COILED COIL AND/OR TETHER CONTAINING PROTEIN COMPLEXES AND USES THEREOF

Field of the Invention

This invention relates to novel engineered proteins, multispecific protein complexes, including multispecific antibodies, methods of constructing them and producing them. This invention also relates to the new application of technologies useful in obtaining the multispecific protein complexes.

Background of the Invention

Finding technologies for building mulitspecific antibodies that are useful and scalable for commercial and therapeutic purposes has been elusive. Many methods have been tried, but nearly all suffer significant drawbacks such as being poorly soluble, inexpressible in mammalian cells, demonstrating low yield of heterodimer formation, technically challenging to manufacture, immunogenic, short half-life in vivo, unstable among other problems (e.g., Hollinger et al., (1993) PNAS 90:6444-6448; US5,932,448; US6,833,441; US 5,591,828; US7,129,330; US7,507,796; Fischer et al., (2007) Pathobiology 74:3-14; Booy (2006) Arch. Immunol. Ther. Exp. 54:85-101; Cao et al (2003) 55:171-197; and Marvin et al., (2006) Current Opinion in Drug Discovery & Development 9(2):184-193. Thus, there is a need for improved technologies and processes to make multispecific antibodies.

Summary of the Invention

The present invention provides novel protein complexes and methods of creating and manufacturing protein complexes. In one aspect, the invention involves a coiled coil domain that is linked to an Fc CH component, which coiled coil domain may or may not be cleavable from the Fc containing protein if desired. In another aspect, the invention involves a protein comprising a tether and an Fc CH component complex, which tether may or may not be cleavable from the protein. In another aspect, the invention involves a protein comprising a coiled coil, a tether and an Fc CH component, optimally able to form a protein complex, which tether and/or coiled coil may or may not be cleavable from the protein depending on the desired effect. In another aspect, the invention provides a process of preparing the protein comprising a tether, wherein the tether is cleaved by a host cell or cleaved by a chemical or

enzymatic reaction in vitro. In another aspect, the invention involves a protein comprising a coiled coil, a tether and an Fc CH component, optimally able to form a protein complex, which tether and/or coiled coil are cleavable from the protein by a host cell that expresses the protein and overexpresses enzymes capable of cleaving the tether and/or coiled coil from the protein.

In another aspect, the invention provides a process of making a protein or protein complex comprising a coiled coil and a tether, wherein the tether and/or the coiled coil is cleaved by a host cell or cleaved by a chemical or enzymatic reaction in vitro. In one specific embodiment the protein complex further comprises an Fc CH component. In another aspect, the invention involves a method for manufacturing a heteromeric protein complex comprising the step of culturing a host cell under conditions that express two different proteins from the same or different recombinant nucleic acid sequences, wherein each protein comprises a coiled coil domain and a tether. In a further embodiment, the host cell comprises a recombinant nucleic acid sequence encoding an enzyme capable of cleaving the tether and/or the coiled coil. In one embodiment, the manufacturing method further comprises the step of isolating the proteins made by the host cell. In another embodiment, the manufacturing method further comprises the step of cleaving the tether and/or the coild coil from a protein produced by the host cell.

In another aspect, the invention involves the protein complexes described herein with or without the tether and/or the coiled coil. In addition to the many advances and advantages provided herein, the invention provides a simple, efficient, high yield production process for manufacturing substantially homogenous heteromultimeric complexes.

In one preferred embodiment, the present invention provides a protein complex comprising two or more polypeptides, wherein

a first polypeptide comprises a first coiled coil domain (CC) and a first Fc CH component (FcCH); and

a second polypeptide comprises (1) a second coiled coil domain (CC) and a second FcCH,

wherein the first CC and the second CC complex with each other; and the first FcCH and second FcCH complex with each other..

In one embodiment, the first CC comprises the sequence of Formula I herein and the second CC comprises the sequence of Formula II herein.

In a second aspect, the invention features a protein complex comprising (a) a first

polypeptide comprising a first coiled coil domain (CC), where the first CC comprises a heptad repeat of Formula I; and (b) a second polypeptide comprising an Fc CH component and a second coiled coil (CC), where the second CC comprises a heptad repeat of Formula II, where n in Formula I and II is greater than or equal to 2, and where, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

In one embodiment, the first polypeptide further comprises a VH domain and a VL domain and the second polypeptide further comprises a VH and VL domain, wherein the VH and VL domains of each polypeptide are linked to each other in the N-terminal to C-terminal order: VL-CL-tether-VH.

In a further embodiment, the VH domain of each polypeptide is different from each other. In another embodiment, the VL domain of each polypeptide is different from each other.

In one embodiment, the protein complex of this invention comprises a hinge region, wherein the hinge region comprises a K222A mutation in its hinge region, a C220A mutation in its hinge region or a K222A and a C220A mutation in its hinge region.

In one embodiment, the protein complex is selected from the group consisting of an antibody, an immunoadhesin, a peptibody or an affibody. Thus, according to a further embodiment, the first and/or second polypeptides can further comprise a target binding sequence of an antibody (e.g., VH or VL domain), peptibody (e.g., peptide), immunoadhesin (e.g., extracellular domain) or a scaffold protein comprising a sequence that binds the target.

According to one embodiment, the protein complex is a one armed antibody.

In one aspect, the invention provides a protein complex comprising a coiled coil comprising (a) a first polypeptide comprising a first coiled coil domain (CC), where the first CC comprises a heptad repeat of Formula I:

$(X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7)_n$ (Formula I) (SEQ ID NO:29)

X_1 is a hydrophobic amino acid residue or Asparagine,

X_2, X_3, and X_6 are each any amino acid residue,

X_4 is a hydrophobic amino acid residue, and

X_5 and X_7 are each a charged amino acid residue; and

(b) a second polypeptide comprising a second coiled coil domain (CC), where the second CC comprises a heptad repeat of Formula II:

$(X'_1\ X'_2\ X'_3\ X'_4\ X'_5\ X'_6\ X'_7)_n$ (Formula II) (SEQ ID NO:30)

X'_1 is a hydrophobic amino acid residue or Asparagine,

X'_2, X'_3, and X'_6 are each any amino acid residue,

X'_4 is a hydrophobic amino acid residue, and

X'_5 and X'_7 are each a charged amino acid residue;

where n in Formula I and II is greater than or equal to 2; and where, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

In an embodiment, the first and second polypeptides each comprise a VH and a CH1 domain, and may each further comprise a hinge domain. In another embodiment, the first and second polypeptides each further comprise a CH2 and a CH3 domain. In yet another embodiment, the first and second polypeptides each comprise VH, CH1, hinge, CH2, and CH3 domains positioned relative to each other in an N-terminal to C-terminal direction: VH-CH1-hinge-CH2-CH3.

In one aspect, the invention provides an antibody comprising (a) a first polypeptide comprising a VH domain and a first coiled coil domain (CC), where the first CC comprises a heptad repeat of Formula I:

$(X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7)_n$ (Formula I)

X_1 is a hydrophobic amino acid residue or Asparagine,

X_2, X_3, and X_6 are each any amino acid residue,

X_4 is a hydrophobic amino acid residue, and

X_5 and X_7 are each a charged amino acid residue; and

(b) a second polypeptide comprising a VH domain and a second coiled coil domain (CC), where the second CC comprises a heptad repeat of Formula II:

$(X'_1\ X'_2\ X'_3\ X'_4\ X'_5\ X'_6\ X'_7)_n$ (Formula II)

X'_1 is a hydrophobic amino acid residue or Asparagine,

X'_2, X'_3, and X'_6 are each any amino acid residue,

X'_4 is a hydrophobic amino acid residue, and

X'_5 and X'_7 are each a charged amino acid residue;

where n in Formula I and II is greater than or equal to 2; and where, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second

CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

In an embodiment, the first and second polypeptides each comprise a VH and a CH1 domain, and may each further comprise a hinge domain. In another embodiment, the first and second polypeptides each further comprise a CH2 and a CH3 domain. In yet another embodiment, the first and second polypeptides each comprise VH, CH1, hinge, CH2, and CH3 domains positioned relative to each other in an N-terminal to C-terminal direction: VH-CH1-hinge-CH2-CH3.

In a particular embodiment the antibody further comprises a third and a fourth polypeptide, where the third polypeptide comprises a first VL domain and the fourth polypeptide comprises a second VL domain. In an embodiment, the VH domain of the first polypeptide is linked to the VL domain of the third polypeptide by a tether and the VH domain of the second polypeptide is linked to the VL domain of the fourth polypeptide by a tether. In another embodiment, the third polypeptide further comprises a first CL domain where the first VL and CL domains are positioned relative to each other within the third polypeptide in an N-terminal to C-terminal direction: VL-CL, and the fourth polypeptide further comprises a second CL domain, and where the second VL and CL domains are positioned relative to each other within the fourth polypeptide in an N-terminal to C-terminal direction: VL-CL.

In an additional embodiment, the sequences of the first VL domain and the second VL domain are the same. In a further embodiment, the N-terminus of the VH of at least one of the first or the second polypeptides is connected to the C-terminus of a CL with a tether.

In a second aspect, the invention features an antibody comprising (a) a first polypeptide comprising a VH domain and a first coiled coil domain (CC), where the first CC comprises a heptad repeat of Formula I; and (b) a second polypeptide comprising a CH2 and CH3 domain and a second coiled coil (CC), where the second CC comprises a heptad repeat of Formula II, where n in Formula I and II is greater than or equal to 2, and where, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

In one embodiment of the second aspect of the invention, the first polypeptide comprises a VH and CH1 domain, and may further comprise a hinge domain. In another embodiment, the first polypeptide further comprises a CH2 and a CH3 domain. In a further

embodiment of the second aspect of the invention, the first polypeptide comprises VH, CH1, hinge, CH2, and CH3 domains positioned relative to each other in an N-terminal to C-terminal direction: VH-CH1-hinge-CH2-CH3. In yet another embodiment of the second aspect of the invention, the antibody further comprises a third polypeptide, where the third polypeptide comprises a VL domain. In one example, the third polypeptide further comprises a CL domain, and the VL and CL domains are positioned relative to each other in an N-terminal to C-terminal direction: VL-CL. In yet another embodiment of the second aspect of the invention, the N-terminus of the VH of the first polypeptide is connected to the C-terminus of a CL with a tether.

In one embodiment, a two armed antibody of this invention comprises one, not two tethers such that the antibody comprises (1) a polypeptide comprising a coiled coil domain and a heavy chain tethered to a light chain according to this invention, (2) a polypeptide comprising a coiled coil domain and a heavy chain and (3) a polypeptide comprising a light chain. In another embodiment, a host cell that expresses such two armed antibody is contemplated.

In other embodiments, the hydrophobic amino acid residue in any of X_1, X'_1, X_4, and X'_4 is selected from the group Alanine, Valine, Leucine, Isoleucine, Tryptophan, Phenylalanine, and Methionine. In another embodiment, the charged amino acid residue in any of X_5, X'_5, X_7, and X'_7 is selected from the group Lysine, Arginine, Histidine, Aspartic Acid, and Glutamic Acid. In a further embodiment, in at least one heptad repeat of the first CC, X_1 is Asparagine, and the respective X'_1 is Asparagine in at least one heptad repeat of the second CC.

In yet other embodiment, the first CC comprises a heptad repeat where X_1 is Leucine or Asparagine, X_2 is Alanine or Glutamine, X_3 is Alanine or Glutamine, X_4 is Leucine, X_5 is Glutamic Acid, X_6 is Lysine or Tryptophan, and X_7 is Glutamic Acid; and the second CC comprises a heptad repeat where X'_1 is Leucine or Asparagine, X'_2 is Alanine or Glutamine, X'_3 is Alanine or Glutamine, X'_4 is Leucine, X'_5 is Lysine, X'_6 is Lysine or Tryptophan, and X'_7 is Lysine.

In further embodiments, n in Formula I and II is greater than or equal to 3, for example, greater than or equal to 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100.

In additional embodiments, at least one of the first or the second CC is linked C-terminal to a constant domain of the protein. For example, the constant domain is a CH3 domain and the first CC is linked C-terminal to a CH3 domain of the first polypeptide and the

second CC is linked C-terminal to a CH3 domain of the second polypeptide. The linkage, for example, is by a cleavable linker sequence. In other embodiments, a Lys-C endopeptidase cleavage site is located N-terminal to at least one of the first or the second CC.

In another aspect, the invention features an antibody comprising a first polypeptide comprising a VL, CL, tether, VH, CH1, CH2, and CH3 domain positioned relative to each other in an N-terminal to C-terminal direction: VL-CL-tether-VH-CH1-CH2-CH3 (Formula III). In one embodiment, the antibody further comprises a second polypeptide of Formula III.

In a particular embodiment, the antibody of the invention is multispecific. For example, the antibody is capable of binding at least 2 antigens, or the antibody a capable of binding at least 2 epitopes on the same antigen. In another embodiment, the antibody is bispecific.

In an additional embodiment, the proteins of this invention comprise a tether comprising Glycine (G) and Serine (S) residues. In one embodiment, the tether, for example, is between 15 and 50 amino acids in length. In a particular embodiment, the tether is between 20 and 32 amino acids in length, for example, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31 or 32 amino acids in length. The tether, in one embodiment, comprises GGS repeats. In another embodiment, the tether is cleavable. In one preferred embodiment, the tether is cleavable in two sites at or near the N and C terminus of the tether by the same enzyme. In one embodiment, the tether comprises the cleavage site for furin. In a further embodiment, the furin cleavage site is RXRXRR (SEQ ID NO:25), wherein X is any amino acid.

In a further embodiment, the antibody of the invention comprises a mutation that removes a Lys-C endopeptidase cleavage site. In one example, the mutation that removes a Lys-C endopeptidase cleavage site is in a hinge domain. For instance, the antibody has a K222A substitution (EU numbering system).

In another embodiment, the tether or the linker is cleavable by one or more of the following endopeptidases: Furin, Thrombin, Genenase, Lys-C, Arg-C, Asp-N, Glu-C, Factor Xa, Tobacco Etch Virus Protease (TEV), Enterokinase, Human Rhinovirus C3 protease (HRV C3), or Kininogenase. In a particular embodiment, the tether or the linker comprises an Asparagine-Glycine peptide bond, for example, a Asparagine-Glycine peptide bond that is cleavable by hydroxylamine.

In one embodiment, an antibody of the invention further comprises mutations in a CL/CH1 and or in a VH/VL interface using KnH technology. In one embodiment, a multispecific antibody of this invention was constructed using a coiled coil of this invention

and a knob and hole at a CL/CH1 interface.

In an additional embodiment, the antibody of the invention comprises a constant region conjugated to a cytotoxic agent.

In yet another embodiment, the antibody of the invention is expressed by eukaryotic cell, for example, a mammalian cell such as a CHO cell. In an alternative embodiment, the antibody is expressed by a prokaryotic cell, for example, an *E. coli* cell.

In a further aspect, the invention features method for producing a protein complex, such as an antibody. Accordingly, the invention provides several new aspects. In one embodiment,this method comprises the step of culturing a cell comprising a vector encoding a protein of this invention in a culture medium. In one embodiment, the method further comprises recovering the protein from the cell or the culture medium. In another embodiment, the method further comprises the steps of (a) capturing the antibody on a column comprising Protein A, (b) eluting the antibody from the column, and (c) diluting the eluted antibody into a solution containing a chaotropic agent or mild detergent.

In yet another aspect, the invention features a method of maintaining a coiled coil containing antibody in solution. This method comprises maintaining the antibody in the presence of a chaotropic agent or mild detergent. Examples, of chaotropic agents or mild detergents that may be used in this method include Arginine, Guanidine-HCl, urea, lithium perchlorate, Histidine, Sodium Dodecyl Sulfate (SDS), Tween, Triton, and NP-40.

In one embodiment, a heteromultimeric complex of this invention binds to two or more target molecules. In another embodiment, each polypeptide in the heteromultimeric complex binds to a different target molecule. In yet another embodiment, the heteromultimeric complex inhibits the biological activity of the target molecule(s) to which it binds. In one embodiment, when a desired biological effect is to bring a cell to be depleted or inactivated in close proximity to an effector cell (e.g., T lymphocyte, natural killer cell (NK), macrophage or other mononuclear cells, one of the target molecules can be CD3, CD16, or CD64.

According to one embodiment, a heteromultimeric complex of this invention binds to at least two target molecules selected from the group consisting of: IL-lalpha and IL-lbeta, IL-12 and IL-18; IL-13 and IL-9; IL-13 and IL-4; IL-13 and IL-5; IL-5 and IL-4; IL-13 and IL-lbeta; IL-13 and IL- 25; IL-13 and TARC; IL-13 and MDC; IL-13 and MEF; IL-13 and TGF-β; IL-13 and LHR agonist; IL-12 and TWEAK, IL-13 and CL25; IL-13 and SPRR2a; IL-13 and SPRR2b; IL-13 and ADAM8, IL-13 and PED2, IL17A and IL17F, CD3 and CD19,

CD138 and CD20; CD138 and CD40; CD19 and CD20; CD20 and CD3; CD38 and CD138; CD38 and CD20; CD38 and CD40; CD40 and CD20; CD-8 and IL-6; CD20 and BR3, TNFalpha and TGF-beta, TNFalpha and IL-lbeta; TNFalpha and IL-2, TNF alpha and IL-3, TNFalpha and IL-4, TNFalpha and IL-5, TNFalpha and IL6, TNFalpha and IL8, TNFalpha and IL-9, TNFalpha and IL-10, TNFalpha and IL-11, TNFalpha and IL-12, TNFalpha and IL-13, TNFalpha and IL-14, TNFalpha and IL-15, TNFalpha and IL-16, TNFalpha and IL-17, TNFalpha and IL-18, TNFalpha and IL-19, TNFalpha and IL-20, TNFalpha and IL-23, TNFalpha and IFNalpha, TNFalpha and CD4, TNFalpha and VEGF, TNFalpha and MIF, TNFalpha and ICAM-1, TNFalpha and PGE4, TNFalpha and PEG2, TNFalpha and RANK ligand,. TNFalpha and Te38; TNFalpha and BAFF; TNFalpha and CD22; TNFalpha and CTLA-4; TNFalpha and GP130; TNFα and IL-12p40; VEGF and HER2, VEGF-A and HER2, VEGF-A and PDGF, HER1 and HER2, VEGF-A and VEGF-C, VEGF-C and VEGF-D, HER2 and DR5,VEGF and IL-8, VEGF and MET, VEGFR and MET receptor, VEGFR and EGFR, HER2 and CD64, HER2 and CD3, HER2 and CD16, HER2 and HER3; EGFR and HER2, EGFR and HER3, EGFR and HER4, IL-13 and CD40L, IL4 and CD40L, TNFR1 and IL-1R, TNFR1 and IL-6R and TNFR1 and IL-18R, EpCAM and CD3, MAPG and CD28, EGFR and CD64, CSPGs and RGM A; CTLA-4 and BTNO2; IGF1 and IGF2; IGF1/2 and Erb2B; MAG and RGM A; NgR and RGM A; NogoA and RGM A; OMGp and RGM A; PDL-I and CTLA-4; and RGM A and RGM B.

In a further embodiment, the invention features an isolated antibody comprising a first heavy chain comprising the sequence of SEQ ID NO:1, a second heavy chain comprising the sequence of SEQ ID NO:2, and a light chain comprising the sequence of SEQ ID NO:3, where the antibody specifically binds FcεR1 and FcγR2b.

In another embodiment, the invention features an isolated antibody comprising a first heavy chain comprising the sequence of SEQ ID NO:4, a second heavy chain comprising the sequence of SEQ ID NO:5, and a light chain comprising the sequence of SEQ ID NO:6, where the antibody specifically binds HER2.

In yet another embodiment, the invention features an isolated antibody comprising a first heavy chain comprising the sequence of SEQ ID NO:7, a second heavy chain comprising the sequence of SEQ ID NO:5, and a light chain comprising the sequence of SEQ ID NO:8, where the antibody specifically binds EGFR.

In an additional embodiment, the invention features an isolated antibody comprising a first light chain sequence and a first heavy chain sequence comprising the sequence of SEQ

ID NO:9, and a second light chain sequence and a second heavy chain sequence comprising the sequence of SEQ ID NO:10, where the antibody specifically binds HER2 and EGFR.

In a further embodiment, the invention features an isolated antibody comprising a first light chain sequence and a first heavy chain sequence comprising the sequence of SEQ ID NO:11, and a second light chain sequence and a second heavy chain sequence comprising the sequence of SEQ ID NO:10, where the antibody specifically binds HER2 and EGFR.

The invention also features use of antibodies made according to the methods described herein in methods of treatment. In one embodiment the invention features use of an antibody that specifically binds FcεR1 and FcγR2b in a method of treating an allergic or inflammatory response (e.g., an autoimmune disease) in a subject. This method includes administering an antibody or antibody fragment to a subject for a time and in an amount sufficient to treat the allergic or inflammatory respone in the subject. In another embodiment, the invention features use of an antibody that specifically binds HER2 or EGFR (or both HER2 and EGFR) in a method of treating a tumor in a subject. This method includes administering an antibody or antibody fragment to a subject for a time and in an amount sufficient to treat the tumor in the subject.

In particular embodiments, the methods of treatment described herein involve the use of an antibody fragment that lacks a coiled coil and/or a tether. In this embodiment, the coiled coil and/or tether sequences are cleaved from the antibody following production and the resultant engineered antibody used for therapeutic administration. In further embodiments, the methods of treatment involve administering to the subject an effective amount of a second drug. The second drug may contain another antibody or antibody fragment, a chemotherapeutic agent, a cytotoxic agent, an anti-angiogenic agent, an immunosuppressive agent, a prodrug, a cytokine, a cytokine antagonist, cytotoxic radiotherapy, a corticosteroid, an anti-emetic, a cancer vaccine, an analgesic, or a growth-inhibitory agent. The second drug can be administered prior or subsequent to the administration of the first drug (e.g., the antibody or antibody fragment). In another embodiment, the second drug is administered concurrently with the first drug.

In additional embodiments, the invention features an isolated polynucleotide encoding the sequence of any one of SEQ ID NO:1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 17-18, 26, 31-32 or 35-36 or a combination thereof, a vector comprising a polynucleotide including the sequence of any one of SEQ ID NO:1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 17-18, 26, 31-32 or 35-36 or a combination thereof, and a host cell comprising such a vector. The host cell can be a

eukaryotic cell, such as a yeast, insect, or mammalian cell. In one emboditment the mammalian cell is a Chinese Hamster Ovary (CHO cell). The host cell can also be a prokaryotic cell, such as an *E. coli* cell. In other embodiments, the invention features an isolated polypeptide comprising any one of the sequence of SEQ ID NO:1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 17-18, 26, 31-32 or 35-36 or a combination thereof.

Other features and advantages of the invention will be apparent from the following Detailed Description, the Drawings, and the Claims.

Brief Description of the Drawings

FIGURE 1 is a schematic diagram showing ionic and hydrophobic interactions between amino acids in an exemplary coiled coil (CC) structure. The residues in the first CC are labeled X_1 through X_7 and the residues in the second CC are labeled X'_1 through X'_7. Ionic interactions between the X_5 residue of the first CC and the X'_7 residue of the second CC and the X_7 residue of the first CC and the X'_5 residue of the second CC are indicated. In addition, hydrophobic interactions between the X_4 and X'_4 and X_1 and X'_1 residues are shown.

FIGURE 2A shows the amino acid sequences of the exemplary ACID.p1 (SEQ ID NO:12) and BASE.p1 (SEQ ID NO:13) coiled coil heterodimerization domains and DNA sequences encoding them (SEQ ID NO:21 and SEQ ID NO:22, respectively).

FIGURE 2B is a schematic diagram showing interactions between the exemplary ACID.p1 and BASE.p1 coiled coil heterodimerization domains and DNA sequences SEQ ID NO:21 and SEQ ID NO:22, respectively.

FIGURE 3 is a schematic diagram showing the structure of an exemplary bispecific antibody containing a common light chain (common LC), a heterodimeric coiled coil, and a mutation in the hinge region (K222A; Kabat numbering system) of the first and second heavy chains (HC1 and HC2) that removes a Lys-C endopeptidase cleavage site.

FIGURE 4A is a schematic diagram showing the structure of an exemplary one-armed antibody containing a full-length heavy chain (HC1), a partial heavy chain (HC2) lacking the VH and CH1 domains, a light chain (common LC), a heterodimeric coiled coil, and a mutation in the hinge region (K222A) of HC1 that removes a Lys-C endopeptidase cleavage site.

FIGURE 4B is a schematic diagram showing the structure of an exemplary conjugated antibody containing two full-length heavy chains, a common light chain, a coiled coil, and a

cytotoxic agent conjugated to one of the heavy chain constant regions. The cytotoxic agent is indicated by the star.

FIGURE 5 is a schematic diagram showing the structure of an exemplary tethered bispecific antibody. The antibody contains two heavy chains (HC1 and HC2) and two light chains (LC1 and LC2). A tether links the N-terminus of the variable heavy chain of HC1 with the C-terminus of the constant light chain of LC1 and a second tether links the N-terminus of the variable heavy chain of HC2 with the C-terminus of the constant light chain of LC2. In this example, the tethers include Glycine Glycine Serine (GGS) repeats. In this figure, the light chains (LC1 and LC2) are different, but a tethered antibody could also contain a common light chain. The exemplary tethered antibody further contains a heterodimeric coiled coil and a mutation in the hinge region (K222A) of HC1 and HC2 that removes a Lys-C endopeptidase cleavage site.

FIGURE 6 is a schematic diagram showing the structure of an exemplary heavy chain (HC) and light chain (LC), as well as an exemplary tether linking the N-terminus of the variable heavy chain with the C-terminus of the constant light chain. In this example, the distance spanned by the tether is approximately 92Å, or approximately 22 amino acids in length. Tethers of 20, 23, and 26 amino acids in length were tested.

FIGURE 7A is a schematic diagram showing the structure of an exemplary antibody containing cleavable tethers and a heterodimeric coiled coil. As indicated in the figure, the exemplary tether links the C-terminus of the light chain (LC) to the N-terminus of the heavy chain (HC). The tether can be cleaved from the antibody at cleavage sites (X) using, for example, Lys-C endopeptidase, Furin (PC1), or NH_2OH (hydroxylamine). The exemplary cleavage sites are located at the N- and C-termini of the tether. The exemplary antibody shown in in Figure 7A also contains a heterodimeric coiled coil, which can be cleaved from the antibody at cleavage sites (X) N-terminal to the coiled coil domains using, for example, Lys-C endopeptidase, Furin (PC1), or NH_2OH.

FIGURE 7B is a series of schematic diagrams showing exemplary cleavable tethers. The top diagram shows an exemplary 26 amino acid tether sequence (SEQ ID NO:17) in SEQ ID NO:31 that can be cleaved by Furin and links the N-terminus of the light chain (LC) and the C-terminus of the heavy chain (HC). Furin can cleave the tether sequence at di-basic sites (Arginine-Arginine) at the N- and C-termini of the tether. The bottom diagram shows an exemplary 26 amino acid tether sequence (SEQ ID NO:18) in SEQ ID NO:32 that can be cleaved by Lys-C endopeptidase at Lysine residues at the N- and C-termini of the tether

sequence.

FIGURE 8 shows the sequences of the heavy chains (HC; Anti-FcγR2b-BASE.p1 sequence and Anti-FcεR1-ACID.p1 sequence) and common light chain (4d5 LC) of a bispecific antibody that binds to both FcεR1 and FcγR2b. The Anti-FcγR2b-BASE.p1 sequence (SEQ ID NO:1) contains the heavy chain sequence of anti-human FcγR2b with a BASE.p1 coiled coil heterodimerization domain sequence and K222A mutation in the hinge region. The Anti-FcεR1-ACID.p1 sequence (SEQ ID NO:2) contains the heavy chain sequence of anti-human FcεR1 with an ACID.p1 coiled coil heterodimerization domain sequence and K222A mutation in the hinge region. The 4d5 antibody light chain (SEQ ID NO:3) is common to both the FcγR2b and FcεR1 HCs of this bispecific antibody.

FIGURES 9-1 and 9-2 are the sequences of used to generate exemplary one-armed antibodies. One exemplary one-armed antibody specifically binds HER2 and contains the Anti-HER2 antibody 1.ACID.p1 sequence (Anti-HER2 antibody 1 HC with an ACID.p1 coiled coiled heterodimerization domain sequence and K222A mutation; SEQ ID NO:4), the truncFC.BASE.p1 sequence (a heavy chain lacking the VH and CH1 domains with a BASE.p1 coiled coil heterodimerization domain sequence; SEQ ID NO:5), and the anti-HER2 antibody 1 LC sequence (SEQ ID NO:6). Another exemplary one-armed antibody specifically binds EGFR and contains the Anti-EGFR (D1.5).ACID.p1 sequence (anti-EGFR (D1.5) HC with an ACID.p1 coiled coiled heterodimerization domain sequence and K222A mutation in the hinge region; SEQ ID NO:7), the truncFC.BASE.p1 sequence (a heavy chain lacking the VH and CH1 domains with a BASE.p1 coiled coil heterodimerization domain sequence; SEQ ID NO:5), and anti-EGFR (D1.5) antibody LC sequence (SEQ ID NO:8).

FIGURE 10 shows the sequences of the tethered HC and LC (Anti-HER2 (antibody 1)26.ACID.p1 and D1.5.26.BASE.p1) of a bispecific antibody that binds both HER2 and EGFR/HER1. The Anti-HER2 (antibody 1)26.ACID.p1 sequence contains the anti-HER2 antibody 1 LC sequence tethered to the anti-HER2 antibody 1 HC sequence by a 26 amino acid Glycine Glycine Serine (GGS) tether with an ACID.p1 coiled coil heterodimerization domain and K222A mutation (SEQ ID NO:9). The D1.5.26.BASE.p1 sequence contains the D1.5 anti-EGFR antibody LC sequence tethered to the D1.5 anti-EGFR antibody HC sequence by a 26 amino acid GGS tether with a BASE.p1 coiled coil heterodimerization domain and K222A mutation (SEQ ID NO:10).

FIGURE 11 shows the sequences of the tethered HC and LC (anti-HER2 (antibody 2).26.ACID.p1 and D1.5.26.BASE.p1) of another exemplary antibody that binds both HER2

and EGFR/HER1. The anti-HER2 (antibody 2).26.ACID.p1 sequence contains the anti-HER2 antibody 2 LC sequence tethered to the anti-HER2 antibody 2 HC sequence by a 26 amino acid GGS tether with a ACID.p1 coiled coil heterodimerization domain and K222A mutation (SEQ ID NO:11). The D1.5.26.BASE.p1 sequence contains the D1.5 anti-EGFR antibody LC sequence tethered to the D1.5 anti-EGFR antibody HC sequence by a 26 amino acid GGS tether with a BASE.p1 coiled coil heterodimerization domain and K222A mutation (SEQ ID NO:10).

FIGURES 12A-1 and 12A-2 and 12B-1, 12B-2, and 12B-3 are partial HC (SEQ ID NO:15) and LC (SEQ ID NO:16) amino acid sequences and DNA sequences SEQ ID NO:23 and SEQ ID NO:24, respectively of the anti-HER2 antibody 1 used to construct coiled coil heterodimerization domain containing antibodies. The start of the anti-HER2 antibody 1 HC sequence is indicated in Figure 12A, as is the location of the K222A mutation in the sequence. The start of the anti-HER2 antibody 1 variable light chain (VL), the end of the anti-HER2 antibody 1 LC, the start of the anti-HER2 antibody 1 variable heavy chain (VH), the end of the anti-HER2 antibody 1 VH, and the location of the K to A mutation is indicated in Figure 12B. The locations of ClaI/Bsp106, BamH1, and ApaI restriction sites useful in constructing vectors containing these sequences are also indicated in Figures 12A and 12B.

FIGURES 13A and 13B are a series of graphs of mass spectrometry results and schematic diagrams showing that the heterodimeric coiled coil can be cleaved from an exemplary α-FcεR1/α-FcγR2b bispecific antibody using Lys-C endopeptidase. The theoretical masses of the antibody with the coiled coil (left diagram) and the antibody without the coiled coil (right diagram) are indicated and are within the margin of error of the experimentally observed masses indicated in the graphs of the mass spectrometry results above the respective diagram, showing that the coiled coil was cleaved from the antibody.

FIGURES 14A and 14B are a series of graphs of mass spectrometry results and schematic diagrams showing that Lys-C endopeptidase (right panels) does not cleave within the LC or HC of an exemplary α-FcεR1/α-FcγR2b bispecific antibody, but does cleave the coiled coil from the HCs (comparison of left two bottom panels and right two bottom panels). The theoretical masses of the light chain (MW=26263), the heavy chain with a coiled coil domain (MW=54917 or 55164), and the heavy chain without a coiled coil domain (MW=50528 and 50767) are within the margin of error of the experimentally observed masses indicated in the graph of the mass spectrometry results for the respective construct.

FIGURE 15 is a series of graphs showing that an exemplary α-FcεR1/α-FcγR2b

bispecific antibody specifically and simultaneously binds both of its antigens.

FIGURE 16 is a graph showing the results for a histamine release assay with an exemplary common LC α-FcεR1/α-FcγR2b bispecific antibody. The concentration of the antibody used in the assay (in μg/ml) is indicated along the x-axis and the amount in histamine release (in ng/ml) is indicated along the y-axis.

FIGURES 17A and 17B are a series of graphs of mass spectrometry results and schematic diagrams showing that the coiled coil can be cleaved from an exemplary one-armed α-EGFR antibody using Lys-C endopeptidase. The theoretical masses of the one-armed antibody with a coiled coil (MW=109112), and the one-armed antibody without a coiled coil (MW=100419) are within the margin of error of the experimentally observed masses indicated in the graph of the mass spectrometry results for the respective construct.

FIGURES 18A, 18B, and 18C are a series of graphs of mass spectrometry results and schematic diagrams showing that Lys-C endopeptidase does not cleave the LC (One-armed Light Chain; left panels), full-length HC (One-armed Heavy Chain; middle panels), or HC lacking the VH and CH1 domains (One-armed Fc; right panels) of an exemplary α-EGFR antibody, but does cleave the coiled coil domain from the HC and the HC lacking the VH and CH1 domains. The theoretical molecular mass for the respective constructs is indicated below the graph showing the mass spectrometry results and, in each case, is within the margin of error of the experimentally observed molecular mass.

FIGURES 19A and 19B are a series of graphs of mass spectrometry results and schematic diagrams showing that the coiled coil can be cleaved from an exemplary tethered α-EGFR/α-HER2 bispecific antibody using Lys-C endopeptidase. The theoretical molecular mass of the cleaved and uncleaved antibodies is also indicated in the figure and is within the margin of error of the respective experimentally observed molecular mass indicated in the mass spectrometry results.

FIGURES 20A and 20B are a series of graphs of mass spectrometry results and schematic diagrams showing that the coiled coil can be cleaved from an exemplary tethered α-EGFR/α-HER2 bispecific antibody using Lys-C endopeptidase where the antibody has first been treated with Lys-C endopeptidase and the sample then subjected to mass spectrometry analysis. The theoretical molecular masses of the cleaved and uncleaved HC/LC complexes are also indicated in the figure and the theoretical molecular mass for each construct is within the margin of error of the experimentally observed molecular mass shown in the mass spectrometry results.

FIGURE 21 is a graph showing the results from an Octet analysis indicating that the wild-type anti-HER2 antibody 1 and wild-type α-EGFR antibody do not cross react with each other's antigen, but do bind their respective antigen.

FIGURE 22 is a graph showing the results from an Octet analysis indicating that the one-armed anti-HER2 antibody 1 and one-armed α-EGFR antibody do not cross react with each other's antigen, but do bind their respective antigen.

FIGURE 23A is a graph showing the results from an Octet analysis indicating that the exemplary tethered bispecific Anti-HER2 antibody 1/α-EGFR antibody (8323) binds both HER2 and EGFR simultaneously. In the top trace, the antibody was first incubated with the EGFR extracellular domain (ECD) and then with the HER2 receptor ECD and in the bottom trace, the antibody was first incubated with the HER2 receptor ECD and then with the EGFR ECD.

FIGURE 23B is a series of graphs showing the binding affinities of an exemplary bispecific Anti-HER2 antibody 1/α-EGFR antibody for HER2 (top) and EGFR1 (bottom).

FIGURE 24 is an image of immunoblots showing that the exemplary bispecific Anti-HER2 antibody 1/α-EGFR (D1.5) antibody inhibits transforming growth factor alpha (TGFα) mediated EGFR (epidermal growth factor receptor) phosphorylation in a dose dependent manner in EGFR expressing NR6 cells (left side). The D1.5 anti-EGFR antibody is used as a control (right side). Phosphorylation levels are determined using an anti-phospho-tyrosine (α-pTyr) antibody and an anti-tubulin antibody (α-tubulin) is used as a loading control.

FIGURE 25 is a series of graphs showing that the bispecific Anti-HER2 antibody 1/α-EGFR(D1.5) antibody inhibits TGFα-induced growth, over a three-day period, in NR6 cells that are stably transfected to express EGFR.

FIGURE 26 is a graph showing that the exemplary bispecific Anti-HER2 antibody 1/α-EGFR(D1.5) antibody inhibits growth of HER2 amplified BT474 cells over a five-day period in a manner similar to the anti-HER2 antibody 1 control.

FIGURE 27 is a series of graphs showing Fc-Fc assay and Fc-Fc ELISA assay results of a ten-day pharmacokinetics (PK) analysis of the D1.5 human IgG1 control antibody (anti-EGFR) using SCID Beige mice.

FIGURES 28A and 28B are a series of graphs showing EGFR-HER2 ELISA and Fc-Fc ELISA assay results of a ten-day PK analysis of the exemplary bispecific Anti-HER2 antibody 1/α-EGFR(D1.5) antibody using SCID Beige mice.

FIGURE 29 is a graph showing a comparison of the exposure of the exemplary

bispecific Anti-HER2 antibody 1/α-EGFR(D1.5) antibody to the control D1.5 (anti-EGFR) and control (anti-HER2 antibody 2) antibodies in mice. The exemplary bispecific Anti-HER2 antibody 1/α-EGFR(D1.5) antibody has an exposure in mice over the tested time period that is similar to the control antibodies.

FIGURES 30A-1 and 30A-2, 30B-1 and 30B-2, 30C-1, 30C-2, 30C-3, 30C-4, and 30C-5, 30D-1, 30D-2, and 30D-3 are mass spectroscopy graphs showing the cleavage products of the heavy chain and the light chain of an antibody after cleavage by furin by a cell co-expressing furin.

FIGURE 31 is a non-reduced mass spectroscopy graph showing a bispecific antibody made by expressing a furin-cleavable, tethered coiled-coil antibody in a CHO cell that coexpressed furin and exposing the antibody to carboxypeptidase digestion.

FIGURE 32 (A) and (B) is a reduced mass spectroscopy graph showing a bispecific antibody made by expressing a furin-cleavable, tethered coiled-coil antibody in a CHO cell that coexpressed furin and exposing the antibody to carboxypeptidase digestion.

Detailed Description

Without being bound by theory, applicants believe that the coiled coil dimerization domains described herein provide the initial trigger that drives the binding of two or more molecules together with a high degree of accuracy and efficiency surprisingly even in the presence of Fc regions of an immunoglobulin, which Fc regions are also naturally attracted to each other under cell culture conditions.

By reducing homodimerization of heavy chains, use of the coiled coil heterodimerization domains described herein provides a breakthrough in the ability to produce a homogeneous population of protein complexes comprising a Fc CH component (e.g., multispecific or one-armed antibodies, etc.). Multispecific complexes are advantageous for use in therapeutic applications because, for example, they can direct the co-localization of a target (e.g., a tumor cell) and an agent directed against the target (e.g., a T cell) or they can eliminate the need for combination therapy and the risk associated with providing two or more therapeutics to a subject. Further, to facilitate the construction of antibodies, including multispecific antibodies, tethers according to the present invention can be used to link the

light and heavy chains of an antibody and thereby aid in the proper association of each light chain to its cognate heavy chain.

I. Definitions

The term "antibody" herein is used in the broadest sense and refers to any immunoglobulin (Ig) molecule comprising two heavy chains and two light chains, and any fragment, mutant, variant or derivation thereof which so long as they exhibit the desired biological activity (e.g., epitope binding activity). Examples of antibodies include monoclonal antibodies, polyclonal antibodies, multispecific antibodies and antibody fragments..

The Kabat numbering system is generally used when referring to a residue in the variable domain (approximately residues 1-107 of the light chain and residues 1-113 of the heavy chain) (e.g, Kabat *et al., Sequences of Immunological Interest.* 5th Ed. Public Health Service, National Institutes of Health, Bethesda, Md. (1991)). The "EU numbering system" or "EU index" is generally used when referring to a residue in an immunoglobulin heavy chain constant region (e.g., the EU index reported in Kabat *et al., supra*). The "EU index as in Kabat" refers to the residue numbering of the human IgG1 EU antibody. Unless stated otherwise herein, references to residue numbers in the variable domain of antibodies means residue numbering by the Kabat numbering system. Unless stated otherwise herein, references to residue numbers in the heavy chain constant domain of antibodies means residue numbering by the EU numbering system.

The term "multispecific antibody" is used in the broadest sense and specifically covers an antibody that has polyepitopic specificity. Such multispecific antibodies include, but are not limited to, an antibody comprising a heavy chain variable domain (V_H) and a light chain variable domain (V_L), where the V_HV_L unit has polyepitopic specificity, antibodies having two or more V_L and V_H domains with each V_HV_L unit binding to a different epitope, antibodies having two or more single variable domains with each single variable domain binding to a different epitope, full length antibodies, antibody fragments such as Fab, Fv, dsFv, scFv, diabodies, bispecific diabodies and triabodies, antibody fragments that have been linked covalently or non-covalently. "Polyepitopic specificity" refers to the ability to specifically bind to two or more different epitopes on the same or different target(s). "Monospecific" refers to the ability to bind only one epitope. According to one embodiment the multispecific antibody is an IgG antibody that binds to each epitope with an affinity of 5

μM to 0.001 pM, 3 μM to 0.001 pM, 1 μM to 0.001 pM, 0.5 μM to 0.001 pM, or 0.1 μM to 0.001 pM.

A naturally occurring basic 4-chain antibody unit is a heterotetrameric glycoprotein composed of two identical light (L) chains and two identical heavy (H) chains (an IgM antibody consists of 5 of the basic heterotetramer units along with an additional polypeptide called J chain, and therefore contains 10 antigen binding sites, while secreted IgA antibodies can polymerize to form polyvalent assemblages comprising 2-5 of the basic 4-chain units along with J chain). In the case of IgGs, the 4-chain unit is generally about 150,000 daltons. Each L chain is linked to an H chain by one covalent disulfide bond, while the two H chains are linked to each other by one or more disulfide bonds depending on the H chain isotype. Each H and L chain also has regularly spaced intrachain disulfide bridges. Each H chain has, at the N-terminus, a variable domain (V_H) followed by three constant domains (C_H) for each of the α and γ chains and four C_H domains for μ and ε isotypes. Each L chain has, at the N-terminus, a variable domain (V_L) followed by a constant domain (C_L) at its other end. The V_L is aligned with the V_H and the C_L is aligned with the first constant domain of the heavy chain (C_H1). Particular amino acid residues are believed to form an interface between the light chain and heavy chain variable domains. The pairing of a V_H and V_L together forms a single antigen-binding site. For the structure and properties of the different classes of antibodies, see, e.g., Basic and Clinical Immunology, 8th edition, Daniel P. Stites, Abba I. Terr and Tristram G. Parslow (eds.), Appleton & Lange, Norwalk, CT, 1994, page 71 and Chapter 6.

The L chain from any vertebrate species can be assigned to one of two clearly distinct types, called kappa and lambda, based on the amino acid sequences of their constant domains. Depending on the amino acid sequence of the constant domain of their heavy chains (C_H), immunoglobulins can be assigned to different classes or isotypes. There are five classes of immunoglobulins: IgA, IgD, IgE, IgG, and IgM, having heavy chains designated α, δ, γ, ε, and μ, respectively. The γ and α classes are further divided into subclasses on the basis of relatively minor differences in C_H sequence and function, e.g., humans express the following subclasses: IgG1, IgG2, IgG3, IgG4, IgA1, and IgA2.

The term "variable" refers to the fact that certain segments of the variable domains differ extensively in sequence among antibodies. The V domain mediates antigen binding and defines specificity of a particular antibody for its particular antigen. However, the

variability is not evenly distributed across the 110-amino acid span of the variable domains. Instead, the V regions consist of relatively invariant stretches called framework regions (FRs) of 15-30 amino acids separated by shorter regions of extreme variability called "hypervariable regions" that are each 9-12 amino acids long. The variable domains of native heavy and light chains each comprise four FRs, largely adopting a beta-sheet configuration, connected by three hypervariable regions, which form loops connecting, and in some cases forming part of, the beta-sheet structure. The hypervariable regions in each chain are held together in close proximity by the FRs and, with the hypervariable regions from the other chain, contribute to the formation of the antigen-binding site of antibodies (see Kabat et al., Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD (1991)). The constant domains are not involved directly in binding an antibody to an antigen, but exhibit various effector functions, such as participation of the antibody in antibody dependent cellular cytotoxicity (ADCC).

The term "hypervariable region," "HVR," or "HV," when used herein refers to the regions of an antibody variable domain which are hypervariable in sequence and/or form structurally defined loops. Generally, antibodies comprise six HVRs; three in the VH (H1, H2, H3), and three in the VL (L1, L2, L3). In native antibodies, H3 and L3 display the most diversity of the six HVRs, and H3 in particular is believed to play a unique role in conferring fine specificity to antibodies. See, *e.g.*, Xu et al., *Immunity* 13:37-45 (2000); Johnson and Wu, in *Methods in Molecular Biology* 248:1-25 (Lo, ed., Human Press, Totowa, NJ, 2003). Indeed, naturally occurring camelid antibodies consisting of a heavy chain only are functional and stable in the absence of light chain. See, *e.g.*, Hamers-Casterman et al., *Nature* 363:446-448 (1993); Sheriff et al., *Nature Struct. Biol.* 3:733-736 (1996).

A number of HVR delineations are in use and are encompassed herein. The Kabat Complementarity Determining Regions (CDRs) are based on sequence variability and are the most commonly used (Kabat *et al., Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991)). Chothia refers instead to the location of the structural loops (Chothia and Lesk *J. Mol. Biol.* 196:901-917 (1987)). The AbM HVRs represent a compromise between the Kabat HVRs and Chothia structural loops, and are used by Oxford Molecular's AbM antibody modeling software. The "contact" HVRs are based on an analysis of the available complex crystal structures. The residues from each of these HVRs are noted below.

Loop	Kabat	AbM	Chothia	Contact
L1	L24-L34	L24-L34	L26-L32	L30-L36
L2	L50-L56	L50-L56	L50-L52	L46-L55
L3	L89-L97	L89-L97	L91-L96	L89-L96
H1	H31-H35B	H26-H35B	H26-H32	H30-H35B
	(Kabat Numbering)			
H1	H31-H35	H26-H35	H26-H32	H30-H35
	(Chothia Numbering)			
H2	H50-H65	H50-H58	H53-H55	H47-H58
H3	H95-H102	H95-H102	H96-H101	H93-H101

HVRs may comprise "extended HVRs" as follows: 24-36 or 24-34 (L1), 46-56 or 50-56 (L2) and 89-97 or 89-96 (L3) in the VL and 26-35 (H1), 50-65 or 49-65 (H2) and 93-102, 94-102, or 95-102 (H3) in the VH. The variable domain residues are numbered according to Kabat et al., supra, for each of these definitions.

"Framework regions" (FR) are those variable domain residues other than the CDR residues. Each variable domain typically has four FRs identified as FR1, FR2, FR3, and FR4. If the CDRs are defined according to Kabat, the light chain FR residues are positioned at about residues 1-23 (LCFR1), 35-49 (LCFR2), 57-88 (LCFR3), and 98-107 (LCFR4) and the heavy chain FR residues are positioned about at residues 1-30 (HCFR1), 36-49 (HCFR2), 66-94 (HCFR3), and 103-113 (HCFR4) in the heavy chain residues. If the CDRs comprise amino acid residues from hypervariable loops, the light chain FR residues are positioned about at residues 1-25 (LCFR1), 33-49 (LCFR2), 53-90 (LCFR3), and 97-107 (LCFR4) in the light chain and the heavy chain FR residues are positioned about at residues 1-25 (HCFRI), 33-52 (HCFR2), 56-95 (HCFR3), and 102-113 (HCFR4) in the heavy chain residues. In some instances, when the CDR comprises amino acids from both a CDR as defined by Kabat and those of a hypervariable loop, the FR residues will be adjusted accordingly. For example, when CDRH1 includes amino acids H26-H35, the heavy chain FR1 residues are at positions 1-25 and the FR2 residues are at positions 36-49.

A "human consensus framework" is a framework that represents the most commonly occurring amino acid residues in a selection of human immunoglobulin VL or VH framework sequences. Generally, the selection of human immunoglobulin VL or VH sequences is from a subgroup of variable domain sequences. Generally, the subgroup of sequences is a subgroup

as in Kabat. In one embodiment, for the VL, the subgroup is subgroup kappa I as in Kabat. In one embodiment, for the VH, the subgroup is subgroup III as in Kabat.

One example of an "intact" antibody is one that comprises an antigen-binding site as well as a C_L and at least heavy chain constant domains, C_H1, C_H2, and C_H3. The constant domains can be native sequence constant domains (e.g., human native sequence constant domains) or amino acid sequence variant thereof.

"Antibody fragments" comprise a portion of an intact antibody, preferably the antigen binding or a variable region of the intact antibody. Examples of antibody fragments include Fab, Fab', $F(ab')_2$, and Fv fragments; diabodies (Db); tandem diabodies (taDb), linear antibodies (e.g., U.S. Patent No. 5,641,870, Example 2; Zapata et al., Protein Eng. 8(10):1057-1062 (1995)); one-armed antibodies, single variable domain antibodies, minibodies, single-chain antibody molecules; and multispecific antibodies formed from antibody fragments (e.g., including but not limited to, Db-Fc, taDb-Fc, taDb-CH3 and (scFV)4-Fc).

The expression "single domain antibodies" (sdAbs) or "single variable domain (SVD) antibodies" generally refers to antibodies in which a single variable domain (VH or VL) can confer antigen binding. In other words, the single variable domain does not need to interact with another variable domain in order to recognize the target antigen. Examples of single domain antibodies include those derived from camelids (lamas and camels) and cartilaginous fish (e.g., nurse sharks) and those derived from recombinant methods from humans and mouse antibodies (Nature (1989) 341:544-546; Dev Comp Immunol (2006) 30:43-56; Trend Biochem Sci (2001) 26:230-235; Trends Biotechnol (2003):21:484-490; WO 2005/035572; WO 03/035694; Febs Lett (1994) 339:285-290; WO00/29004; WO 02/051870).

The expression "linear antibodies" generally refers to the antibodies described in Zapata et al., Protein Eng. 8(10):1057-1062 (1995). Briefly, these antibodies comprise a pair of tandem Fd segments (V_H-C_H1-V_H-C_H1) which, together with complementary light chain polypeptides, form a pair of antigen binding regions. Linear antibodies can be bispecific or monospecific.

The term "knob-into-hole" or "KnH" technology as mentioned herein refers to the technology directing the pairing of two polypeptides together in vitro or in vivo by introducing a pertuberance (knob) into one polypeptide and a cavity (hole) into the other polypeptide at an interface in which they interact. For example, KnHs have been introduced

in the Fc:Fc binding interfaces, CL:CH1 interfaces or VH/VL interfaces of antibodies (e.g., US2007/0178552, WO 96/027011, WO 98/050431and Zhu et al. (1997) Protein Science 6:781-788). This is especially useful in driving the pairing of two different heavy chains together during the manufacture of multispecific antibodies. For example, multispecific antibodies having KnH in their Fc regions can further comprise single variable domains linked to each Fc region, or further comprise different heavy chain variable domains that pair with similar or different light chain variable domains. KnH technology can be also be used to pair two different receptor extracellular domains together or any other polypeptide sequences that comprises different target recognition sequences (e.g., including affibodies, peptibodies and other Fc fusions). Papain digestion of antibodies produces two identical antigen-binding fragments, called "Fab" fragments, and a residual "Fc" fragment, a designation reflecting the ability to crystallize readily. The Fab fragment consists of an entire L chain along with the variable region domain of the H chain (V_H), and the first constant domain of one heavy chain (C_H1). Pepsin treatment of an antibody yields a single large F(ab')$_2$ fragment which roughly corresponds to two disulfide linked Fab fragments having divalent antigen-binding activity and is still capable of cross-linking antigen. Fab' fragments differ from Fab fragments by having additional few residues at the carboxy terminus of the C_H1 domain including one or more cysteines from the antibody hinge region. Fab'-SH is the designation herein for Fab' in which the cysteine residue(s) of the constant domains bear a free thiol group. F(ab')$_2$ antibody fragments originally were produced as pairs of Fab' fragments which have hinge cysteines between them. Other chemical couplings of antibody fragments are also known.

The Fc fragment comprises the carboxy-terminal portions of both H chains held together by disulfides. The effector functions of antibodies are determined by sequences in the Fc region; this region is also the part recognized by Fc receptors (FcR) found on certain types of cells.

"Fv" consists of a dimer of one heavy- and one light-chain variable region domain in tight, non-covalent association. From the folding of these two domains emanate six hypervariable loops (3 loops each from the H and L chain) that contribute the amino acid residues for antigen binding and confer antigen binding specificity to the antibody. However, even a single variable domain (or half of an Fv comprising only three CDRs specific for an antigen) has the ability to recognize and bind antigen, although often at a lower affinity than the entire binding site.

"Single-chain Fv" also abbreviated as "sFv" or "scFv" are antibody fragments that comprise the V_H and V_L antibody domains connected into a single polypeptide chain. Preferably, the sFv polypeptide further comprises a polypeptide linker between the V_H and V_L domains, which enables the sFv to form the desired structure for antigen binding. For a review of sFv, see Pluckthun, The Pharmacology of Monoclonal Antibodies, vol. 113, Rosenburg and Moore eds., Springer-Verlag, New York, pp. 269-315 (1994); Malmborg et al., J. Immunol. Methods 183:7-13, 1995.

The term "diabodies" refers to small antibody fragments prepared by constructing sFv fragments (see preceding paragraph) with short linkers (about 5-10 residues) between the V_H and V_L domains such that inter-chain but not intra-chain pairing of the V domains is achieved, resulting in a bivalent fragment, i.e., fragment having two antigen-binding sites. Bispecific diabodies are heterodimers of two "crossover" sFv fragments in which the V_H and V_L domains of the two antibodies are present on different polypeptide chains. Diabodies are described more fully in, for example, EP 404,097; WO 93/11161; and Hollinger et al., Proc. Natl. Acad. Sci. USA 90:6444-6448 (1993).

The term "one-armed antibody" or "one-armed antibodies" refers to an antibody that comprises (1) a variable domain joined by a peptide bond to a polypeptide comprising a CH2 domain, a CH3 domain or a CH2-CH3 domain and (2) a second CH2, CH3 or CH2-CH3 domain, wherein a variable domain is not joined by a peptide bond to a polypeptide comprising the second CH2, CH3 or CH2-CH3 domain. In one embodiment, the one-armed antibody comprises 3 polypeptides (1) a first polypeptide comprising a variable domain (e.g., VH), CH1, CH2 and CH3, (2) a second polypeptide comprising a variable domain (e.g., VL) and a CL domain, and (3) a third polypeptide comprising a CH2 and CH3 domain. In an embodiment, the third polypeptide does not comprise a variable domain. In another embodiment, the one-armed antibody has a partial hinge region containing the two cysteine residues which form disulphide bonds linking the constant heavy chains. In one embodiment, the variable domains of the one armed antibody form an antigen binding region. In another embodiment, a variable domain of the one armed antibody is a single variable domain, wherein each single variable domain is an antigen binding region.

Antibodies of the invention can be "chimeric" antibodies in which a portion of the heavy and/or light chain is identical with or homologous to corresponding sequences in antibodies derived from a particular species or belonging to a particular antibody class or

subclass, while the remainder of the chain(s) is identical with or homologous to corresponding sequences in antibodies derived from another species or belonging to another antibody class or subclass, as well as fragments of such antibodies, provided that they exhibit the desired biological activity (U.S. Patent No. 4,816,567; and Morrison et al., Proc. Natl. Acad. Sci. USA 81:6851-6855 (1984)). Chimeric antibodies of interest herein include primatized antibodies comprising variable domain antigen-binding sequences derived from a non-human primate (e.g., Old World Monkey, Ape, etc.) and human constant region sequences.

"Humanized" forms of non-human (e.g., rodent) antibodies are chimeric antibodies that contain minimal sequence derived from the non-human antibody. For the most part, humanized antibodies are human immunoglobulins (recipient antibody) in which residues from a hypervariable region of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit or non-human primate having the desired antibody specificity, affinity, and capability. In some instances, framework region (FR) residues of the human immunoglobulin are replaced by corresponding non-human residues. Furthermore, humanized antibodies can comprise residues that are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance. In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable loops correspond to those of a non-human immunoglobulin and all or substantially all of the FRs are those of a human immunoglobulin sequence. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. For further details, see Jones et al., Nature 321:522-525 (1986); Riechmann et al., Nature 332:323-329 (1988); and Presta, Curr. Op. Struct. Biol. 2:593-596 (1992).

"Complex" or "complexed" as used here in refers to the association of two or more molecules that interact with each other through bonds and/or forces (e.g., van der waals, hydrophobic, hydrophilic forces) that are not peptide bonds. In one embodiment, the complex is heteromultimeric. It should be understood that the term "protein complex" or "polypeptide complex" as used herein includes complexes that have a non-protein entity conjugated to a protein in the protein complex (e.g., including, but not limited to, chemical molecules such as a toxin or a detection agent).

The term "heteromultimer" or "heteromultimeric" as used herein describes two or

more polypeptides that interact with each other by a non-peptidic, covalent bond (e.g., disulfide bond) and/or a non-covalent interaction (e.g., hydrogen bonds, ionic bonds, Van der Waals forces, and hydrophobic interactions), wherein at least two of the molecules have different sequences from each other.

As used herein, the term "immunoadhesin" designates molecules which combine the binding specificity of a heterologous protein (an "adhesin") with the effector functions of immunoglobulin constant domains. Structurally, the immunoadhesins comprise a fusion of an amino acid sequence with a desired binding specificity, which amino acid sequence is other than the antigen recognition and binding site of an antibody (i.e., is "heterologous" compared to a constant region of an antibody), and an immunoglobulin constant domain sequence (e.g., CH2 and/or CH3 sequence of an IgG). Exemplary adhesin sequences include contiguous amino acid sequences that comprise a portion of a receptor or a ligand that binds to a protein of interest. Adhesin sequences can also be sequences that bind a protein of interest, but are not receptor or ligand sequences (e.g., adhesin sequences in peptibodies). Such polypeptide sequences can be selected or identified by various methods, include phage display techniques and high throughput sorting methods. The immunoglobulin constant domain sequence in the immunoadhesin can be obtained from any immunoglobulin, such as IgG-1, IgG-2, IgG-3, or IgG-4 subtypes, IgA (including IgA-1 and IgA-2), IgE, IgD, or IgM.

An antibody of this invention "which binds" an antigen of interest is one that binds the antigen with sufficient affinity such that the antibody is useful as a diagnostic and/or therapeutic agent in targeting a protein or a cell or tissue expressing the antigen, and does not significantly cross-react with other proteins. In such embodiments, the extent of binding of the antibody to a "non-target" protein will be less than about 10% of the binding of the antibody to its particular target protein as determined by fluorescence activated cell sorting (FACS) analysis or radioimmunoprecipitation (RIA) or ELISA. With regard to the binding of an antibody to a target molecule, the term "specific binding" or "specifically binds to" or is "specific for" a particular polypeptide or an epitope on a particular polypeptide target means binding that is measurably different from a non-specific interaction (e.g., a non-specific interaction may be binding to bovine serum albumin or casein). Specific binding can be measured, for example, by determining binding of a molecule compared to binding of a control molecule. For example, specific binding can be determined by competition with a control molecule that is similar to the target, for example, an excess of non-labeled target. In this case, specific binding is indicated if the binding of the labeled target to a probe is

competitively inhibited by excess unlabeled target. The term "specific binding" or "specifically binds to" or is "specific for" a particular polypeptide or an epitope on a particular polypeptide target as used herein can be exhibited, for example, by a molecule having a Kd for the target of at least about 200 nM, alternatively at least about 150 nM, alternatively at least about 100 nM, alternatively at least about 60 nM, alternatively at least about 50 nM, alternatively at least about 40 nM, alternatively at least about 30 nM, alternatively at least about 20 nM, alternatively at least about 10 nM, alternatively at least about 8 nM, alternatively at least about 6 nM, alternatively at least about 4 nM, alternatively at least about 2 nM, alternatively at least about 1 nM, or greater. In one embodiment, the term "specific binding" refers to binding where a molecule binds to a particular polypeptide or epitope on a particular polypeptide without substantially binding to any other polypeptide or polypeptide epitope.

"Binding affinity" generally refers to the strength of the sum total of noncovalent interactions between a single binding site of a molecule (e.g., an antibody) and its binding partner (e.g., an antigen). Unless indicated otherwise, as used herein, "binding affinity" refers to intrinsic binding affinity which reflects a 1:1 interaction between members of a binding pair (e.g., antibody and antigen). The affinity of a molecule X for its partner Y can generally be represented by the dissociation constant (Kd). For example, the Kd can be about 200 nM, 150 nM, 100 nM, 60 nM, 50 nM, 40 nM, 30 nM, 20 nM, 10 nM, 8 nM, 6 nM, 4 nM, 2 nM, 1 nM, or stronger. Affinity can be measured by common methods known in the art, including those described herein. Low-affinity antibodies generally bind antigen slowly and tend to dissociate readily, whereas high-affinity antibodies generally bind antigen faster and tend to remain bound longer. A variety of methods of measuring binding affinity are known in the art, any of which can be used for purposes of the present invention.

In one embodiment, the "Kd" or "Kd value" according to this invention is measured by using surface plasmon resonance assays using a BIAcore™-2000 or a BIAcore™-3000 (BIAcore, Inc., Piscataway, NJ) at 25°C with immobilized antigen CM5 chips at ~10 response units (RU). Briefly, carboxymethylated dextran biosensor chips (CM5, BIAcore Inc.) are activated with N-ethyl-N'- (3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and N-hydroxysuccinimide (NHS) according to the supplier's instructions. Antigen is diluted with 10mM sodium acetate, pH 4.8, into 5μg/ml (~0.2μM) before injection at a flow rate of 5 μl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1M ethanolamine is injected to block unreacted groups.

For kinetics measurements, two-fold serial dilutions of Fab (e.g., 0.78 nM to 500 nM) are injected in PBS with 0.05% Tween 20 (PBST) at 25°C at a flow rate of approximately 25 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIAcore Evaluation Software version 3.2) by simultaneous fitting the association and dissociation sensorgram. The equilibrium dissociation constant (Kd) is calculated as the ratio k_{off}/k_{on}. See, e.g., Chen et al., J. Mol. Biol. 293:865-881 (1999). If the on-rate exceeds 10^6 M^{-1} S^{-1} by the surface plasmon resonance assay above, then the on-rate can be determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence emission intensity (excitation = 295 nm; emission = 340 nm, 16 nm band-pass) at 25°C of a 20 nM anti-antigen antibody (Fab form) in PBS, pH 7.2, in the presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophometer (Aviv Instruments) or a 8000-series SLM-Aminco spectrophotometer (ThermoSpectronic) with a stir red cuvette.

An "on-rate" or "rate of association" or "association rate" or "k_{on}" according to this invention can also be determined with the same surface plasmon resonance technique described above using a BIAcore™-2000 or a BIAcore™-3000 (BIAcore, Inc., Piscataway, NJ) at 25°C with immobilized antigen CM5 chips at ~10 response units (RU). Briefly, carboxymethylated dextran biosensor chips (CM5, BIAcore Inc.) are activated with N-ethyl-N'- (3-dimethylaminopropyl)-carbodiimide hydrochloride (EDC) and N-hydroxysuccinimide (NHS) according to the supplier's instructions. Antigen is diluted with 10mM sodium acetate, pH 4.8, into 5 µg/ml (~0.2 µM) before injection at a flow rate of 5 µl/minute to achieve approximately 10 response units (RU) of coupled protein. Following the injection of antigen, 1M ethanolamine is injected to block unreacted groups. For kinetics measurements, two-fold serial dilutions of Fab (e.g., 0.78 nM to 500 nM) are injected in PBS with 0.05% Tween 20 (PBST) at 25°C at a flow rate of approximately 25 µl/min. Association rates (k_{on}) and dissociation rates (k_{off}) are calculated using a simple one-to-one Langmuir binding model (BIAcore Evaluation Software version 3.2) by simultaneous fitting the association and dissociation sensorgram. The equilibrium dissociation constant (Kd) is calculated as the ratio k_{off}/k_{on}. See, e.g., Chen et al., J. Mol. Biol. 293:865-881 (1999). However, if the on-rate exceeds 10^6 M^{-1} S^{-1} by the surface plasmon resonance assay above, then the on-rate is preferably determined by using a fluorescent quenching technique that measures the increase or decrease in fluorescence emission intensity (excitation = 295 nm; emission = 340 nm, 16 nm band-pass) at 25°C of a 20 nM anti-antigen antibody (Fab form) in PBS, pH 7.2, in the

presence of increasing concentrations of antigen as measured in a spectrometer, such as a stop-flow equipped spectrophotometer (Aviv Instruments) or a 8000-series SLM-Aminco spectrophotometer (ThermoSpectronic) with a stirred cuvette.

"Biologically active" and "biological activity" and "biological characteristics" with respect to a polypeptide of this invention, such as an antibody, fragment, or derivative thereof, means having the ability to bind to a biological molecule, except where specified otherwise.

"Peptibody" or "peptibodies" refers to a fusion of randomly generated peptides with an Fc domain. See U.S. Pat. No. 6,660,843, issued Dec. 9, 2003 to Feige et al. (incorporated by reference in its entirety). They include one or more peptides linked to the N-terminus, C-terminus, amino acid sidechains, or to more than one of these sites. Peptibody technology enables design of therapeutic agents that incorporate peptides that target one or more ligands or receptors, tumor-homing peptides, membrane-transporting peptides, and the like. Peptibody technology has proven useful in design of a number of such molecules, including linear and disulfide-constrained peptides, "tandem peptide multimers" (i.e., more than one peptide on a single chain of an Fc domain). See, for example, U.S. Pat. No. 6,660,843; U.S. Pat. App. No. 2003/0195156, published Oct. 16, 2003 (corresponding to WO 02/092620, published Nov. 21, 2002); U.S. Pat. App. No. 2003/0176352, published Sep. 18, 2003 (corresponding to WO 03/031589, published Apr. 17, 2003); U.S. Ser. No. 09/422,838, filed Oct. 22, 1999 (corresponding to WO 00/24770, published May 4, 2000); U.S. Pat. App. No. 2003/0229023, published Dec. 11, 2003; WO 03/057134, published Jul. 17, 2003; U.S. Pat. App. No. 2003/0236193, published Dec. 25, 2003 (corresponding to PCT/US04/010989, filed Apr. 8, 2004); U.S. Ser. No. 10/666,480, filed Sep. 18, 2003 (corresponding to WO 04/026329, published Apr. 1, 2004), each of which is hereby incorporated by reference in its entirety.

"Affibodies" or "Affibody" refers to the use of a protein liked by peptide bond to an Fc region, wherein the protein is used as a scaffold to provide a binding surface for a target molecule. The protein is often a naturally occurring protein such as staphylococcal protein A or IgG-binding B domain, or the Z protein derived therefrom (see Nilsson et al (1987), Prot Eng 1, 107-133, and U.S. Pat. No. 5,143,844) or a fragment or derivative thereof. For example, affibodies can be created from Z proteins variants having altered binding affinity to target molecule(s), wherein a segment of the Z protein has been mutated by random mutagenesis to create a library of variants capable of binding a target molecule. Examples of affibodies include U.S. Pat. No. 6,534,628, Nord K et al, Prot Eng 8:601-608 (1995) and

Nord K et al, Nat Biotech 15:772-777 (1997). Biotechnol Appl Biochem. 2008 Jun;50(Pt 2):97-112.

"Isolated" heteromultimer or complex means a heteromultimer or complex which has been separated and/or recovered from a component of its natural cell culture environment. Contaminant components of its natural environment are materials which would interfere with diagnostic or therapeutic uses for the heteromultimer, and may include enzymes, hormones, and other proteinaceous or nonproteinaceous solutes. In preferred embodiments, the heteromultimer will be purified (1) to greater than 95% by weight of protein as determined by the Lowry method, and most preferably more than 99% by weight, (2) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of a spinning cup sequenator, or (3) to homogeneity by SDS-PAGE under reducing or nonreducing conditions using Coomassie blue or, preferably, silver stain.

The heteromultimers of the present invention are generally purified to substantial homogeneity. The phrases "substantially homogeneous", "substantially homogeneous form" and "substantial homogeneity" are used to indicate that the product is substantially devoid of by-products originated from undesired polypeptide combinations (e.g. homomultimers).

Expressed in terms of purity, substantial homogeneity means that the amount of by-products does not exceed 10%, 9%, 8%, 7%, 6%, 4%, 3%, 2% or 1% by weight or is less than 1% by weight. In one embodiment, the by-product is below 5%.

"Biological molecule" refers to a nucleic acid, a protein, a carbohydrate, a lipid, and combinations thereof. In one embodiment, the biologic molecule exists in nature.

"Isolated," when used to describe the various antibodies disclosed herein, means an antibody that has been identified and separated and/or recovered from a cell or cell culture from which it was expressed. Contaminant components of its natural environment are materials that would typically interfere with diagnostic or therapeutic uses for the polypeptide, and can include enzymes, hormones, and other proteinaceous or non-proteinaceous solutes. In preferred embodiments, the antibody will be purified (1) to a degree sufficient to obtain at least 15 residues of N-terminal or internal amino acid sequence by use of a spinning cup sequenator, or (2) to homogeneity by SDS-PAGE under non-reducing or reducing conditions using Coomassie blue or, preferably, silver stain. Isolated antibody includes antibodies *in situ* within recombinant cells, because at least one component of the polypeptide natural environment will not be present. Ordinarily, however, isolated polypeptide will be prepared by at least one purification step.

By "linked" or "links" as used herein is meant either a direct peptide bond linkage between a first and second amino acid sequence or a linkage that involves a third amino acid sequence that is peptide bonded to and between the first and second amino acid sequences. For example, a linker peptide bonded to the C-terminal end of one amino acid sequence and to the N-terminal end of the other amino acid sequence.

By "linker" as used herein is meant an amino acid sequence of two or more amino acids in length. The linker can consist of neutral polar or nonpolar amino acids. A linker can be, for example, 2 to 100 amino acids in length, such as between 2 and 50 amino acids in length, for example, 3, 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 amino acids in length. A linker can be "cleavable," for example, by auto-cleavage, or enzymatic or chemical cleavage. Cleavage sites in amino acid sequences and enzymes and chemicals that cleave at such sites are well known in the art and are also described herein.

By a "tether" as used herein is meant an amino acid linker that joins two other amino acid sequences. A tether as described herein can link the N-terminus of an immunoglobulin heavy chain variable domain with the C-terminus of an immunoglobulin light chain constant domain. In particular embodiments, a tether is between about 15 and 50 amino acids in length, for example, between 20 and 26 amino acids in length (e.g., 20, 21, 22, 23, 24, 25, or 26 amino acids in length). A tether may be "cleavable," for example, by auto-cleavage, or enzymatic or chemical cleavage using methods and reagents standard in the art.

Enzymatic cleavage of a "linker" or a "tether" may involve the use of an endopeptidase such as, for example, Lys-C, Asp-N, Arg-C, V8, Glu-C, chymotrypsin, trypsin, pepsin, papain, thrombin, Genenase, Factor Xa, TEV (tobacco etch virus cysteine protease), Enterokinase, HRV C3 (human rhinovirus C3 protease), Kininogenase, as well as subtilisin-like proprotein convertases (e.g., Furin (PC1), PC2, or PC3) or N-arginine dibasic convertase. Chemical cleavage may involve use of, for example, hydroxylamine, N-chlorosuccinimide, N-bromosuccinimide, or cyanogen bromide.

A "Lys-C endopeptidase cleavage site" as used herein is a Lysine residue in an amino acid sequence that can be cleaved at the C-terminal side by Lys-C endopeptidase. Lys-C endopeptidase cleaves at the C-terminal side of a Lysine residue.

By a "heptad repeat" as used herein is meant a sequence of 7 consecutive amino acids that are repeated at least once in an amino acid sequence. The heptad repeats may be arranged consecutively in the amino acid sequence with the C-terminus of the first repeat being immediately adjacent to the N-terminus of the second repeat. In one embodiment, the

heptad repeat has the sequence of Formula I or Formula II as defined herein.

By a "coiled coil domain," "coiled coil heterodimerization domain," "coil," or "coil heterodimerization domain" as used herein is meant an amino acid sequence that forms an alpha-helical structure that can interact with a second alpha-helical structure (a second "coiled coil domain") to form a "coiled coil" or "heterodimeric coiled coil." The alpha helical structures may be right-handed alpha helices. In one embodiment, the alpha helical structures are made up of heptad repeats. In one particular example, the coil coil domain has a structure as shown in Figure 1 where residues at the "X_1" and "X_1'" positions of a first and a second alpha helical structure form hydrophobic interactions with each other, residues at the "X_4" and "X_4'" positions of the first and the second alpha helical structure form hydrophobic interactions with each other, residues at the "X_5" positions of the first alpha helical structure form ionic interactions with residues at the "X_7'" position of the second alpha helical structure, and residues at the "X_7" positions of the first alpha helical structure form ionic interactions with residues at the "X_5'" position of the second alpha helical structure. The coiled coil domain may be made up of 2 or more heptad repeats of Formula I or Formula II as defined herein.

By a "hydrophobic residue" is meant Alanine, Valine, Leucine, Isoleucine, Tryptophan, Phenylalanine, Proline, or Methionine. In a particular embodiment, the hydrophobic residue is not Proline.

By a "charged residue" is meant an acidic or basic amino acid. Lysine, Arginine, and Histidine are basic amino acids, and Aspartic Acid and Glutamic Acid are acidic amino acids.

By a "chaotropic agent" is meant a water-soluble substance which disrupts the three-dimensional structure of a protein (e.g., an antibody) by interfering with stabilizing intra-molecular interactions (e.g., hydrogen bonds, van der Waals forces, or hydrophobic effects). Exemplary chaotropic agents include, but are not limited to, urea, Guanidine-HCl, lithium perchlorate, Histidine, and Arginine.

By a "mild detergent" is meant a water-soluble substance which disrupts the three-dimensional structure of a protein (e.g., an antibody) by interfering with stabilizing intra-molecular interactions (e.g., hydrogen bonds, van der Waals forces, or hydrophobic effects), but which does not permanently disrupt the protein structure as to cause a loss of biological activity (i.e., does not denature the protein). Exemplary mild detergents include, but are not limited to, Tween (e.g., Tween-20), Triton (e.g., Triton X-100), NP-40 (nonyl phenoxylpolyethoxylethanol), Nonidet P-40 (octyl phenoxylpolyethoxylethanol), and Sodium

Dodecyl Sulfate (SDS).

"Hinge region" is generally defined as stretching from Glu216 to Pro230 of human IgG1 (Burton, Molec. Immunol.22:161-206 (1985)). Hinge regions of other IgG isotypes may be aligned with the IgG1 sequence by placing the first and last cysteine residues forming inter-heavy chain S-S bonds in the same positions.

The "lower hinge region" of an Fc region is normally defined as the stretch of residues immediately C-terminal to the hinge region, i.e. residues 233 to 239 of the Fc region. Prior to the present invention, FcgammaR binding was generally attributed to amino acid residues in the lower hinge region of an IgG Fc region.

The "CH2 domain" of a human IgG Fc region usually extends from about residues 231 to about 340 of the IgG. The CH2 domain is unique in that it is not closely paired with another domain. Rather, two N-linked branched carbohydrate chains are interposed between the two CH2 domains of an intact native IgG molecule. It has been speculated that the carbohydrate may provide a substitute for the domain-domain pairing and help stabilize the CH2 domain. Burton, Molec. Immunol.22:161-206 (1985).

The "CH3 domain" comprises the stretch of residues C-terminal to a CH2 domain in an Fc region (i.e. from about amino acid residue 341 to about amino acid residue 447 of an IgG).

The term "Fc region" herein is used to define a C-terminal region of an immunoglobulin heavy chain, including native sequence Fc regions and variant Fc regions. Although the boundaries of the Fc region of an immunoglobulin heavy chain might vary, the human IgG heavy chain Fc region is usually defined to stretch from an amino acid residue at position Cys226, or from Pro230, to the carboxyl-terminus thereof. The C-terminal lysine (residue 447 according to the EU numbering system) of the Fc region may be removed, for example, during production or purification of the antibody, or by recombinantly engineering the nucleic acid encoding a heavy chain of the antibody. Accordingly, a composition of intact antibodies may comprise antibody populations with all K447 residues removed, antibody populations with no K447 residues removed, and antibody populations having a mixture of antibodies with and without the K447 residue.

A "functional Fc region" possesses an "effector function" of a native sequence Fc region. Exemplary "effector functions" include C1q binding; CDC; Fc receptor binding; ADCC; phagocytosis; down regulation of cell surface receptors (e.g. B cell receptor; BCR), etc. Such effector functions generally require the Fc region to be combined with a binding

domain (*e.g.*, an antibody variable domain) and can be assessed using various assays as disclosed, for example, in definitions herein.

A "native sequence Fc region" comprises an amino acid sequence identical to the amino acid sequence of an Fc region found in nature. Native sequence human Fc regions include a native sequence human IgG1 Fc region (non-A and A allotypes); native sequence human IgG2 Fc region; native sequence human IgG3 Fc region; and native sequence human IgG4 Fc region as well as naturally occurring variants thereof.

A "variant Fc region" comprises an amino acid sequence which differs from that of a native sequence Fc region by virtue of at least one amino acid modification, preferably one or more amino acid substitution(s). Preferably, the variant Fc region has at least one amino acid substitution compared to a native sequence Fc region or to the Fc region of a parent polypeptide, e.g. from about one to about ten amino acid substitutions, and preferably from about one to about five amino acid substitutions in a native sequence Fc region or in the Fc region of the parent polypeptide. The variant Fc region herein will preferably possess at least about 80% homology with a native sequence Fc region and/or with an Fc region of a parent polypeptide, and most preferably at least about 90% homology therewith, more preferably at least about 95% homology therewith.

"Fc complex" as used herein refers to two CH2 domains of an Fc region interacting together and/or two CH3 domains of an Fc region interacting together, wherein the CH2 domains and/or the CH3 domains interact through bonds and/or forces (e.g., van der waals, hydrophobic, hydrophilic forces) that are not peptide bonds.

"Fc component" as used herein refers to a hinge region, a CH2 domain or a CH3 domain of an Fc region.

"Fc CH component" or "FcCH" as used here in refers to a polypeptide comprising a CH2 domain, a CH3 domain, or CH2 and CH3 domains of an Fc region.

Antibody "effector functions" refer to those biological activities attributable to the Fc region (a native sequence Fc region or amino acid sequence variant Fc region) of an antibody, and vary with the antibody isotype. Examples of antibody effector functions include: C1q binding and complement dependent cytotoxicity; Fc receptor binding; antibody-dependent cell-mediated cytotoxicity (ADCC); phagocytosis; down regulation of cell surface receptors (e.g., B cell receptor); and B cell activation.

"Antibody-dependent cell-mediated cytotoxicity" or "ADCC" refers to a form of

cytotoxicity in which secreted Ig bound onto Fc receptors (FcRs) present on certain cytotoxic cells (e.g., Natural Killer (NK) cells, neutrophils, and macrophages) enable these cytotoxic effector cells to bind specifically to an antigen-bearing target cell and subsequently kill the target cell with cytotoxic agents. The antibodies "arm" the cytotoxic cells and are absolutely required for such killing. The primary cells for mediating ADCC, NK cells, express FcγRIII only, whereas monocytes express FcγRI, FcγRII, and FcγRIII. FcR expression on hematopoietic cells is summarized in Table 3 on page 464 of Ravetch and Kinet, Annu. Rev. Immunol. 9:457-92 (1991). To assess ADCC activity of a molecule of interest, an *in vitro* ADCC assay, such as that described in U.S. Patent No. 5,500,362 or 5,821,337 can be performed. Useful effector cells for such assays include peripheral blood mononuclear cells (PBMC) and Natural Killer (NK) cells. Alternatively, or additionally, ADCC activity of the molecule of interest can be assessed *in vivo*, e.g., in a animal model such as that disclosed in Clynes et al., Proc. Natl. Acad. Sci. USA 95:652-656 (1998).

"Fc receptor" or "FcR" describes a receptor that binds to the Fc region of an antibody. The preferred FcR is a native sequence human FcR. Moreover, a preferred FcR is one that binds an IgG antibody (a gamma receptor) and includes receptors of the FcγRI, FcγRII, and FcγRIII subclasses, including allelic variants and alternatively spliced forms of these receptors. FcγRII receptors include FcγRIIA (an "activating receptor") and FcγRIIB (an "inhibiting receptor"), which have similar amino acid sequences that differ primarily in the cytoplasmic domains thereof. Activating receptor FcγRIIA contains an immunoreceptor tyrosine-based activation motif (ITAM) in its cytoplasmic domain. Inhibiting receptor FcγRIIB contains an immunoreceptor tyrosine-based inhibition motif (ITIM) in its cytoplasmic domain (see review M. in Daëron, Annu. Rev. Immunol. 15:203-234 (1997)). FcRs are reviewed in Ravetch and Kinet, Annu. Rev. Immunol. 9:457-492 (1991); Capel et al., Immunomethods 4:25-34 (1994); and de Haas et al., J. Lab. Clin. Med. 126:330-41 (1995). Other FcRs, including those to be identified in the future, are encompassed by the term "FcR" herein. The term also includes the neonatal receptor, FcRn, which is responsible for the transfer of maternal IgGs to the fetus (Guyer et al., J. Immunol. 117:587 (1976) and Kim et al., J. Immunol. 24:249 (1994)).

"Human effector cells" are leukocytes that express one or more FcRs and perform effector functions. Preferably, the cells express at least FcγRIII and perform ADCC effector function. Examples of human leukocytes that mediate ADCC include peripheral blood mononuclear cells (PBMC), natural killer (NK) cells, monocytes, cytotoxic T cells, and

neutrophils; with PBMCs and NK cells being preferred. The effector cells can be isolated from a native source, e.g., from blood.

"Complement dependent cytotoxicity" or "CDC" refers to the lysis of a target cell in the presence of complement. Activation of the classical complement pathway is initiated by the binding of the first component of the complement system (C1q) to antibodies (of the appropriate subclass) that are bound to their cognate antigen. To assess complement activation, a CDC assay, e.g., as described in Gazzano-Santoro et al., J. Immunol. Methods 202:163 (1996), can be performed.

The term "therapeutically effective amount" refers to an amount of an antibody, antibody fragment, or derivative to treat a disease or disorder in a subject. In the case of tumor (e.g., a cancerous tumor), the therapeutically effective amount of the antibody or antibody fragment (e.g., a multispecific antibody or antibody fragment) may reduce the number of cancer cells; reduce the primary tumor size; inhibit (i.e., slow to some extent and preferably stop) cancer cell infiltration into peripheral organs; inhibit (i.e., slow to some extent and preferably stop) tumor metastasis; inhibit, to some extent, tumor growth; and/or relieve to some extent one or more of the symptoms associated with the disorder. To the extent the antibody or antibody fragment may prevent growth and/or kill existing cancer cells, it may be cytostatic and/or cytotoxic. For cancer therapy, efficacy *in vivo* can, for example, be measured by assessing the duration of survival, time to disease progression (TTP), the response rates (RR), duration of response, and/or quality of life.

By "reduce or inhibit" is meant the ability to cause an overall decrease preferably of 20% or greater, more preferably of 50% or greater, and most preferably of 75%, 85%, 90%, 95%, or greater. Reduce or inhibit can refer to the symptoms of the disorder being treated, the presence or size of metastases, the size of the primary tumor, or the size or number of the blood vessels in angiogenic disorders.

The terms "cancer" and "cancerous" refer to or describe the physiological condition in mammals that is typically characterized by unregulated cell growth/proliferation. Included in this definition are benign and malignant cancers. Examples of cancer include but are not limited to, carcinoma, lymphoma, blastoma, sarcoma, and leukemia. More particular examples of such cancers include squamous cell cancer, small-cell lung cancer, non-small cell lung cancer, adenocarcinoma of the lung, squamous carcinoma of the lung, cancer of the peritoneum, hepatocellular cancer, gastric or stomach cancer including gastrointestinal cancer, pancreatic cancer, glioblastoma, glioma, cervical cancer, ovarian cancer, liver cancer,

bladder cancer, hepatoma, breast cancer, colon cancer, colorectal cancer, endometrial or uterine carcinoma, salivary gland carcinoma, kidney cancer (e.g., renal cell carcinoma), liver cancer, prostate cancer, vulval cancer, thyroid cancer, hepatic carcinoma, anal carcinoma, penile carcinoma, melanoma, and various types of head and neck cancer. By "early stage cancer" is meant a cancer that is not invasive or metastatic or is classified as a Stage 0, I, or II cancer. The term "precancerous" refers to a condition or a growth that typically precedes or develops into a cancer. By "non-metastatic" is meant a cancer that is benign or that remains at the primary site and has not penetrated into the lymphatic or blood vessel system or to tissues other than the primary site. Generally, a non-metastatic cancer is any cancer that is a Stage 0, I, or II cancer, and occasionally a Stage III cancer.

A "non-malignant disease or disorder involving abnormal activation of HER2" is a condition that does not involve a cancer where abnormal activation of HER2 is occurring in cells or tissue of the subject having, or predisposed to, the disease or disorder. Examples of such diseases or disorders include autoimmune disease (e.g., psoriasis), see definition below; endometriosis; scleroderma; restenosis; polyps such as colon polyps, nasal polyps or gastrointestinal polyps; fibroadenoma; respiratory disease (e.g., chronic bronchitis, asthma including acute asthma and allergic asthma, cystic fibrosis, bronchiectasis, allergic or other rhinitis or sinusitis, α1-anti-trypsin deficiency, coughs, pulmonary emphysema, pulmonary fibrosis or hyper-reactive airways, chronic obstructive pulmonary disease, and chronic obstructive lung disorder); cholecystitis; neurofibromatosis; polycystic kidney disease; inflammatory diseases; skin disorders including psoriasis and dermatitis; vascular disease; conditions involving abnormal proliferation of vascular epithelial cells; gastrointestinal ulcers; Menetrier's disease, secreting adenomas or protein loss syndrome; renal disorders; angiogenic disorders; ocular disease such as age related macular degeneration, presumed ocular histoplasmosis syndrome, retinal neovascularization from proliferative diabetic retinopathy, retinal vascularization, diabetic retinopathy, or age related macular degeneration; bone associated pathologies such as osteoarthritis, rickets and osteoporosis; damage following a cerebral ischemic event; fibrotic or edemia diseases such as hepatic cirrhosis, lung fibrosis, carcoidosis, throiditis, hyperviscosity syndrome systemic, Osler Weber-Rendu disease, chronic occlusive pulmonary disease, or edema following burns, trauma, radiation, stroke, hypoxia or ischemia; hypersensitivity reaction of the skin; diabetic retinopathy and diabetic nephropathy; Guillain-Barre syndrome; graft versus host disease or transplant rejection; Paget's disease; bone or joint inflammation; photoaging (e.g. caused by UV radiation of

human skin); benign prostatic hypertrophy; certain microbial infections including microbial pathogens selected from adenovirus, hantaviruses, Borrelia burgdorferi, Yersinia spp. and Bordetella pertussis; thrombus caused by platelet aggregation; reproductive conditions such as endometriosis, ovarian hyperstimulation syndrome, preeclampsia, dysfunctional uterine bleeding, or menometrorrhagia; synovitis; atheroma; acute and chronic nephropathies (including proliferative glomerulonephritis and diabetes-induced renal disease); eczema; hypertrophic scar formation; endotoxic shock and fungal infection; familial adenomatosis polyposis; neurodedenerative diseases (e.g. Alzheimer's disease, AIDS-related dementia, Parkinson's disease, amyotrophic lateral sclerosis, retinitis pigmentosa, spinal muscular atrophy and cerebellar degeneration); myelodysplastic syndromes; aplastic anemia; ischemic injury; fibrosis of the lung, kidney or liver; T-cell mediated hypersensitivity disease; infantile hypertrophic pyloric stenosis; urinary obstructive syndrome; psoriatic arthritis; and Hashimoto's thyroiditis.

An "allergic or inflammatory disorder" herein is a disease or disorder that results from a hyper-activation of the immune system of an individual. Exemplary allergic or inflammatory disorders include, but are not limited to, asthma, psoriasis, rheumatoid arthritis, atopic dermatitis, multiple sclerosis, systemic lupus, erythematosus, eczema, organ transplantation, age-related mucular degeneration, Crohn's disease, ulcerative colitis, eosinophilic esophagitis, and autoimmune diseases associated with inflammation.

An "autoimmune disease" herein is a disease or disorder arising from and directed against an individual's own tissues or a co-segregate or manifestation thereof or resulting condition therefrom. Examples of autoimmune diseases or disorders include, but are not limited to arthritis (rheumatoid arthritis such as acute arthritis, chronic rheumatoid arthritis, gouty arthritis, acute gouty arthritis, chronic inflammatory arthritis, degenerative arthritis, infectious arthritis, Lyme arthritis, proliferative arthritis, psoriatic arthritis, vertebral arthritis, and juvenile-onset rheumatoid arthritis, osteoarthritis, arthritis chronica progrediente, arthritis deformans, polyarthritis chronica primaria, reactive arthritis, and ankylosing spondylitis), inflammatory hyperproliferative skin diseases, psoriasis such as plaque psoriasis, gutatte psoriasis, pustular psoriasis, and psoriasis of the nails, dermatitis including contact dermatitis, chronic contact dermatitis, allergic dermatitis, allergic contact dermatitis, dermatitis herpetiformis, and atopic dermatitis, x-linked hyper IgM syndrome, urticaria such as chronic allergic urticaria and chronic idiopathic urticaria, including chronic autoimmune urticaria, polymyositis/dermatomyositis, juvenile dermatomyositis, toxic epidermal necrolysis,

scleroderma (including systemic scleroderma), sclerosis such as systemic sclerosis, multiple sclerosis (MS) such as spino-optical MS, primary progressive MS (PPMS), and relapsing remitting MS (RRMS), progressive systemic sclerosis, atherosclerosis, arteriosclerosis, sclerosis disseminata, and ataxic sclerosis, inflammatory bowel disease (IBD) (for example, Crohn's disease, autoimmune-mediated gastrointestinal diseases, colitis such as ulcerative colitis, colitis ulcerosa, microscopic colitis, collagenous colitis, colitis polyposa, necrotizing enterocolitis, and transmural colitis, and autoimmune inflammatory bowel disease), pyoderma gangrenosum, erythema nodosum, primary sclerosing cholangitis, episcleritis), respiratory distress syndrome, including adult or acute respiratory distress syndrome (ARDS), meningitis, inflammation of all or part of the uvea, iritis, choroiditis, an autoimmune hematological disorder, rheumatoid spondylitis, sudden hearing loss, IgE-mediated diseases such as anaphylaxis and allergic and atopic rhinitis, encephalitis such as Rasmussen's encephalitis and limbic and/or brainstem encephalitis, uveitis, such as anterior uveitis, acute anterior uveitis, granulomatous uveitis, nongranulomatous uveitis, phacoantigenic uveitis, posterior uveitis, or autoimmune uveitis, glomerulonephritis (GN) with and without nephrotic syndrome such as chronic or acute glomerulonephritis such as primary GN, immune-mediated GN, membranous GN (membranous nephropathy), idiopathic membranous GN or idiopathic membranous nephropathy, membrano- or membranous proliferative GN (MPGN), including Type I and Type II, and rapidly progressive GN, allergic conditions, allergic reaction, eczema including allergic or atopic eczema, asthma such as asthma bronchiale, bronchial asthma, and auto-immune asthma, conditions involving infiltration of T cells and chronic inflammatory responses, chronic pulmonary inflammatory disease, autoimmune myocarditis, leukocyte adhesion deficiency, systemic lupus erythematosus (SLE) or systemic lupus erythematodes such as cutaneous SLE, subacute cutaneous lupus erythematosus, neonatal lupus syndrome (NLE), lupus erythematosus disseminatus, lupus (including nephritis, cerebritis, pediatric, non-renal, extra-renal, discoid, alopecia), juvenile onset (Type I) diabetes mellitus, including pediatric insulin-dependent diabetes mellitus (IDDM), adult onset diabetes mellitus (Type II diabetes), autoimmune diabetes, idiopathic diabetes insipidus, immune responses associated with acute and delayed hypersensitivity mediated by cytokines and T-lymphocytes, tuberculosis, sarcoidosis, granulomatosis including lymphomatoid granulomatosis, Wegener's granulomatosis, agranulocytosis, vasculitides, including vasculitis (including large vessel vasculitis (including polymyalgia rheumatica and giant cell (Takayasu's) arteritis), medium vessel vasculitis (including Kawasaki's disease and polyarteritis nodosa), microscopic

polyarteritis, CNS vasculitis, necrotizing, cutaneous, or hypersensitivity vasculitis, systemic necrotizing vasculitis, and ANCA-associated vasculitis, such as Churg-Strauss vasculitis or syndrome (CSS)), temporal arteritis, aplastic anemia, autoimmune aplastic anemia, Coombs positive anemia, Diamond Blackfan anemia, hemolytic anemia or immune hemolytic anemia including autoimmune hemolytic anemia (AIHA), pernicious anemia (anemia perniciosa), Addison's disease, pure red cell anemia or aplasia (PRCA), Factor VIII deficiency, hemophilia A, autoimmune neutropenia, pancytopenia, leukopenia, diseases involving leukocyte diapedesis, CNS inflammatory disorders, multiple organ injury syndrome such as those secondary to septicemia, trauma or hemorrhage, antigen-antibody complex-mediated diseases, anti-glomerular basement membrane disease, anti-phospholipid antibody syndrome, allergic neuritis, Bechet's or Behcet's disease, Castleman's syndrome, Goodpasture's syndrome, Reynaud's syndrome, Sjogren's syndrome, Stevens-Johnson syndrome, pemphigoid such as pemphigoid bullous and skin pemphigoid, pemphigus (including pemphigus vulgaris, pemphigus foliaceus, pemphigus mucus-membrane pemphigoid, and pemphigus erythematosus), autoimmune polyendocrinopathies, Reiter's disease or syndrome, immune complex nephritis, antibody-mediated nephritis, neuromyelitis optica, polyneuropathies, chronic neuropathy such as IgM polyneuropathies or IgM-mediated neuropathy, thrombocytopenia (as developed by myocardial infarction patients, for example), including thrombotic thrombocytopenic purpura (TTP) and autoimmune or immune-mediated thrombocytopenia such as idiopathic thrombocytopenic purpura (ITP) including chronic or acute ITP, autoimmune disease of the testis and ovary including autoimmune orchitis and oophoritis, primary hypothyroidism, hypoparathyroidism, autoimmune endocrine diseases including thyroiditis such as autoimmune thyroiditis, Hashimoto's disease, chronic thyroiditis (Hashimoto's thyroiditis), or subacute thyroiditis, autoimmune thyroid disease, idiopathic hypothyroidism, Grave's disease, polyglandular syndromes such as autoimmune polyglandular syndromes (or polyglandular endocrinopathy syndromes), paraneoplastic syndromes, including neurologic paraneoplastic syndromes such as Lambert-Eaton myasthenic syndrome or Eaton-Lambert syndrome, stiff-man or stiff-person syndrome, encephalomyelitis such as allergic encephalomyelitis or encephalomyelitis allergica and experimental allergic encephalomyelitis (EAE), myasthenia gravis such as thymoma-associated myasthenia gravis, cerebellar degeneration, neuromyotonia, opsoclonus or opsoclonus myoclonus syndrome (OMS), and sensory neuropathy, multifocal motor neuropathy, Sheehan's syndrome, autoimmune hepatitis, chronic hepatitis, lupoid hepatitis,

giant cell hepatitis, chronic active hepatitis or autoimmune chronic active hepatitis, lymphoid interstitial pneumonitis, bronchiolitis obliterans (non-transplant) vs NSIP, Guillain-Barré syndrome, Berger's disease (IgA nephropathy), idiopathic IgA nephropathy, linear IgA dermatosis, primary biliary cirrhosis, pneumonocirrhosis, autoimmune enteropathy syndrome, Celiac disease, Coeliac disease, celiac sprue (gluten enteropathy), refractory sprue, idiopathic sprue, cryoglobulinemia, amylotrophic lateral sclerosis (ALS; Lou Gehrig's disease), coronary artery disease, autoimmune ear disease such as autoimmune inner ear disease (AIED), autoimmune hearing loss, opsoclonus myoclonus syndrome (OMS), polychondritis such as refractory or relapsed polychondritis, pulmonary alveolar proteinosis, amyloidosis, scleritis, a non-cancerous lymphocytosis, a primary lymphocytosis, which includes monoclonal B cell lymphocytosis (e.g., benign monoclonal gammopathy and monoclonal garnmopathy of undetermined significance, MGUS), peripheral neuropathy, paraneoplastic syndrome, channelopathies such as epilepsy, migraine, arrhythmia, muscular disorders, deafness, blindness, periodic paralysis, and channelopathies of the CNS, autism, inflammatory myopathy, focal segmental glomerulosclerosis (FSGS), endocrine ophthalmopathy, uveoretinitis, chorioretinitis, autoimmune hepatological disorder, fibromyalgia, multiple endocrine failure, Schmidt's syndrome, adrenalitis, gastric atrophy, presenile dementia, demyelinating diseases such as autoimmune demyelinating diseases, diabetic nephropathy, Dressler's syndrome, alopecia areata, CREST syndrome (calcinosis, Raynaud's phenomenon, esophageal dysmotility, sclerodactyly, and telangiectasia), male and female autoimmune infertility, mixed connective tissue disease, Chagas' disease, rheumatic fever, recurrent abortion, farmer's lung, erythema multiforme, post-cardiotomy syndrome, Cushing's syndrome, bird-fancier's lung, allergic granulomatous angiitis, benign lymphocytic angiitis, Alport's syndrome, alveolitis such as allergic alveolitis and fibrosing alveolitis, interstitial lung disease, transfusion reaction, leprosy, malaria, leishmaniasis, kypanosomiasis, schistosomiasis, ascariasis, aspergillosis, Sampter's syndrome, Caplan's syndrome, dengue, endocarditis, endomyocardial fibrosis, diffuse interstitial pulmonary fibrosis, interstitial lung fibrosis, idiopathic pulmonary fibrosis, cystic fibrosis, endophthalmitis, erythema elevatum et diutinum, erythroblastosis fetalis, eosinophilic faciitis, Shulman's syndrome, Felty's syndrome, flariasis, cyclitis such as chronic cyclitis, heterochronic cyclitis, iridocyclitis, or Fuch's cyclitis, Henoch-Schonlein purpura, human immunodeficiency virus (HIV) infection, echovirus infection, cardiomyopathy, Alzheimer's disease, parvovirus infection, rubella virus infection, post-vaccination syndromes, congenital rubella infection, Epstein-Barr virus

infection, mumps, Evan's syndrome, autoimmune gonadal failure, Sydenham's chorea, post-streptococcal nephritis, thromboangitis ubiterans, thyrotoxicosis, tabes dorsalis, chorioiditis, giant cell polymyalgia, endocrine ophthamopathy, chronic hypersensitivity pneumonitis, keratoconjunctivitis sicca, epidemic keratoconjunctivitis, idiopathic nephritic syndrome, minimal change nephropathy, benign familial and ischemia-reperfusion injury, retinal autoimmunity, joint inflammation, bronchitis, chronic obstructive airway disease, silicosis, aphthae, aphthous stomatitis, arteriosclerotic disorders, aspermiogenese, autoimmune hemolysis, Boeck's disease, cryoglobulinemia, Dupuytren's contracture, endophthalmia phacoanaphylactica, enteritis allergica, erythema nodosum leprosum, idiopathic facial paralysis, chronic fatigue syndrome, febris rheumatica, Hamman-Rich's disease, sensoneural hearing loss, haemoglobinuria paroxysmatica, hypogonadism, ileitis regionalis, leucopenia, mononucleosis infectiosa, traverse myelitis, primary idiopathic myxedema, nephrosis, ophthalmia symphatica, orchitis granulomatosa, pancreatitis, polyradiculitis acuta, pyoderma gangrenosum, Quervain's thyreoiditis, acquired spenic atrophy, infertility due to antispermatozoan antibodies, non-malignant thymoma, vitiligo, SCID and Epstein-Barr virus-associated diseases, acquired immune deficiency syndrome (AIDS), parasitic diseases such as Leishmania, toxic-shock syndrome, food poisoning, conditions involving infiltration of T cells, leukocyte-adhesion deficiency, immune responses associated with acute and delayed hypersensitivity mediated by cytokines and T-lymphocytes, diseases involving leukocyte diapedesis, multiple organ injury syndrome, antigen-antibody complex-mediated diseases, antiglomerular basement membrane disease, allergic neuritis, autoimmune polyendocrinopathies, oophoritis, primary myxedema, autoimmune atrophic gastritis, sympathetic ophthalmia, rheumatic diseases, mixed connective tissue disease, nephrotic syndrome, insulitis, polyendocrine failure, peripheral neuropathy, autoimmune polyglandular syndrome type I, adult-onset idiopathic hypoparathyroidism (AOIH), alopecia totalis, dilated cardiomyopathy, epidermolisis bullosa acquisita (EBA), hemochromatosis, myocarditis, nephrotic syndrome, primary sclerosing cholangitis, purulent or nonpurulent sinusitis, acute or chronic sinusitis, ethmoid, frontal, maxillary, or sphenoid sinusitis, an eosinophil-related disorder such as eosinophilia, pulmonary infiltration eosinophilia, eosinophilia-myalgia syndrome, Loffler's syndrome, chronic eosinophilic pneumonia, tropical pulmonary eosinophilia, bronchopneumonic aspergillosis, aspergilloma, or granulomas containing eosinophils, anaphylaxis, seronegative spondyloarthritides, polyendocrine autoimmune disease, sclerosing cholangitis, sclera, episclera, chronic mucocutaneous candidiasis, Bruton's

syndrome, transient hypogammaglobulinemia of infancy, Wiskott-Aldrich syndrome, ataxia telangiectasia, autoimmune disorders associated with collagen disease, rheumatism, neurological disease, ischemic re-perfusion disorder, reduction in blood pressure response, vascular dysfunction, antgiectasis, tissue injury, cardiovascular ischemia, hyperalgesia, cerebral ischemia, and disease accompanying vascularization, allergic hypersensitivity disorders, glomerulonephritides, reperfusion injury, reperfusion injury of myocardial or other tissues, dermatoses with acute inflammatory components, acute purulent meningitis or other central nervous system inflammatory disorders, ocular and orbital inflammatory disorders, granulocyte transfusion-associated syndromes, cytokine-induced toxicity, acute serious inflammation, chronic intractable inflammation, pyelitis, pneumonocirrhosis, diabetic retinopathy, diabetic large-artery disorder, endarterial hyperplasia, peptic ulcer, valvulitis, and endometriosis.

The term "cytotoxic agent" as used herein refers to a substance that inhibits or prevents the function of a cell and/or causes destruction of a cell. The term is intended to include radioactive isotopes (e.g., At^{211}, I^{131}, I^{125}, Y^{90}, Re^{186}, Re^{188}, Sm^{153}, Bi^{212}, Ra^{223}, P^{32}, and radioactive isotopes of Lu), chemotherapeutic agents, e.g., methotrexate, adriamicin, vinca alkaloids (vincristine, vinblastine, etoposide), doxorubicin, melphalan, mitomycin C, chlorambucil, daunorubicin or other intercalating agents, enzymes and fragments thereof such as nucleolytic enzymes, antibiotics, and toxins such as small molecule toxins or enzymatically active toxins of bacterial, fungal, plant or animal origin, including fragments and/or variants thereof, and the various antitumor, anticancer, and chemotherapeutic agents disclosed herein. Other cytotoxic agents are described herein. A tumoricidal agent causes destruction of tumor cells.

A "chemotherapeutic agent" is a chemical compound useful in the treatment of cancer. Examples of chemotherapeutic agents include alkylating agents such as thiotepa and CYTOXAN® cyclosphosphamide; alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, trietylenephosphoramide, triethiylenethiophosphoramide and trimethylolomelamine; acetogenins (especially bullatacin and bullatacinone); delta-9-tetrahydrocannabinol (dronabinol, MARINOL®); beta-lapachone; lapachol; colchicines; betulinic acid; a camptothecin (including the synthetic analogue topotecan (HYCAMTIN®), CPT-11 (irinotecan, CAMPTOSAR®), acetylcamptothecin, scopolectin, and 9-aminocamptothecin);

bryostatin; callystatin; CC-1065 (including its adozelesin, carzelesin and bizelesin synthetic analogues); podophyllotoxin; podophyllinic acid; teniposide; cryptophycins (particularly cryptophycin 1 and cryptophycin 8); dolastatin; duocarmycin (including the synthetic analogues, KW-2189 and CB1-TM1); eleutherobin; pancratistatin; a sarcodictyin; spongistatin; nitrogen mustards such as chlorambucil, chlornaphazine, cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, and ranimnustine; antibiotics such as the enediyne antibiotics (e.g., calicheamicin, especially calicheamicin gamma 1 (see, e.g., Agnew, Chem Intl. Ed. Engl. 33: 183-186 (1994)); dynemicin, including dynemicin A; an esperamicin; as well as neocarzinostatin chromophore and related chromoprotein enediyne antiobiotic chromophores), aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, carabicin, carminomycin, carzinophilin, chromomycinis, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, ADRIAMYCIN® doxorubicin (including morpholino-doxorubicin, cyanomorpholino-doxorubicin, 2-pyrrolino-doxorubicin and deoxydoxorubicin), epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins such as mitomycin C, mycophenolic acid, nogalamycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine; androgens such as calusterone, dromostanolone propionate, epitiostanol, mepitiostane, testolactone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; eniluracil; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elfornithine; elliptinium acetate; an epothilone; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidainine; maytansinoids such as maytansine and ansamitocins; mitoguazone; mitoxantrone; mopidanmol; nitraerine; pentostatin; phenamet; pirarubicin; losoxantrone; 2-ethylhydrazide; procarbazine; PSK® polysaccharide complex (JHS Natural Products, Eugene, OR); razoxane; rhizoxin; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2,2',2''-trichlorotriethylamine; trichothecenes (especially T-2 toxin, verracurin A, roridin A and

anguidine); urethan; vindesine (ELDISINE®, FILDESIN®); dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); thiotepa; taxoids, e.g., TAXOL® paclitaxel (Bristol-Myers Squibb Oncology, Princeton, NJ), ABRAXANETM Cremophor-free, albumin-engineered nanoparticle formulation of paclitaxel (American Pharmaceutical Partners, Schaumberg, IL), and TAXOTERE® doxetaxel (Rhône-Poulenc Rorer, Antony, France); chloranbucil; gemcitabine (GEMZAR®); 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin and carboplatin; vinblastine (VELBAN®); platinum; etoposide (VP-16); ifosfamide; mitoxantrone; vincristine (ONCOVIN®); oxaliplatin; leucovovin; vinorelbine (NAVELBINE®); novantrone; edatrexate; daunomycin; aminopterin; ibandronate; topoisomerase inhibitor RFS 2000; difluorometlhylornithine (DMFO); retinoids such as retinoic acid; capecitabine (XELODA®); pharmaceutically acceptable salts, acids or derivatives of any of the above; as well as combinations of two or more of the above such as CHOP, an abbreviation for a combined therapy of cyclophosphamide, doxorubicin, vincristine, and prednisolone, and FOLFOX, an abbreviation for a treatment regimen with oxaliplatin (ELOXATINTM) combined with 5-FU and leucovovin.

Also included in this definition are anti-hormonal agents that act to regulate, reduce, block, or inhibit the effects of hormones that can promote the growth of cancer, and are often in the form of systemic, or whole-body treatment. They may be hormones themselves. Examples include anti-estrogens and selective estrogen receptor modulators (SERMs), including, for example, tamoxifen (including NOLVADEX® tamoxifen), EVISTA® raloxifene, droloxifene, 4-hydroxytamoxifen, trioxifene, keoxifene, LY117018, onapristone, and FARESTON® toremifene; anti-progesterones; estrogen receptor down-regulators (ERDs); agents that function to suppress or shut down the ovaries, for example, leutinizing hormone-releasing hormone (LHRH) agonists such as LUPRON® and ELIGARD® leuprolide acetate, goserelin acetate, buserelin acetate and tripterelin; other anti-androgens such as flutamide, nilutamide and bicalutamide; and aromatase inhibitors that inhibit the enzyme aromatase, which regulates estrogen production in the adrenal glands, such as, for example, 4(5)-imidazoles, aminoglutethimide, MEGASE® megestrol acetate, AROMASIN® exemestane, formestanie, fadrozole, RIVISOR® vorozole, FEMARA® letrozole, and ARIMIDEX® anastrozole. In addition, such definition of chemotherapeutic agents includes bisphosphonates such as clodronate (for example, BONEFOS® or OSTAC®), DIDROCAL® etidronate, NE-58095, ZOMETA® zoledronic acid/zoledronate, FOSAMAX® alendronate,

AREDIA® pamidronate, SKELID® tiludronate, or ACTONEL® risedronate; as well as troxacitabine (a 1,3-dioxolane nucleoside cytosine analog); antisense oligonucleotides, particularly those that inhibit expression of genes in signaling pathways implicated in abherant cell proliferation, such as, for example, PKC-alpha, Raf, H-Ras, and epidermal growth factor receptor (EGF-R); vaccines such as THERATOPE® vaccine and gene therapy vaccines, for example, ALLOVECTIN® vaccine, LEUVECTIN® vaccine, and VAXID® vaccine; LURTOTECAN® topoisomerase 1 inhibitor; ABARELIX® rmRH; lapatinib ditosylate (an ErbB-2 and EGFR dual tyrosine kinase small-molecule inhibitor also known as GW572016); and pharmaceutically acceptable salts, acids or derivatives of any of the above.

A "growth inhibitory agent" when used herein refers to a compound or composition which inhibits growth of a cell either *in vitro* or *in vivo*. Thus, the growth inhibitory agent may be one which significantly reduces the percentage of cells in S phase. Examples of growth inhibitory agents include agents that block cell cycle progression (at a place other than S phase), such as agents that induce G1 arrest and M-phase arrest. Classical M-phase blockers include the vincas (e.g., vincristine and vinblastine), taxanes, and topoisomerase II inhibitors such as doxorubicin, epirubicin, daunorubicin, etoposide, and bleomycin. The agents that arrest G1 also spill over into S-phase arrest, for example, DNA alkylating agents such as tamoxifen, prednisone, dacarbazine, mechlorethamine, cisplatin, methotrexate, 5-fluorouracil, and ara-C. Further information can be found in The Molecular Basis of Cancer, Mendelsohn and Israel, eds., Chapter 1, entitled "Cell cycle regulation, oncogenes, and antineoplastic drugs" by Murakami et al. (WB Saunders: Philadelphia, 1995), especially p. 13. The taxanes (paclitaxel and docetaxel) are anticancer drugs both derived from the yew tree. Docetaxel (TAXOTERE®, Rhone-Poulenc Rorer), derived from the European yew, is a semisynthetic analogue of paclitaxel (TAXOL®, Bristol-Myers Squibb). Paclitaxel and docetaxel promote the assembly of microtubules from tubulin dimers and stabilize microtubules by preventing depolymerization, which results in the inhibition of mitosis in cells.

"Anti-cancer therapy" as used herein refers to a treatment that reduces or inhibits cancer in a subject. Examples of anti-cancer therapy include cytotoxic radiotherapy as well as the administration of a therapeutically effective amount of a cytotoxic agent, a chemotherapeutic agent, a growth inhibitory agent, a cancer vaccine, an angiogenesis inhibitor, a prodrug,, a cytokine, a cytokine antagonist, a corticosteroid, an

immunosuppressive agent, an anti-emetic, an antibody or antibody fragment, or an analgesic to the subject.

The term "prodrug" as used in this application refers to a precursor or derivative form of a pharmaceutically active substance that is less cytotoxic to tumor cells compared to the parent drug and is capable of being enzymatically activated or converted into the more active parent form. See, e.g., Wilman, "Prodrugs in Cancer Chemotherapy" Biochemical Society Transactions, 14, pp. 375-382, 615th Meeting Belfast (1986) and Stella et al., "Prodrugs: A Chemical Approach to Targeted Drug Delivery," Directed Drug Delivery, Borchardt et al., (ed.), pp. 247-267, Humana Press (1985). Prodrugs include, but are not limited to, phosphate-containing prodrugs, thiophosphate-containing prodrugs, sulfate-containing prodrugs, peptide-containing prodrugs, D-amino acid-modified prodrugs, glycosylated prodrugs, beta-lactam-containing prodrugs, optionally substituted phenoxyacetamide-containing prodrugs or optionally substituted phenylacetamide-containing prodrugs, 5-fluorocytosine and other 5-fluorouridine prodrugs which can be converted into the more active cytotoxic free drug. Examples of cytotoxic drugs that can be derivatized into a prodrug form for use in this invention include, but are not limited to, those chemotherapeutic agents described above.

The term "cytokine" is a generic term for proteins released by one cell population which act on another cell as intercellular mediators. Examples of such cytokines are lymphokines, monokines, and traditional polypeptide hormones. Included among the cytokines are growth hormone such as human growth hormone (HGH), 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); epidermal growth factor (EGF); hepatic growth factor; fibroblast growth factor (FGF); 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-alpha; 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-1alpha, IL-1beta, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8,

IL-9, IL-10, IL-11, IL-12; IL-18 a tumor necrosis factor such as TNF-alpha or TNF-beta; 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.

By "cytokine antagonist" is meant a molecule that partially or fully blocks, inhibits, or neutralizes a biological activity of of at least one cytokine. For example, the cytokine antagonists may inhibit cytokine activity by inhibiting cytokine expression and/or secretion, or by binding to a cytokine or to a cytokine receptor. Cytokine antagonists include antibodies, synthetic or native-sequence peptides, immunoadhesins, and small-molecule antagonists that bind to a cytokine or cytokine receptor. The cytokine antagonist is optionally conjugated with or fused to a cytotoxic agent. Exemplary TNF antagonists are etanercept (ENBREL®), infliximab (REMICADE®), and adalimumab (HUMIRA™).

The term "immunosuppressive agent" as used herein refers to substances that act to suppress or mask the immune system of the subject being treated. This includes substances that suppress cytokine production, downregulate or suppress self-antigen expression, or mask the MHC antigens. Examples of immunosuppressive agents include 2-amino-6-aryl-5-substituted pyrimidines (see U.S. Patent No. 4,665,077); mycophenolate mofetil such as CELLCEPT®; azathioprine (IMURAN®, AZASAN®/6-mercaptopurine; bromocryptine; danazol; dapsone; glutaraldehyde (which masks the MHC antigens, as described in U.S. Patent No. 4,120,649); anti-idiotypic antibodies for MHC antigens and MHC fragments; cyclosporin A; steroids such as corticosteroids and glucocorticosteroids, e.g., prednisone, prednisolone such as PEDIAPRED® (prednisolone sodium phosphate) or ORAPRED® (prednisolone sodium phosphate oral solution), methylprednisolone, and dexamethasone; methotrexate (oral or subcutaneous) (RHEUMATREX®, TREXALL™); hydroxycloroquine/chloroquine; sulfasalazine; leflunomide; cytokine or cytokine receptor antagonists including anti-interferon-γ, -β, or -α antibodies, anti-tumor necrosis factor-α antibodies (infliximab or adalimumab), anti-TNFα immunoadhesin (ENBREL®, etanercept), anti-tumor necrosis factor-β antibodies, anti-interleukin-2 antibodies and anti-IL-2 receptor antibodies; anti-LFA-1 antibodies, including anti-CD11a and anti-CD18 antibodies; anti-L3T4 antibodies; heterologous anti-lymphocyte globulin; polyclonal or pan-T antibodies, or monoclonal anti-CD3 or anti-CD4/CD4a antibodies; soluble peptide containing a LFA-3 binding domain (WO 90/08187); streptokinase; TGF-β; streptodornase; RNA or DNA from the host; FK506; RS-61443; deoxyspergualin; rapamycin; T-cell receptor (Cohen et al., U.S.

Patent No. 5,114,721); T-cell receptor fragments (Offner et al. Science 251: 430-432 (1991); WO 90/11294; Ianeway, Nature 341:482 (1989); and WO 91/01133); T cell receptor antibodies (EP 340,109) such as T10B9; cyclophosphamide (CYTOXAN®); dapsone; penicillamine (CUPRIMINE®); plasma exchange; or intravenous immunoglobulin (IVIG). These may be used alone or in combination with each other, particularly combinations of steroid and another immunosuppressive agent or such combinations followed by a maintenance dose with a non-steroid agent to reduce the need for steroids.

An "analgesic" refers to a drug that acts to inhibit or suppress pain in a subject. Exemplary analgesics include non-steroidal anti-inflammatory drugs (NSAIDs) including ibuprofen (MOTRIN®), naproxen (NAPROSYN®), acetylsalicylic acid, indomethacin, sulindac, and tolmetin, including salts and derivatives thereof, as well as various other medications used to reduce the stabbing pains that may occur, including anticonvulsants (gabapentin, phenyloin, carbamazepine) or tricyclic antidepressants. Specific examples include acetaminophen, aspirin, amitriptyline (ELAVIL®), carbamazepine (TEGRETOL®), phenyltoin (DILANTIN®), gabapentin (NEURONTIN®), (E)-N-Vanillyl-8-methyl-6-noneamid (CAPSAICIN®), or a nerve blocker.

"Corticosteroid" refers to any one of several synthetic or naturally occurring substances with the general chemical structure of steroids that mimic or augment the effects of the naturally occurring corticosteroids. Examples of synthetic corticosteroids include prednisone, prednisolone (including methylprednisolone), dexamethasone triamcinolone, and betamethasone.

A "cancer vaccine," as used herein is a composition that stimulates an immune response in a subject against a cancer. Cancer vaccines typically consist of a source of cancer-associated material or cells (antigen) that may be autologous (from self) or allogenic (from others) to the subject, along with other components (e.g., adjuvants) to further stimulate and boost the immune response against the antigen. Cancer vaccines can result in stimulating the immune system of the subject to produce antibodies to one or several specific antigens, and/or to produce killer T cells to attack cancer cells that have those antigens.

"Cytotoxic radiotherapy" as used herein refers to radiation therapy that inhibits or prevents the function of cells and/or causes destruction of cells. Radiation therapy may include, for example, external beam irradiation or therapy with a radioactive labeled agent, such as an antibody. The term is intended to include use of radioactive isotopes (e.g., At^{211}, I^{131}, I^{125}, Y^{90}, Re^{186}, Re^{188}, Sm^{153}, Bi^{212}, Ra^{223}, P^{32}, and radioactive isotopes of Lu).

"Target molecule" refers to a molecule which can bind to a protein complex of this invention (preferably with affinity higher than 1uM Kd according to scatchard analysis). Examples of target molecules include, but are not limited to, serum soluble proteins and their receptors, such as cytokines and cytokine receptors, adhesins, growth factors and their receptors, hormones, viral particles (e.g., RSV F protein, CMV, StaphA, influenza, hepatitis C virus), micoorganisms (e.g., bacterial cell proteins, fungal cells), adhesins, CD proteins and their receptors.

An "anti-emetic" is a compound that reduces or prevents nausea in a subject. Anti-emetic compounds include, for example, neurokinin-1 receptor antagonists, 5HT3 receptor antagonists (such as ondansetron, granisetron, tropisetron, and zatisetron), GABAB receptor agonists, such as baclofen, a corticosteroid such as dexamethasone, KENALOG®, ARISTOCORT®, or NASALIDE®, an antidopaminergic, phenothiazines (for example prochlorperazine, fluphenazine, thioridazine and mesoridazine), dronabinol, metroclopramide, domperidone, haloperidol, cyclizine, lorazepam, prochlorperazine, and levomepromazine.

A "subject" is a vertebrate, such as a mammal, e.g., a human. Mammals include, but are not limited to, farm animals (such as cows), sport animals, pets (such as cats, dogs and horses), primates, mice, and rats.

Commercially available reagents referred to in the Examples were used according to manufacturer's instructions unless otherwise indicated. The source of those cells identified in the following Examples, and throughout the specification, by ATCC accession numbers is the American Type Culture Collection, Manassas, VA. Unless otherwise noted, the present invention uses standard procedures of recombinant DNA technology, such as those described hereinabove and in the following textbooks: Sambrook et al., supra; Ausubel et al., Current Protocols in Molecular Biology (Green Publishing Associates and Wiley Interscience, NY, 1989); Innis et al., PCR Protocols: A Guide to Methods and Applications (Academic Press, Inc., NY, 1990); Harlow et al., Antibodies: A Laboratory Manual (Cold Spring Harbor Press, Cold Spring Harbor, 1988); Gait, Oligonucleotide Synthesis (IRL Press, Oxford, 1984); Freshney, Animal Cell Culture, 1987; Coligan et al., Current Protocols in Immunology, 1991.

Throughout this specification and claims, the word "comprise," or variations such as "comprises" or "comprising," will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

II. Construction of Coiled Coil Containing and Tethered Antibodies

Protein complexes described herein may be constructed by using a heterodimerizing domain (e.g., a coiled coil domain) and/or a tether.

Use of a heterodimerizing domain enables the construction of a relatively pure population of antibodies that have different heavy chains within a single antibody. In particular, as described above, antibodies typically include two identical heavy chains, which are each paired with an identical light chain. Use of the coiled coil heterodimerization domain technology of the invention enables different antibody heavy chains to preferentially dimerize with each other in the formation of a single antibody. The resulting antibody thus includes two different heavy chains, each of which is typically (but need not be) paired with an identical light chain. Each pair of heavy and light chains within such an antibody has different binding specificity, due to the presence of the different heavy chains, and thus the antibody can be considered as a multispecific antibody. Tethers can also be exploited to engineer antibodies of the invention, either alone or in combination with the coiled-coil technology. The tethers can connect the C-terminus of a constant light chain to the N-terminus of a variable heavy chain, thus enabling proper light chain and heavy chain association, as well as recombinant antibody production using a single antibody-encoding plasmid. Antibodies including coiled coils and/or tethers are further described below.

A. Coiled coil domains

The heterodimerizing domain used to generate the protein complexes described herein can be an alpha helix (e.g., a right-handed alpha helix) that can form a coiled coil upon association with a second alpha helix containing oppositely charged residues. To generate homogeneous or nearly homogeneous populations of heterodimeric molecules, the heterodimerization domain must have a strong preference for forming heterodimers over homodimers. In this respect, the heterodimerization domains described herein provide a significant advantage over Fos/Jun leucine zipper domains because Jun readily forms homodimers. Exemplary alpha-helical heterodimerization domains are illustrated in Figures 1, 2A, and 2B. In particular embodiments, the first coiled coil domain contains a heptad repeat of Formula I:

$(X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7)_n$ (Formula I), where

X_1 is a hydrophobic amino acid residue or Asparagine,

X_2, X_3, and X_6 are each any amino acid residue,

X_4 is a hydrophobic amino acid residue, and

X_5 and X_7 are each a charged amino acid residue,

and the second coiled coil domain contains a heptad repeat of Formula II:

$(X'_1\ X'_2\ X'_3\ X'_4\ X'_5\ X'_6\ X'_7)_n$ (Formula II), where

X'_1 is a hydrophobic amino acid residue or Asparagine,

X'_2, X'_3, and X'_6 are each any amino acid residue,

X'_4 is a hydrophobic amino acid residue, and

X'_5 and X'_7 are each a charged amino acid residue.

In both Formula I and Formula II, n is greater than or equal to 2 (e.g., greater than or equal to 3 or 4), and less than or equal to 100. In one embodiment, n is between 2 and 20.

The X_5 and X_7 residues of the first coiled coil domain and the X'_5 and X'_7 residues of the second coiled coil domain may have, but need not have, the same charge. Thus, in one example, the X_5 and X_7 residues of the first coiled coil domain are basic residues, and the X'_5 and X'_7 residues of the second coiled coil domain are acidic residues. In another example, X_5 in the first coiled coil domain is a basic residue, and X_7 of the first coiled coil domain is an acidic residue. In this example, the second coiled coil domain has a basic residue in the X'_5 position, and an acidic residue in the X'_7 position. As shown in Figure 1, an ionic interaction occurs between the X_5 residue of the first coiled coil domain and the X'_7 residue of the second coiled coil domain, as well as between the X_7 residue of the first coiled coil domain and the X'_5 residue of the second coiled coil domain. In a related example, X_5 in the first coiled coil domain is an acidic residue, X_7 in the first coiled coil domain is a basic residue, X'_5 in the second coiled coil domain is an acidic residue, and X'_7 in the second coiled coil domain is a basic residue. In addition, inclusion of at least one heptad repeat with an Asparagine at the X_1/X'_1 position of both the first and second coiled coil domains may be used to ensure a parallel orientation of the first and second coiled coil domains.

The hydrophobic residues in the heptad repeats are preferably chosen from Alanine, Valine, Leucine, Isoleucine, Tryptophan, Phenylalanine, and Methionine. Proline, while hydrophobic, is in one embodiment not included in a coiled coil domain of Formula I or Formula II because the presence of Proline in an amino acid sequence can limit its ability to form an alpha helical structure. In addition, in other embodiments, the coiled coil domain of Formula I or Formula II does not contain a Glycine residue because, due to its conformational flexibility, Glycine does not readily adopt the constrained alpha helical structure. Charged residues that may be included in a coiled coil domain of Formula I or Formula II include

Lysine, Arginine, Histidine, Aspartic Acid, and Glutamic Acid, where Lysine, Arginine, and Histidine are basic residues, and Aspartic Acid and Glutamic Acid are acidic residues.

Construction of an antibody described herein may use a coiled coil domain of Formula I and a coiled coil domain of Formula II (a first and a second coiled coil domain) where the first coiled coil domain is linked to a first constant domain of the antibody (e.g., CH3 of a first heavy chain) and the second coiled coil domain is linked to a second constant domain of the antibody (e.g., CH3 of a second heavy chain). The linkage may be a direct linkage by a peptide bond or may be through a linker sequence. A linker can be peptide bonded to the C-terminal end of one amino acid sequence (e.g., the constant region) and to the N-terminal end of the other amino acid sequence (e.g., the coiled coil domain). The linker can be long enough to allow for cleavage of the coiled coil domain from the antibody constant region, as described further elsewhere herein, but short enough to confer heterodimeric association of two antibody constant regions (e.g., two heavy chain constant regions). As such, a linker may be an amino acid sequence of 2 to 100 amino acids in length. In a particular embodiment, the linker is between 2 and 50 amino acids in length, for example, 3, 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 amino acids in length. The linker can consist of, for example, neutral polar or nonpolar amino acids.

B. Multispecific antibodies

It should be understood that the variable domains of such antibodies can be derived from several methods. For example, the variable domains of the antibodies of this invention can be the same as existing antibodies known in the art.

A coiled coil domain may be used to generate a multispecific antibody (an antibody that binds to at least two antigens or to at least two epitopes on the same antigen). In one example, the multispecific antibody is a bispecific antibody. Typically, in naturally occurring IgG antibodies, the variable regions of each pair of heavy and light chains in the antibody are identical. Use of coiled coil domains according to the present invention enables the two heavy chains within an antibody to be different, resulting in antibodies having antigen binding domains with different binding specificities. In particular, coiled coil heterodimerization domains on each heavy chain (e.g., C-terminal to CH3) promote binding between different heavy chains. Optionally the coiled coil domains are linked to the heavy chain constant regions by a linker that can be cleaved so that the coiled coil can be removed from the antibody after assembly.

A schematic representation of an exemplary bispecific antibody, which includes two different heavy chains (HC1 and HC2) and two identical or common light chains, is shown in Figure 3. The exemplary bispecific antibody in Figure 3 also contains a heterodimeric coiled coil. The antibody may also contain a Lys-C endopeptidase cleavage site N-terminal to each coiled coil heterodimerization domain that allows for the removal of the coiled coil from the antibody once the antibody has been assembled. Both of the heavy chains in this exemplary bispecific antibody also contain a K222A mutation in the hinge region to remove a Lys-C endopeptidase cleavage site, so that Lys-C endopeptidase treatment results only in removal of the coiled coil and not cleavage within the heavy chain constant regions.

While the exemplary antibody contains a mutation that removes a Lys-C endopeptidase cleavage site in the hinge region, the location of Lys-C endopeptidase cleavage sites can vary depending on the antibody sequence used. One skilled in the art can readily scan the sequence of an antibody to determine whether there are any cleavage sites (e.g., a Lys-C endopeptidase cleavage site) in the heavy or light chain sequences that would need to be removed to avoid cleavage of the antibody itself upon removal of the coiled coil or tether sequences.

Further, multispecific antibodies may be constructed using the methods described herein where the heavy chain lacks the CH1 domain (the VH is directly connected to the hinge-CH2 domain) and the corresponding light chain lacks the CL domain. Such antibodies can be used to bring to different antigens together or to associate B and T cells.

C. One-armed antibodies

Heterodimerizing coiled coil domains can also be used to generate one-armed antibodies A schematic diagram illustrating an example of a one-armed antibody is shown in Figure 4A. The exemplary antibody shown in Figure 4A includes a light chain (LC), one full-length heavy chain (HC1), and a second heavy chain (HC2) lacks the VH and CH1 domains and part of the hinge region. Both the HC1 and the HC2 include a coiled coil heterodimerization domain at the C-terminus. The HC1 sequence in this example contains a K222A mutation in the hinge region to remove a Lys-C endopeptidase cleavage site, so that Lys-C cleavage only removes the coiled coil and does not result in cleavage within the heavy chain.

D. Conjugated protein complexes

Coiled coil heterodimerization domains may also be used to generate protein complexes such as antibodies (e.g., monospecific, bispecific, multispecific, one-armed, or tethered antibodies) in which a constant region is modified by conjugation to a cytotoxic agent. For instance, the coiled coil heterodimerization domain enables the construction of antibodies where one of the heavy chain constant regions (HC1 or HC2) contains a modification that allows for conjugation to a cytotoxic agent, while the other heavy chain constant region does not. In one example, HC1 is conjugated to a cytotoxic agent while HC2 is not. A schematic diagram illustrating an example of a conjugated antibody is shown in Figure 4B. The exemplary antibody includes two full-length heavy chains and two identical light chains (common light chain), as well as a coiled coil. As indicated by the star, one of the heavy chains has been conjugated to a cytotoxic agent (for example, a toxin). Similarly, in an alternative antibody construct, one of the light chain constant regions may be conjugated to a cytotoxic agent, while the other light chain constant region is not (e.g., LC1 is conjugated to a cytotoxic agent and LC2 is not).

In one particular example, a constant region of the antibody may be modified to introduce electrophilic moieties which can react with nucleophilic substituents on a linker reagent used to conjugate the cytotoxic agent to the antibody or on the cytotoxic agent itself. The sugars of glycosylated antibodies may be oxidized, e.g., with periodate oxidizing reagents, to form aldehyde or ketone groups which may react with the amine group of linker reagents or a cytotoxic agent. The resulting imine Schiff base groups may form a stable linkage, or may be reduced, e.g., by borohydride reagents, to form stable amine linkages. Nucleophilic groups on a cytotoxic agent include, but are not limited to, amine, thiol, hydroxyl, hydrazide, oxime, hydrazine, thiosemicarbazone, hydrazine carboxylate, and arylhydrazide groups capable of reacting to form covalent bonds with electrophilic groups on antibody regions and linker reagents including: (i) active esters such as NHS esters, HOBt esters, haloformates, and acid halides; (ii) alkyl and benzyl halides such as haloacetamides; and (iii) aldehydes, ketones, carboxyl, and maleimide groups.

E. Tethered Protein Complexes

The invention also provides protein complexes constructed using tethers, for example, an antibody can have a tether that links the C-terminus of a constant light chain to the N-terminus of a variable heavy chain. The tether aids in proper association of the light chain

and the heavy chain (i.e., association of the light chain with the heavy chain to which it is tethered). Such a tethered antibody can be constructed with or without a heterodimerizing domain, as described above. A schematic diagram of an exemplary tethered antibody containing a coiled coil is shown in Figure 5. The exemplary antibody shown in Figure 5 contains two different heavy chains (HC1 and HC2), as well as two different light chains (LC1 and LC2). Tethered antibodies can also be constructed to contain common light chains and/or common heavy chains. In the exemplary antibody, HC1 and HC2 contain a K222A mutation in the hinge region to remove a Lys-C endopeptidase cleavage site, as described above, as well as coiled coil heterodimerization domains at their C-termini.

The addition of a heterodimerizing domain to a tethered antibody aids in bringing the heavy chain/light chain complexes together and thereby reduces or eliminates homodimerization of such complexes. In a particular embodiment, tethers are long enough to span the distance between the N-terminus of the variable heavy chain and the C-terminus of the constant light chain in the assembled antibody (Figure 6) to allow for the proper light chain/heavy chain association, but are short enough to prevent interchain association (i.e., association of the light chain with a heavy chain to which it is not tethered). In the example shown in Figure 6, the distance between the N-terminus of the variable heavy chain and the C-terminus of the constant light chain is approximately 92Å. A peptide bond spans about 4.3Å. In this example, a tether should be about 22 amino acids in length to span the distance between the N-terminus of the variable heavy chain and the C-terminus of the constant light chain. The distance between the C-terminus of the constant light chain and the N-terminus of the variable heavy chain can differ between antibodies and the length of a tether therefore can also vary between antibodies. Tethers of 20, 23, and 26 amino acids in length were tested and, in general, tethers of 15-50 amino acids are effective. A tether may remain flexible and not form secondary structures, and for this purpose a tether containing Glycine (G) and Serine (S) residues can be used. A tether may consist solely of G and S residues, but also may include other residues, as long as the tether remains flexible to allow for the assembly of the light chain and heavy chain of the antibody. In a particular embodiment, the tether contains GGS repeats (Figure 5). For a tether of 15-30 amino acids in length, the tether, in one embodiment, contains at least 5 GGS repeats. An exemplary tether described herein and having the sequence of SEQ ID NO:14 contains 8 GGS repeats and contains an additional Glycine residue at both the N- and C-termini. Other exemplary tether sequences are show in in Figure 7B and contain either Furin or Lys-C endopeptidase cleavage sites at their N- and C-

termini.

F. Cleavage of tether and linker sequences

Once a protein complex is assembled, the tether may no longer be required and can, if desired, be cleaved from the antibody. Cleavage sites found in the tether, but not in the antibody sequence, can be used to remove the tether. Similarly, the coiled coil is also no longer required once the antibody has been assembled and can also, if desired, be cleaved from the antibody.

Figure 7A illustrates the location of exemplary cleavage sites in a tether as well as a linker sequence that joins the coiled coil to the antibody. In general, cleavage sites in the tether are located at or close to the C- and N-terminus of the tether sequence or within the antibody sequence at or close to the site where the antibody and tether are joined. A cleavage site for a linker generally is located at the N-terminus of the linker sequence (or coiled coil) or in the antibody sequence at or close to the site where the antibody and linker (or coiled coil) are joined. If the linker is cleaved using Lys-C endopeptidase (e.g., at a Lysine residue at the C-terminus of the constant heavy chain), the sequence of the antibody may need to be modified to remove Lys-C endopeptidase cleavage sites. An example of such a modification is the mutation of a Lysine in the hinge region to an Alanine (e.g., K222A, Kabat numbering system; K222A, EU numbering system in exemplary antibodies described herein). Modifications of other cleavage sites may be required and made in a similar manner when different cleavage agents are selected for use in the invention.

Cleavage of amino acid sequences at particular sites is standard in the art and can involve enzymatic cleavage, chemical cleavage, or auto-processing. For example, a tether or linker may be cleaved from an protein using an endopeptidase. Exemplary endopeptidases include, without limitation, Lys-C, Asp-N, Arg-C, V8, Glu-C, Thrombin, Genenase (a variant of subtilisin BPN' protease), Factor Xa, TEV (tobacco etch virus cysteine protease), Enterokinase, HRV C3 (human rhinovirus C3 protease), Kininogenase, chymotrypsin, trypsin, pepsin, and papain, all of which are commercially available (e.g., from Boehringer Mannheim, Thermo Scientific, or New England Biolabs). Lys-C cleaves at the carboxyl side of Lysine residues, V8 and Glu-C cleave at the carboxyl side of Glutamate residues, Arg-C cleaves at the carboxyl side of Arginine residues, Asp-N cleaves at the amino side of Aspartate residues, chymotropsin cleaves at the carboxyl side of Tyrosine, Phenylalanine, Tryptophan, and Leucine residues, and trypsin cleaves at the carboxyl side of Arginine and

Lysine residues. TEV cleaved the amino acid sequence GluAsnLeuTyrPheGlnGly (SEQ ID NO:19) between the "Gln" and "Gly" residues. Use of such enzymes is standard in the art and protocols are available from the manufacturers.

Alternatively a tether or linker may be cleaved from an protein using a chemical, such as hydroxylamine. Hydroxylamine cleaves Asparagine-Glycine peptide bonds. If hydroxylamine is used to cleave the tether and linker from a protein, several Glycine or Asparagine residues in the protein may need to be mutated to avoid fragmenting the protein.

Numerous other chemicals that cleave peptide bonds are known in the art. For example, N-chlorosuccinimide cleaves at the C-terminal side of Tryptophan residues (Shechter et al., Biochemistry 15:5071-5075 (1976)). N-bromosuccinimide and cyanogen bromide also cleave at the C-terminal side of Tryptophan residues. In addition, 2-nitrothiocyanobenzoic acid or organophosphines may be used to cleave a protein at the N-terminal side of a Cysteine residue (see, e.g., EP 0339217).

A linker or tether may also be cleaved at dibasic sites (e.g., an Arginine-Arginine, Lysine-Arginine, or Lysine-Lysine site). Enzymes that cleave at dibasic sites are known in the art and include, for example, N-arginine dibasic convertase (Chow et al., JBC 275:19545-19551 (2000)) and subtilisin-like proprotein convertases such as Furin (PC1), PC2, and PC3 (Steiner (1991) in Peptide Biosynthesis and Processing (Fricker ed.) pp. 1-16, CRC Press, Boca Raton, FL; Muller et al., JBC 275:39213-39222, (2000)).

Proteins are also known to auto-process. For example, the Hedgehog protein is processed at a Gly.AspTrpAsnAlaArgTrp.CysPhe cleavage site (SEQ ID NO:20) by a proteolytic activity within the protein. An autoproteolytic cleavage site may also be included in a linker or tether sequence.

G. Other protein features

Proteins according to the invention can include sequences from any source, including human or murine sources, or combinations thereof. The sequences of certain portions of the proteins (e.g., the hypervariable regions) can also be artificial sequences, such as sequences identified by screening a library (e.g., a phage display library) including random sequences.

In the case of antibodies including sequences from different sources, the antibodies can be "chimeric" antibodies in which a portion of the heavy and/or light chain is identical with or homologous to corresponding sequences in antibodies derived from a particular species or belonging to a particular antibody class or subclass, while the remainder of the

chain(s) is identical with or homologous to corresponding sequences in antibodies derived from another species or belonging to another antibody class or subclass, as well as fragments of such antibodies, provided that they exhibit the desired biological activity (U.S. Patent No. 4,816,567; and Morrison et al., Proc. Natl. Acad. Sci. USA 81:6851-6855 (1984)). Such chimeric antibodies may, for example, include murine variable regions (or portions thereof) and human constant regions.

The chimeric antibodies can optionally also be "humanized" antibodies, which contain minimal sequence derived from the non-human antibody. Humanized antibodies typically are human antibodies (recipient antibody) in which residues from a hypervariable region of the recipient are replaced by residues from a hypervariable region of a non-human species (donor antibody) such as mouse, rat, rabbit or non-human primate having the desired antibody specificity, affinity, and capability. In some instances, framework region (FR) residues of the human immunoglobulin are replaced by corresponding non-human residues. Furthermore, humanized antibodies can comprise residues that are not found in the recipient antibody or in the donor antibody. These modifications are made to further refine antibody performance. In general, the humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the hypervariable loops correspond to those of a non-human immunoglobulin and all or substantially all of the FRs are those of a human immunoglobulin sequence. The humanized antibody optionally also will comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin. For further details, see Jones et al., Nature 321:522-525 (1986); Riechmann et al., Nature 332:323-329 (1988); and Presta, Curr. Op. Struct. Biol. 2:593-596 (1992).

In more detail, a humanized antibody can have one or more amino acid residues introduced into it from a source that is non-human. These non-human amino acid residues are often referred to as "import" residues, which are typically taken from an "import" variable domain. Humanization can be essentially performed following the method of Winter and co-workers (Jones et al., Nature 321:522-525 (1986); Riechmann et al., Nature 332:323-327 (1988); Verhoeyen et al., Science 239:1534-1536 (1988)), by substituting rodent CDRs or CDR sequences for the corresponding sequences of a human antibody. Accordingly, such "humanized" antibodies are chimeric antibodies (U.S. Patent No. 4,816,567) wherein substantially less than an intact human variable domain has been substituted by the corresponding sequence from a non-human species. In practice, humanized antibodies are typically human antibodies in which some CDR residues and possibly some FR residues are

substituted by residues from analogous sites in rodent antibodies.

The choice of human variable domains, both light and heavy, to be used in making the humanized antibodies is very important to reduce antigenicity. According to the so-called "best-fit" method, the sequence of the variable domain of a rodent antibody is screened against the entire library of known human variable-domain sequences. The human sequence that is closest to that of the rodent is then accepted as the human framework (FR) for the humanized antibody (Sims et al., J. Immunol. 151:2296 (1993); Chothia et al., J. Mol. Biol. 196:901 (1987)). Another method uses a particular framework derived from the consensus sequence of all human antibodies of a particular subgroup of light or heavy chains. The same framework may be used for several different humanized antibodies (Carter et al., Proc. Natl. Acad. Sci. USA 89:4285 (1992); Presta et al., J. Immnol. 151:2623 (1993)).

It is further important that antibodies be humanized with retention of high affinity for the antigen and other favorable biological properties. To achieve this goal, according to an exemplary method, humanized antibodies are prepared by a process of analysis of the parental sequences and various conceptual humanized products using three-dimensional models of the parental and humanized sequences. Three-dimensional immunoglobulin models are commonly available and are familiar to those skilled in the art. Computer programs are available that illustrate and display probable three-dimensional conformational structures of selected candidate immunoglobulin sequences. Inspection of these displays permits analysis of the likely role of the residues in the functioning of the candidate immunoglobulin sequence, i.e., the analysis of residues that influence the ability of the candidate immunoglobulin to bind its antigen. In this way, FR residues can be selected and combined from the recipient and import sequences so that the desired antibody characteristic, such as increased affinity for the target antigen(s), is achieved. In general, the CDR residues are directly and most substantially involved in influencing antigen binding.

III. Vectors, Host Cells, and Recombinant Methods

For recombinant production of an antibody of the invention, the nucleic acid encoding it is isolated and inserted into a replicable vector for further cloning (amplification of the DNA) or for expression. DNA encoding the antibody is readily isolated and sequenced using conventional procedures (e.g., by using oligonucleotide probes that are capable of binding specifically to genes encoding the heavy and light chains of the antibody). Many vectors are available. The choice of vector depends in part on the host cell to be used. Generally,

preferred host cells are of either prokaryotic or eukaryotic (generally mammalian, but also including fungi (e.g., yeast), insect, plant, and nucleated cells from other multicellular organisms) origin. It will be appreciated that constant regions of any isotype can be used for this purpose, including IgG, IgM, IgA, IgD, and IgE constant regions, and that such constant regions can be obtained from any human or animal species.

a. Generating antibodies using prokaryotic host cells

i. Vector construction

Polynucleotide sequences encoding polypeptide components of the antibody of the invention can be obtained using standard recombinant techniques. Desired polynucleotide sequences may be isolated and sequenced from antibody producing cells such as hybridoma cells. Alternatively, polynucleotides can be synthesized using nucleotide synthesizer or PCR techniques. Once obtained, sequences encoding the polypeptides are inserted into a recombinant vector capable of replicating and expressing heterologous polynucleotides in prokaryotic hosts. Many vectors that are available and known in the art can be used for the purpose of the present invention. Selection of an appropriate vector will depend mainly on the size of the nucleic acids to be inserted into the vector and the particular host cell to be transformed with the vector. Each vector contains various components, depending on its function (amplification or expression of heterologous polynucleotide, or both) and its compatibility with the particular host cell in which it resides. The vector components generally include, but are not limited to: an origin of replication, a selection marker gene, a promoter, a ribosome binding site (RBS), a signal sequence, the heterologous nucleic acid insert and a transcription termination sequence.

In general, plasmid vectors containing replicon and control sequences which are derived from species compatible with the host cell are used in connection with these hosts. The vector ordinarily carries a replication site, as well as marking sequences which are capable of providing phenotypic selection in transformed cells. For example, *E. coli* is typically transformed using pBR322, a plasmid derived from an *E. coli* species. pBR322 contains genes encoding ampicillin (Amp) and tetracycline (Tet) resistance and thus provides easy means for identifying transformed cells. pBR322, its derivatives, or other microbial plasmids or bacteriophage may also contain, or be modified to contain, promoters which can be used by the microbial organism for expression of endogenous proteins. Examples of pBR322 derivatives used for expression of particular antibodies are described in detail in

Carter et al., U.S. Patent No. 5,648,237.

In addition, phage vectors containing replicon and control sequences that are compatible with the host microorganism can be used as transforming vectors in connection with these hosts. For example, bacteriophage such as λGEM.TM.-11 may be utilized in making a recombinant vector which can be used to transform susceptible host cells such as *E. coli* LE392.

The expression vector of the invention may comprise two or more promoter-cistron pairs, encoding each of the polypeptide components. A promoter is an untranslated regulatory sequence located upstream (5') to a cistron that modulates its expression. Prokaryotic promoters typically fall into two classes, inducible and constitutive. An inducible promoter is a promoter that initiates increased levels of transcription of the cistron under its control in response to changes in the culture condition, e.g., the presence or absence of a nutrient or a change in temperature.

A large number of promoters recognized by a variety of potential host cells are well known. The selected promoter can be operably linked to cistron DNA encoding the light or heavy chain by removing the promoter from the source DNA via restriction enzyme digestion and inserting the isolated promoter sequence into the vector of the invention. Both the native promoter sequence and many heterologous promoters may be used to direct amplification and/or expression of the target genes. In some embodiments, heterologous promoters are utilized, as they generally permit greater transcription and higher yields of expressed target gene as compared to the native target polypeptide promoter.

Promoters suitable for use with prokaryotic hosts include the PhoA promoter, the β-galactamase and lactose promoter systems, a tryptophan (trp) promoter system and hybrid promoters such as the tac or the trc promoter. However, other promoters that are functional in bacteria (such as other known bacterial or phage promoters) are suitable as well. Their nucleotide sequences have been published, thereby enabling a skilled worker to ligate them to cistrons encoding the target light and heavy chains (Siebenlist et al., (1980) Cell 20:269) using linkers or adaptors to supply any required restriction sites.

In one aspect of the invention, each cistron within the recombinant vector comprises a secretion signal sequence component that directs translocation of the expressed polypeptides across a membrane. In general, the signal sequence may be a component of the vector, or it may be a part of the target polypeptide DNA that is inserted into the vector. The signal sequence selected for the purpose of this invention should be one that is recognized and

processed (i.e., cleaved by a signal peptidase) by the host cell. For prokaryotic host cells that do not recognize and process the signal sequences native to the heterologous polypeptides, the signal sequence is substituted by a prokaryotic signal sequence selected, for example, from the group consisting of the alkaline phosphatase, penicillinase, Ipp, or heat-stable enterotoxin II (STII) leaders, LamB, PhoE, PelB, OmpA, and MBP. In one embodiment of the invention, the signal sequences used in both cistrons of the expression system are STII signal sequences or variants thereof.

In another aspect, the production of the immunoglobulins according to the invention can occur in the cytoplasm of the host cell, and therefore does not require the presence of secretion signal sequences within each cistron. In that regard, immunoglobulin light and heavy chains are expressed, folded and assembled to form functional immunoglobulins within the cytoplasm. Certain host strains (e.g., the *E. coli* trxB- strains) provide cytoplasm conditions that are favorable for disulfide bond formation, thereby permitting proper folding and assembly of expressed protein subunits (Proba and Pluckthun, Gene, 159:203 (1995)).

Prokaryotic host cells suitable for expressing antibodies of the invention include Archaebacteria and Eubacteria, such as Gram-negative or Gram-positive organisms. Examples of useful bacteria include Escherichia (e.g., *E. coli*), Bacilli (e.g., *B. subtilis*), Enterobacteria, Pseudomonas species (e.g., *P. aeruginosa*), *Salmonella typhimurium*, *Serratia marcescans*, Klebsiella, Proteus, Shigella, Rhizobia, Vitreoscilla, or Paracoccus. In one embodiment, gram-negative cells are used. In one embodiment, *E. coli* cells are used as hosts for the invention. Examples of *E. coli* strains include strain W3110 (Bachmann, Cellular and Molecular Biology, vol. 2 (Washington, D.C.: American Society for Microbiology, 1987), pp. 1190-1219; ATCC Deposit No. 27,325) and derivatives thereof, including strain 33D3 having genotype W3110 ΔfhuA (ΔtonA) ptr3 lac Iq lacL8 ΔompTΔ(nmpc-fepE) degP41 kanR (U.S. Pat. No. 5,639,635). Other strains and derivatives thereof, such as *E. coli* 294 (ATCC 31,446), *E. coli* B, *E. coli* λ 1776 (ATCC 31,537) and *E. coli* RV308 (ATCC 31,608) are also suitable. These examples are illustrative rather than limiting. Methods for constructing derivatives of any of the above-mentioned bacteria having defined genotypes are known in the art and described in, for example, Bass et al., Proteins 8:309-314 (1990). It is generally necessary to select the appropriate bacteria taking into consideration replicability of the replicon in the cells of a bacterium. For example, *E. coli*, Serratia, or Salmonella species can be suitably used as the host when well-known plasmids such as pBR322, pBR325, pACYC177, or pKN410 are used to supply the replicon. Typically the host cell should

secrete minimal amounts of proteolytic enzymes, and additional protease inhibitors may desirably be incorporated in the cell culture.

ii. Antibody production

Host cells are transformed with the above-described expression vectors and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

Transformation means introducing DNA into the prokaryotic host so that the DNA is replicable, either as an extrachromosomal element or by chromosomal integrant. Depending on the host cell used, transformation is done using standard techniques appropriate to such cells. The calcium treatment employing calcium chloride is generally used for bacterial cells that contain substantial cell-wall barriers. Another method for transformation employs polyethylene glycol/DMSO. Yet another technique used is electroporation.

Prokaryotic cells used to produce the polypeptides of the invention are grown in media known in the art and suitable for culture of the selected host cells. Examples of suitable media include Luria broth (LB) plus necessary nutrient supplements. In some embodiments, the media also contains a selection agent, chosen based on the construction of the expression vector, to selectively permit growth of prokaryotic cells containing the expression vector. For example, ampicillin is added to media for growth of cells expressing ampicillin resistant gene.

Any necessary supplements besides carbon, nitrogen, and inorganic phosphate sources may also be included at appropriate concentrations introduced alone or as a mixture with another supplement or medium such as a complex nitrogen source. Optionally the culture medium may contain one or more reducing agents selected from the group consisting of glutathione, cysteine, cystamine, thioglycollate, dithioerythritol, and dithiothreitol.

The prokaryotic host cells are cultured at suitable temperatures. For *E. coli* growth, for example, the preferred temperature ranges from about 20°C to about 39°C, more preferably from about 25°C to about 37°C, even more preferably at about 30°C. The pH of the medium may be any pH ranging from about 5 to about 9, depending mainly on the host organism. For *E. coli*, the pH is preferably from about 6.8 to about 7.4, and more preferably about 7.0.

If an inducible promoter is used in the expression vector of the invention, protein expression is induced under conditions suitable for the activation of the promoter. In one aspect of the invention, PhoA promoters are used for controlling transcription of the

polypeptides. Accordingly, the transformed host cells are cultured in a phosphate-limiting medium for induction. Preferably, the phosphate-limiting medium is the C.R.A.P medium (see, e.g., Simmons et al., J. Immunol. Methods (2002), 263:133-147). A variety of other inducers may be used, according to the vector construct employed, as is known in the art.

In one embodiment, the expressed polypeptides of the present invention are secreted into and recovered from the periplasm of the host cells. Protein recovery typically involves disrupting the microorganism, generally by such means as osmotic shock, sonication or lysis. Once cells are disrupted, cell debris or whole cells may be removed by centrifugation or filtration. The proteins may be further purified, for example, by affinity resin chromatography. Alternatively, proteins can be transported into the culture media and isolated therein. Cells may be removed from the culture and the culture supernatant being filtered and concentrated for further purification of the proteins produced. The expressed polypeptides can be further isolated and identified using commonly known methods such as polyacrylamide gel electrophoresis (PAGE) and Western blot assay.

In one aspect of the invention, antibody production is conducted in large quantity by a fermentation process. Various large-scale fed-batch fermentation procedures are available for production of recombinant proteins. Large-scale fermentations have at least 1000 liters of capacity, preferably about 1,000 to 100,000 liters of capacity. These fermentors use agitator impellers to distribute oxygen and nutrients, especially glucose (the preferred carbon/energy source). Small-scale fermentation refers generally to fermentation in a fermentor that is no more than approximately 100 liters in volumetric capacity, and can range from about 1 liter to about 100 liters.

In a fermentation process, induction of protein expression is typically initiated after the cells have been grown under suitable conditions to a desired density, e.g., an OD550 of about 180-220, at which stage the cells are in the early stationary phase. A variety of inducers may be used, according to the vector construct employed, as is known in the art and described above. Cells may be grown for shorter periods prior to induction. Cells are usually induced for about 12-50 hours, although longer or shorter induction time may be used.

To improve the production yield and quality of the polypeptides of the invention, various fermentation conditions can be modified. For example, to improve the proper assembly and folding of the secreted antibody polypeptides, additional vectors overexpressing chaperone proteins, such as Dsb proteins (DsbA, DsbB, DsbC, DsbD, and/or DsbG) or FkpA (a peptidylprolyl cis,trans-isomerase with chaperone activity) can be used to co-transform the

host prokaryotic cells. The chaperone proteins have been demonstrated to facilitate the proper folding and solubility of heterologous proteins produced in bacterial host cells (Chen et al., (1999) J. Biol. Chem. 274:19601-19605; Georgiou et al., U.S. Patent No. 6,083,715; Georgiou et al., U.S. Patent No. 6,027,888; Bothmann and Pluckthun (2000) J. Biol. Chem. 275:17100-17105; Ramm and Pluckthun, (2000) J. Biol. Chem. 275:17106-17113; Arie et al., (2001) Mol. Microbiol. 39:199-210).

To minimize proteolysis of expressed heterologous proteins (especially those that are proteolytically sensitive), certain host strains deficient for proteolytic enzymes can be used for the present invention. For example, host cell strains may be modified to effect genetic mutation(s) in the genes encoding known bacterial proteases such as Protease III, OmpT, DegP, Tsp, Protease I, Protease Mi, Protease V, Protease VI, and combinations thereof. Some *E. coli* protease-deficient strains are available and described in, for example, Joly et al., (1998), Proc. Natl. Acad. Sci. USA 95:2773-2777; Georgiou et al., U.S. Patent No. 5,264,365; Georgiou et al., U.S. Patent No. 5,508,192; Hara et al., Microbial Drug Resistance, 2:63-72 (1996).

In one embodiment, *E. coli* strains deficient for proteolytic enzymes and transformed with plasmids overexpressing one or more chaperone proteins are used as host cells in the expression system of the invention.

iii. Antibody purification

Standard protein purification methods known in the art can be employed. The following procedures are exemplary of suitable purification procedures: fractionation on immunoaffinity or ion-exchange columns, ethanol precipitation, reverse phase HPLC, chromatography on silica or on a cation-exchange resin such as DEAE, chromatofocusing, SDS-PAGE, ammonium sulfate precipitation, and gel filtration using, for example, Sephadex G-75.

In one aspect, Protein A immobilized on a solid phase is used for immunoaffinity purification of the full length antibody products of the invention. Protein A is a 41kD cell wall protein from *Staphylococcus aureus* which binds with a high affinity to the Fc region of antibodies. Lindmark et al., (1983) J. Immunol. Meth. 62:1-13. The solid phase to which Protein A is immobilized is preferably a column comprising a glass or silica surface, more preferably a controlled pore glass column or a silicic acid column. In some applications, the column has been coated with a reagent, such as glycerol, in an attempt to prevent nonspecific adherence of contaminants.

As the first step of purification, the preparation derived from the cell culture as described above is applied onto the Protein A immobilized solid phase to allow specific binding of the antibody of interest to Protein A. The solid phase is then washed to remove contaminants non-specifically bound to the solid phase. The antibody of interest may be recovered from the solid phase by elution into a solution containing a chaotropic agent or mild detergent. Exemplary chaotropic agents and mild detergents include, but are not limited to, Guanidine-HCl, urea, lithium perclorate, Arginine, Histidine, SDS (sodium dodecyl sulfate), Tween, Triton, and NP-40, all of which are commercially available. Diluting the antibody into a solution containing a chaotropic agent or mild detergent after elution from the column (e.g., mAbSure column) maintains the stability of the antibody post elution and allows for the efficient removal of the coiled coil by Lys-C endopeptidase.

b. Generating antibodies using eukaryotic host cells

The vector components generally include, but are not limited to, one or more of the following: a signal sequence, an origin of replication, one or more marker genes, an enhancer element, a promoter, and a transcription termination sequence.

i. Signal sequence component

A vector for use in a eukaryotic host cell may contain a signal sequence or other polypeptide having a specific cleavage site at the N-terminus of the mature protein or polypeptide of interest. The heterologous signal sequence selected can be one that is recognized and processed (i.e., cleaved by a signal peptidase) by the host cell. In mammalian cell expression, mammalian signal sequences as well as viral secretory leaders, for example, the herpes simplex gD signal, are available. The DNA for such precursor region is ligated in reading frame to DNA encoding the antibody.

ii. Origin of replication

Generally, an origin of replication component is not needed for mammalian expression vectors. For example, the SV40 origin may typically be used, but only because it contains the early promoter.

iii. Selection gene component

Expression and cloning vectors may contain a selection gene, also termed a selectable marker. Typical selection genes encode proteins that (a) confer resistance to antibiotics or other toxins, e.g., ampicillin, neomycin, methotrexate, or tetracycline, (b) complement auxotrophic deficiencies, where relevant, or (c) supply critical nutrients not available from

complex media.

One example of a selection scheme utilizes a drug to arrest growth of a host cell. Those cells that are successfully transformed with a heterologous gene produce a protein conferring drug resistance and thus survive the selection regimen. Examples of such dominant selection use the drugs neomycin, mycophenolic acid, and hygromycin.

Another example of suitable selectable markers for mammalian cells are those that enable the identification of cells competent to take up the antibody nucleic acid, such as DHFR, thymidine kinase, metallothionein-I and -II, preferably primate metallothionein genes, adenosine deaminase, ornithine decarboxylase, etc.

For example, cells transformed with the DHFR selection gene are first identified by culturing all of the transformants in a culture medium that contains methotrexate (Mtx), a competitive antagonist of DHFR. An appropriate host cell when wild-type DHFR is employed is the Chinese hamster ovary (CHO) cell line deficient in DHFR activity (e.g., ATCC CRL-9096).

Alternatively, host cells (particularly wild-type hosts that contain endogenous DHFR) transformed or co-transformed with DNA sequences encoding an antibody, wild-type DHFR protein, and another selectable marker such as aminoglycoside 3'-phosphotransferase (APH) can be selected by cell growth in medium containing a selection agent for the selectable marker such as an aminoglycosidic antibiotic, e.g., kanamycin, neomycin, or G418. See, for example, U.S. Patent No. 4,965,199.

iv. Promoter component

Expression and cloning vectors usually contain a promoter that is recognized by the host organism and is operably linked to the antibody polypeptide nucleic acid. Promoter sequences are known for eukaryotes. Virtually all eukaryotic genes have an AT-rich region located approximately 25 to 30 bases upstream from the site where transcription is initiated. Another sequence found 70 to 80 bases upstream from the start of transcription of many genes is a CNCAAT region where N may be any nucleotide. At the 3' end of most eukaryotic genes is an AATAAA sequence that may be the signal for addition of the poly A tail to the 3' end of the coding sequence. All of these sequences are suitably inserted into eukaryotic expression vectors.

Antibody polypeptide transcription from vectors in mammalian host cells is controlled, for example, by promoters obtained from the genomes of viruses such as, for example, polyoma virus, fowlpox virus, adenovirus (such as Adenovirus 2), bovine papilloma

virus, avian sarcoma virus, cytomegalovirus, a retrovirus, hepatitis-B virus, and Simian Virus 40 (SV40), from heterologous mammalian promoters, e.g., the actin promoter or an immunoglobulin promoter, or from heat-shock promoters, provided such promoters are compatible with the host cell systems.

The early and late promoters of the SV40 virus are conveniently obtained as an SV40 restriction fragment that also contains the SV40 viral origin of replication. The immediate early promoter of the human cytomegalovirus is conveniently obtained as a HindIII E restriction fragment. A system for expressing DNA in mammalian hosts using the bovine papilloma virus as a vector is disclosed in U.S. Patent No. 4,419,446. A modification of this system is described in U.S. Patent No. 4,601,978. Alternatively, the Rous Sarcoma Virus long terminal repeat can be used as the promoter.

v. Enhancer element component

Transcription of DNA encoding an antibody polypeptide by higher eukaryotes can be increased by inserting an enhancer sequence into the vector. Many enhancer sequences are now known from mammalian genes (e.g., globin, elastase, albumin, α-fetoprotein, and insulin genes). Also, one may use an enhancer from a eukaryotic cell virus. Examples include the SV40 enhancer on the late side of the replication origin (bp 100-270), the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers. See also Yaniv, Nature 297:17-18 (1982) for a description of elements for enhancing activation of eukaryotic promoters. The enhancer may be spliced into the vector at a position 5' or 3' to the antibody polypeptide-encoding sequence, provided that enhancement is achieved, but is generally located at a site 5' from the promoter.

vi. Transcription termination component

Expression vectors used in eukaryotic host cells will typically also contain sequences necessary for the termination of transcription and for stabilizing the mRNA. Such sequences are commonly available from the 5' and, occasionally 3', untranslated regions of eukaryotic or viral DNAs or cDNAs. These regions contain nucleotide segments transcribed as polyadenylated fragments in the untranslated portion of the mRNA encoding an antibody. One useful transcription termination component is the bovine growth hormone polyadenylation region. See WO 94/11026 and the expression vector disclosed therein.

vii. Selection and transformation of host cells

Suitable host cells for cloning or expressing the DNA in the vectors herein include higher eukaryote cells described herein, including vertebrate host cells. Propagation of

vertebrate cells in culture (tissue culture) has become a routine procedure. Examples of useful mammalian host cell lines are monkey kidney CV1 line transformed by SV40 (COS-7, ATCC CRL 1651); human embryonic kidney line (293 or 293 cells subcloned for growth in suspension culture, Graham et al., J. Gen. Virol. 36:59 (1977)); baby hamster kidney cells (BHK, ATCC CCL 10); Chinese hamster ovary cells/-DHFR (CHO, Urlaub et al., Proc. Natl. Acad. Sci. USA 77:4216 (1980)); mouse sertoli cells (TM4, Mather, Biol. Reprod. 23:243-251 (1980)); monkey kidney cells (CV1 ATCC CCL 70); African green monkey kidney cells (VERO-76, ATCC CRL-1587); human cervical carcinoma cells (HELA, ATCC CCL 2); canine kidney cells (MDCK, ATCC CCL 34); buffalo rat liver cells (BRL 3A, ATCC CRL 1442); human lung cells (W138, ATCC CCL 75); human liver cells (Hep G2, HB 8065); mouse mammary tumor (MMT 060562, ATCC CCL51); TRI cells (Mather et al., Annals N.Y. Acad. Sci. 383:44-68 (1982)); MRC 5 cells; FS4 cells; and a human hepatoma line (Hep G2).

Host cells are transformed with the above-described expression or cloning vectors for antibody production and cultured in conventional nutrient media modified as appropriate for inducing promoters, selecting transformants, or amplifying the genes encoding the desired sequences.

viii. Culturing the host cells

The host cells used to produce an antibody of this invention may be cultured in a variety of media. Commercially available media such as Ham's F10 (Sigma), Minimal Essential Medium ((MEM), (Sigma), RPMI-1640 (Sigma), and Dulbecco's Modified Eagle's Medium ((DMEM), Sigma) are suitable for culturing the host cells. In addition, any of the media described in Ham et al., Meth. Enz. 58:44 (1979), Barnes et al., Anal. Biochem. 102:255 (1980), U.S. Patent Nos. 4,767,704; 4,657,866; 4,927,762; 4,560,655; or 5,122,469; WO 90/03430; WO 87/00195; or U.S. Patent Re. 30,985 may be used as culture media for the host cells. Any of these media may be supplemented as necessary with hormones and/or other growth factors (such as insulin, transferrin, or epidermal growth factor), salts (such as sodium chloride, calcium, magnesium, and phosphate), buffers (such as HEPES), nucleotides (such as adenosine and thymidine), antibiotics (such as GENTAMYCIN™ drug), trace elements (defined as inorganic compounds usually present at final concentrations in the micromolar range), and glucose or an equivalent energy source. Any other necessary supplements may also be included at appropriate concentrations that would be known to those skilled in the art. The culture conditions, such as temperature, pH, and the like, are those

previously used with the host cell selected for expression, and will be apparent to the ordinarily skilled artisan.

ix. Purification of antibody

When using recombinant techniques, the antibody can be produced intracellularly, or directly secreted into the medium. If the antibody is produced intracellularly, as a first step, the particulate debris, either host cells or lysed fragments, are removed, for example, by centrifugation or ultrafiltration. Where the antibody is secreted into the medium, supernatants from such expression systems are generally first concentrated using a commercially available protein concentration filter, for example, an Amicon or Millipore Pellicon ultrafiltration unit. A protease inhibitor such as PMSF may be included in any of the foregoing steps to inhibit proteolysis and antibiotics may be included to prevent the growth of adventitious contaminants.

The antibody composition prepared from the cells can be purified using, for example, hydroxylapatite chromatography, gel electrophoresis, dialysis, and affinity chromatography, with affinity chromatography being the preferred purification technique. The suitability of protein A as an affinity ligand depends on the species and isotype of any immunoglobulin Fc domain that is present in the antibody. Protein A can be used to purify antibodies that are based on human γ1, γ2, or γ4 heavy chains (Lindmark et al., J. Immunol. Meth. 62:1-13 (1983)). Protein G is recommended for all mouse isotypes and for human γ3 (Guss et al., EMBO J. 5:15671575 (1986)). The matrix to which the affinity ligand is attached is most often agarose, but other matrices are available. Mechanically stable matrices such as controlled pore glass or poly(styrenedivinyl)benzene allow for faster flow rates and shorter processing times than can be achieved with agarose. Where the antibody comprises a CH3 domain, the Bakerbond ABX™resin (J. T. Baker, Phillipsburg, NJ) is useful for purification. Other techniques for protein purification such as fractionation on an ion-exchange column, ethanol precipitation, Reverse Phase HPLC, chromatography on silica, chromatography on heparin SEPHAROSE™ chromatography on an anion or cation exchange resin (such as a polyaspartic acid column), chromatofocusing, SDS-PAGE, and ammonium sulfate precipitation are also available depending on the antibody to be recovered.

In one embodiment, the antibody of interest is recovered from the solid phase of a column by elution into a solution containing a chaotropic agent or mild detergent. Exemplary chaotropic agents and mild detergents include, but are not limited to, Guanidine-HCl, urea, lithium perclorate, Arginine, Histidine, SDS (sodium dodecyl sulfate), Tween, Triton, and

NP-40, all of which are commercially available.

Following any preliminary purification step(s), the mixture comprising the antibody of interest and contaminants may be subjected to low pH hydrophobic interaction chromatography using an elution buffer at a pH between about 2.5-4.5, preferably performed at low salt concentrations (e.g., from about 0-0.25 M salt).

x. Antibody production using baculovirus

Recombinant baculovirus may be generated by co-transfecting a plasmid encoding an antibody or antibody fragment and BaculoGold™ virus DNA (Pharmingen) into an insect cell such as a *Spodoptera frugiperda* cell (e.g., Sf9 cells; ATCC CRL 1711) or a *Drosophila melanogaster* S2 cell using, for example, lipofectin (commercially available from GIBCO-BRL). In a particular example, an antibody sequence is fused upstream of an epitope tag contained within a baculovirus expression vector. Such epitope tags include poly-His tags. A variety of plasmids may be employed, including plasmids derived from commercially available plasmids such as pVL1393 (Novagen) or pAcGP67B (Pharmingen). Briefly, the sequence encoding an antibody or a fragment thereof may be amplified by PCR with primers complementary to the 5' and 3' regions. The 5' primer may incorporate flanking (selected) restriction enzyme sites. The product may then be digested with the selected restriction enzymes and subcloned into the expression vector.

After tranfection with the expression vector, the host cells (e.g., Sf9 cells) are incubated for 4-5 days at 28°C and the released virus is harvested and used for further amplifications. Viral infection and protein expression may be performed as described, for example, by O'Reilley et al. (Baculovirus expression vectors: A Laboratory Manual. Oxford: Oxford University Press (1994)).

Expressed poly-His tagged antibody can then be purified, for example, by Ni^{2+}-chelate affinity chromatography as follows. Extracts can be prepared from recombinant virus-infected Sf9 cells as described by Rupert et al. (Nature 362:175-179 (1993)). Briefly, Sf9 cells are washed, resuspended in sonication buffer (25 mL HEPES pH 7.9; 12.5 mM $MgCl_2$; 0.1 mM EDTA; 10% glycerol; 0.1% NP-40; 0.4 M KCl), and sonicated twice for 20 seconds on ice. The sonicates are cleared by centrifugation, and the supernatant is diluted 50-fold in loading buffer (50 mM phosphate; 300 mM NaCl; 10% glycerol pH 7.8) and filtered through a 0.45 μm filter. A Ni^{2+}-NTA agarose column (commercially available from Qiagen) is prepared with a bed volume of 5 mL, washed with 25 mL of water, and equilibrated with 25 mL of loading buffer. The filtered cell extract is loaded onto the column at 0.5 mL per

minute. The column is washed to baseline A_{280} with loading buffer, at which point fraction collection is started. Next, the column is washed with a secondary wash buffer (50 mM phosphate; 300 mM NaCl; 10% glycerol pH 6.0), which elutes nonspecifically bound protein. After reaching A_{280} baseline again, the column is developed with a 0 to 500 mM Imidazole gradient in the secondary wash buffer. One mL fractions are collected and analyzed by SDS-PAGE and silver staining or Western blot with Ni^{2+}-NTA-conjugated to alkaline phosphatase (Qiagen). Fractions containing the eluted His_{10}-tagged antibody are pooled and dialyzed against loading buffer.

Alternatively, purification of the antibody can be performed using known chromatography techniques, including for instance, Protein A or protein G column chromatography. The antibody of interest may be recovered from the solid phase of the column by elution into a solution containing a chaotropic agent or mild detergent. Exemplary chaotropic agents and mild detergents include, but are not limited to, Guanidine-HCl, urea, lithium perclorate, Arginine, Histidine, SDS (sodium dodecyl sulfate), Tween, Triton, and NP-40, all of which are commercially available.

c. Optimized purification technique

One particular purification approach that may be used for coiled coil containing antibodies is shown below.

Coiled coil containing antibody loaded onto a Protein A (e.g., mAbSure) column at 4° C

↓

Column washed with KPO_4, then PBS + 0.1% Trition X114

↓

Sample eluted into Tris pH 8.0 (200mM) plus Arginine (100mM)

↓

Sample pH adjusted to 8.0 and cleaved for 1 hr at 37° C, 1:500 wt:wt LysC

↓

Sample concentrated using 1ml mAbSure resin/10mg protein and eluted into Tris/Arg buffer

↓

Sample Loaded onto S200 gel filtration column in PBS + 0.3M NaCl + 100mM Arg

↓

Collect fractions, pool & dialyze into PBS

In addition to Arginine, other chaotropic agents or mild detergents that can be used in the above purification protocol after the initial Protein A column step include, but are not limited to, Guanidine-HCl, urea, lithium perclorate, Histidine, SDS (sodium dodecyl sulfate), Tween, Triton, and NP-40, all of which are commercially available. Diluting the antibody

into a solution containing a chaotropic agent or mild detergent after elution from the initial Protein A containing column (e.g., mAbSure column) maintains the stability of the antibody post elution and allows for the efficient removal of the coiled coil by Lys-C endopeptidase.

IV. Conjugated Proteins

The invention also provides conjugated proteins such as conjugated antibodies or immunoconjugates (for example, "antibody-drug conjugates" or "ADC"), comprising any of the antibodies described herein (e.g., a coiled coil containing antibody, a tethered antibody, or an antibody made according to the methods described herein) where one of the constant regions of the light chain or the heavy chain is conjugated to a chemical molecule such as a dye or cytotoxic agent such as a chemotherapeutic agent, a drug, a growth inhibitory agent, a toxin (e.g., an enzymatically active toxin of bacterial, fungal, plant, or animal origin, or fragments thereof), or a radioactive isotope (i.e., a radioconjugate). In particular, as described herein, the use of coiled coil domains enables the construction of antibodies containing two different heavy chains (HC1 and HC2) as well as two different light chains (LC1 and LC2). An immunoconjugate constructed using the methods described herein may contain the cytotoxic agent conjugated to a constant region of only one of the heavy chains (HC1 or HC2) or only one of the light chains (LC1 or LC2). Also, because the immunoconjugate can have the cytotoxic agent attached to only one heavy or light chain, the amount of the cytotoxic agent being administered to a subject is reduced relative to administration of an antibody having the cytotoxic agent attached to both heavy or light chains. Reducing the amount of cytotoxic agent being administered to a subject limits adverse side effects associated with the cytotoxic agent.

The use of antibody-drug conjugates for the local delivery of cytotoxic or cytostatic agents, i.e., drugs to kill or inhibit tumor cells in the treatment of cancer (Syrigos and Epenetos, Anticancer Research 19:605-614 (1999); Niculescu-Duvaz and Springer, Adv. Drg. Del. Rev. 26:151-172 (1997); U.S. Patent No. 4,975,278) allows targeted delivery of the drug moiety to tumors, and intracellular accumulation therein, where systemic administration of these unconjugated drug agents may result in unacceptable levels of toxicity to normal cells as well as the tumor cells sought to be eliminated (Baldwin et al., Lancet (Mar. 15, 1986):603-605 (1986); Thorpe, (1985) "Antibody Carriers Of Cytotoxic Agents In Cancer Therapy: A Review," in Monoclonal Antibodies '84: Biological And Clinical Applications, A. Pinchera et al. (ed.s), pp. 475-506). Maximal efficacy with minimal toxicity is sought

thereby. Both polyclonal antibodies and monoclonal antibodies have been reported as useful in these strategies (Rowland et al., Cancer Immunol. Immunother. 21:183-187 (1986)). Drugs used in these methods include daunomycin, doxorubicin, methotrexate, and vindesine (Rowland et al., (1986) supra). Toxins used in antibody-toxin conjugates include bacterial toxins such as diphtheria toxin, plant toxins such as ricin, small molecule toxins such as geldanamycin (Mandler et al., Jour. of the Nat. Cancer Inst. 92(19):1573-1581 (2000); Mandler et al., Bioorganic & Med. Chem. Letters 10:1025-1028 (2000); Mandler et al., Bioconjugate Chem. 13:786-791 (2002)), maytansinoids (EP 1391213; Liu et al., Proc. Natl. Acad. Sci. USA 93:8618-8623 (1996)), and calicheamicin (Lode et al., Cancer Res. 58:2928 (1998); Hinman et al., Cancer Res. 53:3336-3342 (1993)). The toxins may effect their cytotoxic and cytostatic effects by mechanisms including tubulin binding, DNA binding, or topoisomerase inhibition. Some cytotoxic drugs tend to be inactive or less active when conjugated to large antibodies or protein receptor ligands.

Chemotherapeutic agents useful in the generation of immunoconjugates are described herein (e.g., above). Enzymatically active toxins and fragments thereof that can be used include diphtheria A chain, nonbinding active fragments of diphtheria toxin, exotoxin A chain (from *Pseudomonas aeruginosa*), ricin A chain, abrin A chain, modeccin A chain, alpha-sarcin, *Aleurites fordii* proteins, dianthin proteins, *Phytolaca americana* proteins (PAPI, PAPII, and PAP-S), momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, enomycin, and the tricothecenes. See, e.g., WO 93/21232 published October 28, 1993. A variety of radionuclides are available for the production of radioconjugated antibodies. Examples include ^{212}Bi, ^{131}I, ^{131}In, ^{90}Y, and ^{186}Re. Conjugates of the antibody and cytotoxic agent are made using a variety of bifunctional protein-coupling agents such as N-succinimidyl-3-(2-pyridyldithiol) propionate (SPDP), iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCl), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). For example, a ricin immunotoxin can be prepared as described in Vitetta et al., Science 238:1098 (1987). Carbon-14-labeled 1-isothiocyanatobenzyl-3-methyldiethylene triaminepentaacetic acid (MX-DTPA) is an exemplary chelating agent for conjugation of radionucleotide to the antibody. See, e.g.,

WO94/11026.

Conjugates of an antibody and one or more small molecule toxins, such as a calicheamicin, maytansinoids, dolastatins, aurostatins, a trichothecene, and CC1065, and the derivatives of these toxins that have toxin activity, are also contemplated herein.

i. Maytansine and maytansinoids

In some embodiments, the immunoconjugate comprises an antibody (full length or fragments) of the invention conjugated to one or more maytansinoid molecules.

Maytansinoids are mitototic inhibitors which act by inhibiting tubulin polymerization. Maytansine was first isolated from the east African shrub *Maytenus serrata* (U.S. Patent No. 3,896,111). Subsequently, it was discovered that certain microbes also produce maytansinoids, such as maytansinol and C-3 maytansinol esters (U.S. Patent No. 4,151,042). Synthetic maytansinol and derivatives and analogues thereof are disclosed, for example, in U.S. Patent Nos. 4,137,230; 4,248,870; 4,256,746; 4,260,608; 4,265,814; 4,294,757; 4,307,016; 4,308,268; 4,308,269; 4,309,428; 4,313,946; 4,315,929; 4,317,821; 4,322,348; 4,331,598; 4,361,650; 4,364,866; 4,424,219; 4,450,254; 4,362,663; and 4,371,533.

Maytansinoid drug moieties are attractive drug moieties in antibody drug conjugates because they are: (i) relatively accessible to prepare by fermentation or chemical modification, derivatization of fermentation products, (ii) amenable to derivatization with functional groups suitable for conjugation through the non-disulfide linkers to antibodies, (iii) stable in plasma, and (iv) effective against a variety of tumor cell lines.

Immunoconjugates containing maytansinoids, methods of making same, and their therapeutic use are disclosed, for example, in U.S. Patent Nos. 5,208,020, 5,416,064 and European Patent EP 0 425 235 B1, the disclosures of which are hereby expressly incorporated by reference. Liu et al., Proc. Natl. Acad. Sci. USA 93:8618-8623 (1996) described immunoconjugates comprising a maytansinoid designated DM1 linked to the monoclonal antibody C242 directed against human colorectal cancer. The conjugate was found to be highly cytotoxic towards cultured colon cancer cells, and showed antitumor activity in an *in vivo* tumor growth assay. Chari et al., Cancer Research 52:127-131 (1992) describe immunoconjugates in which a maytansinoid was conjugated via a disulfide linker to the murine antibody A7 binding to an antigen on human colon cancer cell lines, or to another murine monoclonal antibody TA.1 that binds the HER-2/neu oncogene. The cytotoxicity of the TA.1-maytansinoid conjugate was tested *in vitro* on the human breast cancer cell line SK-BR-3, which expresses 3 x 10^5 HER-2 surface antigens per cell. The drug conjugate achieved

a degree of cytotoxicity similar to the free maytansinoid drug, which could be increased by increasing the number of maytansinoid molecules per antibody molecule. The A7-maytansinoid conjugate showed low systemic cytotoxicity in mice.

Antibody-maytansinoid conjugates are prepared by chemically linking an antibody to a maytansinoid molecule without significantly diminishing the biological activity of either the antibody or the maytansinoid molecule. See, e.g., U.S. Patent No. 5,208,020 (the disclosure of which is hereby expressly incorporated by reference). An average of 3-4 maytansinoid molecules conjugated per antibody molecule has shown efficacy in enhancing cytotoxicity of target cells without negatively affecting the function or solubility of the antibody, although even one molecule of toxin/antibody would be expected to enhance cytotoxicity over the use of naked antibody. Maytansinoids are well known in the art and can be synthesized by known techniques or isolated from natural sources. Suitable maytansinoids are disclosed, for example, in U.S. Patent No. 5,208,020 and in the other patents and nonpatent publications referred to hereinabove. Preferred maytansinoids are maytansinol and maytansinol analogues modified in the aromatic ring or at other positions of the maytansinol molecule, such as various maytansinol esters.

There are many linking groups known in the art for making antibody-maytansinoid conjugates, including, for example, those disclosed in U.S. Patent No. 5,208,020 or EP Patent 0 425 235 B1, Chari et al., Cancer Research 52:127-131 (1992), and U.S. Patent Application Publication No. 2005/0169933, the disclosures of which are hereby expressly incorporated by reference. Antibody-maytansinoid conjugates comprising the linker component SMCC may be prepared as disclosed in U.S. Patent Application Publication No. 2005/0169933. The linking groups include disulfide groups, thioether groups, acid labile groups, photolabile groups, peptidase labile groups, or esterase labile groups, as disclosed in the above-identified patents, disulfide and thioether groups being preferred. Additional linking groups are described and exemplified herein.

Conjugates of the antibody and maytansinoid may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridyldithio) propionate (SPDP), succinimidyl-4-(N-maleimidomethyl) cyclohexane-1-carboxylate (SMCC), iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCl), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-

diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). Particularly preferred coupling agents include N-succinimidyl-3-(2-pyridyldithio) propionate (SPDP) (Carlsson et al., Biochem. J. 173:723-737 (1978)) and N-succinimidyl-4-(2-pyridylthio)pentanoate (SPP) to provide for a disulfide linkage.

The linker may be attached to the maytansinoid molecule at various positions, depending on the type of the link. For example, an ester linkage may be formed by reaction with a hydroxyl group using conventional coupling techniques. The reaction may occur at the C-3 position having a hydroxyl group, the C-14 position modified with hydroxymethyl, the C-15 position modified with a hydroxyl group, and the C-20 position having a hydroxyl group. In a preferred embodiment, the linkage is formed at the C-3 position of maytansinol or a maytansinol analogue.

ii. Auristatins and dolastatins

In some embodiments, the immunoconjugate comprises an antibody of the invention conjugated to dolastatins or dolostatin peptidic analogs and derivatives, the auristatins (U.S. Patent Nos. 5,635,483 and 5,780,588). Dolastatins and auristatins have been shown to interfere with microtubule dynamics, GTP hydrolysis, and nuclear and cellular division (Woyke et al., Antimicrob. Agents and Chemother. 45(12):3580-3584 (2001)) and have anticancer (U.S. Patent No. 5,663,149) and antifungal activity (Pettit et al., Antimicrob. Agents Chemother. 42:2961-2965 (1998)). The dolastatin or auristatin drug moiety may be attached to the antibody through the N- (amino) terminus or the C- (carboxyl) terminus of the peptidic drug moiety (WO 02/088172).

Exemplary auristatin embodiments include the N-terminus linked monomethylauristatin drug moieties DE and DF, disclosed in "Monomethylvaline Compounds Capable of Conjugation to Ligands," U.S. Application Publication No. 2005/0238649, the disclosure of which is expressly incorporated by reference in its entirety.

Typically, peptide-based drug moieties can be prepared by forming a peptide bond between two or more amino acids and/or peptide fragments. Such peptide bonds can be prepared, for example, according to the liquid phase synthesis method (see E. Schröder and K. Lübke, "The Peptides," volume 1, pp. 76-136, 1965, Academic Press) that is well known in the field of peptide chemistry. The auristatin/dolastatin drug moieties may be prepared according to the methods of: U.S. Patent Nos. 5,635,483 and 5,780,588; Pettit et al., J. Nat. Prod. 44:482-485 (1981); Pettit et al., Anti-Cancer Drug Design 13:47-66 (1998); Poncet, Curr. Pharm. Des. 5:139-162 (1999); and Pettit, Fortschr. Chem. Org. Naturst. 70:1-79

(1997). See also Doronina, Nat. Biotechnol. 21(7):778-784 (2003); and "Monomethylvaline Compounds Capable of Conjugation to Ligands," U.S. Application Publication No. 2005/0238649, hereby incorporated by reference in its entirety (disclosing, e.g., linkers and methods of preparing monomethylvaline compounds such as MMAE and MMAF conjugated to linkers).

iii. Calicheamicin

In other embodiments, the immunoconjugate comprises an antibody of the invention conjugated to one or more calicheamicin molecules. The calicheamicin family of antibiotics are capable of producing double-stranded DNA breaks at sub-picomolar concentrations. For the preparation of conjugates of the calicheamicin family, see U.S. Patent Nos. 5,712,374, 5,714,586, 5,739,116, 5,767,285, 5,770,701, 5,770,710, 5,773,001, and 5,877,296 (all to American Cyanamid Company). Structural analogues of calicheamicin which may be used include, but are not limited to, γ_1^I, α_2^I, α_3^I, N-acetyl-γ_1^I, PSAG and θ^I_1 (Hinman et al., Cancer Research 53:3336-3342 (1993), Lode et al., Cancer Research 58:2925-2928 (1998) and the aforementioned U.S. patents to American Cyanamid). Another anti-tumor drug that the antibody can be conjugated is QFA, which is an antifolate. Both calicheamicin and QFA have intracellular sites of action and do not readily cross the plasma membrane. Therefore, cellular uptake of these agents through antibody mediated internalization greatly enhances their cytotoxic effects.

iv. Other cytotoxic agents

Other antitumor agents that can be conjugated to the antibodies of the invention or made according to the methods described herein include BCNU, streptozoicin, vincristine and 5-fluorouracil, the family of agents known collectively LL-E33288 complex described in U.S. Patent Nos. 5,053,394 and 5,770,710, as well as esperamicins (U.S. Patent No. 5,877,296).

Enzymatically active toxins and fragments thereof which can be used include diphtheria A chain, nonbinding active fragments of diphtheria toxin, exotoxin A chain (from *Pseudomonas aeruginosa*), ricin A chain, abrin A chain, modeccin A chain, alpha-sarcin, Aleurites fordii proteins, dianthin proteins, *Phytolaca americana* proteins (PAPI, PAPII, and PAP-S), momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, enomycin and the tricothecenes (see, for example, WO 93/21232, published October 28, 1993).

The present invention further contemplates an immunoconjugate formed between an antibody and a compound with nucleolytic activity (e.g., a ribonuclease or a DNA

endonuclease such as a deoxyribonuclease; DNase).

For selective destruction of a tumor, the antibody may comprise a highly radioactive atom. A variety of radioactive isotopes are available for the production of radioconjugated antibodies. Examples include At^{211}, I^{131}, I^{125}, Y^{90}, Re^{186}, Re^{188}, Sm^{153}, Bi^{212}, P^{32}, Pb^{212} and radioactive isotopes of Lu. When the conjugate is used for detection, it may comprise a radioactive atom for scintigraphic studies, for example tc^{99m} or I^{123}, or a spin label for nuclear magnetic resonance (NMR) imaging (also known as magnetic resonance imaging, mri), such as iodine-123 again, iodine-131, indium-111, fluorine-19, carbon-13, nitrogen-15, oxygen-17, gadolinium, manganese or iron.

The radio- or other labels may be incorporated in the conjugate in known ways. For example, the peptide may be biosynthesized or may be synthesized by chemical amino acid synthesis using suitable amino acid precursors involving, for example, fluorine-19 in place of hydrogen. Labels such as tc^{99m} or I^{123}, Re^{186}, Re^{188} and In^{111} can be attached via a cysteine residue in the peptide. Yttrium-90 can be attached via a lysine residue. The IODOGEN method (Fraker et al., Biochem. Biophys. Res. Commun. 80:49-57 (1978)) can be used to incorporate iodine-123. "Monoclonal Antibodies in Immunoscintigraphy" (Chatal, CRC Press 1989) describes other methods in detail.

Conjugates of the antibody and cytotoxic agent may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridyldithio) propionate (SPDP), succinimidyl-4-(N-maleimidomethyl) cyclohexane-1-carboxylate (SMCC), iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCl), active esters (such as disuccinimidyl suberate), aldehydes (such as glutaraldehyde), bis-azido compounds (such as bis (p-azidobenzoyl) hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). For example, a ricin immunotoxin can be prepared as described in Vitetta et al., Science 238:1098 (1987). Carbon-14-labeled 1-isothiocyanatobenzyl-3-methyldiethylene triaminepentaacetic acid (MX-DTPA) is an exemplary chelating agent for conjugation of radionucleotide to the antibody. See, e.g., WO94/11026. The linker may be a "cleavable linker" facilitating release of the cytotoxic drug in the cell. For example, an acid-labile linker, peptidase-sensitive linker, photolabile linker, dimethyl linker or disulfide-containing linker (Chari et al., Cancer Research 52:127-131 (1992); U.S. Patent No. 5,208,020) may be used.

The compounds of the invention expressly contemplate, but are not limited to, ADC prepared with cross-linker reagents: BMPS, EMCS, GMBS, HBVS, LC-SMCC, MBS, MPBH, SBAP, SIA, SIAB, SMCC, SMPB, SMPH, sulfo-EMCS, sulfo-GMBS, sulfo-KMUS, sulfo-MBS, sulfo-SIAB, sulfo-SMCC, and sulfo-SMPB, and SVSB (succinimidyl-(4-vinylsulfone)benzoate) which are commercially available (e.g., from Pierce Biotechnology, Inc., Rockford, IL., U.S.A). See pages 467-498, 2003-2004 Applications Handbook and Catalog.

v. Preparation of conjugated antibodies

In the conjugated antibodies of the invention, an antibody is conjugated to one or more moieties (for example, drug moieties), e.g. about 1 to about 20 moieties per antibody, optionally through a linker. The conjugated antibodies may be prepared by several routes, employing organic chemistry reactions, conditions, and reagents known to those skilled in the art, including: (1) reaction of a nucleophilic group of an antibody with a bivalent linker reagent via a covalent bond, followed by reaction with a moiety of interest; and (2) reaction of a nucleophilic group of a moiety with a bivalent linker reagent via a covalent bond, followed by reaction with the nucleophilic group of an antibody. Additional methods for preparing conjugated antibodies are described herein.

The linker reagent may be composed of one or more linker components. Exemplary linker components include 6-maleimidocaproyl ("MC"), maleimidopropanoyl ("MP"), valine-citrulline ("val-cit"), alanine-phenylalanine ("ala-phe"), p-aminobenzyloxycarbonyl ("PAB"), N-Succinimidyl 4-(2-pyridylthio) pentanoate ("SPP"), N-Succinimidyl 4-(N-maleimidomethyl) cyclohexane-1 carboxylate ("SMCC'), and N-Succinimidyl (4-iodo-acetyl) aminobenzoate ("SIAB"). Additional linker components are known in the art and some are described herein. See also "Monomethylvaline Compounds Capable of Conjugation to Ligands," U.S. Application Publication No. 2005/0238649, the contents of which are hereby incorporated by reference in its entirety.

In some embodiments, the linker may comprise amino acid residues. Exemplary amino acid linker components include a dipeptide, a tripeptide, a tetrapeptide or a pentapeptide. Exemplary dipeptides include: valine-citrulline (vc or val-cit), alanine-phenylalanine (af or ala-phe). Exemplary tripeptides include: glycine-valine-citrulline (gly-val-cit) and glycine-glycine-glycine (gly-gly-gly). Amino acid residues which comprise an amino acid linker component include those occurring naturally, as well as minor amino acids and non-naturally occurring amino acid analogs, such as citrulline. Amino acid linker

components can be designed and optimized in their selectivity for enzymatic cleavage by a particular enzymes, for example, a tumor-associated protease, cathepsin B, C and D, or a plasmin protease.

Nucleophilic groups on antibodies include, but are not limited to: (i) N-terminal amine groups, (ii) side chain amine groups, e.g. lysine, (iii) side chain thiol groups, e.g. cysteine, and (iv) sugar hydroxyl or amino groups where the antibody is glycosylated. Amine, thiol, and hydroxyl groups are nucleophilic and capable of reacting to form covalent bonds with electrophilic groups on linker moieties and linker reagents including: (i) active esters such as NHS esters, HOBt esters, haloformates, and acid halides; (ii) alkyl and benzyl halides such as haloacetamides; (iii) aldehydes, ketones, carboxyl, and maleimide groups. Certain antibodies have reducible interchain disulfides, i.e., cysteine bridges. Antibodies may be made reactive for conjugation with linker reagents by treatment with a reducing agent such as DTT (dithiothreitol). Each cysteine bridge will thus form, theoretically, two reactive thiol nucleophiles. Additional nucleophilic groups can be introduced into antibodies through the reaction of lysines with 2-iminothiolane (Traut's reagent) resulting in conversion of an amine into a thiol. Reactive thiol groups may be introduced into the antibody (or fragment thereof) by introducing one, two, three, four, or more cysteine residues (e.g., preparing mutant antibodies comprising one or more non-native cysteine amino acid residues).

Conjugated antibodies of the invention may also be produced by modification of the antibody to introduce electrophilic moieties, which can react with nucleophilic substituents on the linker reagent or drug or other moiety. The sugars of glycosylated antibodies may be oxidized, e.g., with periodate oxidizing reagents, to form aldehyde or ketone groups which may react with the amine group of linker reagents or drug or other moieties. The resulting imine Schiff base groups may form a stable linkage, or may be reduced, e.g., by borohydride reagents to form stable amine linkages. In one embodiment, reaction of the carbohydrate portion of a glycosylated antibody with either glactose oxidase or sodium meta-periodate may yield carbonyl (aldehyde and ketone) groups in the protein that can react with appropriate groups on the drug or other moiety (Hermanson, Bioconjugate Techniques). In another embodiment, proteins containing N-terminal serine or threonine residues can react with sodium meta-periodate, resulting in production of an aldehyde in place of the first amino acid (Geoghegan and Stroh, Bioconjugate Chem. 3:138-146 (1992); U.S. Patent No. 5,362,852). Such aldehyde can be reacted with a drug moiety or linker nucleophile.

Likewise, nucleophilic groups on a moiety (such as a drug moiety) include, but are not

limited to: amine, thiol, hydroxyl, hydrazide, oxime, hydrazine, thiosemicarbazone, hydrazine carboxylate, and arylhydrazide groups capable of reacting to form covalent bonds with electrophilic groups on linker moieties and linker reagents including: (i) active esters such as NHS esters, HOBt esters, haloformates, and acid halides; (ii) alkyl and benzyl halides such as haloacetamides; and (iii) aldehydes, ketones, carboxyl, and maleimide groups.

Alternatively, a fusion protein comprising the antibody and cytotoxic agent may be made, e.g., by recombinant techniques or peptide synthesis. The length of DNA may comprise respective regions encoding the two portions of the conjugate either adjacent one another or separated by a region encoding a linker peptide which does not destroy the desired properties of the conjugate. In yet another embodiment, the antibody may be conjugated to a "receptor" (such streptavidin) for utilization in tumor pre-targeting wherein the antibody-receptor conjugate is administered to the individual, followed by removal of unbound conjugate from the circulation using a clearing agent and then administration of a "ligand" (e.g., avidin) which is conjugated to a cytotoxic agent (e.g., a radionucleotide).

V. Therapeutic Uses

The protein complexes such as antibodies and antibody fragments described herein (e.g., a coiled coil containing antibody, a tethered antibody, or an antibody made according to the methods described herein) may be used for therapeutic applications. For example, such antibodies and antibody fragments can be used for the treatment of tumors, including pre-cancerous, non-metastatic, metastatic, and cancerous tumors (e.g., early stage cancer), for the treatment of allergic or inflammatory disorders, or for the treatment of autoimmune disease, or for the treatment of a subject at risk for developing cancer (for example, breast cancer, colorectal cancer, lung cancer, renal cell carcinoma, glioma, or ovarian cancer), an allergic or inflammatory disorder, or an autoimmune disease.

The term cancer embraces a collection of proliferative disorders, including but not limited to pre-cancerous growths, benign tumors, and malignant tumors. Benign tumors remain localized at the site of origin and do not have the capacity to infiltrate, invade, or metastasize to distant sites. Malignant tumors will invade and damage other tissues around them. They can also gain the ability to break off from where they started and spread to other parts of the body (metastasize), usually through the bloodstream or through the lymphatic system where the lymph nodes are located. Primary tumors are classified by the type of tissue from which they arise; metastatic tumors are classified by the tissue type from which the

cancer cells are derived. Over time, the cells of a malignant tumor become more abnormal and appear less like normal cells. This change in the appearance of cancer cells is called the tumor grade and cancer cells are described as being well-differentiated, moderately-differentiated, poorly-differentiated, or undifferentiated. Well-differentiated cells are quite normal appearing and resemble the normal cells from which they originated. Undifferentiated cells are cells that have become so abnormal that it is no longer possible to determine the origin of the cells.

The tumor can be a solid tumor or a non-solid or soft tissue tumor. Examples of soft tissue tumors include leukemia (e.g., chronic myelogenous leukemia, acute myelogenous leukemia, adult acute lymphoblastic leukemia, acute myelogenous leukemia, mature B-cell acute lymphoblastic leukemia, chronic lymphocytic leukemia, polymphocytic leukemia, or hairy cell leukemia), or lymphoma (e.g., non-Hodgkin's lymphoma, cutaneous T-cell lymphoma, or Hodgkin's disease). A solid tumor includes any cancer of body tissues other than blood, bone marrow, or the lymphatic system. Solid tumors can be further separated into those of epithelial cell origin and those of non-epithelial cell origin. Examples of epithelial cell solid tumors include tumors of the gastrointestinal tract, colon, breast, prostate, lung, kidney, liver, pancreas, ovary, head and neck, oral cavity, stomach, duodenum, small intestine, large intestine, anus, gall bladder, labium, nasopharynx, skin, uterus, male genital organ, urinary organs, bladder, and skin. Solid tumors of non-epithelial origin include sarcomas, brain tumors, and bone tumors.

Epithelial cancers generally evolve from a benign tumor to a preinvasive stage (e.g., carcinoma *in situ*), to a malignant cancer, which has penetrated the basement membrane and invaded the subepithelial stroma.

Multispecific protein complexes can also be used in these therapeutic applications, and antibodies that bind HER2 can in particular be used to treat breast cancer, colorectal cancer, lung cancer, renal cell carcinoma, glioma, or ovarian cancer.

Other subjects that are candidates for receiving compositions of this invention have, or are at risk for developing, abnormal proliferation of fibrovascular tissue, acne rosacea, acquired immune deficiency syndrome, artery occlusion, atopic keratitis, bacterial ulcers, Bechets disease, blood borne tumors, carotid obstructive disease, choroidal neovascularization, chronic inflammation, chronic retinal detachment, chronic uveitis, chronic vitritis, contact lens overwear, corneal graft rejection, corneal neovascularization, corneal graft neovascularization, Crohn's disease, Eales disease, epidemic

keratoconjunctivitis, fungal ulcers, Herpes simplex infections, Herpes zoster infections, hyperviscosity syndromes, Kaposi's sarcoma, leukemia, lipid degeneration, Lyme's disease, marginal keratolysis, Mooren ulcer, Mycobacteria infections other than leprosy, myopia, ocular neovascular disease, optic pits, Osler-Weber syndrome (Osler-Weber-Rendu), osteoarthritis, Paget's disease, pars planitis, pemphigoid, phylectenulosis, polyarteritis, post-laser complications, protozoan infections, pseudoxanthoma elasticum, pterygium keratitis sicca, radial keratotomy, retinal neovascularization, retinopathy of prematurity, retrolental fibroplasias, sarcoid, scleritis, sickle cell anemia, Sogren's syndrome, solid tumors, Stargart's disease, Steven's Johnson disease, superior limbic keratitis, syphilis, systemic lupus, Terrien's marginal degeneration, toxoplasmosis, tumors of Ewing sarcoma, tumors of neuroblastoma, tumors of osteosarcoma, tumors of retinoblastoma, tumors of rhabdomyosarcoma, ulcerative colitis, vein occlusion, Vitamin A deficiency, Wegener's sarcoidosis, undesired angiogenesis associated with diabetes, parasitic diseases, abnormal wound healing, hypertrophy following surgery, injury or trauma (e.g., acute lung injury/ARDS), inhibition of hair growth, inhibition of ovulation and corpus luteum formation, inhibition of implantation, and inhibition of embryo development in the uterus.

Examples of allergic or inflammatory disorders or autoimmune diseases or disorders that may be treated using a coiled coil containing antibody, a tethered antibody, or an antibody made according to the methods described herein include, but are not limited to arthritis (rheumatoid arthritis such as acute arthritis, chronic rheumatoid arthritis, gouty arthritis, acute gouty arthritis, chronic inflammatory arthritis, degenerative arthritis, infectious arthritis, Lyme arthritis, proliferative arthritis, psoriatic arthritis, vertebral arthritis, and juvenile-onset rheumatoid arthritis, osteoarthritis, arthritis chronica progrediente, arthritis deformans, polyarthritis chronica primaria, reactive arthritis, and ankylosing spondylitis), inflammatory hyperproliferative skin diseases, psoriasis such as plaque psoriasis, gutatte psoriasis, pustular psoriasis, and psoriasis of the nails, dermatitis including contact dermatitis, chronic contact dermatitis, allergic dermatitis, allergic contact dermatitis, dermatitis herpetiformis, and atopic dermatitis, x-linked hyper IgM syndrome, urticaria such as chronic allergic urticaria and chronic idiopathic urticaria, including chronic autoimmune urticaria, polymyositis/dermatomyositis, juvenile dermatomyositis, toxic epidermal necrolysis, scleroderma (including systemic scleroderma), sclerosis such as systemic sclerosis, multiple sclerosis (MS) such as spino-optical MS, primary progressive MS (PPMS), and relapsing remitting MS (RRMS), progressive systemic sclerosis, atherosclerosis, arteriosclerosis,

sclerosis disseminata, and ataxic sclerosis, inflammatory bowel disease (IBD) (for example, Crohn's disease, autoimmune-mediated gastrointestinal diseases, colitis such as ulcerative colitis, colitis ulcerosa, microscopic colitis, collagenous colitis, colitis polyposa, necrotizing enterocolitis, and transmural colitis, and autoimmune inflammatory bowel disease), pyoderma gangrenosum, erythema nodosum, primary sclerosing cholangitis, episcleritis), respiratory distress syndrome, including adult or acute respiratory distress syndrome (ARDS), meningitis, inflammation of all or part of the uvea, iritis, choroiditis, an autoimmune hematological disorder, rheumatoid spondylitis, sudden hearing loss, IgE-mediated diseases such as anaphylaxis and allergic and atopic rhinitis, encephalitis such as Rasmussen's encephalitis and limbic and/or brainstem encephalitis, uveitis, such as anterior uveitis, acute anterior uveitis, granulomatous uveitis, nongranulomatous uveitis, phacoantigenic uveitis, posterior uveitis, or autoimmune uveitis, glomerulonephritis (GN) with and without nephrotic syndrome such as chronic or acute glomerulonephritis such as primary GN, immune-mediated GN, membranous GN (membranous nephropathy), idiopathic membranous GN or idiopathic membranous nephropathy, membrano- or membranous proliferative GN (MPGN), including Type I and Type II, and rapidly progressive GN, allergic conditions, allergic reaction, eczema including allergic or atopic eczema, asthma such as asthma bronchiale, bronchial asthma, and auto-immune asthma, conditions involving infiltration of T-cells and chronic inflammatory responses, chronic pulmonary inflammatory disease, autoimmune myocarditis, leukocyte adhesion deficiency, systemic lupus erythematosus (SLE) or systemic lupus erythematodes such as cutaneous SLE, subacute cutaneous lupus erythematosus, neonatal lupus syndrome (NLE), lupus erythematosus disseminatus, lupus (including nephritis, cerebritis, pediatric, non-renal, extra-renal, discoid, alopecia), juvenile onset (Type I) diabetes mellitus, including pediatric insulin-dependent diabetes mellitus (IDDM), adult onset diabetes mellitus (Type II diabetes), autoimmune diabetes, idiopathic diabetes insipidus, immune responses associated with acute and delayed hypersensitivity mediated by cytokines and T-lymphocytes, tuberculosis, sarcoidosis, granulomatosis including lymphomatoid granulomatosis, Wegener's granulomatosis, agranulocytosis, vasculitides, including vasculitis (including large vessel vasculitis (including polymyalgia rheumatica and giant cell (Takayasu's) arteritis), medium vessel vasculitis (including Kawasaki's disease and polyarteritis nodosa), microscopic polyarteritis, CNS vasculitis, necrotizing, cutaneous, or hypersensitivity vasculitis, systemic necrotizing vasculitis, and ANCA-associated vasculitis, such as Churg-Strauss vasculitis or syndrome (CSS)), temporal arteritis, aplastic anemia, autoimmune aplastic anemia, Coombs

positive anemia, Diamond Blackfan anemia, hemolytic anemia or immune hemolytic anemia including autoimmune hemolytic anemia (AIHA), pernicious anemia (anemia perniciosa), Addison's disease, pure red cell anemia or aplasia (PRCA), Factor VIII deficiency, hemophilia A, autoimmune neutropenia, pancytopenia, leukopenia, diseases involving leukocyte diapedesis, CNS inflammatory disorders, multiple organ injury syndrome such as those secondary to septicemia, trauma or hemorrhage, antigen-antibody complex- mediated diseases, anti-glomerular basement membrane disease, anti-phospholipid antibody syndrome, allergic neuritis, Bechet's or Behcet's disease, Castleman's syndrome, Goodpasture's syndrome, Reynaud's syndrome, Sjogren's syndrome, Stevens-Johnson syndrome, pemphigoid such as pemphigoid bullous and skin pemphigoid, pemphigus (including pemphigus vulgaris, pemphigus foliaceus, pemphigus mucus-membrane pemphigoid, and pemphigus erythematosus), autoimmune polyendocrinopathies, Reiter's disease or syndrome, immune complex nephritis, antibody-mediated nephritis, neuromyelitis optica, polyneuropathies, chronic neuropathy such as IgM polyneuropathies or IgM-mediated neuropathy, thrombocytopenia (as developed by myocardial infarction patients, for example), including thrombotic thrombocytopenic purpura (TTP) and autoimmune or immune-mediated thrombocytopenia such as idiopathic thrombocytopenic purpura (ITP) including chronic or acute ITP, autoimmune disease of the testis and ovary including autoimune orchitis and oophoritis, primary hypothyroidism, hypoparathyroidism, autoimmune endocrine diseases including thyroiditis such as autoimmune thyroiditis, Hashimoto's disease, chronic thyroiditis (Hashimoto's thyroiditis), or subacute thyroiditis, autoimmune thyroid disease, idiopathic hypothyroidism, Grave's disease, polyglandular syndromes such as autoimmune polyglandular syndromes (or polyglandular endocrinopathy syndromes), paraneoplastic syndromes, including neurologic paraneoplastic syndromes such as Lambert-Eaton myasthenic syndrome or Eaton-Lambert syndrome, stiff-man or stiff-person syndrome, encephalomyelitis such as allergic encephalomyelitis or encephalomyelitis allergica and experimental allergic encephalomyelitis (EAE), myasthenia gravis such as thymoma-associated myasthenia gravis, cerebellar degeneration, neuromyotonia, opsoclonus or opsoclonus myoclonus syndrome (OMS), and sensory neuropathy, multifocal motor neuropathy, Sheehan's syndrome, autoimmune hepatitis, chronic hepatitis, lupoid hepatitis, giant cell hepatitis, chronic active hepatitis or autoimmune chronic active hepatitis, lymphoid interstitial pneumonitis, bronchiolitis obliterans (non-transplant) vs NSIP, Guillain-Barré syndrome, Berger's disease (IgA nephropathy), idiopathic IgA nephropathy, linear IgA

dermatosis, primary biliary cirrhosis, pneumonocirrhosis, autoimmune enteropathy syndrome, Celiac disease, Coeliac disease, celiac sprue (gluten enteropathy), refractory sprue, idiopathic sprue, cryoglobulinemia, amylotrophic lateral sclerosis (ALS; Lou Gehrig's disease), coronary artery disease, autoimmune ear disease such as autoimmune inner ear disease (AIED), autoimmune hearing loss, opsoclonus myoclonus syndrome (OMS), polychondritis such as refractory or relapsed polychondritis, pulmonary alveolar proteinosis, amyloidosis, scleritis, a non-cancerous lymphocytosis, a primary lymphocytosis, which includes monoclonal B cell lymphocytosis (e.g., benign monoclonal gammopathy and monoclonal garnmopathy of undetermined significance, MGUS), peripheral neuropathy, paraneoplastic syndrome, channelopathies such as epilepsy, migraine, arrhythmia, muscular disorders, deafness, blindness, periodic paralysis, and channelopathies of the CNS, autism, inflammatory myopathy, focal segmental glomerulosclerosis (FSGS), endocrine ophthalmopathy, uveoretinitis, chorioretinitis, autoimmune hepatological disorder, fibromyalgia, multiple endocrine failure, Schmidt's syndrome, adrenalitis, gastric atrophy, presenile dementia, demyelinating diseases such as autoimmune demyelinating diseases, diabetic nephropathy, Dressler's syndrome, alopecia areata, CREST syndrome (calcinosis, Raynaud's phenomenon, esophageal dysmotility, sclerodactyly, and telangiectasia), male and female autoimmune infertility, mixed connective tissue disease, Chagas' disease, rheumatic fever, recurrent abortion, farmer's lung, erythema multiforme, post-cardiotomy syndrome, Cushing's syndrome, bird-fancier's lung, allergic granulomatous angiitis, benign lymphocytic angiitis, Alport's syndrome, alveolitis such as allergic alveolitis and fibrosing alveolitis, interstitial lung disease, transfusion reaction, leprosy, malaria, leishmaniasis, kypanosomiasis, schistosomiasis, ascariasis, aspergillosis, Sampter's syndrome, Caplan's syndrome, dengue, endocarditis, endomyocardial fibrosis, diffuse interstitial pulmonary fibrosis, interstitial lung fibrosis, idiopathic pulmonary fibrosis, cystic fibrosis, endophthalmitis, erythema elevatum et diutinum, erythroblastosis fetalis, eosinophilic faciitis, Shulman's syndrome, Felty's syndrome, flariasis, cyclitis such as chronic cyclitis, heterochronic cyclitis, iridocyclitis, or Fuch's cyclitis, Henoch-Schonlein purpura, human immunodeficiency virus (HIV) infection, echovirus infection, cardiomyopathy, Alzheimer's disease, parvovirus infection, rubella virus infection, post-vaccination syndromes, congenital rubella infection, Epstein-Barr virus infection, mumps, Evan's syndrome, autoimmune gonadal failure, Sydenham's chorea, post-streptococcal nephritis, thromboangitis ubiterans, thyrotoxicosis, tabes dorsalis, chorioiditis, giant cell polymyalgia, endocrine ophthamopathy, chronic hypersensitivity pneumonitis,

keratoconjunctivitis sicca, epidemic keratoconjunctivitis, idiopathic nephritic syndrome, minimal change nephropathy, benign familial and ischemia-reperfusion injury, retinal autoimmunity, joint inflammation, bronchitis, chronic obstructive airway disease, silicosis, aphthae, aphthous stomatitis, arteriosclerotic disorders, aspermiogenese, autoimmune hemolysis, Boeck's disease, cryoglobulinemia, Dupuytren's contracture, endophthalmia phacoanaphylactica, enteritis allergica, erythema nodosum leprosum, idiopathic facial paralysis, chronic fatigue syndrome, febris rheumatica, Hamman-Rich's disease, sensoneural hearing loss, haemoglobinuria paroxysmatica, hypogonadism, ileitis regionalis, leucopenia, mononucleosis infectiosa, traverse myelitis, primary idiopathic myxedema, nephrosis, ophthalmia symphatica, orchitis granulomatosa, pancreatitis, polyradiculitis acuta, pyoderma gangrenosum, Quervain's thyreoiditis, acquired spenic atrophy, infertility due to antispermatozoan antobodies, non-malignant thymoma, vitiligo, SCID and Epstein-Barr virus- associated diseases, acquired immune deficiency syndrome (AIDS), parasitic diseases such as Leishmania, toxic-shock syndrome, food poisoning, conditions involving infiltration of T-cells, leukocyte-adhesion deficiency, immune responses associated with acute and delayed hypersensitivity mediated by cytokines and T-lymphocytes, diseases involving leukocyte diapedesis, multiple organ injury syndrome, antigen-antibody complex-mediated diseases, antiglomerular basement membrane disease, allergic neuritis, autoimmune polyendocrinopathies, oophoritis, primary myxedema, autoimmune atrophic gastritis, sympathetic ophthalmia, rheumatic diseases, mixed connective tissue disease, nephrotic syndrome, insulitis, polyendocrine failure, peripheral neuropathy, autoimmune polyglandular syndrome type I, adult-onset idiopathic hypoparathyroidism (AOIH), alopecia totalis, dilated cardiomyopathy, epidermolisis bullosa acquisita (EBA), hemochromatosis, myocarditis, nephrotic syndrome, primary sclerosing cholangitis, purulent or nonpurulent sinusitis, acute or chronic sinusitis, ethmoid, frontal, maxillary, or sphenoid sinusitis, an eosinophil-related disorder such as eosinophilia, pulmonary infiltration eosinophilia, eosinophilia-myalgia syndrome, Loffler's syndrome, chronic eosinophilic pneumonia, tropical pulmonary eosinophilia, bronchopneumonic aspergillosis, aspergilloma, or granulomas containing eosinophils, anaphylaxis, seronegative spondyloarthritides, polyendocrine autoimmune disease, sclerosing cholangitis, sclera, episclera, chronic mucocutaneous candidiasis, Bruton's syndrome, transient hypogammaglobulinemia of infancy, Wiskott-Aldrich syndrome, ataxia telangiectasia, autoimmune disorders associated with collagen disease, rheumatism, neurological disease, ischemic re-perfusion disorder, reduction in blood pressure response,

vascular dysfunction, antgiectasis, tissue injury, cardiovascular ischemia, hyperalgesia, cerebral ischemia, and disease accompanying vascularization, allergic hypersensitivity disorders, glomerulonephritides, reperfusion injury, reperfusion injury of myocardial or other tissues, dermatoses with acute inflammatory components, acute purulent meningitis or other central nervous system inflammatory disorders, ocular and orbital inflammatory disorders, granulocyte transfusion-associated syndromes, cytokine-induced toxicity, acute serious inflammation, chronic intractable inflammation, pyelitis, pneumonocirrhosis, diabetic retinopathy, diabetic large-artery disorder, endarterial hyperplasia, peptic ulcer, valvulitis, and endometriosis.

In addition to therapeutic uses, the antibodies of the invention can be used for other purposes, including diagnostic methods, such as diagnostic methods for the diseases and conditions described herein.

VI. Dosages, Formulations, and Duration

The proteins of this invention will be formulated, dosed, and administered in a fashion consistent with good medical practice. Factors for consideration in this context include the particular disorder being treated, the particular mammal being treated, the clinical condition of the individual subject, the cause of the disorder, the site of delivery of the agent, the method of administration, the scheduling of administration, and other factors known to medical practitioners. The "therapeutically effective amount" of the proteins to be administered will be governed by such considerations, and is the minimum amount necessary to prevent, ameliorate, or treat a particular disorder (for example, a cancer, allergic or inflammatory disorder, or autoimmune disorder). The proteins need not be, but are optionally, formulated with one or more agents currently used to prevent or treat the disorder. The effective amount of such other agents depends on the amount of proteins present in the formulation, the type of disorder or treatment, and other factors discussed above. These are generally used in the same dosages and with administration routes as used hereinbefore or about from 1 to 99% of the heretofore employed dosages. Generally, alleviation or treatment of a cancer involves the lessening of one or more symptoms or medical problems associated with the cancer. The therapeutically effective amount of the drug can accomplish one or a combination of the following: reduce (by at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% or more) the number of cancer cells; reduce or inhibit the tumor size or tumor burden; inhibit (i.e., to decrease to some extent and/or stop) cancer cell infiltration into peripheral organs; reduce hormonal secretion in the case of adenomas; reduce vessel density;

inhibit tumor metastasis; reduce or inhibit tumor growth; and/or relieve to some extent one or more of the symptoms associated with the cancer. In some embodiments, the proteins are used to prevent the occurrence or reoccurrence of cancer or an autoimmune disorder in the subject.

In one embodiment, the present invention can be used for increasing the duration of survival of a human subject susceptible to or diagnosed with a cancer or autoimmune disorder. Duration of survival is defined as the time from first administration of the drug to death. Duration of survival can also be measured by stratified hazard ratio (HR) of the treatment group versus control group, which represents the risk of death for a subject during the treatment.

In yet another embodiment, the treatment of the present invention significantly increases response rate in a group of human subjects susceptible to or diagnosed with a cancer who are treated with various anti-cancer therapies. Response rate is defined as the percentage of treated subjects who responded to the treatment. In one aspect, the combination treatment of the invention using proteins of this invention and surgery, radiation therapy, or one or more chemotherapeutic agents significantly increases response rate in the treated subject group compared to the group treated with surgery, radiation therapy, or chemotherapy alone, the increase having a Chi-square p-value of less than 0.005. Additional measurements of therapeutic efficacy in the treatment of cancers are described in U.S. Patent Application Publication No. 20050186208.

Therapeutic formulations are prepared using standard methods known in the art by mixing the active ingredient having the desired degree of purity with optional physiologically acceptable carriers, excipients or stabilizers (Remington's Pharmaceutical Sciences (20^{th} edition), ed. A. Gennaro, 2000, Lippincott, Williams & Wilkins, Philadelphia, PA). Acceptable carriers, include saline, or buffers such as phosphate, citrate and other organic acids; antioxidants including ascorbic acid; low molecular weight (less than about 10 residues) polypeptides; proteins, such as serum albumin, gelatin or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone, amino acids such as glycine, glutamine, asparagines, arginine or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugar alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/or nonionic surfactants such as TWEEN™, PLURONICS™, or PEG.

Optionally, but preferably, the formulation contains a pharmaceutically acceptable salt, preferably sodium chloride, and preferably at about physiological concentrations. Optionally, the formulations of the invention can contain a pharmaceutically acceptable preservative. In some embodiments the preservative concentration ranges from 0.1 to 2.0%, typically v/v. Suitable preservatives include those known in the pharmaceutical arts. Benzyl alcohol, phenol, m-cresol, methylparaben, and propylparaben are preferred preservatives. Optionally, the formulations of the invention can include a pharmaceutically acceptable surfactant at a concentration of 0.005 to 0.02%.

The formulation herein may also contain more than one active compound as necessary for the particular indication being treated, preferably those with complementary activities that do not adversely affect each other. Such molecules are suitably present in combination in amounts that are effective for the purpose intended.

The active ingredients may also be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization, for example, hydroxymethylcellulose or gelatin-microcapsule and poly-(methylmethacylate) microcapsule, respectively, in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules) or in macroemulsions. Such techniques are disclosed in Remington's Pharmaceutical Sciences, *supra*.

Sustained-release preparations may be prepared. Suitable examples of sustained-release preparations include semipermeable matrices of solid hydrophobic polymers containing the antibody, which matrices are in the form of shaped articles, e.g., films, or microcapsule. Examples of sustained-release matrices include polyesters, hydrogels (for example, poly(2-hydroxyethyl-methacrylate), or poly(vinylalcohol)), polylactides (U.S. Patent No. 3,773,919), copolymers of L-glutamic acid and γ ethyl-L-glutamate, non-degradable ethylene-vinyl acetate, degradable lactic acid-glycolic acid copolymers such as the LUPRON DEPOT™ (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly-D-(-)-3-hydroxybutyric acid. While polymers such as ethylene-vinyl acetate and lactic acid-glycolic acid enable release of molecules for over 100 days, certain hydrogels release proteins for shorter time periods. When encapsulated antibodies remain in the body for a long time, they may denature or aggregate as a result of exposure to moisture at 37°C, resulting in a loss of biological activity and possible changes in immunogenicity. Rational strategies can be devised for stabilization depending on the mechanism involved. For example, if the aggregation mechanism is discovered to be

intermolecular S-S bond formation through thio-disulfide interchange, stabilization may be achieved by modifying sulfhydryl residues, lyophilizing from acidic solutions, controlling moisture content, using appropriate additives, and developing specific polymer matrix compositions.

The proteins described herein (e.g., a coiled coil containing antibody, a tethered antibody, or an antibody made according to the methods described herein) are administered to a human subject, in accord with known methods, such as intravenous administration as a bolus or by continuous infusion over a period of time, by intramuscular, intraperitoneal, intracerobrospinal, subcutaneous, intra-articular, intrasynovial, intrathecal, oral, topical, or inhalation routes. Local administration may be particularly desired if extensive side effects or toxicity is associated with antagonism to the target molecule recognized by the proteins. An *ex vivo* strategy can also be used for therapeutic applications. *Ex vivo* strategies involve transfecting or transducing cells obtained from the subject with a polynucleotide encoding a protein of this invention. The transfected or transduced cells are then returned to the subject. The cells can be any of a wide range of types including, without limitation, hemopoietic cells (e.g., bone marrow cells, macrophages, monocytes, dendritic cells, T cells, or B cells), fibroblasts, epithelial cells, endothelial cells, keratinocytes, or muscle cells.

In one example, the protein complex is (e.g., a coiled coil containing antibody, a tethered antibody, or an antibody made according to the methods described herein) is administered locally, e.g., by direct injections, when the disorder or location of the tumor permits, and the injections can be repeated periodically. The protein complex can also be delivered systemically to the subject or directly to the tumor cells, e.g., to a tumor or a tumor bed following surgical excision of the tumor, in order to prevent or reduce local recurrence or metastasis.

VII. Articles of Manufacture

Another embodiment of the invention is an article of manufacture containing one or more protein complexes described herein, and materials useful for the treatment or diagnosis of a disorder (for example, an autoimmune disease or cancer). The article of manufacture comprises a container and a label or package insert on or associated with the container. Suitable containers include, for example, bottles, vials, syringes, etc. The containers may be formed from a variety of materials such as glass or plastic. The container holds a composition that is effective for treating the condition and may have a sterile access port (for

example the container may be an intravenous solution bag or a vial having a stopper pierceable by a hypodermic injection needle). At least one active agent in the composition is an antibody or antibody fragment antibody of the invention. The label or package insert indicates that the composition is used for treating the particular condition. The label or package insert will further comprise instructions for administering the antibody composition to the subject. Articles of manufacture and kits comprising combinatorial therapies described herein are also contemplated.

Package insert refers to instructions customarily included in commercial packages of therapeutic products that contain information about the indications, usage, dosage, administration, contraindications and/or warnings concerning the use of such therapeutic products. In certain embodiments, the package insert indicates that the composition is used for treating breast cancer, colorectal cancer, lung cancer, renal cell carcinoma, glioma, or ovarian cancer.

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

Kits are also provided that are useful for various purposes, e.g., for purification or immunoprecipitation of an antigen (e.g., HER2 or EGFR) from cells. For isolation and purification of an antigen (e.g., HER2 or EGFR) the kit can contain an antibody (e.g., an EGFR/HER2 antibody) coupled to beads (e.g., sepharose beads). Kits can be provided which contain the antibodies for detection and quantitation of the antigen *in vitro*, e.g., in an ELISA or a Western blot. As with the article of manufacture, the kit comprises a container and a label or package insert on or associated with the container. The container holds a composition comprising at least one multispecific antibody or antibody fragment of the invention. Additional containers may be included that contain, e.g., diluents and buffers or control antibodies. The label or package insert may provide a description of the composition as well as instructions for the intended in vitro or diagnostic use.

The foregoing written description is considered to be sufficient to enable one skilled in the art to practice the invention. The following Examples are offered for illustrative purposes only, and are not intended to limit the scope of the present invention in any way. Indeed, various modifications of the invention in addition to those shown and described

herein will become apparent to those skilled in the art from the foregoing description and fall within the scope of the appended claims.

VII. TARGET MOLECULES

Examples of molecules that may be targeted by a complex of this invention include, but are not limited to, soluble serum proteins and their receptors and other membrane bound proteins (e.g., adhesins).

In another embodiment the binding protein of the invention is capable of binding one, two or more cytokines, cytokine-related proteins, and cytokine receptors selected from the group consisting of BMPl, BMP2, BMP3B (GDFlO), BMP4, BMP6, BMP8, CSFl (M-CSF), CSF2 (GM-CSF), CSF3 (G-CSF), EPO, FGFl (aFGF), FGF2 (bFGF), FGF3 (int-2), FGF4 (HST), FGF5, FGF6 (HST-2), FGF7 (KGF), FGF9, FGF10, FGF11, FGF12, FGF12B, FGF14, FGF16, FGF17, FGF19, FGF20, FGF21, FGF23, IGF1, IGF2, IFNAl, IFNA2, IFNA4, IFNA5, IFNA6, IFNA7, IFNBl, IFNG, IFNWl, FELl, FELl (EPSELON), FELl (ZETA), ILlA, ILlB, IL2, IL3, IL4, IL5, IL6, IL7, IL8, IL9, IL10, ILll, IL12A, IL12B, IL13, IL14, IL15, IL16, IL17, IL17B, IL18, IL19, IL20, IL22, IL23, IL24, IL25, IL26, IL27, IL28A, IL28B, IL29, IL30, PDGFA, PDGFB, TGFA, TGFB1, TGFB2, TGFB3, LTA (TNF-b), LTB, TNF (TNF-a), TNFSF4 (OX40 ligand), TNFSF5 (CD40 ligand), TNFSF6 (FasL), TNFSF7 (CD27 ligand), TNFSF8 (CD30 ligand), TNFSF9 (4-1BB ligand), TNFSFl0 (TRAIL), TNFSFll (TRANCE), TNFSF12 (APO3L), TNFSF13 (April), TNFSF13B, TNFSF14 (HVEM-L), TNFSF15 (VEGI), TNFSF18, HGF (VEGFD), VEGF, VEGFB, VEGFC, ILlR1, IL1R2, IL1RL1, LL1RL2, IL2RA, IL2RB, IL2RG, IL3RA, IL4R, IL5RA, IL6R, IL7R, IL8RA, IL8RB, IL9R, ILl0RA, ILl0RB, IL11RA, IL12RB1, IL12RB2, IL13RA1, IL13RA2, IL15RA, IL17R, IL18R1, IL20RA, IL21R, IL22R, IL1HY1, ILlRAP, IL1RAPL1, IL1RAPL2, ILlRN, IL6ST, IL18BP, IL18RAP, IL22RA2, AIFl, HGF, LEP (leptin), PTN, and THPO.

In another embodiment, a target molecule is a chemokine, chemokine receptor, or a chemokine-related protein selected from the group consisting of CCLl (I- 309), CCL2 (MCP -1 / MCAF), CCL3 (MIP-Ia), CCL4 (MIP-Ib), CCL5 (RANTES), CCL7 (MCP- 3), CCL8 (mcp-2), CCLH (eotaxin), CCL13 (MCP-4), CCL15 (MIP-Id), CCL16 (HCC-4), CCL17 (TARC), CCL18 (PARC), CCL19 (MDP-3b), CCL20 (MIP-3a), CCL21 (SLC / exodus-2), CCL22 (MDC / STC-I), CCL23 (MPIF-I), CCL24 (MPIF-2 / eotaxin-2), CCL25 (TECK), CCL26 (eotaxin- 3), CCL27 (CTACK / ILC), CCL28, CXCLl (GROl), CXCL2 (GRO2), CXCL3 (GR03), CXCL5 (ENA-78), CXCL6 (GCP-2), CXCL9 (MIG), CXCLlO (IP

10), CXCLIl (I-TAC), CXCL12 (SDFl), CXCL13, CXCL14, CXCL16, PF4 (CXCL4), PPBP (CXCL7), CX3CL1 (SCYDl), SCYEl, XCLl (lymphotactin), XCL2 (SCM-Ib), BLRl (MDR15), CCBP2 (D6 / JAB61), CCRl (CKRl / HM145), CCR2 (mcp-lRB / RA), CCR3 (CKR3 / CMKBR3), CCR4, CCR5 (CMKBR5 / ChemR13), CCR6 (CMKBR6 / CKR-L3 / STRL22 / DRY6), CCR7 (CKR7 / EBIl), CCR8 (CMKBR8 / TERl / CKR- Ll), CCR9 (GPR-9-6), CCRLl (VSHKl), CCRL2 (L-CCR), XCRl (GPR5 / CCXCRl), CMKLRl, CMKORl (RDCl), CX3CR1 (V28), CXCR4, GPR2 (CCRlO), GPR31, GPR81 (FKSG80), CXCR3 (GPR9/CKR-L2), CXCR6 (TYMSTR /STRL33 / Bonzo), HM74, IL8RA (IL8Ra), IL8RB (IL8Rb), LTB4R (GPR16), TCPlO, CKLFSF2, CKLFSF3, CKLFSF4, CKLFSF5, CKLFSF6, CKLFSF7, CKLFSF8, BDNF, C5R1, CSF3, GRCClO (ClO), EPO, FY (DARC), GDF5, HDFlA, DL8, PRL, RGS3, RGS13, SDF2, SLIT2, TLR2, TLR4, TREMl, TREM2, and VHL.

In another embodiment the binding proteins of the invention are capable of binding one or more targets selected from the group consisting of ABCFl; ACVRl; ACVRlB; ACVR2; ACVR2B; ACVRLl; ADORA2A; Aggrecan; AGR2; AICDA; AIFl; AIGl; AKAPl; AKAP2; AMH; AMHR2; ANGPTl; ANGPT2; ANGPTL3; ANGPTL4; ANPEP; APC; APOCl; AR; AZGPl (zinc-a- glycoprotein); B7.1; B7.2; BAD; BAFF (BLys); BAGl; BAIl; BCL2; BCL6; BDNF; BLNK; BLRl (MDR15); BMPl; BMP2; BMP3B (GDFlO); BMP4; BMP6; BMP8; BMPRlA; BMPRlB; BMPR2; BPAGl (plectin); BRCAl; C19orflO (IL27w); C3; C4A; C5; C5R1; CANTl; CASP1; CASP4; CAVl; CCBP2 (D6 / JAB61); CCLl (1-309); CCLIl (eotaxin); CCL13 (MCP-4); CCL15 (MIP-Id); CCL16 (HCC-4); CCL17 (TARC); CCL18 (PARC); CCL19 (MIP-3b); CCL2 (MCP -1); MCAF; CCL20 (MIP-3a); CCL21 (MTP-2); SLC; exodus-2; CCL22 (MDC / STC-I); CCL23 (MPIF- 1); CCL24 (MPIF-2 / eotaxin-2); CCL25 (TECK); CCL26 (eotaxin-3); CCL27 (CTACK / ILC); CCL28; CCL3 (MTP-Ia); CCL4 (MDP-Ib); CCL5 (RANTES); CCL7 (MCP-3); CCL8 (mcp-2); CCNAl; CCNA2; CCNDl; CCNEl; CCNE2; CCRl (CKRl / HM145); CCR2 (mcp-lRB / RA);CCR3 (CKR3 / CMKBR3); CCR4; CCR5 (CMKBR5 / ChemR13); CCR6 (CMKBR6 / CKR-L3 / STRL22 / DRY6); CCR7 (CKR7 / EBIl); CCR8 (CMKBR8 / TERl / CKR-Ll); CCR9 (GPR-9-6); CCRLl (VSHKl); CCRL2 (L-CCR); CD164; CD19; CDlC; CD20; CD200; CD22; CD24; CD28; CD3; CD37; CD38; CD3E; CD3G; CD3Z; CD4; CD40; CD40L; CD44; CD45RB; CD52; CD69; CD72; CD74; CD79A; CD79B; CD8; CD80; CD81; CD83; CD86; CDHl (E-cadherin); CDH10; CDH12; CDH13; CDH18; CDH19; CDH20; CDH5; CDH7; CDH8; CDH9; CDK2; CDK3; CDK4; CDK5; CDK6; CDK7; CDK9; CDKNlA

(p21Wapl/Cipl); CDKNlB (p27Kipl); CDKNlC; CDKN2A (P16INK4a); CDKN2B; CDKN2C; CDKN3; CEBPB; CERl; CHGA; CHGB; Chitinase; CHST10; CKLFSF2; CKLFSF3; CKLFSF4; CKLFSF5; CKLFSF6; CKLFSF7; CKLFSF8; CLDN3;CLDN7 (claudin-7); CLN3; CLU (clusterin); CMKLRl; CMKORl (RDCl); CNRl; COL18A1; COLlAl; COL4A3; COL6A1; CR2; CRP; CSFl (M-CSF); CSF2 (GM-CSF); CSF3 (GCSF);CTLA4; CTNNBl (b-catenin); CTSB (cathepsin B); CX3CL1 (SCYDl); CX3CR1 (V28); CXCLl (GROl); CXCL10 (IP-10); CXCLll (I-TAC / IP-9); CXCL12 (SDFl); CXCL13; CXCL14;CXCL16; CXCL2 (GRO2); CXCL3 (GRO3); CXCL5 (ENA-78 / LIX); CXCL6 (GCP-2); CXCL9 (MIG); CXCR3 (GPR9/CKR-L2); CXCR4; CXCR6 (TYMSTR /STRL33 / Bonzo); CYB5; CYCl; CYSLTRl; DAB2IP; DES; DKFZp451J0118; DNCLl; DPP4; E2F1; ECGFl; EDGl; EFNAl; EFNA3; EFNB2; EGF; EGFR; ELAC2; ENG; ENO1; ENO2; ENO3; EPHB4; EPO; ERBB2 (Her-2); EREG; ERK8; ESRl; ESR2; F3 (TF); FADD; FasL; FASN; FCERlA; FCER2; FCGR3A; FGF; FGFl (aFGF); FGF10; FGF11; FGF12; FGF12B; FGF13; FGF14; FGF16; FGF17; FGF18; FGF19; FGF2 (bFGF); FGF20; FGF21; FGF22; FGF23; FGF3 (int-2); FGF4 (HST); FGF5; FGF6 (HST-2); FGF7 (KGF); FGF8; FGF9; FGFR3; FIGF (VEGFD); FELl (EPSILON); FILl (ZETA); FLJ12584; FLJ25530; FLRTl (fibronectin); FLTl; FOS; FOSLl (FRA-I); FY (DARC); GABRP (GABAa); GAGEBl; GAGECl; GALNAC4S-6ST; GATA3; GDF5; GFIl; GGT1; GM-CSF; GNASl; GNRHl; GPR2 (CCRlO); GPR31; GPR44; GPR81 (FKSG80); GRCClO (ClO); GRP; GSN (Gelsolin); GSTPl; HAVCR2; HDAC4; HDAC5; HDAC7A; HDAC9; HGF; HIFlA; HDPl; histamine and histamine receptors; HLA-A; HLA-DRA; HM74; HMOXl ; HUMCYT2A; ICEBERG; ICOSL; ID2; IFN-a; IFNAl; IFNA2; IFNA4; IFNA5; IFNA6; IFNA7; IFNB1; IFNgamma; DFNWl; IGBPl; IGFl; IGFlR; IGF2; IGFBP2; IGFBP3; IGFBP6; IL-I; IL10; IL10RA; IL10RB; IL11; IL11RA; IL-12; IL12A; IL12B; IL12RB1; IL12RB2; IL13; IL13RA1; IL13RA2; IL14; IL15; IL15RA; IL16; IL17; IL17B; IL17C; IL17R; IL18; IL18BP; IL18R1; IL18RAP; IL19; IL1A; IL1B; ILlF10; IL1F5; IL1F6; IL1F7; IL1F8; IL1F9; IL1HYl; IL1Rl; IL1R2; IL1RAP; IL1RAPL1; IL1RAPL2; IL1RL1; IL1RL2, ILlRN; IL2; IL20; IL20RA; IL21R; IL22; IL22R; IL22RA2; IL23; IL24; IL25; IL26; IL27; IL28A; IL28B; IL29; IL2RA; IL2RB; IL2RG; IL3; IL30; IL3RA; IL4; IL4R; IL5; IL5RA; IL6; IL6R; IL6ST (glycoprotein 130); EL7; EL7R; EL8; IL8RA; DL8RB; IL8RB; DL9; DL9R; DLK; INHA; INHBA;INSL3; INSL4; IRAKI; ERAK2; ITGAl; ITGA2; ITGA3; ITGA6 (a6 integrin); ITGAV; ITGB3; ITGB4 (b 4 integrin); JAGl; JAKl; JAK3; JUN; K6HF; KAIl; KDR; KITLG; KLF5 (GC Box BP); KLF6; KLKlO; KLK12; KLK13; KLK14; KLK15; KLK3;

KLK4; KLK5; KLK6; KLK9; KRT1; KRT19 (Keratin 19); KRT2A; KHTHB6 (hair-specific type H keratin); LAMAS; LEP (leptin); Lingo-p75; Lingo-Troy; LPS; LTA (TNF-b); LTB; LTB4R (GPR16); LTB4R2; LTBR; MACMARCKS; MAG or Omgp ; MAP2K7 (c-Jun); MDK; MIBl; midkine; MEF; MIP-2; MKI67; (Ki-67); MMP2; MMP9; MS4A1; MSMB; MT3 (metallothionectin-III); MTSSl; MUCl (mucin); MYC; MYD88; NCK2; neurocan; NFKBl; NFKB2; NGFB (NGF); NGFR; NgR-Lingo; NgR- Nogo66 (Nogo); NgR-p75; NgR-Troy; NMEl (NM23A); N0X5; NPPB; NROBl; NR0B2; NRIDl; NR1D2; NR1H2; NR1H3; NR1H4; NR1I2; NR1I3; NR2C1; NR2C2; NR2E1; NR2E3; NR2F1; NR2F2; NR2F6; NR3C1; NR3C2; NR4A1; NR4A2; NR4A3; NR5A1; NR5A2; NR6A1; NRPl; NRP2; NT5E; NTN4; ODZl; OPRDl; P2RX7; PAP; PARTl; PATE; PAWR; PCA3; PCNA; PDGFA; PDGFB; PECAMl; PF4 (CXCL4); PGF; PGR; phosphacan; PIAS2; PIK3CG; PLAU (uPA); PLG; PLXDCl; PPBP (CXCL7); PPID; PRl; PRKCQ; PRKDl; PRL; PROC; PROK2; PSAP; PSCA; PTAFR; PTEN; PTGS2 (COX-2); PTN; RAC2 (p21Rac2); RARB; RGSl; RGS13; RGS3; RNFIlO (ZNF144); ROBO2; S100A2; SCGB1D2 (lipophilin B); SCGB2A1 (mammaglobin2); SCGB2A2 (mammaglobin 1); SCYEl (endothelial Monocyte-activating cytokine); SDF2; SERPINAl; SERPINA3; SERP1NB5 (maspin); SERPINEl (PAI-I); SERPDMF1; SHBG; SLA2; SLC2A2; SLC33A1; SLC43A1; SLIT2; SPPl; SPRRlB (Sprl); ST6GAL1; STABl; STAT6; STEAP; STEAP2; TB4R2; TBX21; TCPlO; TDGFl; TEK; TGFA; TGFBl; TGFBlIl; TGFB2; TGFB3; TGFBI; TGFBRl; TGFBR2; TGFBR3; THlL; THBSl (thrombospondin-1); THBS2; THBS4; THPO; TIE (Tie-1); TMP3; tissue factor; TLRlO; TLR2; TLR3; TLR4; TLR5; TLR6; TLR7; TLR8; TLR9; TNF; TNF-a; TNFAEP2 (B94); TNFAIP3; TNFRSFIIA; TNFRSFlA; TNFRSFlB; TNFRSF21; TNFRSF5; TNFRSF6 (Fas); TNFRSF7; TNFRSF8; TNFRSF9; TNFSFlO (TRAIL); TNFSFl 1 (TRANCE); TNFSF12 (APO3L); TNFSF13 (April); TNFSF13B; TNFSF14 (HVEM-L); TNFSF15 (VEGI); TNFSF18; TNFSF4 (OX40 ligand); TNFSF5 (CD40 ligand); TNFSF6 (FasL); TNFSF7 (CD27 ligand); TNFSF8 (CD30 ligand); TNFSF9 (4-1BB ligand); TOLLIP; Toll-like receptors; TOP2A (topoisomerase Ea); TP53; TPMl; TPM2; TRADD; TRAFl; TRAF2; TRAF3; TRAF4; TRAF5; TRAF6; TREMl; TREM2; TRPC6; TSLP; TWEAK; VEGF; VEGFB; VEGFC; versican; VHL C5; VLA-4; XCLl (lymphotactin); XCL2 (SCM-Ib); XCRl(GPR5 / CCXCRl); YYl; and ZFPM2.

Preferred molecular target molecules for antibodies encompassed by the present invention include CD proteins such as CD3, CD4, CD8, CD16, CD19, CD20, CD34; CD64, CD200 members of the ErbB receptor family such as the EGF receptor, HER2, HER3 or

HER4 receptor; cell adhesion molecules such as LFA-1, Mac1, p150.95, VLA-4, ICAM-1, VCAM, alpha4/beta7 integrin, and alphav/beta3 integrin including either alpha or beta subunits thereof (e.g. anti-CD11a, anti-CD18 or anti-CD11b antibodies); growth factors such as VEGF-A, VEGF-C; tissue factor (TF); alpha interferon (alphaIFN); TNFalpha, an interleukin, such as IL-1beta, IL-3, IL-4, IL-5, IL-8, IL-9, IL-13, IL17A/F, IL-18, IL-13Ralpha1, IL13Ralpha2, IL-4R, IL-5R, IL-9R, IgE; blood group antigens; flk2/flt3 receptor; obesity (OB) receptor; mpl receptor; CTLA-4; RANKL, RANK, RSV F protein, protein C etc.

In one embodiment, the heteromultimeric complexes of this invention binds to at least two target molecules selected from the group consisting of: IL-lalpha and IL-lbeta, IL-12 and IL-18; IL-13 and IL-9; IL-13 and IL-4; IL-13 and IL-5; IL-5 and IL-4; IL-13 and IL-lbeta; IL-13 and IL- 25; IL-13 and TARC; IL-13 and MDC; IL-13 and MEF; IL-13 and TGF-β; IL-13 and LHR agonist; IL-12 and TWEAK, IL-13 and CL25; IL-13 and SPRR2a; IL-13 and SPRR2b; IL-13 and ADAM8, IL-13 and PED2, IL17A and IL17F, CD3 and CD19, CD138 and CD20; CD138 and CD40; CD19 and CD20; CD20 and CD3; CD38 and CD138; CD38 and CD20; CD38 and CD40; CD40 and CD20; CD-8 and IL-6; CD20 and BR3, TNFalpha and TGF-beta, TNFalpha and IL-lbeta; TNFalpha and IL-2, TNF alpha and IL-3, TNFalpha and IL-4, TNFalpha and IL-5, TNFalpha and IL6, TNFalpha and IL8, TNFalpha and IL-9, TNFalpha and IL-10, TNFalpha and IL-11, TNFalpha and IL-12, TNFalpha and IL-13, TNFalpha and IL-14, TNFalpha and IL-15, TNFalpha and IL-16, TNFalpha and IL-17, TNFalpha and IL-18, TNFalpha and IL-19, TNFalpha and IL-20, TNFalpha and IL-23, TNFalpha and IFNalpha, TNFalpha and CD4, TNFalpha and VEGF, TNFalpha and MIF, TNFalpha and ICAM-1, TNFalpha and PGE4, TNFalpha and PEG2, TNFalpha and RANK ligand,. TNFalpha and Te38; TNFalpha and BAFF; TNFalpha and CD22; TNFalpha and CTLA-4; TNFalpha and GP130; TNFα and IL-12p40; VEGF and HER2, VEGF-A and HER2, VEGF-A and PDGF, HER1 and HER2, VEGF-A and VEGF-C, VEGF-C and VEGF-D, HER2 and DR5,VEGF and IL-8, VEGF and MET, VEGFR and MET receptor, VEGFR and EGFR, HER2 and CD64, HER2 and CD3, HER2 and CD16, HER2 and HER3; EGFR(HER1) and HER2, EGFR and HER3, EGFR and HER4, IL-13 and CD40L, IL4 and CD40L, TNFR1 and IL-1R, TNFR1 and IL-6R and TNFR1 and IL-18R, EpCAM and CD3, MAPG and CD28, EGFR and CD64, CSPGs and RGM A; CTLA-4 and BTNO2; IGF1 and IGF2; IGF1/2 and Erb2B; MAG and RGM A; NgR and RGM A; NogoA and RGM A; OMGp and RGM A; PDL-I and CTLA-4; and RGM A and RGM B.

Soluble antigens or fragments thereof, optionally conjugated to other molecules, can be used as immunogens for generating antibodies. For transmembrane molecules, such as receptors, fragments of these (e.g. the extracellular domain of a receptor) can be used as the immunogen. Alternatively, cells expressing the transmembrane molecule can be used as the immunogen. Such cells can be derived from a natural source (e.g. cancer cell lines) or may be cells which have been transformed by recombinant techniques to express the transmembrane molecule. Other antigens and forms thereof useful for preparing antibodies will be apparent to those in the art.

All patents, patent applications, patent application publications, and other publications cited or referred to in this specification are herein incorporated by reference to the same extent as if each independent patent, patent application, patent application publication or publication was specifically and individually indicated to be incorporated by reference. Such patent applications specifically include United States provisional application nos. 61/243,105 and 61/266,992, filed on September 16, 2009 and December 4, 2009, respectively, from which this application claims benefit.

EXAMPLES

Example 1. Construction of Vectors for the Expression of Coiled Coil Containing Antibodies

The coiled coil heterodimerization domains described herein can be linked to a constant chain (e.g., the C-terminus of the HC) of any antibody. Numerous antibody sequences that can be used to construct coiled coil containing antibodies are known in the art and techniques required to manipulate DNA sequences are also well known in the art. An exemplary method for constructing coiled coil containing antibodies is described below.

The HC backbone for the generation of antibodies containing a coiled coil was constructed as follows. Sense and anti-sense oligonucleotides were designed and synthesized to encode either the ACID.p1 (GGSAQLEKELQALEKENAQLEWELQALEKELAQGAT; SEQ ID NO:33) or BASE.p1 (GGSAQLKKKLQALKKKNAQLKWKLQALKKKLAQGAT; SEQ ID NO:34) coiled coil domain sequence with 5' AscI and 3' XbaI overhangs. The oligonucleotides were annealed, phosphorylated, and ligated into a digested and dephosphorylated pRK plasmid (Genentech Inc.; Eaton et al., Biochemistry 25:8343-8347

(1986)). The C_H1 through C_H3 domain of a hIgG1 was prepared using PCR (polymerase chain reaction) to include a 5' multiple cloning site (MCS) (ClaI-BamHI-KpnI-ApaI) and a 3' AscI site and cloned into the previously prepared pRK-ACID.p1 or pRK-BASE.p1 vector using ClaI and AscI. Finally, the Lysine residue at position H222 (Kabat numbering scheme) was mutated into an Alanine residue using Stratagene's Quikchange II XL site-directed mutagenesis kit to prevent Fab release during Lys-C cleavage.

Antibodies containing a coiled coil domain were constructed as follows. For common LC and one-armed antibodies, the V_H domain of the desired antibody was prepared using PCR to include 5' ClaI and 3' ApaI restriction sites. The PCR fragments were digested and cloned into a similarly prepared backbone vector. No changes had to be made to the LC constructs already available for these antibodies.

For tethered antibodies the V_H domain (minus the signal sequence) of the desired antibody was first prepared using PCR where the 5' primer contained the 3' half of a GGS tether and terminated in a 5' BamHI site and the 3' primer terminated in a 3' ApaI site. The fragments were digested and cloned into a similarly prepared backbone vector. The cognate LC of the desired antibody was then prepared using PCR where the 5' primer terminated in a 5' ClaI site and the 3' primer contained the 5' portion of the GGS tether and terminated in a 3' BamHI. The LC fragment was joined to its cognate HC (now in the backbone vector) by cloning the fragment in front of the V_H using ClaI and BamHI. The completed tether sequence linking the LC to the V_H was GGGSGGSGGSGGSGGSGGSGGSGGSG (SEQ ID NO:14). The vectors were transfected into mammalian cells (CHO or 293 cells) using standard transfection techniques.

A bispecific antibody that specifically binds both FcεR1 and FcγR2b and having a common LC was prepared using the methods described herein. This antibody has a "BASE.p1" sequence containing an anti-human FcγR2b HC sequence with a BASE.p1 coiled coil domain sequence and the K222A mutation (SEQ ID NO:1), an "ACID.p1" sequence containing an anti-human FcεR1 HC sequence with an ACID.p1 coiled coil domain sequence and the K222A mutation (SEQ ID NO:2), and a common LC sequence (SEQ ID NO:3) (Figure 8).

One-armed antibodies that specifically bind either HER2 or EGFR were also prepared. The antibody that specifically binds HER2 contains an anti-HER2 antibody 1 HC sequence with an ACID.p1 coiled coil domain sequence and the K222A mutation (SEQ ID NO:4), an HC region lacking the VH and CH1 domains with a BASE.p1 coiled coil domain sequence

(SEQ ID NO:5), and an antib-HER2 antibody 1 LC sequence (SEQ ID NO:6). The antibody that specifically binds EGFR contains an anti-EGFR HC sequence with an ACID.p1 coiled coil domain sequence and the K222A mutation (SEQ ID NO:7), an HC region lacking the VH and CH1 domains with a BASE.p1 coiled coil domain sequence (SEQ ID NO:5), and an anti-EGFR (D1.5) LC sequence (SEQ ID NO:8) (Figures 9-1 and 9-2).

Tethered antibodies that specifically bind HER2 and EGFR/HER1 were also prepared (FIGURES 10 and 11). One antibody that specifically binds HER2 and EGFR contains (1) an anti-HER2 antibody 1 LC sequence tethered to an anti-HER2 antibody 1 HC sequence by a 26 amino acid GGS tether, an ACID.p1 coiled coil domain sequence, and the K222A mutation (SEQ ID NO:9) and (2) an anti-EGFR antibody LC sequence tethered to an anti-EGFR antibody HC sequence by a 26 amino acid GGS tether, a BASE.p1 coiled coil domain sequence, and the K222A mutation (SEQ ID NO:10) (Figure 10). A second antibody that specifically binds HER2 and EGFR contains (1) the anti-HER2 antibody 2 LC sequence tethered to the anti-HER2 antibody 2 HC sequence by a 26 amino acid GGS tether, an ACID.p1 coiled coil domain sequence, and the K222A mutation (SEQ ID NO:11) and (2) an anti-EGFR antibody LC sequence tethered to an anti-EGFR antibody HC sequence by a 26 amino acid GGS tether, a BASE.p1 coiled coil domain sequence, and the K222A mutation (SEQ ID NO:10) (Figure 11). Anti-HER2 antibody 1 LC and HC sequences used in the construction of the coiled coil containing antibodies are shown in Figures 12A and 12B (SEQ ID NOS:15 and 16). The location of various restriction sites used in constructing the vectors encoding these antibodies is also shown in Figures 12B1-3.

Example 2. Purification of Coiled Coil Containing Antibodies

An exemplary schema that can be used to purify coiled coil containing antibodies is shown below.

Coiled coil containing antibody loaded onto a Protein A (e.g., mAbSure) column at 4° C

↓

Column washed with KPO_4, then PBS + 0.1% Trition X114

↓

Sample eluted into Tris pH 8.0 (200mM) plus Arginine (100mM)

↓

Sample pH adjusted to 8.0 and cleaved for 1 hr at 37° C, 1:500 wt:wt LysC

↓

Sample concentrated using 1ml mAbSure resin/10mg protein and eluted into Tris/Arg buffer

↓

Sample Loaded onto S200 gel filtration column in PBS + 0.3M NaCl + 100mM Arg
↓
Collect fractions, pool & dialyze into PBS

In particular, antibodies were purified from conditioned media using mAbSure Select resin from GE Healthcare (Sweden) overnight at 4°C. The column was washed with two column volumes (CV) of PBS (phosphate buffered saline), followed by 10 CV of PBS + 0.1% Triton X114 detergent, followed by 10 CV potassium phosphate buffer. The columns were eluted with 10 mM Acetic Acid (pH 2.9) and immediately diluted with Arginine (100 mM final concentration) and Tris (200 mM final concentration), pH 8.0. Coiled coils were removed from antibodies upon treatment with a 1:500 (weight:weight) ratio of Lys-C endopeptidase (Wako Pure Chemical Laboratories) at 37°C for 1-5 hours. Cleaved samples were loaded back over an mAbSure resin column to separate cleaved coiled-coils from antibodies and eluted as above. Antibody concentrations were adjusted to 10 mg/ml prior to separation via size exclusion chromatography using a Sephacryl S200 column run in PBS, 150 mM NaCl, 100 mM Arginine, and 1 mM NaN_3. Peak fractions were pooled and dialyzed against PBS overnight prior to mass spectrum analysis to ensure identity and purity.

In addition to Arginine, other chaotropic agents or mild detergents that can be used in the above purification protocol after the initial mAbSure resin column step include, but are not limited to, Guanidine-HCl, urea, lithium perclorate, Histidine, SDS (sodium dodecyl sulfate), Tween, Triton, and NP-40, all of which are commercially available. Diluting the antibody into a solution containing a chaotropic agent or mild detergent after elution from the initial Protein A containing column (e.g., mAbSure column) maintains the stability of the antibody post elution and allows for the efficient removal of the coiled coil by Lys-C endopeptidase.

Table 1 shows a summary of the purification results for Anti-HER2 antibody 1/α-EGFR (D 1.5) antibodies.

TABLE 1

Sample Volume	mAb Sure Column Recovery	S200 Column Recovery	Yield	Aggregation
40L	200 mg	147 mg	73%	18%
50L	246 mg	196 mg	80%	13%
50L	280 mg	213 mg	76%	11%

The coiled coil was removed from the antibody by Lys-C endopeptidase during the purification process.

An antibody constructed using coiled coil heterdimerization domains, but which no longer contains the coiled coil, is referred to as an "engineered antibody" in the following examples.

Example 3. Cleavage of Coiled Coil Containing Antibodies

The various coiled coil containing antibodies were subjected to cleavage experiments to show that the coiled coil (and tether, if present) could be cleaved from the antibody sequence while leaving the antibody sequence intact. In particular, Figures 13A and B show that the coiled coil was cleaved from an exemplary α-FcεR1/α-FcγR2b antibody using Lys-C endopeptidase and that the antibody remained intact. The theoretical mass for the antibody with the coiled coil is within the margin of error of the mass experimentally observed by mass spectrometry. Similary, the theoretical mass for the engineered antibody without the coiled coil is within the margin of error of that experimentally observed by mass spectrometry showing that Lys-C cleaved the coiled coil from the antibody.

Mass spectrometry results also demonstrated that Lys-C endopeptidase did not cleave the LC or HC of the exemplary α-FcεR1/α-FcγR2b antibody (Figures 14A and B). In particular, the molecular mass was determined both pre-Lys-C endopeptidase treatment (left panels) and post-Lys-C endopeptidase treatment (right panels) for the LC (top two panels) and the α-FcεR1 and α-FcγR2b HCs (bottom four panels) using mass spectrometry. The experimentally observed molecular masses are within the margin of error of the theoretical masses for the various contructs showing that Lys-C endopeptidase cleaved the coiled coil domain from the HC, but did not cleave the LC or HC itself.

Similarly, mass spectrometry results demonstrated that the coiled coil was cleaved from an exemplary one-armed α-EGFR antibody using Lys-C endopeptidase (Figures 17A and B). In particular, the experimentally observed molecular mass was within the margin of error of the theoretical mass for both the one-armed antibody with the coiled coil and for the one-armed antibody without the coiled coil. As shown in Figures 18A-C, the theoretical molecular mass was within the margin of error of the experimentally observed molecular mass for each construct, indicating that Lys-C endopeptidase did not cleave the LC, HC, or HC lacking the VH and CH1 domains (one-armed Fc) of the exemplary α-EGFR antibody,

but did cleave the coiled coil domains from the HC and HC lacking the VH anc CH1 domains.

In addition, mass spectrometry results showed that the coiled coil was cleaved from an exemplary tethered α-HER2/α-EGFR antibody using Lys-C endopeptidase (Figures 19A and B). As shown in Figure 19B, the theoretical and experimentally observed molecular masses are within the margin of error for each construct. The coiled coil was also cleaved from the exemplary tethered α-HER2/α-EGFR antibody using Lys-C endopeptidase where the antibody had first treated with Lys-C endopeptidase and the sample then was subjected to mass spectrometry analysis (Figures 20A-B). The theoretical molecular mass for each construct is within the margin of error of the experimentally observed molecular mass, indicating that the coiled coil is indeed cleaved from the antibody sequence and that the antibody sequence itself is not cleaved. The mass spectrometry results, including the molecular mass (MS), for exemplary coiled coil containing antibodies are summarized in Table 2.

TABLE 2

Sample	Conc.	LLS Agg.	MS Intact	MS Reduced	MS Cleaved, FL	MS Cleaved, Reduced
Common LC anti-FcεR1/ anti-FcγR2b	0.64 mg/ml	5.20%	156503	LC 23262 HC-1 54918 HC-2 55165	147800	LC 23263 HC-1 50525 HC-2 50763
One-Armed Anti-HER2 (antibody 1)	1.0 mg/ml		109359	LC 23440 FC 30907 HC 55016	100665	LC 23440 FC 26568 HC 50665
One-Armed EGFR	1.0 mg/ml	5.50%	109119	LC 23326 FC 30910 HC 54881	100419	LC 23326 FC 26568 HC 50532
Tethered anti-EGFR(D1.5)/ Anti-HER2 (antibody 1)	10 mg/ml	1.80%	160057	EGFR 79903 HER 80156	151367	EGFR 75561 HER 75810

FL = Full Length; Conc.= Concentration; Agg.= Aggregation

Example 4. Characterization of Engineered Antibodies

To determine whether the exemplary engineered antibodies constructed using coiled coil heterodimerization domains retained the binding properties of the antibodies from which their sequences were derived, binding assays were conducted. These binding assays were run using the kinetics wizard program on the ForteBio Octet system. All samples tested were at a

concentration of 25 μg/ml, a concentration that indicates saturation of the anti-human IgG probes in repeat experiments and among varying samples. The probes were loaded with the first sample for 15 minutes and washed for 30 seconds in PBS. All associations for the second and third samples were carried out for 10 minutes with 30-second PBS washes between associations.

In particular, the common LC anti-FcεR1/anti-FcγR2b bispecific engineered antibody was loaded onto an anti-human IgG probe (Octet) by incubating the probe with 25 μg/ml of the antibody for 15 minutes followed by a PBS wash step. To evaluate binding, the loaded probe was incubated with 25 μg/ml of FcεR1 and subsequently 25 μg/ml of FcγR2b. A PBS wash step was performed between the two binding incubations. The data represented in Figure 15 shows that the bispecific, engineered antibody simultaneously bound both of its antigens.

To test the functionality of the engineered antibodies, a rat basophil leukemia (RBL) cell line created to express human FcεRIa and human FcγR2b1 was cultured for 72 hours at 37°C with 1 μg/ml NP-specific human IgE (JW8.5.13) in complete growth media (MEM with Earle's salts Gibco Cat# 11090, 1mM glutamine (Genentech Inc.), 1mM sodium pyruvate (Gibco Cat# 11360-070), 0.1mM nonessential amino acids (Gibco Cat# 11140-050), 1.5g/L sodium bicarbonate (Gibco Cat# 25080-094), 15% fetal bovine serum (Hyclone Cat# SH30071.03). Cells were trypsinized and plated onto a 96-well, flat bottom tissue culture plate at 3.5 x 10^5 cells/ml in 200 μl of complete growth media containing 1 μg/ml NP-specific human IgE and allowed to adhere for 2 hours. Next, the cells were washed three times with fresh media to remove unbound NP-specific human IgE. Cells were treated with 0-10 μg/ml of bispecific antibody and incubated for 1 hour at 37°C, prior to activation with antigen. Cells were activated by incubation with 0.1 μg/ml NP-conjugated ovalbumin (Biosearch Technologies, Inc. Cat. N-5051-10) or 45 minutes at 37°C. Following incubation, the histamine levels in the cell supernatants (cell culture medium) were measured by ELISA (enzyme linked immunosorbent assay) using a Histamine ELISA kit (KMI Diagnostics, Minneapolis, MN). Background histamine levels were obtained from cells treated with NP-specific human IgE alone with no activation (Figure 16).

Octet binding studies were also performed for exemplary one-armed antibodies and tethered engineered antibodies. As a control, octet analysis was used to show that the wild-type anti-HER2 antibody 1 and wild-type α-EGFR antibody did not cross react with each other's antigen, but do bind their respective antigen (Figure 21). To test the exemplary coiled

coil containing antibodies, a one-armed anti-HER2 antibody 1 was loaded at 25 μg/ml onto an anti-human IgG antibody probe for 15 minutes, and the probe was subsequently washed with PBS for 30 seconds. The loaded probe was then incubated with EGFR ECD (extracellular domain) at 25 μg/ml, which showed no binding signal. The probe was then washed for 30 seconds in PBS and incubated with HER2 receptor ECD at 25 μg/ml, which showed a strong binding signal (Figure 22; top trace).

A one-armed EGFR engineered antibody was loaded at 25 μg/ml onto an anti-human IgG antibody probe for 15 minutes and subsequently washed with PBS for 30 seconds. The probe was then incubated with HER2 ECD at 25 μg/ml, which showed no binding signal. The probe was washed for 30 seconds in PBS and incubated with EGFR ECD at 25 μg/ml, which showed a strong binding signal (Figure 22; bottom trace).

A tethered bispecific anti-EGFR(D1.5) /anti-HER2 engineered antibody was incubated with an anti-human IgG antibody probe at 25 μg/ml for 15 minutes and subsequently washed with PBS for 30 seconds. This incubation loaded the probe with the bispecific antibody. The probe was then incubated with EGFR ECD at 25 μg/ml for 3 minutes followed by a 30 second PBS wash then subsequently incubated with the HER2 receptor ECD at 25 μg/ml for 3 minutes (Figure 23A; top trace). For the results shown in the bottom trace of Figure 23A, the bispecific loaded probe was first incubated with the HER2 receptor ECD then with the EGFR ECD. The data show that the bispecific, engineered antibody bound both the EGF and HER2 receptors simultaneously. As shown in Figure 23B, the bispecific anti-EGFR(D1.5) /anti-HER2 antibody bound HER2 with a Kd of approximately 0.06 nM and bound EGF receptor with a Kd of approximately 0.660 nM.

To further analyze the binding characteristics of the engineered antibodies, cell based assays were performed on two cell lines, either NR6 expressing EGFR or HER2, or HCA7 cells which co-express both EGFR and HER2. Prior to performing the binding assays, cells were harvested and allowed to cool for 30 minutes on ice in binding buffer (RPMI medium with 1% fetal bovine serum (FBS), 10 mM HEPES, and 0.2% NaN_3). Unlabeled antibody was prepared at the desired starting concentration and diluted 1:1 with binding buffer to give multiple data points. Labeled antibody was prepared at one concentration to be used throughout the entire assay. Equilibrium binding studies were carried out using radiolabeled antibody competed with various concentrations of unlabeled antibody. Unlabeled antibody was placed in a 96-well plate, followed by labeled material, and cells were then added to the mixture. The plate was incubated for 2 hours at room temperature. After the incubation, the

plate was harvested using Millipore Membrane Multi-Screen Plates to separate the solution from the cells. The cell-bound radiolabeled antibody was then counted on a Perkin Elmer Gamma counter and the data was analyzed using New Ligand software. The results of the affinity binding studies for one-armed and tethered engineered antibody constructs are summarized in Table 3.

TABLE 3

Antibody	Cell Line	Kd (nM)
Wt α-EGFR (D1.5)	NR6 expressing EGFR	0.56 +/- 0.19
α-EGFR Fab	NR6 expressing EGFR	2.20 +/- 0.23
1-armed α-EGFR	NR6 expressing EGFR	1.15 +/- 0.05
Tethered α-EGFR/Anti-HER2 (antibody 1)	NR6 expressing EGFR	2.79 +/- 0.13
Wt Anti-HER2 (antibody 1)	NR6 expressing HER2	0.94 +/- 0.17
Anti-HER2 (antibody 1) Fab	NR6 expressing HER2	2.78 +/- 0.11
1-armed Anti-HER2 (antibody 1)	NR6 expressing HER2	1.70 +/- 0.09
Tethered α-EGFR/Anti-HER2 (antibody 1)	NR6 expressing HER2	5.13 +/- 0.36
Tethered α-EGFR/Anti-HER2 (antibody 1)	HCA7 co-expressing EGFR and HER2	0.93 +/- 0.11
Wt α-EGFR (D1.5)	HCA7 co-expressing EGFR and HER2	0.34 +/- 0.06
Wt Anti-HER2 (antibody 1)	HCA7 co-expressing EGFR and HER2	0.12 +/- 0.03

The functional properties of exemplary engineered antibodies were also characterized biochemically. EGFR-expressing NR6 cells were plated in 12-well plates. Following serum starvation cells were pre-incubated with various concentrations of antibodies for 2 hours at 37°C. Subsequently, cells were stimulated with the TGFα for 12 minutes. Whole cell lysates were subjected to SDS-PAGE analysis, and immunoblots were probed with anti-phosphotyrosine, anti-phosphoAkt, or anti-tubulin as a loading control (Figure 24). These results show that the exemplary α-EGFR(D1.5)/Anti-HER2 (antibody 1) engineered antibody, like the D1.5 IgG1 control antibody, inhibited TGFα-induced phosphorylation in EGFR-

expressing NR6 cells in a dose-dependent manner.

For cell proliferation assays, cells were plated in 96-well plates (EGFR-NR6: 2,000 cells/well) (BT474: 10,000 cells/well) and incubated overnight at 37°C. The next day, the medium was removed and cells were treated in 1% serum containing medium. To compare the effect on cell growth of the α-EGFR(D1.5)/Anti-HER2 (antibody 1) engineered antibody to the D1.5 antibody on EGFR-NR6 cells, 3 nM TGFα was added to the medium, and cells were treated with various concentrations of antibodies. After 3 days AlamarBlue was added to the wells and fluorescence was read using a 96-well fluorometer with excitation at 530 nm and emission of 590 nm. The results are expressed in relative fluorescence units (RFU) (Figure 25). To compare the effect on cell growth of the α-EGFR(D1.5)/Anti-HER2 (antibody 1) engineered antibody to the anti-HER2 antibody 1, BT474 cells were treated in 1% serum containing medium with various concentrations of antibody (Figure 26). After 5 days AlamarBlue assays were performed as described above. These results show that the exemplary α-EGFR(D1.5)/Anti-HER2 (antibody 1) engineered antibody, like the D1.5 IgG1 control antibody, inhibited TGFα-induced phosphorylation in EGFR-expressing NR6 cells in a dose-dependent manner and, like the anti-HER2 antibody 1, inhibited growth of BT474 cells.

Example 5. Pharmacokinetic Analysis of Engineered Antibodies

Pharmacokinetic studies were conducted to compare the pharmacokinetics (PK) of a bispecific engineered antibody with those of typical human IgG (hIgG) antibodies, and to determine the dosing for efficacy experiments. Like the D1.5 hIgG1 control antibody, the HER1/HER2 (D1.5/Anti-HER2 antibody 1) engineered antibody also showed cross-reactivity with mice. The anti-HER2 antibody 2 hIgG1 control antibody did not show cross-reactivity with mice.

The PK of the D1.5 hIgG1 positive control antibody was determined over a 10-day period using SCID Beige mice. In particular, the serum concentration of the antibody over time was determined using an Fc-Fc assay after administration of the antibody at various doses (0.5 mg/kg, 5 mg/kg, and 50 mg/kg). In addition, the serum concentration relative to dose was monitored for ten days using an Fc-Fc ELISA assay (FIGURE 27). The area under the curve (AUC), normalized by dose, was also determined and is summarized in Table 4. The D1.5 hIgG1 antibody showed nonlinear PK in mice in the tested dose range.

TABLE 4

Dose (mg/kg)	AUC till day 10 normalized by dose
0.5	11.8
5	53.8
50	135

In addition, the PK of the anti-HER2 antibody 2 hIgG1 positive control antibodies was also determined over a 10-day period using SCID Beige mice. The serum concentration of the antibody over time was determined using an Fc-Fc ELISA or a HER2-ECD (extracellular domain) ELISA after administration of the antibody at 10 mg/kg. The AUC normalized by dose was also determined and is summarized in Table 5.

TABLE 5

Molecule	Assay Format	AUC till day 10 normalized by dose
10 mg/kg anti-HER2 (antibody 2) hIgG1	HER2-ECD	42.9
	Fc-Fc	63.3

Similarly, the PK of the HER1(EGFR)/HER2 (D1.5/Anti-HER2 antibody 1) engineered antibody was determined over a ten-day period in SCID Beige mice. The serum concentration of the antibody over time was determined using an Fc-Fc ELISA or an EGFR-HER2 ELISA after administration of the antibody at various doses (0.5 mg/kg, 5 mg/kg, and 20 mg/kg). In addition, the serum concentration relative to dose was monitored for ten days using an Fc-Fc ELISA or EGFR-HER2 ELISA (FIGURE 28). The AUC normalized by dose was also determined and is summarized in Table 6. The HER1(EGFR)/HER2 (D1.5/Anti-HER2 antibody 1) engineered antibody showed nonlinear PK in mice in the tested dose range.

TABLE 6

Dose mg/kg	Assay format	AUC till day 10 normalized by dose
0.5	EGFR-HER2	83.8
	Fc-Fc	104
5	EGFR-HER2	42.6
	Fc-Fc	53.2

20	EGFR-HER2	95.0
	Fc-Fc	148

Based on the results of the PK assays, the HER1(EGFR)/HER2 (D1.5/Anti-HER2 antibody 1) engineered antibody was determined to have similar or better exposure in mice over the tested time period (until day 10) in comparison to the D1.5 hIgG1 control antibo xzzzdy (FIGURE 29).

Example 6 – Producing Tethered Antibodies in Mammalian Cell Lines Engineered to Express Enzymes to Cleave Tethers

For construction of the 26AA Furin cleavable tethered coiled coil antibodies (Figure 30A) the VH domain (minus the signal sequence) of the desired antibody was first prepared using PCR wherein the 5' primer contained the 3' half of a GGS-Furin tether and terminated in a 5' BamHI site and the 3' primer terminated in a 3' ApaI site. The fragments were digested and cloned into a similarly prepared antibody-coiled coil backbone vector. The cognate LC of the desired antibody was then prepared using PCR wherein the 5' primer terminated in a 5' ClaI site and the 3' primer contained the 5' portion of the Furin-GGS tether and terminated in a 3' BamHI. The LC fragment was joined to its cognate HC (now in the antibody coiled coil backbone) by cloning the fragment in front of the VH via ClaI and BamHI. The completed tether sequence linking the CL to the VH was RCRRGSGGSGGSGGSGGSGGSGRSRKRR (SEQ ID NO:35). For construction of the 26AA Furin-cleavable tether (-C) (FIGURE 30B), two mutations were introduced into the above mentioned construct. The c-terminal Cys residue of the LC was mutated into and Ala residue using Stratagene's Quikchange II XL site-directed mutagenesis kit. According to the Kabat numbering system, the Cys terminal residue in the CL is at position 214. C220 of the HC was also mutated into an A to eliminate possible mis-folding due to this newly non-disulfide bonded Cys .

The methods used in constructing the 32AA Furin cleavable tether (FIGURE 30C) was identical to the construction of the 26AA Furin cleavable tether except that the finished tether sequence was RKRKRRGSGGSGGSGGSGGSGGSGRSRKRR (SEQ ID NO:36). For Furin over-expression, human or murine Furin was cloned into the pRK vector system and co-transfected with the antibody chain plasmids.

Carboxypeptidase B digestion (Figure 30D) was carried out in 50mM Sodium Borate

pH8.0 for 1hr. at 37C with 1:20wt:wt of CpB.

Figures 30A1-2 is a diagram and reduced Mass Spec (MS) results for the 26 amino acid FURIN cleavable tether. The heavy chain MS trace or graph shows a heavy chain (1) which has fully native n- and c-termini as well as a smaller amount of "full length antibody" (i.e., for these studies, was not cleaved at either Furin site (FL)). The light chain MS trace shows a peak corresponding to the LC plus the entire length of tether (1) and three other peaks (2-4) corresponding to the erosion of the 3' end of the tether, presumably due to Carboxypeptidase B activity in the CHO media. Evidenced by the lack of MS peaks within the region of the bottom trace indicated by the purple oval, there is no cleavage at the n-terminal Furin site. A cartoon of the resulting antibody is provided showing the non-native residues (underlined "R") as well as the 23-26 amino acid tether still attached to the c-terminus of the LC

Figure 30B1-2 is a diagram and reduced Mass Spec (MS) results for the 26 amino acid FURIN cleavable tether ("-C"). In this construct, the C residue was removed and replaced). The heavy chain MS trace shows a heavy chain (1) which has fully native n- and c-termini and no remaining "full length antibody" (FL). The light chain MS trace shows a peak corresponding to the LC plus 2 additional R residues (peak 2) plus one additional R residue (peak 3) and with it's native c-terminus (peak 4), presumably due to Carboxypeptidase B activity in the CHO media. A cartoon of the resulting antibody is provided showing the non-native residues (yellow) as well as the 0,1 or 2 R residues still attached to the c-terminus of the LC.

Figure 30C1-5 is a diagram and reduced Mass Spec (MS) results for the 32 amino acid FURIN cleavable tether. Figure 30C3 shows a Heavy chain (peak 1) which has fully native n- and c-termini as well as a smaller amount of "full length antibody" (FL) which was not cleaved at either Furin site. Figures 30C2 and 30C3 show the resulting material obtained from CHO cells expressing native levels of Furin whereasFigures 30C4 and 30C5 show the resulting material obtained from CHO cells over-expressing Furin. Figure 30C2 shows a peak corresponding to the LC plus the entire length of tether (peak 1) and five other peaks (peaks 2-6) corresponding to the erosion of the 3' end of the tether as well as an additional peak showing the LC with only the Furin recognition sequence still attached (peak 7) and five additional peaks (peaks 8-12) corresponding to the erosion of the c-terminal basic residues , presumably due to Carboxypeptidase B activity in the CHO media. Figure 30C5 shows a heavy chain (1) which has fully native n- and c-termini and no remaining Full length

antibody (FL) and Figure 30C4 shows the LC now fully cleaved at the n-terminal Furin site (7) and four additional peaks (8-11) corresponding to the erosion of the c-terminal basic residues.

Figure 30D2 is the same as Figure 30C4. After a 1hr. incubation at 37C with 1:20 wt:wt of CpB, the remaining residues (corresponding to peaks 7-11) were completely removed resulting in a LC with a native c-terminus (Figure 30D3). A cartoon is provided showing the only non-native residues to be the K222A mutation in each HC and an otherwise completely native (compared to parentals) bispecific antibody.

Example 7 – Expression of Enzyme-Cleavable Tethered Coiled-Coil Multisecific Antibody in Eukaryotic Cells and Production of Multispecific Antibody Without Tethers or Coiled Coils

Tethered. coiled coil bispecific antibodies comprising two different VH and VL, each arm recognizing a different target, was produced in CHO cells overexpressing human furin as described above. The antibody, which also contained a K222A mutation, was treated with Lys-C endopeptidase to remove the coiled coil and with Carboxypeptidase B. It was not necessary to mutate the antibody any further in the hinge, and constant regions to achieve the final product. Figure 31 shows a non-reduced mass spec trace of the finished product. Although a small amount of homodimer is observable in the non-reduced MS, this is due to the imbalance in the expression level of the two Ab chains and is easily corrected by modulating their relative expression levels. Figure 32 shows a reduced mass spec trace of the finished product. The observed masses of the LCs and HCs confirm that the Ab chains all have native n- and c-termini.

These results show that this platform can be used for the production of several types of one-armed and bispecific antibodies in mammalian cells. In our hands, we have been able to generate mature bispecific antibodies differing from their parental wt Abs only by a single Lys-Ala mutation within the hinge region of each HC. These antibodies retain their specificity, and bispecific variants are able to bind both antigens simultaneously. These antibodies bind their antigens with high affinity.

Claims

What is claimed is:

1. An antibody comprising:

(a) a first polypeptide comprising a VH domain and a first coiled coil domain (CC), wherein the first CC comprises a heptad repeat of Formula I:

$(X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7)_n$ (Formula I)

X_1 is a hydrophobic amino acid residue or Asparagine,

X_2, X_3, and X_6 are each any amino acid residue,

X_4 is a hydrophobic amino acid residue, and

X_5 and X_7 are each a charged amino acid residue; and

(b) a second polypeptide comprising a VH domain and a second coiled coil domain (CC), wherein the second CC comprises a heptad repeat of Formula II:

$(X'_1\ X'_2\ X'_3\ X'_4\ X'_5\ X'_6\ X'_7)_n$ (Formula II)

X'_1 is a hydrophobic amino acid residue or Asparagine,

X'_2, X'_3, and X'_6 are each any amino acid residue,

X'_4 is a hydrophobic amino acid residue, and

X'_5 and X'_7 are each a charged amino acid residue;

wherein n in Formula I and II is greater than or equal to 2; and

wherein, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

2. The antibody of claim 1, wherein the first and second polypeptides each comprise a VH and a CH1 domain.

3. The antibody of claim 2, wherein the first and second polypeptides each further comprise a hinge domain.

4. The antibody of any one of claims 1-3, wherein said first and second polypeptides each further comprise a CH2 and a CH3 domain.

5. The antibody of claim 1, wherein the first and second polypeptides each comprise VH, CH1, hinge, CH2, and CH3 domains positioned relative to each other in an N-terminal to C-

terminal direction: VH-CH1-hinge-CH2-CH3.

6. The antibody of any one of claims 1-5, wherein said antibody further comprises a third and a fourth polypeptide, wherein said third polypeptide comprises a first VL domain and said fourth polypeptide comprises a second VL domain.

7. The antibody of claim 6, wherein said VH domain of the first polypeptide is linked to the VL domain of the third polypeptide by a tether and the VH domain of the second polypeptide is linked to the VL domain of the fourth polypeptide by a tether.

8. The antibody of claim 6, wherein the third polypeptide further comprises a first CL domain wherein said first VL and CL domains are positioned relative to each other within the third polypeptide in an N-terminal to C-terminal direction: VL-CL, and the fourth polypeptide further comprises a second CL domain, and wherein said second VL and CL domains are positioned relative to each other within the fourth polypeptide in an N-terminal to C-terminal direction: VL-CL.

9. The antibody of any one of claims 6-8, wherein the sequences of said first VL domain and said second VL domain are the same.

10. The antibody of any one of claims 1-9, wherein the N-terminus of the VH of at least one of said first or said second polypeptides is connected to the C-terminus of a CL with a tether.

11. An antibody comprising:

(a) a first polypeptide comprising a VH domain and a first coiled coil domain (CC), wherein the first CC comprises a heptad repeat of Formula I:

$(X_1\ X_2\ X_3\ X_4\ X_5\ X_6\ X_7)_n$ (Formula I)

X_1 is a hydrophobic amino acid residue or Asparagine,

X_2, X_3, and X_6 are each any amino acid residue,

X_4 is a hydrophobic amino acid residue, and

X_5 and X_7 are each a charged amino acid residue; and

(b) a second polypeptide comprising a CH2 and CH3 domain and a second coiled coil

(CC), wherein the second CC comprises a heptad repeat of Formula II:

$(X'_1\ X'_2\ X'_3\ X'_4\ X'_5\ X'_6\ X'_7)_n$ (Formula II)

X'_1 is a hydrophobic amino acid residue or Asparagine,

X'_2, X'_3, and X'_6 are each any amino acid residue,

X'_4 is a hydrophobic amino acid residue, and

X'_5 and X'_7 are each a charged amino acid residue;

wherein n in Formula I and II is greater than or equal to 2; and

wherein, in each heptad repeat, the first CC comprises an X_5 residue that is opposite in charge to the X'_7 residue in the second CC and the first CC comprises an X_7 residue that is opposite in charge to the X'_5 residue in the second CC.

12. The antibody of claim 11, wherein the first polypeptide comprises a VH and CH1 domain.

13. The antibody of claim 12, wherein the first polypeptide further comprises a hinge domain.

14. The antibody of claim 12 or 13, wherein the first polypeptide further comprises a CH2 and a CH3 domain.

15. The antibody of claim 11, wherein the first polypeptide comprises VH, CH1, hinge, CH2, and CH3 domains positioned relative to each other in an N-terminal to C-terminal direction: VH-CH1-hinge-CH2-CH3.

16. The antibody of any one of claims 11-15, wherein the antibody further comprises a third polypeptide, wherein the third polypeptide comprises a VL domain.

17. The antibody of claim 16, wherein said third polypeptide further comprises a CL domain, and the VL and CL domains are positioned relative to each other in an N-terminal to C-terminal direction: VL-CL.

18. The antibody of any one of claims 11-17, wherein the N-terminus of the VH of said first polypeptide is connected to the C-terminus of a CL with a tether.

19. The antibody of any one of claims 1-18, wherein said hydrophobic amino acid residue in any of X_1, X'_1, X_4, and X'_4 is selected from the group consisting of Alanine, Valine, Leucine, Isoleucine, Tryptophan, Phenylalanine, and Methionine.

20. The antibody of any one of claims 1-19, wherein said charged amino acid residue in any of X_5, X'_5, X_7, and X'_7 is selected from the group consisting of Lysine, Arginine, Histidine, Aspartic Acid, and Glutamic Acid.

21. The antibody of any one of claims 1-20, wherein, in at least one heptad repeat of said first CC, X_1 is Asparagine, and wherein the respective X'_1 is Asparagine in at least one heptad repeat of said second CC.

22. The antibody of any one of claims 1-21, wherein

(a) the first CC comprises a heptad repeat wherein

X_1 is Leucine or Asparagine,

X_2 is Alanine or Glutamine,

X_3 is Alanine or Glutamine,

X_4 is Leucine,

X_5 is Glutamic Acid,

X_6 is Lysine or Tryptophan, and

X_7 is Glutamic Acid; and

(b) the second CC comprises a heptad repeat wherein

X'_1 is Leucine or Asparagine,

X'_2 is Alanine or Glutamine,

X'_3 is Alanine or Glutamine,

X'_4 is Leucine,

X'_5 is Lysine,

X'_6 is Lysine or Tryptophan, and

X'_7 is Lysine.

23. The antibody of any one of claims 1-22, wherein n is greater than or equal to 3.

24. The antibody of claim 23, wherein n is greater than or equal to 4.

25. The antibody of any one of claims 1-24, wherein at least one of said first or said second CC is linked C-terminal to a constant domain of the antibody.

26. The antibody of claim 25, wherein said constant domain is a CH3 domain and the first CC is linked C-terminal to a CH3 domain of the first polypeptide and the second CC is linked C-terminal to a CH3 domain of the second polypeptide.

27. The antibody of claim 25 or 26, wherein linkage is by a cleavable linker sequence.

28. The antibody of any one of claims 1-27, wherein a Lys-C endopeptidase cleavage site is located N-terminal to at least one of said first or said second CC.

29. An antibody comprising a first polypeptide comprising a VL, CL, tether, VH, CH1, CH2, and CH3 domain positioned relative to each other in an N-terminal to C-terminal direction: VL-CL-tether-VH-CH1-CH2-CH3 (Formula III).

30. The antibody of claim 29, wherein said antibody further comprises a second polypeptide of Formula III.

31. The antibody of any one of claims 1-9 or 30, wherein the antibody is multispecific.

32. The antibody of claim 31, wherein the antibody is capable of binding at least 2 antigens.

33. The antibody of claim 31, wherein the antibody a capable of binding at least 2 epitopes on the same antigen.

34. The antibody of any one of claims 1-9 or 30, wherein said antibody is bispecific.

35. The antibody of any one of claims 7, 10, 18, 29, or 30, wherein said tether comprises Glycine (G) and Serine (S) residues.

36. The antibody of any one of claims 7, 10, 18, 29, 30, or 35, wherein said tether is between 15 and 50 amino acids in length.

37. The antibody of claim 36, wherein said tether is between 20 and 26 amino acids in length.

38. The antibody of any one of claims 7, 10, 18, 29, 30, or 35-37, wherein said tether comprises GGS repeats.

39. The antibody of any one of claims 7, 10, 18, 29, 30, or 35-38, wherein said tether is cleavable.

40. The antibody of any one of claims 28-39, wherein said antibody comprises a mutation that removes a Lys-C endopeptidase cleavage site.

41. The antibody of claim 40, wherein said mutation that removes a Lys-C endopeptidase cleavage site is in a hinge domain.

42. The antibody of claim 41, wherein said antibody has a K222A substitution (EU numbering system).

43. The antibody of claim 27 or 39, wherein said tether or said linker is cleavable by one or more of the following endopeptidases: Furin, Thrombin, Genenase, Lys-C, Arg-C, Asp-N, Glu-C, Factor Xa, Tobacco Etch Virus Protease (TEV), Enterokinase, Human Rhinovirus C3 protease (HRV C3), and Kininogenase.

44. The antibody of claim 27 or 39, wherein said tether or said linker comprises an Asparagine-Glycine peptide bond.

45. The antibody of claim 44, wherein said Asparagine-Glycine peptide bond is cleavable by hydroxylamine.

46. The antibody of any one of claims 1-45, wherein said antibody comprises a constant region conjugated to a cytotoxic agent.

47. The antibody of any one of claims 1-45, wherein said antibody is expressed by a mammalian cell.

48. The antibody of claim 47, wherein said mammalian cell is a CHO cell.

49. The antibody of any one of claims 1-45, wherein said antibody is expressed by a prokaryotic cell.

50. The antibody of claim 49, wherein said prokaryotic cell is an *E. coli* cell.

51. A method of producing an antibody, said method comprising the step of culturing a cell comprising a vector encoding the antibody of any one of claims 1-45 in a culture medium.

52. The method of claim 51, wherein said method further comprises recovering said antibody from said cell or said culture medium.

53. The method of claim 52, further comprising the steps of
(a) capturing said antibody on a column comprising Protein A,
(b) eluting said antibody from said column, and
(c) diluting said eluted antibody into a solution containing a chaotropic agent or mild detergent.

54. A method of maintaining a coiled coil containing antibody in solution, said method comprising maintaining said antibody in the presence of a chaotropic agent or mild detergent.

55. The method of claim 53 or 54, wherein said chaotropic agent or mild detergent is Arginine, Guanidine-HCl, urea, lithium perchlorate, Histidine, Sodium Dodecyl Sulfate (SDS), Tween, Triton, or NP-40.