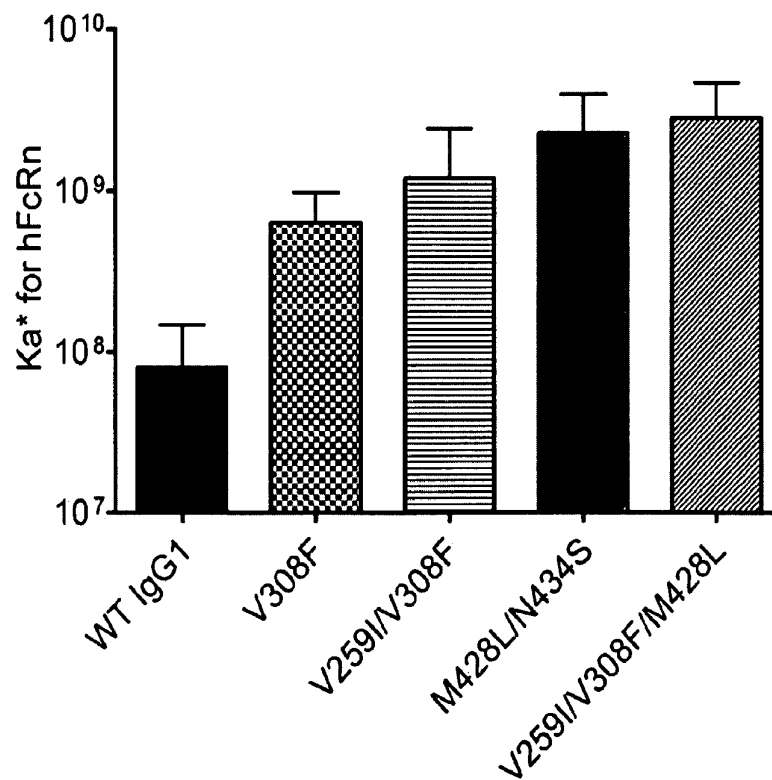


Figure 9

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1	Anti-VEGF		1.00	
T250I	IgG1	Anti-VEGF	1	1.31	
M252Q	IgG1	Anti-VEGF	5	2.36	3.07
M252Y	IgG1	Anti-VEGF	2	4.82	0.62
M252E	IgG1	Anti-VEGF	1	NB	
M252P	IgG1	Anti-VEGF	1	0.03	
M252R	IgG1	Anti-VEGF	1	0.02	
M252D	IgG1	Anti-VEGF	1	NB	
M252K	IgG1	Anti-VEGF	1	0.64	
R255Y	IgG1	Anti-VEGF	1	1.24	
P257L	IgG1	Anti-VEGF	1	3.39	
P257N	IgG1	Anti-VEGF	1	3.53	
V259I	IgG1	Anti-VEGF	2	1.14	0.19
V259F	IgG1	Anti-VEGF	1	1.44	
V259G	IgG1	Anti-VEGF		ND	
V259H	IgG1	Anti-VEGF		ND	
V259M	IgG1	Anti-VEGF	1	0.68	
V259N	IgG1	Anti-VEGF	1	1.87	
V259S	IgG1	Anti-VEGF		ND	
V259T	IgG1	Anti-VEGF		ND	
V259W	IgG1	Anti-VEGF		ND	
V259Y	IgG1	Anti-VEGF		ND	
T307Q	IgG1	Anti-VEGF	1	3.41	
T307N	IgG1	Anti-VEGF	1	0.83	
T307G	IgG1	Anti-VEGF	1	1.72	
V308F	IgG1	Anti-VEGF	6	4.96	1.06
Y319L	IgG1	Anti-VEGF	1	1.43	
Y319I	IgG1	Anti-VEGF	2	1.48	0.53
Y319A	IgG1	Anti-VEGF	1	2.66	
Y319G	IgG1	Anti-VEGF		ND	
Y319H	IgG1	Anti-VEGF	1	1.81	
Y319M	IgG1	Anti-VEGF	1	1.95	
Y319N	IgG1	Anti-VEGF		ND	
Y319Q	IgG1	Anti-VEGF		ND	
Y319S	IgG1	Anti-VEGF		ND	
Y319T	IgG1	Anti-VEGF		ND	
Y319V	IgG1	Anti-VEGF	1	2.03	

Figure 9 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
Y319W	IgG1	Anti-VEGF	1	1.51	
E380A	IgG1	Anti-VEGF		ND	
E380Q	IgG1	Anti-VEGF	1	2.01	
E380R	IgG1	Anti-VEGF	1	3.41	
E380S	IgG1	Anti-VEGF	1	2.55	
E380V	IgG1	Anti-VEGF		ND	
M428L	IgG1	Anti-VEGF	3	3.00	0.37
N434A	IgG1	Anti-VEGF	4	2.15	0.54
N434S	IgG1	Anti-VEGF	6	3.77	0.79
N434M	IgG1	Anti-VEGF	3	4.83	1.23
N434T	IgG1	Anti-VEGF	1	3.32	
N434V	IgG1	Anti-VEGF		ND	
N434Y	IgG1	Anti-VEGF		ND	
P245G/V308F	IgG1	Anti-VEGF	1	2.89	
T250I/V308F	IgG1	Anti-VEGF	2	6.75	0.10
T250Q/M428L	IgG1	Anti-VEGF	3	6.30	0.82
M252Y/V259I	IgG1	Anti-VEGF	1	3.56	
M252Q/V259I	IgG1	Anti-VEGF	1	0.14	
M252Q/T307Q	IgG1	Anti-VEGF	1	0.43	
M252Q/V308F	IgG1	Anti-VEGF	1	1.04	
M252Y/V308F	IgG1	Anti-VEGF	2	9.63	0.32
M252Q/Y319I	IgG1	Anti-VEGF	1	0.21	
M252Y/Y319I	IgG1	Anti-VEGF	1	2.37	
M252Q/M428L	IgG1	Anti-VEGF	1	0.35	
M252Y/M428L	IgG1	Anti-VEGF	1	5.32	
M252Y/N434A	IgG1	Anti-VEGF	1	11.94	
M252Y/N434S	IgG1	Anti-VEGF	2	11.46	2.73
M252Q/N434M	IgG1	Anti-VEGF	1	0.20	
M252Q/N434S	IgG1	Anti-VEGF	1	0.48	
M252Y/N434M	IgG1	Anti-VEGF	1	2.79	
M252Y/N434Y	IgG1	Anti-VEGF	1	61.60	
S254T/V308F	IgG1	Anti-VEGF	1	3.56	
T256V/V308F	IgG1	Anti-VEGF	2	5.04	1.94
T256E/N434Y	IgG1	Anti-VEGF	1	35.53	
V259I/V308F	IgG1	Anti-VEGF	12	9.79	2.72
V259A/V308F	IgG1	Anti-VEGF	1	4.81	
V259L/V308F	IgG1	Anti-VEGF		ND	



Figure 9 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
V259I/Y319I	IgG1	Anti-VEGF	1	2.00	
V259I/M428L	IgG1	Anti-VEGF	1	4.53	
V259I/N434S	IgG1	Anti-VEGF	1	5.67	
V259I/N434M	IgG1	Anti-VEGF	1	0.87	
V259I/N434Y	IgG1	Anti-VEGF	1	24.81	
L306I/V308F	IgG1	Anti-VEGF	1	7.92	
T307P/V308F	IgG1	Anti-VEGF	1	3.17	
T307Q/V308F	IgG1	Anti-VEGF	2	5.57	0.69
T307S/V308F	IgG1	Anti-VEGF	1	5.22	
T307Q/M428L	IgG1	Anti-VEGF	1	7.25	
T307Q/N434S	IgG1	Anti-VEGF	1	14.18	
T307Q/N434M	IgG1	Anti-VEGF	1	1.99	
T307Q/N434Y	IgG1	Anti-VEGF	1	50.43	
V308F/L309Y	IgG1	Anti-VEGF	1	5.37	
V308F/L309N	IgG1	Anti-VEGF	1	1.00	
V308F/Q311P	IgG1	Anti-VEGF		ND	
V308F/Y319L	IgG1	Anti-VEGF	2	5.84	0.30
V308F/Y319F	IgG1	Anti-VEGF	1	3.10	
V308F/M428L	IgG1	Anti-VEGF	4	13.71	2.13
V308F/N434M	IgG1	Anti-VEGF	2	4.20	0.78
V308F/N434S	IgG1	Anti-VEGF	2	14.63	0.28
V308F/N434Y	IgG1	Anti-VEGF	1	41.55	
Q311A/N434Y	IgG1	Anti-VEGF	1	27.42	
Y319I/V308F	IgG1	Anti-VEGF	3	4.93	0.82
Y319I/M428L	IgG1	Anti-VEGF	1	4.70	
Y319I/N434M	IgG1	Anti-VEGF	1	4.22	
Y319I/N434S	IgG1	Anti-VEGF	1	4.42	
Y319I/N434Y	IgG1	Anti-VEGF		ND	
M428L/N434A	IgG1	Anti-VEGF	1	12.74	
M428L/N434S	IgG1	Anti-VEGF	14	17.28	6.70
M428L/N434M	IgG1	Anti-VEGF	1	1.88	
M428L/N434Y	IgG1	Anti-VEGF	1	39.54	
N434S/Y436F	IgG1	Anti-VEGF	1	4.43	
N434S/Y436M	IgG1	Anti-VEGF	1	2.58	
T250I/V259I/V308F	IgG1	Anti-VEGF	1	11.29	
T250Q/V308F/M428L	IgG1	Anti-VEGF	1	17.08	
T250I/V308F/N434S	IgG1	Anti-VEGF	1	12.26	

Figure 9 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
M252Y/S254T/T256E	IgG1	Anti-VEGF	10	11.37	2.90
M252Q/V259I/N434S	IgG1	Anti-VEGF	1	0.65	
M252Y/V308F/M428L	IgG1	Anti-VEGF	1	10.62	
M252Q/V308F/N434S	IgG1	Anti-VEGF	1	2.37	
M252Y/V308F/N434M	IgG1	Anti-VEGF	1	11.09	
M252Y/V308F/N434S	IgG1	Anti-VEGF	1	12.13	
M252Q/M428L/N434S	IgG1	Anti-VEGF	1	1.90	
V259I/T307Q/V308F	IgG1	Anti-VEGF	2	7.40	1.54
V259I/V308F/Y319L	IgG1	Anti-VEGF	1	3.53	
V259I/V308F/Y319I	IgG1	Anti-VEGF	1	4.10	
V259I/V308F/M428L	IgG1	Anti-VEGF	13	19.94	10.46
V259I/V308F/N434S	IgG1	Anti-VEGF	3	10.86	3.38
V259I/V308F/N434M	IgG1	Anti-VEGF	1	7.06	
V259I/Y319I/N434S	IgG1	Anti-VEGF	1	7.90	
V259I/M428L/N434S	IgG1	Anti-VEGF	1	9.57	
V259I/M428L/N434S	IgG1	Anti-VEGF	1	11.91	
T307Q/V308F/Y319L	IgG1	Anti-VEGF	1	4.24	
T307Q/V308F/N434S	IgG1	Anti-VEGF	1	4.04	
V308F/Y319I/M428L	IgG1	Anti-VEGF	1	10.20	
V308F/Y319L/M428L	IgG1	Anti-VEGF	1	NF	
V308F/Y319L/N434S	IgG1	Anti-VEGF	2	12.39	5.63
V308F/Y319I/N434M	IgG1	Anti-VEGF	1	3.78	
V308F/Y319I/N434S	IgG1	Anti-VEGF	1	NF	
V308F/M428L/N434S	IgG1	Anti-VEGF	5	16.68	4.89
V308F/M428L/N434M	IgG1	Anti-VEGF	1	8.14	
Y319I/M428L/N434S	IgG1	Anti-VEGF	1	13.90	
M252Y/S254T/T256E/N434A	IgG1	Anti-VEGF	1	11.37	
M252Y/S254T/T256E/N434S	IgG1	Anti-VEGF	2	10.29	2.99
M252Y/S254T/T256E/V308F	IgG1	Anti-VEGF	2	9.84	4.04
M252Y/S254T/T256E/M428L	IgG1	Anti-VEGF	2	11.43	6.01
M252Y/S254T/T256E/T307Q	IgG1	Anti-VEGF	1	13.50	
M252Y/S254T/T256E/N434M	IgG1	Anti-VEGF	1	3.62	
V259I/V308F/M428L/N434S	IgG1	Anti-VEGF	1	24.22	
V259I/V308F/M428L/N434S	IgG1	Anti-VEGF	2	14.23	0.75
V308F/Y319I/M428L/N434S	IgG1	Anti-VEGF	1	10.37	
M252Y/S254T/T256E/M428L/N434S	IgG1	Anti-VEGF	1	7.21	

Figure 10

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG2	Anti-VEGF		1.00	
V259I	IgG2	Anti-VEGF	1	1.02	
V308F	IgG2	Anti-VEGF	2	3.66	2.07
M428L	IgG2	Anti-VEGF	1	4.19	
N434A	IgG2	Anti-VEGF	1	3.83	
N434S	IgG2	Anti-VEGF	2	4.88	1.05
N434G	IgG2	Anti-VEGF	1	1.60	
N434H	IgG2	Anti-VEGF	1	1.45	
N434M	IgG2	Anti-VEGF	1	1.51	
N434T	IgG2	Anti-VEGF	1	1.22	
N434Y	IgG2	Anti-VEGF	1	21.39	
N434D	IgG2	Anti-VEGF	1	NB	
N434E	IgG2	Anti-VEGF	1	NB	
N434F	IgG2	Anti-VEGF	1	16.79	
N434K	IgG2	Anti-VEGF	1	NB	
N434P	IgG2	Anti-VEGF	1	0.26	
N434R	IgG2	Anti-VEGF	1	0.44	
N434V	IgG2	Anti-VEGF	1	0.48	
N434W	IgG2	Anti-VEGF	1	39.81	
T250Q/M428L	IgG2	Anti-VEGF	1	7.62	
V259I/V308F	IgG2	Anti-VEGF	1	6.58	
V308F/M428L	IgG2	Anti-VEGF	1	16.13	
V308F/N434S	IgG2	Anti-VEGF	1	16.36	
M428L/N434S	IgG2	Anti-VEGF	1	14.80	
M252Y/S254T/T256E	IgG2	Anti-VEGF	1	8.34	
V259I/V308F/M428L	IgG2	Anti-VEGF	1	15.29	

Figure 10 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1/2	Anti-VEGF		1.00	
N434S	IgG1/2	Anti-VEGF	1	5.28	
L251A/N434S	IgG1/2	Anti-VEGF	1	0.65	
L251F/N434S	IgG1/2	Anti-VEGF	1	1.95	
L251I/N434S	IgG1/2	Anti-VEGF	1	1.28	
L251M/N434S	IgG1/2	Anti-VEGF	1	2.83	
L251N/N434S	IgG1/2	Anti-VEGF	1	1.34	
L251V/N434S	IgG1/2	Anti-VEGF	1	2.31	
R255H/N434S	IgG1/2	Anti-VEGF	1	2.23	
R255Q/N434S	IgG1/2	Anti-VEGF	1	1.53	
T307I/N434S	IgG1/2	Anti-VEGF	1	4.09	
T307V/N434S	IgG1/2	Anti-VEGF	1	5.25	
Q311A/N434S	IgG1/2	Anti-VEGF	1	4.35	
Q311D/N434S	IgG1/2	Anti-VEGF	1	1.39	
Q311E/N434S	IgG1/2	Anti-VEGF	1	1.94	
Q311F/N434S	IgG1/2	Anti-VEGF	1	2.95	
Q311G/N434S	IgG1/2	Anti-VEGF	1	1.26	
Q311I/N434S	IgG1/2	Anti-VEGF	1	15.81	
Q311K/N434S	IgG1/2	Anti-VEGF	1	4.57	
Q311L/N434S	IgG1/2	Anti-VEGF	1	9.00	
Q311M/N434S	IgG1/2	Anti-VEGF	1	9.12	
Q311N/N434S	IgG1/2	Anti-VEGF	1	2.27	
Q311P/N434S	IgG1/2	Anti-VEGF	1	0.56	
Q311R/N434S	IgG1/2	Anti-VEGF	1	5.96	
Q311T/N434S	IgG1/2	Anti-VEGF	1	5.17	
Q311V/N434S	IgG1/2	Anti-VEGF	1	14.17	
Q311W/N434S	IgG1/2	Anti-VEGF	1	2.97	
Q311Y/N434S	IgG1/2	Anti-VEGF	1	2.65	
L314F/N434S	IgG1/2	Anti-VEGF	1	3.35	
L314I/N434S	IgG1/2	Anti-VEGF	1	3.54	
L314M/N434S	IgG1/2	Anti-VEGF	1	3.05	
L314Q/N434S	IgG1/2	Anti-VEGF	1	1.75	
L314V/N434S	IgG1/2	Anti-VEGF	1	2.34	
H429N/N434S	IgG1/2	Anti-VEGF	1	1.78	
H429V/N434S	IgG1/2	Anti-VEGF	1	0.69	
E430A/N434S	IgG1/2	Anti-VEGF	1	3.24	
E430D/N434S	IgG1/2	Anti-VEGF	1	1.79	

Figure 10 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
E430F/N434S	IgG1/2	Anti-VEGF	1	3.79	
E430I/N434S	IgG1/2	Anti-VEGF	1	5.27	
E430L/N434S	IgG1/2	Anti-VEGF	1	4.40	
E430Q/N434S	IgG1/2	Anti-VEGF	1	4.20	
E430S/N434S	IgG1/2	Anti-VEGF	1	2.58	
E430T/N434S	IgG1/2	Anti-VEGF	1	2.37	
A431F/N434S	IgG1/2	Anti-VEGF	1	5.21	
A431G/N434S	IgG1/2	Anti-VEGF	1	4.31	
A431H/N434S	IgG1/2	Anti-VEGF	1	6.29	
A431N/N434S	IgG1/2	Anti-VEGF	1	5.06	
A431S/N434S	IgG1/2	Anti-VEGF	1	3.18	
A431T/N434S	IgG1/2	Anti-VEGF	1	2.46	
A431V/N434S	IgG1/2	Anti-VEGF	1	4.64	
L432A/N434S	IgG1/2	Anti-VEGF	1	4.83	
L432F/N434S	IgG1/2	Anti-VEGF	1	1.14	
L432G/N434S	IgG1/2	Anti-VEGF	1	1.71	
L432H/N434S	IgG1/2	Anti-VEGF	1	1.69	
L432I/N434S	IgG1/2	Anti-VEGF	1	1.96	
L432N/N434S	IgG1/2	Anti-VEGF	1	1.43	
L432Q/N434S	IgG1/2	Anti-VEGF	1	1.59	
L432V/N434S	IgG1/2	Anti-VEGF	1	2.24	
H433A/N434S	IgG1/2	Anti-VEGF	1	2.41	
H433D/N434S	IgG1/2	Anti-VEGF	1	0.75	
H433E/N434S	IgG1/2	Anti-VEGF	1	0.73	
H433F/N434S	IgG1/2	Anti-VEGF	1	0.76	
H433I/N434S	IgG1/2	Anti-VEGF	1	0.94	
H433K/N434S	IgG1/2	Anti-VEGF	1	3.65	
H433L/N434S	IgG1/2	Anti-VEGF	1	1.14	
H433M/N434S	IgG1/2	Anti-VEGF	1	1.91	
H433P/N434S	IgG1/2	Anti-VEGF	1	6.33	
H433S/N434S	IgG1/2	Anti-VEGF	1	3.68	
H433T/N434S	IgG1/2	Anti-VEGF	1	0.88	
H433V/N434S	IgG1/2	Anti-VEGF	1	2.41	
H433Y/N434S	IgG1/2	Anti-VEGF	1	0.56	
N434S/Y436A	IgG1/2	Anti-VEGF	1	0.03	
N434S/Y436D	IgG1/2	Anti-VEGF	1	1.79	
N434S/Y436E	IgG1/2	Anti-VEGF	1	4.36	

Figure 10 (continued)

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
N434S/Y436G	IgG1/2	Anti-VEGF	1	4.24	
N434S/Y436H	IgG1/2	Anti-VEGF	1	7.63	
N434S/Y436I	IgG1/2	Anti-VEGF	1	30.57	
N434S/Y436K	IgG1/2	Anti-VEGF	1	9.00	
N434S/Y436L	IgG1/2	Anti-VEGF	1	12.81	
N434S/Y436N	IgG1/2	Anti-VEGF	1	0.39	
N434S/Y436Q	IgG1/2	Anti-VEGF	1	2.14	
N434S/Y436R	IgG1/2	Anti-VEGF	1	5.60	
N434S/Y436S	IgG1/2	Anti-VEGF	1	6.67	
N434S/Y436T	IgG1/2	Anti-VEGF	1	4.71	
N434S/Y436V	IgG1/2	Anti-VEGF	1	17.46	
N434S/Y436W	IgG1/2	Anti-VEGF	1	19.47	
N434S/T437I	IgG1/2	Anti-VEGF	1	2.96	
G236R/L328R	IgG1	Anti-VEGF	1	1.25	
V308F/I332E	IgG1	Anti-VEGF	1	4.15	
I332E/N434S	IgG1	Anti-VEGF	1	3.91	
G236A/V308F/I332E	IgG1/2 ELLG 327A	Anti-VEGF	1	1.82	
G236A/I332E/N434S	IgG1/2 ELLG 327A	Anti-VEGF	1	3.87	

Figure 11a

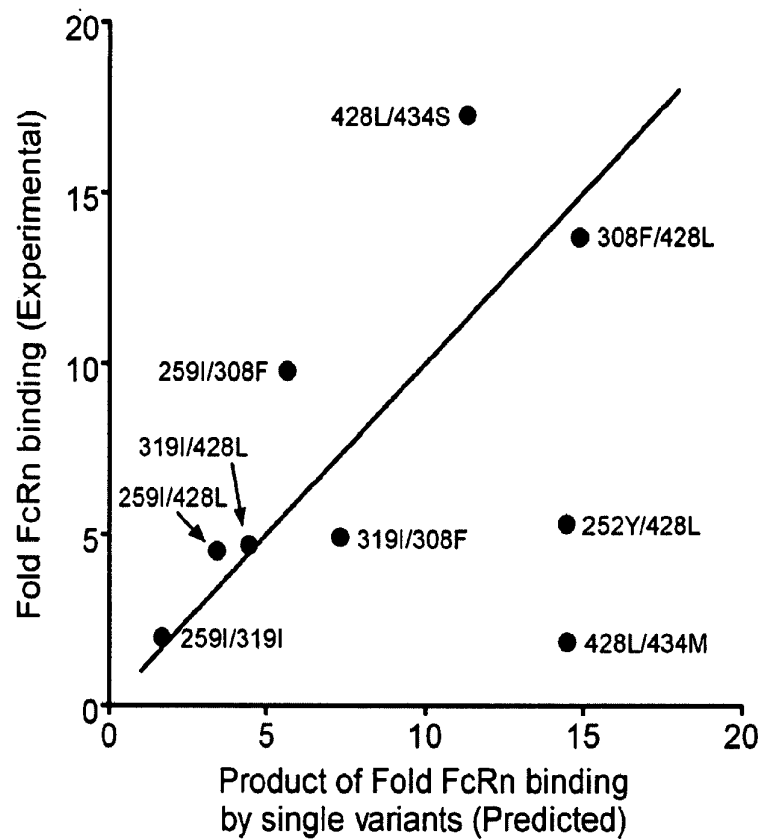


Figure 11b

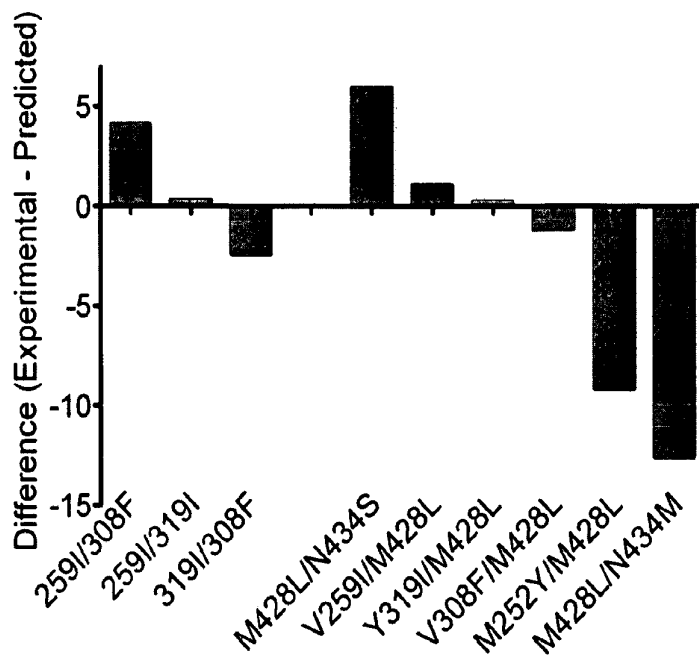


Figure 11c

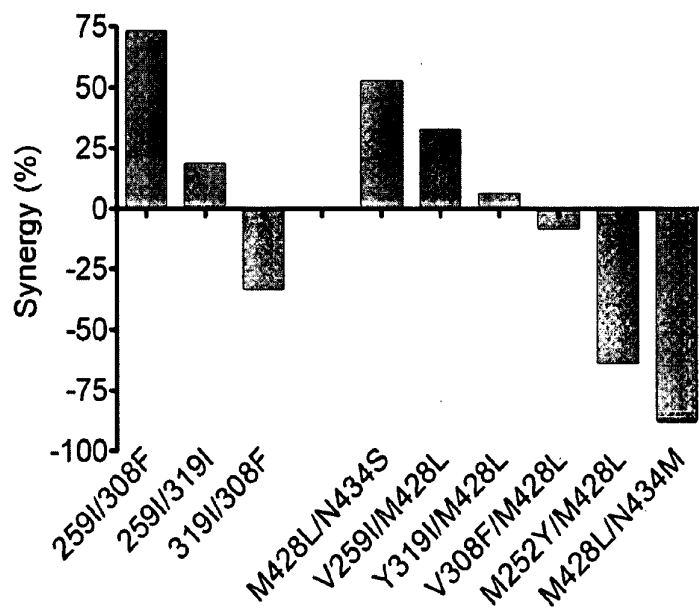




Figure 12a

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1	Anti-TNF		1.00	
V259I/V308F	IgG1	Anti-TNF	3	13.25	5.09
M428L/N434S	IgG1	Anti-TNF	2	19.76	4.42
V259I/V308F/M428L	IgG1	Anti-TNF	2	49.85	5.09
G236R/L328R	IgG1	Anti-TNF	1	0.99	
WT	IgG2	Anti-TNF		1.00	
N434S	IgG2	Anti-TNF	2	3.12	0.79
M428L/N434S	IgG2	Anti-TNF	3	19.99	8.69
L328R	IgG2	Anti-TNF	1	0.97	
L328R/M428L/N434S	IgG2	Anti-TNF	1	19.67	
WT	IgG1/2	Anti-TNF		1.00	
N434S	IgG1/2	Anti-TNF	2	7.22	0.16
M428L/N434S	IgG1/2	Anti-TNF	3	25.39	5.13
L328R	IgG1/2	Anti-TNF	1	1.87	
L328R/M428L/N434S	IgG1/2	Anti-TNF	1	39.90	

Figure 12b

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1	Anti-CD25		1.00	
V259I/V308F	IgG1	Anti-CD25	1	3.49	
V259I/V308F/M428L	IgG1	Anti-CD25	1	19.97	
WT	IgG1/2	Anti-CD25		1.00	
N434S	IgG1/2	Anti-CD25	1	5.16	
M428L/N434S	IgG1/2	Anti-CD25	1	28.00	

**Figure 12c**

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1	Anti-EGFR		1.00	
V259I/V308F	IgG1	Anti-EGFR	3	14.23	8.51
V259I/V308F/M428L	IgG1	Anti-EGFR	2	32.96	20.16
WT	IgG1/2	Anti-EGFR		1.00	
N434S	IgG1/2	Anti-EGFR	1	1.61	
N434S/M428L	IgG1/2	Anti-EGFR	1	5.93	

**Figure 12d**

Variant	IgG	Fv	n	Fold FcRn	
				Mean	SD
WT	IgG1	Anti-IgE		1.00	
M428L	IgG1	Anti-IgE	1	3.06	
N434S	IgG1	Anti-IgE	1	4.38	
V259I/V308F	IgG1	Anti-IgE	1	8.34	
V308F/Y319I	IgG1	Anti-IgE	1	5.39	
V308F/M428L	IgG1	Anti-IgE	1	14.25	
M428L/N434S	IgG1	Anti-IgE	1	12.63	
M252Y/S254T/T256E	IgG1	Anti-IgE	1	9.56	
V259I/V308F/M428L	IgG1	Anti-IgE	1	20.27	
V259I/V308F/M428L/N434S	IgG1	Anti-IgE	1	27.29	

Figure 13a

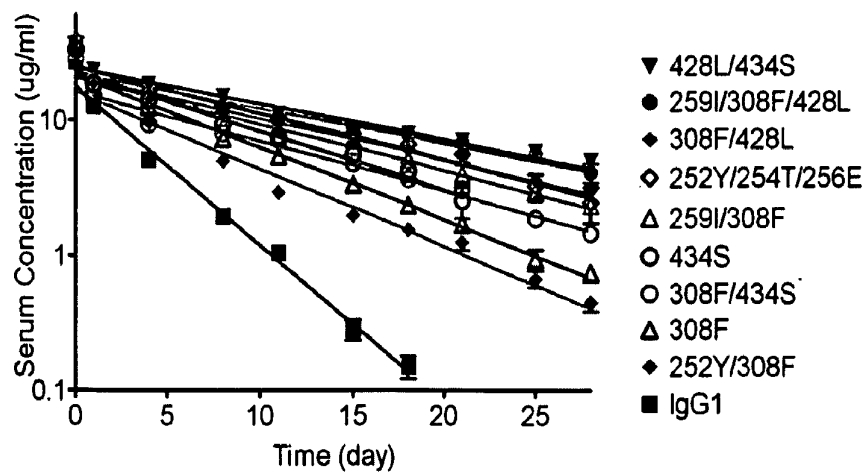


Figure 13b

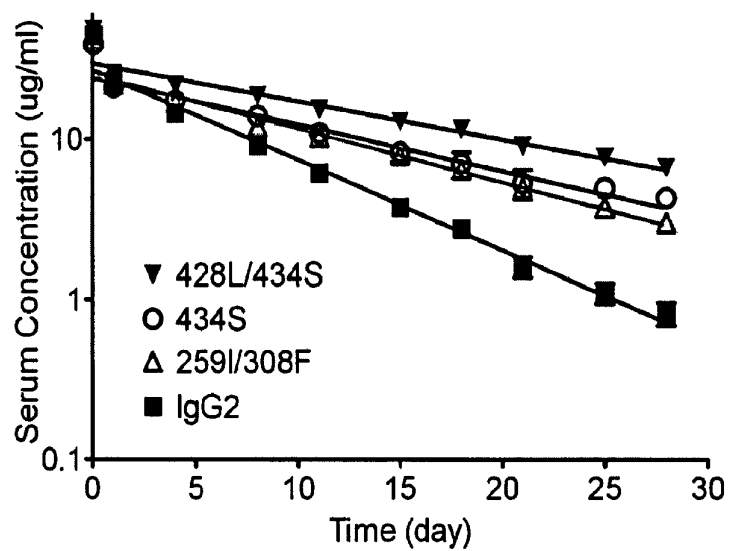


Figure 14

Fc variant	IgG	n	Half-Life			Cmax		AUC		Clearance	
			(day)			(ug/mL)		(day*ug/mL)		(mL/day/kg)	
			Mean	SD	Fold	Mean	SD	Mean	SD	Mean	SD
Study 1											
WT (Native IgG1)	IgG1	6	3	0.5	1.0	28.5	7.3	69.8	8.4	29.1	4.2
P257L	IgG1	6	1.9	0.4	0.6	18.1	8.4	38	11.3	59.5	28.8
P257N	IgG1	6	0.9	0.1	0.3	30.1	4.7	38.2	6.1	53.4	8.8
V308F	IgG1	6	4.9	0.3	1.6	30.1	9.4	129.2	11	15.6	1.3
T250Q/M428L	IgG1	6	8.4	2.8	2.8	22.3	3.8	186	52.5	12	5.4
M252Y/S254T/T256E	IgG1	4	10.9	1.2	3.6	34.6	10.1	330.8	57.3	6.2	1.1
N434A	IgG1	6	5.5	2.1	1.8	24.5	6.2	143.1	26.9	14.3	2.2
Study 2											
WT (Native IgG1)	IgG1	7	3.9	0.52	1.0	36	5.6	92	13	22	2.9
V308F	IgG1	7	6.8	0.99	1.7	28	8.7	152	34.6	14	3.4
M252T/S254T/T256E	IgG1	7	11.3	1.2	2.9	25	7	241	64.2	8.9	2.6
Study 3											
WT (Native IgG1)	IgG1	6	2.8	0.3	1.0	27	6	69	10	29.4	4.6
V308F	IgG1	6	5.9	0.4	2.1	33	3	173	33	11.8	1.9
M252T/S254T/T256E	IgG1	6	10.4	1.5	3.7	34	6	317	67	6.6	1.5
N434S	IgG1	6	7.7	1.5	2.8	33	11	228	75	10	4.6
V259I/V308F	IgG1	6	9.2	1.5	3.3	36	5	262	47	7.9	1.4
V308F/M428L	IgG1	6	11.2	1.1	4.0	38	6	307	50	6.7	1.1
M252Y/V308F	IgG1	6	5.7	0.4	2.0	40	6	140	24	14.7	2.6
M428L/N434S	IgG1	6	12	2.9	4.3	37	9	400	112	5.5	2
V308F/N434S	IgG1	6	8.6	0.3	3.1	28	3	195	25	10.4	1.3
V259I/V308F/M428L	IgG1	6	13.3	2.7	4.8	37	6	383	68	5.3	0.8

Figure 14 (continued)

Fc variant	IgG	n	Half-Life			Cmax		AUC		Clearance	
			(day)			(ug/mL)		(day*ug/mL)		(mL/day/kg)	
			Mean	SD	Fold	Mean	SD	Mean	SD	Mean	SD
Study 4											
WT (Native IgG1)	IgG1	6	2.9	0.4	1.0	32.5	3.1	72.7	5.8	27.6	2.3
M252Y/S254T/T256E	IgG1	6	11.3	1.8	3.9	40.6	5.8	376.5	60.7	5.4	0.8
V308F/N434M	IgG1	6	4.9	0.8	1.7	38.6	5.4	153.6	21.3	13.2	1.9
V259I/V308F	IgG1	6	7.5	0.8	2.6	37.9	3.8	234.5	23.1	8.6	0.9
V308F	IgG1	6	6.1	0.4	2.1	37.8	1.9	172.2	16.7	11.7	1.2
V308F/Y319I	IgG1	6	6	0.5	2.1	38.1	6.5	206.5	71	10.5	3.1
M428L/N434S	IgG1	6	11.8	0.6	4.1	42	4.6	392.4	52.2	5.2	0.7
V308F/M428L/N434S	IgG1	6	9	0.4	3.1	31.8	7.9	204.6	34.2	10	1.8
V259I/V308F/N434S	IgG1	6	8.5	1.8	2.9	33.4	7.3	254.9	29	7.9	0.9
V259I/V308F/M428L	IgG1	6	10.9	0.6	3.8	35	7.5	295.1	54.5	7	1.3
Study 5											
WT (Native IgG2)	IgG2	6	5.9	0.9	1.0	43.8	5	212.3	33.8	9.6	1.5
N434S	IgG2	6	12.2	1.3	2.1	39.1	6.4	381.6	91.6	5.5	1.2
V259I/V308F	IgG2	6	10.2	0.6	1.7	42.3	1.3	342	21.2	5.9	0.4
M428L/N434S	IgG2	6	16.5	1.1	2.8	48	5.8	603.3	72.9	3.4	0.4

Figure 15a

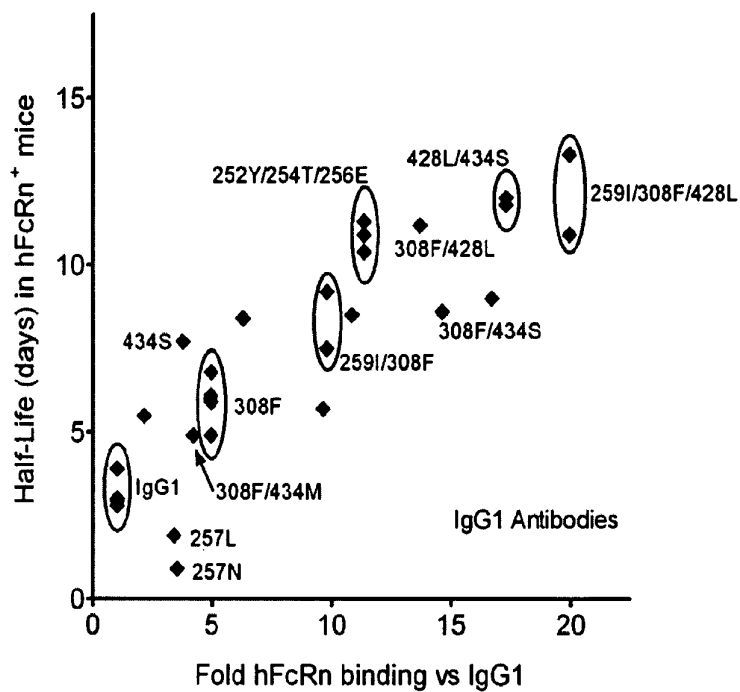


Figure 15b

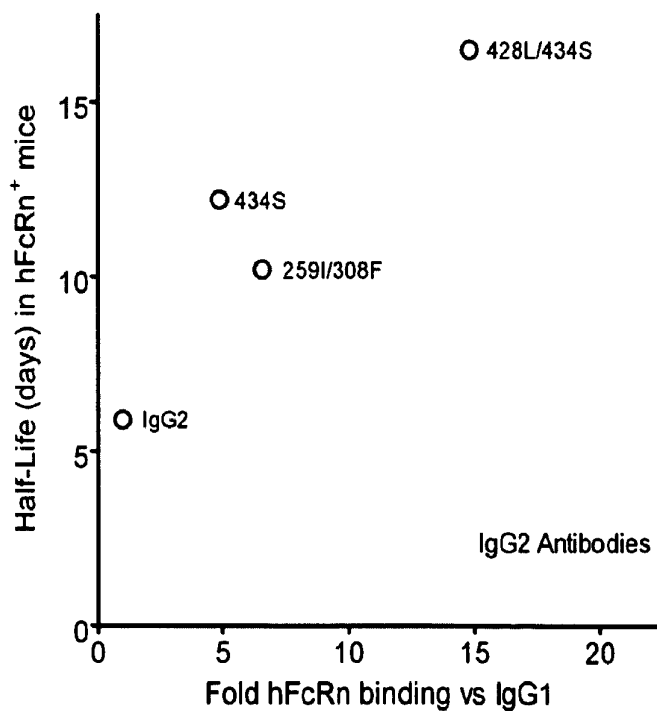


Figure 15c

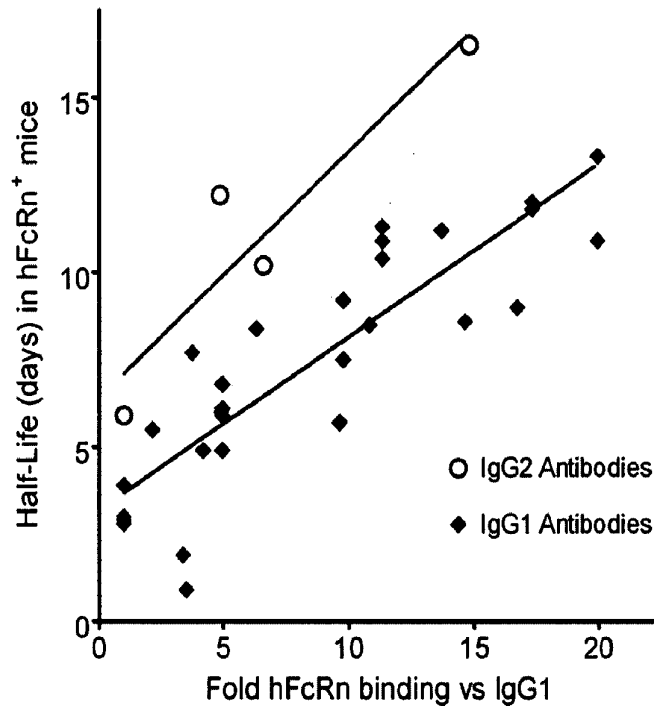


Figure 16

**Anti-TNF Fc fusion with IgG1 Fc (SEQ ID NO:30)**

MAPVAVWAALAVGLELWAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTCRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGPPSPPAEGST  
 GDEPKSCDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVDVSHEDPEVKFNWY  
 VDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYS  
 KLTVDKSRWQQGNVVFSCSVMHLEALHNHYTQKSLSLSPGK

**Anti-TNF Fc fusion with IgG2 Fc (SEQ ID NO:31)**

MAPVAVWAALAVGLELWAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTCRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGPPSPPAEGST  
 GDEPKSCDKTHTCPPCPAPPVAGPSVFLFPPKPKDTLMISRTPEVTCVVDVSHEDPEVQFNWY  
 VDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEYKCKVSNKGLPAPIEKTISKTKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPMLDSDGSFFLY  
 SKLTVDKSRWQQGNVVFSCSVMHLEALHNHYTQKSLSLSPGK

Figure 16 (continued)

**Anti-TNF Fc fusion with IgG1 259I/308F Fc (SEQ ID NO:32)**

MAPVAVWAALAVGLELWAAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGSPSPAEGST  
 GDEPKSCDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEITCVVVDVSHEDPEVKFNWY  
 VDGVEVHNAKTKPREEQYNSTYRVVSVLTLFQHQLNGKEYCKKVSNAKALPAPIEKTISKAKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSGDSFFLYS  
 KLTVDKSRWQQGNVFCFSVMHEALHNHYTQKSLSLSPGK

**Anti-TNF Fc fusion with IgG1 428L/434S Fc (SEQ ID NO:33)**

MAPVAVWAALAVGLELWAAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGSPSPAEGST  
 GDEPKSCDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWY  
 VDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEYCKKVSNAKALPAPIEKTISKAKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSGDSFFLYS  
 KLTVDKSRWQQGNVFCFSVLHEALHSHYTQKSLSLSPGK

**Anti-TNF Fc fusion with IgG2 434S Fc (SEQ ID NO:34)**

MAPVAVWAALAVGLELWAAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGSPSPAEGST  
 GDEPKSCDKTHTCPPCPAPPVAGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQFNWY  
 VDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEYCKKVSNAKGLPAPIEKTISKTKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPMLDSDGDSFFLY  
 SKLTVDKSRWQQGNVFCFSVMHEALHSHYTQKSLSLSPGK

**Anti-TNF Fc fusion with IgG2 428L/434S Fc (SEQ ID NO:35)**

MAPVAVWAALAVGLELWAAAHALPAQVAFTPYAPEPGSTCRLREYYDQTAQMCCSKCSPGQHA  
 KVFCTKTSDTVCDSCEDSTYTQLWNWVPECLSCGSRCSDDQVETQACTREQNRICTRPGWYC  
 ALSKQEGCRLCAPLRKCRPGFGVARPGTETSDVVCCKPCAPGTFSNTTSSTDICRPHQICNVVAIP  
 GNASMDAVCTSTSPTRSMAPGAVHLPQPVSTRSQHTQPTPEPSTAPSTSFLPMGSPSPAEGST  
 GDEPKSCDKTHTCPPCPAPPVAGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQFNWY  
 VDGVEVHNAKTKPREEQFNSTFRVSVLTVVHQDWLNGKEYCKKVSNAKGLPAPIEKTISKTKGQP  
 REPQVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPMLDSDGDSFFLY  
 SKLTVDKSRWQQGNVFCFSVLHEALHSHYTQKSLSLSPGK



Figure 17

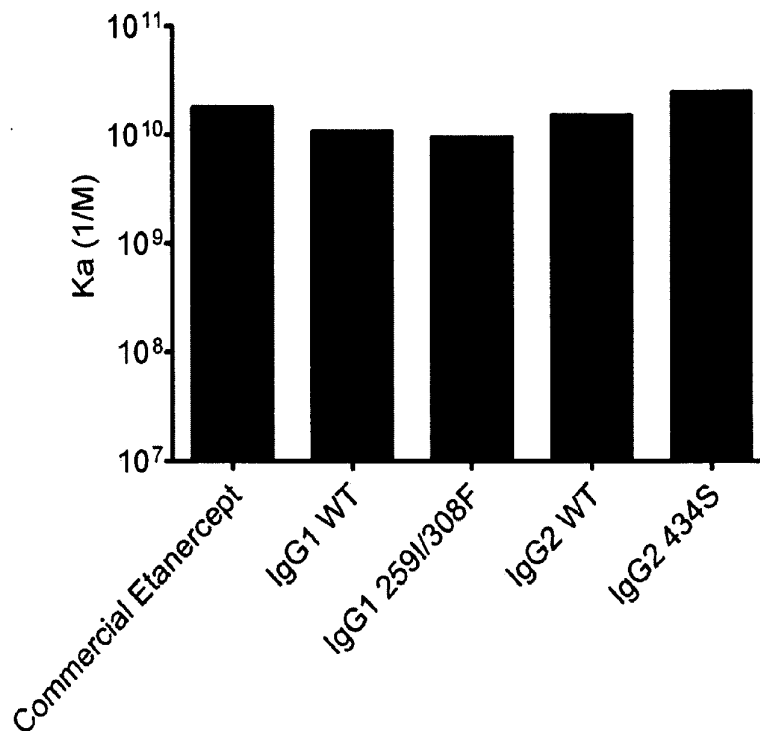


Figure 18

Variant	Fc region	Fusion partner	n	Fold FcRn	
				Mean	SD
WT	IgG1	TNFR		1.00	
V259I/V308F	IgG1	TNFR	4	4.86	2.22
M428L/N434S	IgG1	TNFR	2	7.24	1.57
WT	IgG2	TNFR		1.00	
N434S	IgG2	TNFR	3	6.93	2.02
M428L/N434S	IgG2	TNFR	3	11.78	4.33

Figure 19

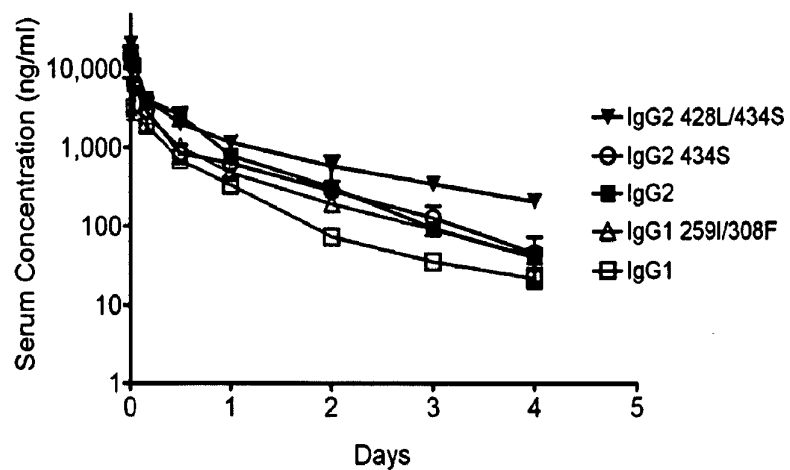


Figure 20

Fc variant	Fc	n	Half-Life (day)	Half-Life Increase (%)	Cmax (ng/mL)	AUC (day*ng/mL)	Clearance (mL/day/kg)
WT	IgG1	12	0.60	n/a	22253.3	1324.7	1177.7
V259I/V308F	IgG1	12	0.81	136	12175.6	2291.5	741.9
WT	IgG2	12	0.65	n/a	14580.2	3686.3	423.2
N434S	IgG2	12	0.77	119	12086.8	2531.3	655.8
M428L/N434S	IgG2	12	1.01	156	30676.7	4405.2	354.1

Figure 21a

	Fold cyno FcRn			Fold human FcRn		
	n	Mean	SD	n	Mean	SD
WT IgG1		1.00			1.00	
M252Y/S254T/T256E	2	11.95	2.23	10	11.37	2.90
V259I/V308F	2	8.60	1.86	12	9.79	2.72
M428L/N434S	3	12.18	1.23	14	17.28	6.70
V259I/V308F/M428L	4	12.43	0.57	13	19.94	10.46

Figure 21b

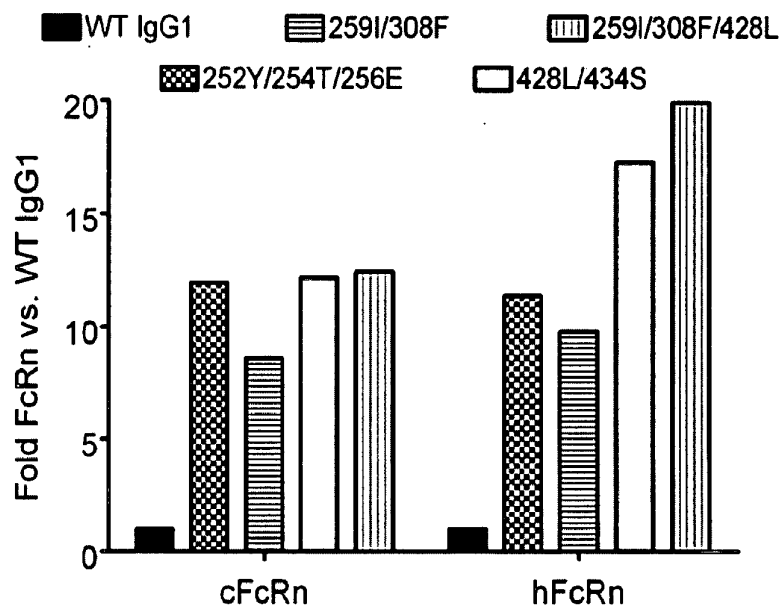


Figure 22

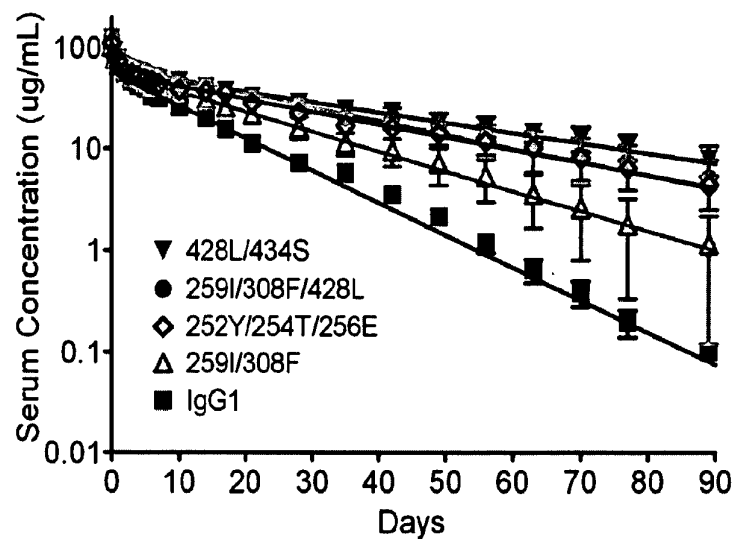


Figure 23

Fc variant	IgG	n	Half-Life			Cmax		AUC		Clearance	
			(day)			(ug/mL)		Day*ug/mL		mL/day/kg	
			Mean	SD	Fold	Mean	SD	Mean	SD	Mean	SD
WT (Native IgG1)	IgG1	3	9.7		1.0	101.2		822.9		4.9	
M252Y/S254T/T256E	IgG1	3	24.2	1.6	2.5	111.2	13.9	1919	210.1	2.1	0.2
V259I/V308F	IgG1	3	16.2	6.4	1.7	102.8	3.2	1352.6	367	3.1	0.9
M428L/N434S	IgG1	3	31.1	7.9	3.2	126	17	2660.9	791	1.6	0.6
V259I/V308F/M428L	IgG1	3	25.1	5.9	2.6	124.6	14.3	2301.6	922.5	1.9	0.8