

**Title Of The Invention:****PD-1-Binding Molecules and Methods of Use Thereof****Cross-Reference to Related Applications**

**[0001]** This application claims priority to U.S. Patent Applications Serial No. 62/198,867 (filed on July 30, 2015; pending), 62/239,559 (filed on October 9, 2015; pending), 62/255,140 (filed on November 13, 2015; pending), and 62/322,974 (filed on April 15, 2016; pending), each of which applications is herein incorporated by reference in its entirety.

**Reference To Sequence Listing**

**[0002]** This application includes one or more Sequence Listings pursuant to 37 C.F.R. 1.821 et seq., which are disclosed in computer-readable media (file name: 1301\_0122PCT\_Sequence\_Listing\_ST25.txt, created on July 1, 2016, and having a size of 282,789 bytes), which file is herein incorporated by reference in its entirety.

**Field Of The Invention**

**[0003]** The present invention is directed to PD-1 binding molecules that comprise the PD-1-binding domain of selected anti-PD-1 antibodies capable of binding to both cynomolgus monkey PD-1 and to human PD-1: PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15. The invention particularly concerns PD-1 binding molecules that are humanized or chimeric versions of such antibodies, or that comprise PD-1 binding-fragments of such anti-PD-1 antibodies (especially immunoconjugates, diabodies, BiTEs, bispecific antibodies, *etc.*). The invention particularly concerns such PD-1-binding molecules that are additionally capable of binding an epitope of a molecule involved in regulating an immune check point that is present on the surface of an immune cell. The present invention also pertains to methods of using such PD-1-binding molecules to detect PD-1 or to stimulate an immune response. The present invention also pertains to methods of combination therapy in which a PD-1-binding molecule that comprises one or more PD-1-binding domain(s) of such selected anti-PD-1 antibodies is administered in combination with one or more additional molecules that are effective in stimulating an immune response and/or in combination with one or more additional molecules that specifically bind a cancer antigen.

## Background Of The Invention

### I. Cell Mediated Immune Responses

[0004] The immune system of humans and other mammals is responsible for providing protection against infection and disease. Such protection is provided both by a humoral immune response and by a cell-mediated immune response. The humoral response results in the production of antibodies and other biomolecules that are capable of recognizing and neutralizing foreign targets (antigens). In contrast, the cell-mediated immune response involves the activation of macrophages, Natural Killer cells (NK), and antigen specific cytotoxic T-lymphocytes by T-cells, and the release of various cytokines in response to the recognition of an antigen (Dong, C. *et al.* (2003) “*Immune Regulation by Novel Costimulatory Molecules*,” Immunolog. Res. 28(1):39-48).

[0005] The ability of T-cells to optimally mediate an immune response against an antigen requires two distinct signaling interactions (Viglietta, V. *et al.* (2007) “*Modulating Co-Stimulation*,” Neurotherapeutics 4:666-675; Korman, A.J. *et al.* (2007) “*Checkpoint Blockade in Cancer Immunotherapy*,” Adv. Immunol. 90:297-339). First, antigen that has been arrayed on the surface of Antigen-Presenting Cells (APC) must be presented to an antigen-specific naive CD4<sup>+</sup> T-cell. Such presentation delivers a signal via the T-Cell Receptor (TCR) that directs the T-cell to initiate an immune response that will be specific to the presented antigen. Second, a series of costimulatory and inhibitory signals, mediated through interactions between the APC and distinct T-cell surface molecules, triggers first the activation and proliferation of the T-cells and ultimately their inhibition. Thus, the first signal confers specificity to the immune response whereas the second signal serves to determine the nature, magnitude and duration of the response.

[0006] The immune system is tightly controlled by costimulatory and co-inhibitory ligands and receptors. These molecules provide the second signal for T-cell activation and provide a balanced network of positive and negative signals to maximize immune responses against infection while limiting immunity to self (Wang, L. *et al.* (March 7, 2011) “*VISTA, A Novel Mouse Ig Superfamily Ligand That Negatively Regulates T-Cell Responses*,” J. Exp. Med. 10.1084/jem.20100619:1-16; Lepenies, B. *et al.* (2008) “*The Role Of Negative Costimulators During Parasitic Infections*,” Endocrine, Metabolic & Immune Disorders - Drug Targets 8:279-288). Of particular importance is binding between the B7.1 (CD80) and B7.2 (CD86) ligands of the Antigen-Presenting Cell and the CD28 and CTLA-4 receptors of the CD4<sup>+</sup> T

lymphocyte (Sharpe, A.H. *et al.* (2002) “*The B7-CD28 Superfamily*,” *Nature Rev. Immunol.* 2:116-126; Dong, C. *et al.* (2003) “*Immune Regulation by Novel Costimulatory Molecules*,” *Immunolog. Res.* 28(1):39-48; Lindley, P.S. *et al.* (2009) “*The Clinical Utility Of Inhibiting CD28-Mediated Costimulation*,” *Immunol. Rev.* 229:307-321). Binding of B7.1 or of B7.2 to CD28 stimulates T-cell activation; binding of B7.1 or B7.2 to CTLA-4 inhibits such activation (Dong, C. *et al.* (2003) “*Immune Regulation by Novel Costimulatory Molecules*,” *Immunolog. Res.* 28(1):39-48; Lindley, P.S. *et al.* (2009) “*The Clinical Utility Of Inhibiting CD28-Mediated Costimulation*,” *Immunol. Rev.* 229:307-321; Greenwald, R.J. *et al.* (2005) “*The B7 Family Revisited*,” *Ann. Rev. Immunol.* 23:515-548). CD28 is constitutively expressed on the surface of T-cells (Gross, J., *et al.* (1992) “*Identification And Distribution Of The Costimulatory Receptor CD28 In The Mouse*,” *J. Immunol.* 149:380–388), whereas CTLA-4 expression is rapidly upregulated following T-cell activation (Linsley, P. *et al.* (1996) “*Intracellular Trafficking Of CTLA4 And Focal Localization Towards Sites Of TCR Engagement*,” *Immunity* 4:535–543). Since CTLA-4 is the higher affinity receptor (Sharpe, A.H. *et al.* (2002) “*The B7-CD28 Superfamily*,” *Nature Rev. Immunol.* 2:116-126), binding first initiates T-cell proliferation (via CD28) and then inhibits it (via nascent expression of CTLA-4), thereby dampening the effect when proliferation is no longer needed.

**[0007]** Further investigations into the ligands of the CD28 receptor have led to the identification and characterization of a set of related B7 molecules (the “B7 Superfamily”) (Coyle, A.J. *et al.* (2001) “*The Expanding B7 Superfamily: Increasing Complexity In Costimulatory Signals Regulating T-Cell Function*,” *Nature Immunol.* 2(3):203-209; Sharpe, A.H. *et al.* (2002) “*The B7-CD28 Superfamily*,” *Nature Rev. Immunol.* 2:116-126; Greenwald, R.J. *et al.* (2005) “*The B7 Family Revisited*,” *Ann. Rev. Immunol.* 23:515-548; Collins, M. *et al.* (2005) “*The B7 Family Of Immune-Regulatory Ligands*,” *Genome Biol.* 6:223.1-223.7; Loke, P. *et al.* (2004) “*Emerging Mechanisms Of Immune Regulation: The Extended B7 Family And Regulatory T-Cells*,” *Arthritis Res. Ther.* 6:208-214; Korman, A.J. *et al.* (2007) “*Checkpoint Blockade in Cancer Immunotherapy*,” *Adv. Immunol.* 90:297-339; Flies, D.B. *et al.* (2007) “*The New B7s: Playing a Pivotal Role in Tumor Immunity*,” *J. Immunother.* 30(3):251-260; Agarwal, A. *et al.* (2008) “*The Role Of Positive Costimulatory Molecules In Transplantation And Tolerance*,” *Curr. Opin. Organ Transplant.* 13:366-372; Lenschow, D.J. *et al.* (1996) “*CD28/B7 System of T-Cell Costimulation*,” *Ann. Rev. Immunol.* 14:233-258; Wang, S. *et al.* (2004) “*Co-Signaling Molecules Of The B7-CD28 Family In Positive And Negative Regulation Of T Lymphocyte Responses*,” *Microbes Infect.* 6:759-766). There are

currently several known members of the family: B7.1 (CD80), B7.2 (CD86), the inducible co-stimulator ligand (ICOS-L), the programmed death-1 ligand (PD-L1; B7-H1), the programmed death-2 ligand (PD-L2; B7-DC), B7-H3, B7-H4 and B7-H6 (Collins, M. *et al.* (2005) “*The B7 Family Of Immune-Regulatory Ligands*,” *Genome Biol.* 6:223.1-223.7; Flajnik, M.F. *et al.* (2012) “*Evolution Of The B7 Family: Co-Evolution Of B7H6 And Nkp30, Identification Of A New B7 Family Member, B7H7, And Of B7's Historical Relationship With The MHC*,” *Immunogenetics* epub doi.org/10.1007/s00251-012-0616-2).

## II. Programmed Death-1 (“PD-1”)

**[0008]** Programmed Death-1 (“PD-1,” also known as “CD279”) is an approximately 31 kD type I membrane protein member of the extended CD28/CTLA-4 family of T-cell regulators that broadly negatively regulates immune responses (Ishida, Y. *et al.* (1992) “*Induced Expression Of PD-1, A Novel Member Of The Immunoglobulin Gene Superfamily, Upon Programmed Cell Death*,” *EMBO J.* 11:3887-3895; United States Patent Application Publication No. 2007/0202100; 2008/0311117; 2009/00110667; United States Patents Nos. 6,808,710; 7,101,550; 7,488,802; 7,635,757; 7,722,868; PCT Publication No. WO 01/14557).

**[0009]** PD-1 is expressed on activated T-cells, B-cells, and monocytes (Agata, Y. *et al.* (1996) “*Expression Of The PD-1 Antigen On The Surface Of Stimulated Mouse T And B Lymphocytes*,” *Int. Immunol.* 8(5):765-772; Yamazaki, T. *et al.* (2002) “*Expression Of Programmed Death 1 Ligands By Murine T-Cells And APC*,” *J. Immunol.* 169:5538-5545) and at low levels in natural killer (NK) T-cells (Nishimura, H. *et al.* (2000) “*Facilitation Of Beta Selection And Modification Of Positive Selection In The Thymus Of PD-1-Deficient Mice*,” *J. Exp. Med.* 191:891-898; Martin-Orozco, N. *et al.* (2007) “*Inhibitory Costimulation And Anti-Tumor Immunity*,” *Semin. Cancer Biol.* 17(4):288-298).

**[0010]** The extracellular region of PD-1 consists of a single immunoglobulin (Ig)V domain with 23% identity to the equivalent domain in CTLA-4 (Martin-Orozco, N. *et al.* (2007) “*Inhibitory Costimulation And Anti-Tumor Immunity*,” *Semin. Cancer Biol.* 17(4):288-298). The extracellular IgV domain is followed by a transmembrane region and an intracellular tail. The intracellular tail contains two phosphorylation sites located in an immunoreceptor tyrosine-based inhibitory motif and an immunoreceptor tyrosine-based switch motif, which suggests that PD-1 negatively regulates TCR signals (Ishida, Y. *et al.* (1992) “*Induced Expression Of PD-1, A Novel Member Of The Immunoglobulin Gene Superfamily, Upon Programmed Cell Death*,” *EMBO J.* 11:3887-3895; Blank, C. *et al.* (2006) “*Contribution Of The PD-L1/PD-1*

*Pathway To T-Cell Exhaustion: An Update On Implications For Chronic Infections And Tumor Evasion Cancer,*” Immunol. Immunother. 56(5):739-745).

**[0011]** PD-1 mediates its inhibition of the immune system by binding to B7-H1 and B7-DC (Flies, D.B. *et al.* (2007) “*The New B7s: Playing a Pivotal Role in Tumor Immunity,*” J. Immunother. 30(3):251-260; United States Patents Nos. 6,803,192; 7,794,710; United States Patent Application Publication Nos. 2005/0059051; 2009/0055944; 2009/0274666; 2009/0313687; PCT Publication Nos. WO 01/39722; WO 02/086083).

**[0012]** B7-H1 and B7-DC are broadly expressed on the surfaces of human and murine tissues, such as heart, placenta, muscle, fetal liver, spleen, lymph nodes, and thymus as well as murine liver, lung, kidney, islets cells of the pancreas and small intestine (Martin-Orozco, N. *et al.* (2007) “*Inhibitory Costimulation And Anti-Tumor Immunity,*” Semin. Cancer Biol. 17(4):288-298). In humans, B7-H1 protein expression has been found in human endothelial cells (Chen, Y. *et al.* (2005) “*Expression of B7-H1 in Inflammatory Renal Tubular Epithelial Cells,*” Nephron. Exp. Nephrol. 102:e81-e92; de Haij, S. *et al.* (2005) “*Renal Tubular Epithelial Cells Modulate T-Cell Responses Via ICOS-L And B7-H1*” Kidney Int. 68:2091-2102; Mazanet, M.M. *et al.* (2002) “*B7-H1 Is Expressed By Human Endothelial Cells And Suppresses T-Cell Cytokine Synthesis,*” J. Immunol. 169:3581-3588), myocardium (Brown, J.A. *et al.* (2003) “*Blockade Of Programmed Death-1 Ligands On Dendritic Cells Enhances T-Cell Activation And Cytokine Production,*” J. Immunol. 170:1257-1266), syncytiotrophoblasts (Petroff, M.G. *et al.* (2002) “*B7 Family Molecules: Novel Immunomodulators At The Maternal-Fetal Interface,*” Placenta 23:S95-S101). The molecules are also expressed by resident macrophages of some tissues, by macrophages that have been activated with interferon (IFN)- $\gamma$  or tumor necrosis factor (TNF)- $\alpha$  (Latchman, Y. *et al.* (2001) “*PD-L2 Is A Second Ligand For PD-1 And Inhibits T-Cell Activation,*” Nat. Immunol 2:261-268), and in tumors (Dong, H. (2003) “*B7-H1 Pathway And Its Role In The Evasion Of Tumor Immunity,*” J. Mol. Med. 81:281-287).

**[0013]** The interaction between B7-H1 and PD-1 has been found to provide a crucial negative costimulatory signal to T and B-cells (Martin-Orozco, N. *et al.* (2007) “*Inhibitory Costimulation And Anti-Tumor Immunity,*” Semin. Cancer Biol. 17(4):288-298) and functions as a cell death inducer (Ishida, Y. *et al.* (1992) “*Induced Expression Of PD-1, A Novel Member Of The Immunoglobulin Gene Superfamily, Upon Programmed Cell Death,*” EMBO J. 11:3887-3895; Subudhi, S.K. *et al.* (2005) “*The Balance Of Immune Responses: Costimulation*

*Verse Coinhibition*,” J. Molec. Med. 83:193-202). More specifically, interaction between low concentrations of the PD-1 receptor and the B7-H1 ligand has been found to result in the transmission of an inhibitory signal that strongly inhibits the proliferation of antigen-specific CD8<sup>+</sup> T-cells; at higher concentrations the interactions with PD-1 do not inhibit T-cell proliferation but markedly reduce the production of multiple cytokines (Sharpe, A.H. *et al.* (2002) “*The B7-CD28 Superfamily*,” Nature Rev. Immunol. 2:116-126). T-cell proliferation and cytokine production by both resting and previously activated CD4 and CD8 T-cells, and even naive T-cells from umbilical-cord blood, have been found to be inhibited by soluble B7-H1-Fc fusion proteins (Freeman, G.J. *et al.* (2000) “*Engagement Of The PD-1 Immunoinhibitory Receptor By A Novel B7 Family Member Leads To Negative Regulation Of Lymphocyte Activation*,” J. Exp. Med. 192:1-9; Latchman, Y. *et al.* (2001) “*PD-L2 Is A Second Ligand For PD-1 And Inhibits T-Cell Activation*,” Nature Immunol. 2:261-268; Carter, L. *et al.* (2002) “*PD-1:PD-L Inhibitory Pathway Affects Both CD4(+) and CD8(+) T-cells And Is Overcome By IL-2*,” Eur. J. Immunol. 32(3):634-643; Sharpe, A.H. *et al.* (2002) “*The B7-CD28 Superfamily*,” Nature Rev. Immunol. 2:116-126).

**[0014]** The role of B7-H1 and PD-1 in inhibiting T-cell activation and proliferation has suggested that these biomolecules might serve as therapeutic targets for treatments of inflammation and cancer. Thus, the use of anti-PD-1 antibodies to treat infections and tumors and up-modulate an adaptive immune response has been proposed (see, United States Patent Application Publication Nos. 2010/0040614; 2010/0028330; 2004/0241745; 2008/0311117; 2009/0217401; United States Patents Nos. 7,521,051; 7,563,869; 7,595,048; PCT Publications Nos. WO 2004/056875; WO 2008/083174). Antibodies capable of specifically binding to PD-1 have been reported by Agata, T. *et al.* (1996) “*Expression Of The PD-1 Antigen On The Surface Of Stimulated Mouse T And B Lymphocytes*,” Int. Immunol. 8(5):765-772; and Berger, R. *et al.* (2008) “*Phase I Safety And Pharmacokinetic Study Of CT-011, A Humanized Antibody Interacting With PD-1, In Patients With Advanced Hematologic Malignancies*,” Clin. Cancer Res. 14(10):3044-3051 (see, also, United States Patent Nos. 8,008,449 and 8,552,154; US Patent Publication Nos. 2007/0166281; 2012/0114648; 2012/0114649; 2013/0017199; 2013/0230514 and 2014/0044738; and PCT Patent Publication Nos. WO 2003/099196; WO 2004/004771; WO 2004/056875; WO 2004/072286; WO 2006/121168; WO 2007/005874; WO 2008/083174; WO 2009/014708; WO 2009/073533; WO 2012/135408, WO 2012/145549; and WO 2013/014668).

**[0015]** However, despite all such prior advances, a need remains for improved compositions capable of more vigorously directing the body's immune system to attack cancer cells or pathogen-infected cells, especially at lower therapeutic concentrations. For although the adaptive immune system can be a potent defense mechanism against cancer and disease, it is often hampered by immune suppressive mechanisms in the tumor microenvironment, such as the expression of PD-1. Furthermore, co-inhibitory molecules expressed by tumor cells, immune cells, and stromal cells in the tumor milieu can dominantly attenuate T-cell responses against cancer cells. Thus, a need remains for potent PD-1-binding molecules. In particular, a need exists for potent PD-1-binding molecules having a desirable binding kinetic profile and that antagonize the PD-1/PD-L1 axis by blocking the PD-1/PD-L1 interaction, which could provide improved therapeutic value to patients suffering from cancer or other diseases and conditions. The present invention is directed to these and other goals.

## **Summary**

**[0016]** The present disclosure is directed to PD-1 binding molecules that comprise the PD-1-binding domain of selected anti-PD-1 antibodies capable of binding to both cynomolgus monkey PD-1 and to human PD-1: PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15. The disclosure particularly concerns PD-1 binding molecules that are humanized or chimeric versions of such antibodies, or that comprise PD-1 binding-fragments of such anti-PD-1 antibodies (especially immunoconjugates, diabodies, BiTEs, bispecific antibodies, *etc.*). The disclosure particularly concerns such PD-1-binding molecules that are additionally capable of binding an epitope of a molecule involved in regulating an immune check point that is present on the surface of an immune cell. The present disclosure also pertains to methods of using such PD-1-binding molecules to detect PD-1 or to stimulate an immune response. The present disclosure also pertains to methods of combination therapy in which a PD-1-binding molecule that comprises one or more PD-1-binding domain(s) of such selected anti-PD-1 antibodies is administered in combination with one or more additional molecules that are effective in stimulating an immune response and/or in combination with one or more additional molecules that specifically bind a cancer antigen.

**[0017]** In detail, the disclosure provides an anti-human PD-1-binding molecule that comprises the three Heavy Chain CDR Domains, CDR<sub>H1</sub>, CDR<sub>H2</sub> and CDR<sub>H3</sub> and the three Light Chain CDR Domains, CDR<sub>L1</sub>, CDR<sub>L2</sub>, and CDR<sub>L3</sub>, wherein:

- (A) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 1, and respectively have the amino acid sequences: **SEQ ID NO:71, SEQ ID NO:72, and SEQ ID NO:73**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 1, and respectively have the amino acid sequences: **SEQ ID NO:76, SEQ ID NO:77, and SEQ ID NO:78**;

or

- (B) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 2, and respectively have the amino acid sequences: **SEQ ID NO:85, SEQ ID NO:86, and SEQ ID NO:87**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 2, and, respectively have the amino acid sequences: **SEQ ID NO:90, SEQ ID NO:91, and SEQ ID NO:92**;

or

- (C) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 3, and respectively have the amino acid sequences: **SEQ ID NO:99, SEQ ID NO:100, and SEQ ID NO:101**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 3, and, respectively have the amino acid sequences: **SEQ ID NO:104, SEQ ID NO:105, and SEQ ID NO:106**;

or

- (D) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 4, and respectively have the amino acid sequences: **SEQ ID NO:109, SEQ ID NO:110, and SEQ ID NO:111**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 4, and, respectively have the amino acid sequences: **SEQ ID NO:114, SEQ ID NO:115, and SEQ ID NO:116**;

or

- (E) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 5, and respectively have the amino acid sequences: **SEQ ID NO:119**, **SEQ ID NO:120**, and **SEQ ID NO:121**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 5, and, respectively have the amino acid sequences: **SEQ ID NO:124**, **SEQ ID NO:125**, and **SEQ ID NO:126**;

or

- (F) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 6, and respectively have the amino acid sequences: **SEQ ID NO:129**, **SEQ ID NO:130**, and **SEQ ID NO:131**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 6, and, respectively have the amino acid sequences: **SEQ ID NO:134**, **SEQ ID NO:135**, and **SEQ ID NO:136**;

or

- (G) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 7, and respectively have the amino acid sequences: **SEQ ID NO:139**, **SEQ ID NO:140**, and **SEQ ID NO:141**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 7, and, respectively have the amino acid sequences: **SEQ ID NO:144**, **SEQ ID NO:145**, and **SEQ ID NO:146**;

or

- (H) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 8, and respectively have the amino acid sequences: **SEQ ID NO:161**, **SEQ ID NO:162**, and **SEQ ID NO:163**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 8, and, respectively have the amino acid sequences: **SEQ ID NO:166**, **SEQ ID NO:167**, and **SEQ ID NO:168**;

or

- (I) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 9, and respectively have the amino acid sequences: **SEQ ID NO:171**, **SEQ ID NO:172**, and **SEQ ID NO:173**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 9, and, respectively have the amino acid sequences: **SEQ ID NO:176**, **SEQ ID NO:177**, and **SEQ ID NO:178**;
- or
- (J) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 10, and respectively have the amino acid sequences: **SEQ ID NO:192**, **SEQ ID NO:193**, and **SEQ ID NO:194**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 10, and, respectively have the amino acid sequences: **SEQ ID NO:197**, **SEQ ID NO:198**, and **SEQ ID NO:199**;
- or
- (K) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 11, and respectively have the amino acid sequences: **SEQ ID NO:202**, **SEQ ID NO:203**, and **SEQ ID NO:204**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 11, and, respectively have the amino acid sequences: **SEQ ID NO:207**, **SEQ ID NO:208**, and **SEQ ID NO:209**;
- or
- (L) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 12, and respectively have the amino acid sequences: **SEQ ID NO:212**, **SEQ ID NO:213**, and **SEQ ID NO:214**; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 12, and, respectively have the amino acid sequences: **SEQ ID NO:217**, **SEQ ID NO:218**, and **SEQ ID NO:219**
- or
- (M) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 13, and respectively have the amino

acid sequences: **SEQ ID NO:222**, **SEQ ID NO:223**, and **SEQ ID NO:224**; and

- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 13, and, respectively have the amino acid sequences: **SEQ ID NO:227**, **SEQ ID NO:228**, and **SEQ ID NO:229**;

or

- (N) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 14, and respectively have the amino acid sequences: **SEQ ID NO:232**, **SEQ ID NO:233**, and **SEQ ID NO:234**; and

- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 14, and, respectively have the amino acid sequences: **SEQ ID NO:237**, **SEQ ID NO:238**, and **SEQ ID NO:239**;

or

- (O) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of PD-1 mAb 15, and respectively have the amino acid sequences: **SEQ ID NO:242**, **SEQ ID NO:243**, and **SEQ ID NO:244**; and

- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of PD-1 mAb 15, and, respectively have the amino acid sequences: **SEQ ID NO:247**, **SEQ ID NO:248**, and **SEQ ID NO:249**;

or

- (P) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of hPD-1 mAb 7(1.2), and respectively have the amino acid sequences: **SEQ ID NO:139**, **SEQ ID NO:140**, and **SEQ ID NO:141**; and

- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain are the Light Chain CDRs of hPD-1 mAb 7(1.2), and, respectively have the amino acid sequences: **SEQ ID NO:157**, **SEQ ID NO:145**, and **SEQ ID NO:146**;

or

- (Q) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain are the Heavy Chain CDRs of hPD-1 mAb 7(1.3), and respectively have the

amino acid sequences: **SEQ ID NO:139**, **SEQ ID NO:140**, and **SEQ ID NO:141**; and

- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain are the Light Chain CDRs of hPD-1 mAb 7(1.3), and, respectively have the amino acid sequences: **SEQ ID NO:157**, **SEQ ID NO:158**, and **SEQ ID NO:145**;

or

- (R) (1) the CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain are the Heavy Chain CDRs of hPD-1 mAb 9(2.2), and respectively have the amino acid sequences: **SEQ ID NO:183**, **SEQ ID NO:172**, and **SEQ ID NO:173**; and
- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain are the Light Chain CDRs of hPD-1 mAb 9(2.2), and, respectively have the amino acid sequences: **SEQ ID NO:188**, **SEQ ID NO:189**, and **SEQ ID NO:178**.

**[0017a]** In a first aspect, the present disclosure refers to a multispecific anti-human PD-1-binding molecule that comprises a Variable Heavy Chain Domain and a Variable Light Chain Domain, wherein:

said Variable Heavy Chain Domain comprises the amino acid sequence of **SEQ ID NO:147**, and said Variable Light Chain Domain comprises the amino acid sequence of **SEQ ID NO:153**..

**[0018]** The disclosure further concerns the examples of all such anti-human PD-1-binding molecules wherein the molecule is an antibody, and especially wherein the molecule is a chimeric antibody or a humanized antibody.

**[0019]** The disclosure further concerns the examples of such anti-human PD-1-binding molecules wherein the Heavy Chain Variable Domain has the amino acid sequence of **SEQ ID NO:79**, **SEQ ID NO:93**, **SEQ ID NO:147**, **SEQ ID NO:149**, **SEQ ID NO:179**, **SEQ ID NO:181**, or **SEQ ID NO:250**.

**[0020]** The disclosure further concerns the examples of such anti-human PD-1-binding molecules wherein the Light Chain Variable Domain has the amino acid sequence of **SEQ ID NO:81**, **SEQ ID NO:95**, **SEQ ID NO:151**, **SEQ ID NO:153**, **SEQ ID NO:155**, **SEQ ID NO:184**, **SEQ ID NO:186**, or **SEQ ID NO:251**.

**[0021]** The disclosure further concerns the example wherein the anti-human PD-1-binding molecule is a bispecific binding molecule, capable of simultaneously binding to human PD-1 and to a second epitope, and particularly concerns the example wherein the second epitope is an epitope of a molecule involved in regulating an immune check point present on the surface of an immune cell (especially wherein the second epitope is an epitope of B7-H3,

B7-H4, BTLA, CD40, CD40L, CD47, CD70, CD80, CD86, CD94, CD137, CD137L, CD226, CTLA-4, Galectin-9, GITR, GITRL, HHLA2, ICOS, ICOSL, KIR, LAG-3, LIGHT, MHC class I or II, NKG2a, NKG2d, OX40, OX40L, PD1H, PD-1, PD-L1, PD-L2, PVR, SIRPa, TCR, TIGIT, TIM-3 or VISTA, and most particularly wherein the second epitope is an epitope of CD137, CTLA-4, LAG-3, OX40, TIGIT, or TIM-3).

**[0022]** The disclosure further concerns the examples wherein the anti-human PD-1-binding molecule is a bispecific molecule comprising a LAG-3 epitope-binding site, particularly wherein the LAG-3 epitope-binding site comprises:

- (A) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain of the Variable Heavy Chain of LAG-3 mAb 1, having the amino acid sequences: **SEQ ID NO:42**, **SEQ ID NO:43**, and **SEQ ID NO:44**, respectively; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain of the Variable Light Chain of LAG-3 mAb 1, having the amino acid sequences: **SEQ ID NO:46**, **SEQ ID NO:47**, and **SEQ ID NO:48**, respectively;

or

- (B) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain of the Variable Heavy Chain of hLAG-3 mAb 1 VH1, having the amino acid sequences: **SEQ ID NO:42**, **SEQ ID NO:43**, and **SEQ ID NO:44**, respectively; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain of the Variable Light Chain of hLAG-3 mAb 1 VL4, having the amino acid sequences: **SEQ ID NO:55**, **SEQ ID NO:47**, and **SEQ ID NO:48**, respectively;

or

- (C) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain of the Variable Heavy Chain of LAG-3 mAb 6, having the amino acid sequences: **SEQ ID NO:57**, **SEQ ID NO:58**, and **SEQ ID NO:59**, respectively; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain of the Variable Light Chain of LAG-3 mAb 6, having the amino acid

sequences: **SEQ ID NO:61**, **SEQ ID NO:62**, and **SEQ ID NO:63**, respectively;

or

- (D) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain of the Variable Heavy Chain of hLAG-3 mAb 6 VH1, having the amino acid sequences: **SEQ ID NO:57**, **SEQ ID NO:58**, and **SEQ ID NO:59**, respectively; and
- (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain of the Variable Light Chain of LAG-3 mAb 6, having the amino acid sequences: **SEQ ID NO:298**, **SEQ ID NO:62**, and **SEQ ID NO:63**, respectively.

**[0023]** The disclosure further concerns the example of such anti-human PD-1-binding molecules wherein the molecule is a diabody, and especially, wherein the diabody is a covalently bonded complex that comprises two, or three, or four, or five polypeptide chains. The disclosure further concerns the example of such anti-human PD-1-binding molecules wherein the molecule is a trivalent binding molecule, and especially wherein the trivalent binding molecule is a covalently bonded complex that comprises three, four, five or more than five polypeptide chains. The disclosure additionally concerns the example of such anti-human PD-1-binding molecules in which the molecule comprises an Fc Region. The disclosure additionally concerns the example of such anti-human PD-1-binding molecules in which the molecule comprises an Albumin-Binding Domain, and especially a deimmunized Albumin-Binding Domain.

**[0024]** The disclosure further concerns the examples of all such anti-human PD-1-binding molecules wherein the molecule comprises an Fc Region, and wherein the Fc Region is a variant Fc Region that comprises one or more amino acid modifications that reduces the affinity of the variant Fc Region for an FcγR and/or enhances the serum half-life, and more particularly, wherein the modifications comprise at least one amino acid substitution selected from the group consisting of:

- (1) L234A; L235A;
- (2) L234A and L235A;
- (3) M252Y; M252Y and S254T;
- (4) M252Y and T256E;

- (5) M252Y, S254T and T256E; or  
(6) K288D and H435K;

wherein the numbering is that of the EU index as in Kabat.

**[0024a]** In a second aspect, the present disclosure refers to a composition comprising:

- (A) the multispecific anti-human PD-1-binding molecule of the first aspect; and  
(B) a pharmaceutically acceptable carrier.

**[0025]** The disclosure further concerns the examples in which any of the above-described PD-1-binding molecules is used to stimulate a T-cell mediate immune response. The disclosure additionally concerns the examples in which any of the above-described PD-1-binding molecules is used in the treatment of a disease or condition associated with a suppressed immune system, especially cancer or an infection.

**[0025a]** In a third aspect, the present disclosure refers to the multispecific anti-human PD-1-binding molecule of the first aspect, or the composition of the second aspect, for use in:

- (A) a method of stimulating a T-cell mediated immune response of a subject in need thereof; or  
(B) the treatment of a disease or condition associated with a suppressed immune system.

**[0025b]** In a fourth aspect, the present disclosure refers to use of the multispecific anti-human PD-1-binding molecule of the first aspect or the composition of the second aspect in the manufacture of a medicament for treatment of a cancer or an infection.

**[0026]** The disclosure particularly concerns such use in the treatment or diagnosis or prognosis of cancer, wherein the cancer is characterized by the presence of a cancer cell selected from the group consisting of a cell of: an adrenal gland tumor, an AIDS-associated cancer, an alveolar soft part sarcoma, an astrocytic tumor, bladder cancer, bone cancer, a brain and spinal cord cancer, a metastatic brain tumor, a breast cancer, a carotid body tumors, a cervical cancer, a chondrosarcoma, a chordoma, a chromophobe renal cell carcinoma, a clear cell carcinoma, a colon cancer, a colorectal cancer, a cutaneous benign fibrous histiocytoma, a desmoplastic small round cell tumor, an ependymoma, a Ewing's tumor, an extraskeletal myxoid chondrosarcoma, a fibrogenesis imperfecta ossium, a fibrous dysplasia of the bone, a gallbladder or bile duct cancer, gastric cancer, a gestational trophoblastic disease, a germ cell tumor, a head and neck cancer, hepatocellular carcinoma, an islet cell tumor, a Kaposi's Sarcoma, a kidney cancer, a leukemia, a lipoma/benign lipomatous tumor, a liposarcoma/malignant lipomatous tumor, a liver cancer, a lymphoma, a lung cancer, a medulloblastoma, a melanoma, a meningioma, a multiple endocrine neoplasia, a multiple myeloma, a myelodysplastic syndrome, a neuroblastoma, a neuroendocrine tumors, an ovarian cancer, a pancreatic cancer, a papillary thyroid carcinoma, a parathyroid tumor, a pediatric cancer, a peripheral nerve sheath tumor, a pheochromocytoma, a pituitary tumor, a prostate cancer, a posterior uveal melanoma, a rare hematologic disorder, a renal metastatic cancer, a rhabdoid tumor, a rhabdomyosarcoma, a sarcoma, a skin cancer, a soft-tissue sarcoma, a squamous cell cancer, a stomach cancer, a synovial sarcoma, a testicular cancer, a thymic carcinoma, a thymoma, a thyroid metastatic cancer, and a uterine cancer.

**[0027]** The disclosure particularly concerns such use in the treatment or diagnosis or prognosis of cancer, wherein the cancer is colorectal cancer, hepatocellular carcinoma, glioma, kidney cancer, breast cancer, multiple myeloma, bladder cancer, neuroblastoma; sarcoma, non-

Hodgkin's lymphoma, non-small cell lung cancer, ovarian cancer, pancreatic cancer, a rectal cancer, acute myeloid leukemia (AML), chronic myelogenous leukemia (CML), acute B lymphoblastic leukemia (B-ALL), chronic lymphocytic leukemia (CLL), hairy cell leukemia (HCL), blastic plasmacytoid dendritic cell neoplasm (BPDCN), non-Hodgkin's lymphomas (NHL), including mantle cell leukemia (MCL), and small lymphocytic lymphoma (SLL), Hodgkin's lymphoma, systemic mastocytosis, or Burkitt's lymphoma.

**[0028]** The disclosure further concerns the examples in which any of the above-described PD-1-binding molecules is detectably labeled and is used in the detection of PD-1.

**[0028a]** In a fifth aspect, the present disclosure refers to use of the multispecific anti-human PD-1-binding molecule of the first aspect in the *in vitro* detection of PD-1, wherein said molecule is detectably labeled.

### **Brief Description of the Drawings**

**[0029]** **Figure 1** provides a schematic of a representative covalently bonded diabody having two epitope-binding sites composed of two polypeptide chains, each having an E-coil or K-coil Heterodimer-Promoting Domain. A cysteine residue may be present in a linker and/or in the Heterodimer-Promoting Domain as shown in **Figure 3B**. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern.

**[0030]** **Figure 2** provides a schematic of a representative covalently bonded diabody molecule having two epitope-binding sites composed of two polypeptide chains, each having a CH2 and CH3 Domain, such that the associated chains form all or part of an Fc Region. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern.

**[0031]** **Figures 3A-3C** provide schematics showing representative tetravalent diabodies having four epitope-binding sites composed of two pairs of polypeptide chains (*i.e.*, four polypeptide chains in all). One polypeptide of each pair possesses a CH2 and CH3 Domain, such that the associated chains form all or part of an Fc Region. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern. The two pairs of polypeptide chains may be same. In such embodiments wherein the VL and VH Domains recognize different epitopes (as shown in **Figures 3A-3C**), the resulting molecule possesses four epitope-binding sites and is bispecific and bivalent with respect to each bound epitope. In such embodiments wherein the VL and VH Domains recognize the same epitope (*e.g.*, the same VL Domain CDRs and the same VH Domain CDRs are used on both chains), the resulting molecule possesses four epitope-binding sites and is monospecific and tetravalent with respect to a single epitope. Alternatively, the two pairs of polypeptides may be different. In such

embodiments wherein the VL and VH Domains of each pair of polypeptides recognize different epitopes (as shown in **Figures 3A-3C**), the resulting molecule possesses four epitope-binding sites and is tetraspecific and monovalent with respect to each bound epitope. **Figure 3A** shows an Fc diabody which contains a peptide Heterodimer-Promoting Domain comprising a cysteine residue. **Figure 3B** shows an Fc Region-containing diabody, which contains E-coil and K-coil Heterodimer-Promoting Domains comprising a cysteine residue and a linker (with an optional cysteine residue). **Figure 3C**, shows an Fc-Region-Containing diabody, which contains antibody CH1 and CL domains.

**[0032] Figures 4A and 4B** provide schematics of a representative covalently bonded diabody molecule having two epitope-binding sites composed of three polypeptide chains. Two of the polypeptide chains possess a CH2 and CH3 Domain, such that the associated chains form all or part of an Fc Region. The polypeptide chains comprising the VL and VH Domain further comprise a Heterodimer-Promoting Domain. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern.

**[0033] Figure 5** provides the schematics of a representative covalently bonded diabody molecule having four epitope-binding sites composed of five polypeptide chains. Two of the polypeptide chains possess a CH2 and CH3 Domain, such that the associated chains form an Fc Region that comprises all or part of an Fc Region. The polypeptide chains comprising the linked VL and VH Domains further comprise a Heterodimer-Promoting Domain. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern.

**[0034] Figures 6A-6F** provide schematics of representative Fc Region-containing trivalent binding molecules having three epitope-binding sites. **Figures 6A and 6B**, respectively, illustrate schematically the domains of trivalent binding molecules comprising two diabody-type binding domains and a Fab-type binding domain having different domain orientations in which the diabody-type binding domains are N-terminal or C-terminal to an Fc Region. The molecules in **Figures 6A and 6B** comprise four chains. **Figures 6C and 6D**, respectively, illustrate schematically the domains of trivalent binding molecules comprising two diabody-type binding domains N-terminal to an Fc Region, and a Fab-type binding domain in which the light chain and heavy chain are inked via a polypeptide spacer, or an scFv-type binding domain. The trivalent binding molecules in **Figures 6E and 6F**, respectively illustrate schematically the domains of trivalent binding molecules comprising two diabody-type binding domains C-terminal to an Fc Region, and a linked Fab-type binding domain, or an scFv-type binding

domain in which the diabody-type binding domains are. The trivalent binding molecules in **Figures 6C-6F** comprise three chains. VL and VH Domains that recognize the same epitope are shown using the same shading or fill pattern.

**[0035]** **Figures 7A-7D** shows that the anti-PD-1 antibodies PD-1 mAb 1-15 bind to human PD-1. Binding curves for binding to shPD-1-His are shown in **Figure 7A** (PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 4 and PD-1 mAb 9), **Figure 7B** (PD-1 mAb 5, PD-1 mAb 6, and PD-1 mAb 7), and **Figure 7C** (PD-1 mAb 3, PD-1 mAb 8, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and PD-1 mAb 15). Binding curves for binding to shPD-1-human Fc are shown in **Figure 7D** (PD-1 mAb 3, PD-1 mAb 8, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and PD-1 mAb 15).

**[0036]** **Figures 8A-8C** shows that the anti-PD-1 antibodies PD-1 mAb 1-15 bind to cynomolgus monkey PD-1. Binding curves for binding to scynoPD-1-hFc are shown in **Figure 8A** (PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7), **Figure 8B** (PD-1 mAb 9), and **Figure 8C** (PD-1 mAb 3, PD-1 mAb 8, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and PD-1 mAb 15).

**[0037]** **Figures 9A-9D** show the ability of the anti-PD-1 antibodies PD-1 mAb 1-15 to block the binding of human PD-L1 to human PD-1. Inhibition curves are shown in **Figure 9A** (PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 15, and PD-1 mAb A), **Figure 9B** (PD-1 mAb 4), **Figure 9C** (PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, and PD-1 mAb A), and **Figure 9D** (PD-1 mAb 3, PD-1 mAb 8, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, PD-1 mAb 15, and PD-1 mAb A).

**[0038]** **Figures 10A-10B** show the tissue specificity of the anti-human PD-1 antibody PD-1 mAb 7. **Figure 10A** shows histological stains of normal colon (**Panels i and vii**), liver (**Panels ii and viii**), lung (**Panels iii and ix**), pancreas (**Panels iv and x**), kidney (**Panels v and xi**) and heart (**Panels vi and xii**) tissue. **Figure 10A, Panels i-vi** show the results of tissue incubated with labeled PD-1 mAb 7 (0.313 µg/mL). **Figure 10A, Panels vii-xii** show the results of tissue incubated with labeled isotype control mAb (0.314 µg/mL). **Figure 10B** shows histological stains of skin (**Panels i and iv**), tonsils (**Panels ii and v**), and NSO cells expressing PD-1 (**Panels iii and vi**). **Figure 10B, Panels i-iii** show the results of tissue incubated with labeled PD-1 mAb 7 (0.313 µg/mL).

[0039] **Figure 11** shows the binding profiles of humanized anti-human PD-1 antibodies hPD-1 mAb 2, hPD-1 mAb 7(1.1), hPD-1 mAb 7(1.2), hPD-1 mAb 9(1.1), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B having IgG1 (AA) or IgG4 (P) for binding to cell surface PD-1.

[0040] **Figures 12A-12B** show the ability of humanized anti-PD antibodies hPD-1 mAb 2, hPD-1 mAb 7(1.1), hPD-1 mAb 7(1.2), hPD-1 mAb 9(1.1), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B, having IgG1 (AA) or IgG4 (P) to block the binding of soluble human PD-L1 (**Figure 12A**) and soluble human PD-L2 (**Figure 12B**) to cell surface human PD-1.

[0041] **Figure 13** shows the ability of humanized anti-PD antibodies hPD-1 mAb 2, hPD-1 mAb 7(1.1), hPD-1 mAb 7(1.2), hPD-1 mAb 9(1.1), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B, having IgG1 (AA) or IgG4 (P) to antagonize the PD-1/PD-L1 axis by blocking the PD-1/PD-L1 interaction and preventing down-regulation of T-cell responses in a Jurkat-luc-NFAT / CHO-PD-L1 luciferase reporter assay.

[0042] **Figure 14** shows that PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9 and PD-1 mAb 15 are able to stimulate cytokine production to levels comparable or higher than the referenced anti-PD-1 antibodies (PD-1 mAb A and PD-1 mAb B) and that treatment with PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9 and PD-1 mAb 15 in combination with LAG-3 mAb 1 provided the largest enhancement of cytokine release. IFN $\gamma$  secretion profiles from *Staphylococcal* enterotoxin B (SEB)-stimulated PBMCs treated with anti-PD-1 and anti-LAG-3 antibodies alone and in combination.

[0043] **Figures 15A-15B** show the ability of humanized anti-PD antibodies hPD-1 mAb 2, hPD-1 mAb 7(1.2), hPD-1 mAb 9(1.1), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B, having IgG1 (AA) or IgG4 (P) to stimulate cytokine production. IFN $\gamma$  (**Figure 15A**) and TNF $\alpha$  (**Figure 15B**), secretion profiles from SEB-stimulated PBMCs treated with anti-PD-1 antibodies.

[0044] **Figures 16A-16B** show that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART A, DART D, DART E, DART F, DART G and DART H, are able to stimulate cytokine production to levels comparable or higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A + LAG-3 mAb A), and that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART A, DART D, DART E, DART

F and DART G provided the largest enhancement of cytokine release. IFN $\gamma$  secretion profiles of PBMCs stimulated with a low concentration of SEB (0.2 ng/mL) treated with PD-1  $\times$  LAG-3 bispecific diabodies, or anti-PD-1 and anti-LAG-3 antibodies alone and in combination are plotted. The results using PBMCs from two representative donors are shown in **Figure 16A** and **Figure 16B**.

[0045] **Figures 17A-17B** show that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART A, DART B and DART C are able to stimulate cytokine production to levels higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A + LAG-3 mAb A). IFN $\gamma$  secretion profiles of PBMCs from two representative donors, stimulated with a high concentration of SEB (85 ng/mL) treated with PD-1  $\times$  LAG-3 bispecific diabodies, or anti-PD-1 and anti-LAG-3 antibodies alone and in combination are plotted. The results using PBMCs from two representative donors are shown in **Figure 17A** and **Figure 17B**.

[0046] **Figures 18A-18B** show that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART A, DART B and DART C are able to stimulate cytokine production to levels higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A + LAG-3 mAb A). IFN $\gamma$  secretion profiles of PBMCs from two representative donors, stimulated with a middle concentration of SEB (0.5 ng/mL) treated with PD-1  $\times$  LAG-3 bispecific diabodies, or anti-PD-1 and anti-LAG-3 antibodies alone and in combination are plotted. The results using PBMCs from two representative donors are shown in **Figure 18A** and **Figure 18B**.

[0047] **Figure 19** shows that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART D and DART H are able to stimulate cytokine production to levels comparable or higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A + LAG-3 mAb A), and that DART D provided the largest enhancement of cytokine release. IL-2 secretion profiles of PBMCs from a representative donor stimulated with a high concentration of SEB (85 ng/mL) treated with PD-1  $\times$  LAG-3 bispecific diabodies, or anti-PD-1 and anti-LAG-3 antibodies alone and in combination are plotted.

[0048] **Figure 20** shows that the PD-1  $\times$  LAG-3 bispecific diabody constructs DART B and DART I are able to stimulate cytokine production to levels higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A

+ LAG-3 mAb A, hPD-1 mAb 7(1.2) + hLAG-3 mAb 1(1.4), hPD-1 mAb 7(1.2) + hLAG-3 mAb 6(1.1)). IFN $\gamma$  secretion profiles of PBMCs from a representative donor, stimulated with a middle concentration of SEB (0.5 ng/mL) treated with PD-1  $\times$  LAG-3 bispecific diabodies, or anti-PD-1 and anti-LAG-3 antibodies alone and in combination are plotted.

**[0049]** **Figures 21A-21D** show that the that the PD-1  $\times$  LAG-3 bispecific diabody DART I is able to stimulate cytokine production to levels higher than that observed upon the administration of the combination of an anti-PD-1 mAb + an anti-LAG-3 mAb (PD-1 mAb A + LAG-3 mAb A). IFN $\gamma$  (**Figures 21A and 21C**) and IL-2 (**Figures 21B and 21D**) secretion profiles of CD4 memory cells from two representative donors, stimulated with tetanus toxoid (5  $\mu$ g/mL) treated with the PD-1  $\times$  LAG-3 bispecific diabody DART-I, anti-PD-1 and anti-LAG-3 antibodies in combination, or an isotype control are plotted. The results at day 7 using CD4 memory T cells from two representative donors are shown in **Figures 21A-B** and **Figures 21C-D**.

**[0050]** **Figure 22** shows that the the pharmacokinetics of the PD-1  $\times$  LAG-3 bispecific molecule, DART I are comparable to those of the anti-PD-1 antibody, PD-1 mAb A IgG4 (P) in cynomolgus monkey. The lines indicate the mean serum concentration of DART I (solid) and PD-1 mAb A (dashed). The individual values for the male (filled) and female (open) monkeys are plotted for DART I (triangles) and PD-1 mAb A (circles).

**[0051]** **Figures 23A-23C** show serum antibody concentrations and percentage of bound PD-1 on the surface of CD4<sup>+</sup> or CD8<sup>+</sup> T cells over time in animals following treatment with different anti-PD-1 antibodies. The percentage of bound PD 1 on the surface of CD4<sup>+</sup> or CD8<sup>+</sup> T cells following anti-PD 1 mAb treatment is plotted on the right y-axes; symbols represent % bound PD 1 on T cells for each individual animal and dashed lines represent the mean values. Serum mAb concentrations are plotted on the left y-axes; symbols represent serum levels for each individual animal and solid lines represent nonlinear fits of the data. Each panel presents data for animals (n = 1/sex/group) administered 10 mg/kg hPD-1 mAb 7 (1.2) IgG4 (P) (**Figure 23A**), PD-1 mAb A IgG4 (P) (**Figure 23B**), or PD-1 mAb B IgG4 (P) (**Figure 23B**) by IV infusion on Day 1.

### Detailed Description of the Invention

**[0052]** The present invention is directed to PD-1-binding molecules that comprise the PD-1-binding domain of selected anti-PD-1 antibodies capable of binding to both cynomolgus

monkey PD-1 and to human PD-1: PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15. The invention particularly concerns PD-1-binding molecules that are humanized or chimeric versions of such antibodies, or that comprise PD-1-binding fragments of such anti-PD-1 antibodies (especially immunoconjugates, diabodies (including but not limited to DART-A, DART-B, DART-C, DART-D, DART-E, DART-F, DART-G, DART-H, DART-I, and DART-J), BiTEs, bispecific antibodies, *etc.*). The invention particularly concerns such PD-1-binding molecules that are additionally capable of binding an epitope of a molecule involved in regulating an immune check point that is present on the surface of an immune cell. The present invention also pertains to methods of using such PD-1-binding molecules to detect PD-1 or to stimulate an immune response. The present invention also pertains to methods of combination therapy in which a PD-1-binding molecule that comprises one or more PD-1-binding domain(s) of such selected anti-PD-1 antibodies is administered in combination with one or more additional molecules that are effective in stimulating an immune response and/or in combination with one or more additional molecules that specifically bind a cancer antigen.

## **I. Antibodies and Their Binding Domains**

**[0053]** The antibodies of the present invention are immunoglobulin molecules capable of specific binding to a target, such as a carbohydrate, polynucleotide, lipid, polypeptide, *etc.*, through at least one antigen recognition site, located in the Variable Domain of the immunoglobulin molecule. As used herein, the terms “**antibody**” and “**antibodies**” refer to monoclonal antibodies, multispecific antibodies, human antibodies, humanized antibodies, synthetic antibodies, chimeric antibodies, polyclonal antibodies, camelized antibodies, single-chain Fvs (scFv), single-chain antibodies, Fab fragments, F(ab') fragments, disulfide-linked bispecific Fvs (sdFv), intrabodies, and epitope-binding fragments of any of the above. In particular, antibodies include immunoglobulin molecules and immunologically active fragments of immunoglobulin molecules, *i.e.*, molecules that contain an antigen-binding site. Immunoglobulin molecules can be of any type (*e.g.*, IgG, IgE, IgM, IgD, IgA and IgY), class (*e.g.*, IgG<sub>1</sub>, IgG<sub>2</sub>, IgG<sub>3</sub>, IgG<sub>4</sub>, IgA<sub>1</sub> and IgA<sub>2</sub>) or subclass. In addition to their known uses in diagnostics, antibodies have been shown to be useful as therapeutic agents. Antibodies are capable of immunospecifically binding to a polypeptide or protein or a non-protein molecule due to the presence on such molecule of a particular domain or moiety or conformation (an “**epitope**”). An epitope-containing molecule may have immunogenic activity, such that it

elicits an antibody production response in an animal; such molecules are termed “**antigens**”). The last few decades have seen a revival of interest in the therapeutic potential of antibodies, and antibodies have become one of the leading classes of biotechnology-derived drugs (Chan, C.E. *et al.* (2009) “*The Use Of Antibodies In The Treatment Of Infectious Diseases*,” Singapore Med. J. 50(7):663-666). Over 200 antibody-based drugs have been approved for use or are under development.

**[0054]** The term “**monoclonal antibody**” refers to a homogeneous antibody population wherein the monoclonal antibody is comprised of amino acids (naturally occurring and non-naturally occurring) that are involved in the selective binding of an antigen. Monoclonal antibodies are highly specific, being directed against a single epitope (or antigenic site). The term “monoclonal antibody” encompasses not only intact monoclonal antibodies and full-length monoclonal antibodies, but also fragments thereof (such as Fab, Fab', F(ab')<sub>2</sub> Fv), single-chain (scFv), mutants thereof, fusion proteins comprising an antibody portion, humanized monoclonal antibodies, chimeric monoclonal antibodies, and any other modified configuration of the immunoglobulin molecule that comprises an antigen recognition site of the required specificity and the ability to bind to an antigen. It is not intended to be limited as regards to the source of the antibody or the manner in which it is made (*e.g.*, by hybridoma, phage selection, recombinant expression, transgenic animals, *etc.*). The term includes whole immunoglobulins as well as the fragments *etc.* described above under the definition of “antibody.” Methods of making monoclonal antibodies are known in the art. One method which may be employed is the method of Kohler, G. *et al.* (1975) “*Continuous Cultures Of Fused Cells Secreting Antibody Of Predefined Specificity*,” *Nature* 256:495-497 or a modification thereof. Typically, monoclonal antibodies are developed in mice, rats or rabbits. The antibodies are produced by immunizing an animal with an immunogenic amount of cells, cell extracts, or protein preparations that contain the desired epitope. The immunogen can be, but is not limited to, primary cells, cultured cell lines, cancerous cells, proteins, peptides, nucleic acids, or tissue. Cells used for immunization may be cultured for a period of time (*e.g.*, at least 24 hours) prior to their use as an immunogen. Cells may be used as immunogens by themselves or in combination with a non-denaturing adjuvant, such as Ribi (see, *e.g.*, Jennings, V.M. (1995) “*Review of Selected Adjuvants Used in Antibody Production*,” *ILAR J.* 37(3):119-125). In general, cells should be kept intact and preferably viable when used as immunogens. Intact cells may allow antigens to be better detected than ruptured cells by the immunized animal. Use of denaturing or harsh adjuvants, *e.g.*, Freud's adjuvant, may rupture cells and

therefore is discouraged. The immunogen may be administered multiple times at periodic intervals such as, bi-weekly, or weekly, or may be administered in such a way as to maintain viability in the animal (*e.g.*, in a tissue recombinant). Alternatively, existing monoclonal antibodies and any other equivalent antibodies that are immunospecific for a desired pathogenic epitope can be sequenced and produced recombinantly by any means known in the art. In one embodiment, such an antibody is sequenced and the polynucleotide sequence is then cloned into a vector for expression or propagation. The sequence encoding the antibody of interest may be maintained in a vector in a host cell and the host cell can then be expanded and frozen for future use. The polynucleotide sequence of such antibodies may be used for genetic manipulation to generate the monospecific or multispecific (*e.g.*, bispecific, trispecific and tetraspecific) molecules of the invention as well as an affinity optimized, a chimeric antibody, a humanized antibody, and/or a caninized antibody, to improve the affinity, or other characteristics of the antibody. The general principle in humanizing an antibody involves retaining the basic sequence of the antigen-binding portion of the antibody, while swapping the non-human remainder of the antibody with human antibody sequences.

**[0055]** Natural antibodies (such as IgG antibodies) are composed of two **Light Chains** complexed with two **Heavy Chains**. Each light chain contains a Variable Domain (**VL**) and a Constant Domain (**CL**). Each heavy chain contains a Variable Domain (**VH**), three Constant Domains (**CH1**, **CH2** and **CH3**), and a hinge domain located between the **CH1** and **CH2** Domains. The basic structural unit of naturally occurring immunoglobulins (*e.g.*, IgG) is thus a tetramer having two light chains and two heavy chains, usually expressed as a glycoprotein of about 150,000 Da. The amino-terminal (“N-terminal”) portion of each chain includes a Variable Domain of about 100 to 110 or more amino acids primarily responsible for antigen recognition. The carboxy-terminal (“C-terminal”) portion of each chain defines a constant region, with light chains having a single Constant Domain and heavy chains usually having three Constant Domains and a Hinge Domain. Thus, the structure of the light chains of an IgG molecule is n-VL-CL-c and the structure of the IgG heavy chains is n-VH-CH1-H-CH2-CH3-c (where H is the hinge domain, and n and c represent, respectively, the N-terminus and the C-terminus of the polypeptide). The Variable Domains of an IgG molecule consist of the complementarity determining regions (**CDR**), which contain the residues in contact with epitope, and non-CDR segments, referred to as framework segments (**FR**), which in general maintain the structure and determine the positioning of the CDR loops so as to permit such contacting (although certain framework residues may also contact antigen). Thus, the VL and

VH Domains have the structure n-FR1-CDR1-FR2-CDR2-FR3-CDR3-FR4-c. Polypeptides that are (or may serve as) the first, second and third CDR of an antibody Light Chain are herein respectively designated **CDR<sub>L</sub>1 Domain**, **CDR<sub>L</sub>2 Domain**, and **CDR<sub>L</sub>3 Domain**. Similarly, polypeptides that are (or may serve as) the first, second and third CDR of an antibody heavy chain are herein respectively designated **CDR<sub>H</sub>1 Domain**, **CDR<sub>H</sub>2 Domain**, and **CDR<sub>H</sub>3 Domain**. Thus, the terms CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, CDR<sub>L</sub>3 Domain, CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain are directed to polypeptides that when incorporated into a protein cause that protein to be able to bind to a specific epitope regardless of whether such protein is an antibody having light and heavy chains or a diabody or a single-chain binding molecule (*e.g.*, an scFv, a BiTe, *etc.*), or is another type of protein. Accordingly, as used herein, the term “**epitope-binding fragment**” means a fragment of an antibody capable of immunospecifically binding to an epitope, and the term “**epitope-binding site**” refers to that portion of a molecule comprising an epitope-binding fragment that is responsible for epitope binding. An epitope-binding site may contain 1, 2, 3, 4, 5 or all 6 of the CDR Domains of such antibody and, although capable of immunospecifically binding to such epitope, may exhibit an immunospecificity, affinity or selectivity toward such epitope that differs from that of such antibody. Preferably, however, an epitope-binding fragment will contain all 6 of the CDR Domains of such antibody. An epitope-binding fragment of an antibody may be a single polypeptide chain (*e.g.*, an scFv), or may comprise two or more polypeptide chains, each having an amino terminus and a carboxy terminus (*e.g.*, a diabody, a Fab fragment, an F(ab')<sub>2</sub> fragment, *etc.*).

[0056] The invention particularly encompasses single-chain Variable Domain fragments (“**scFv**”) of the anti-PD-1 antibodies of this invention and multispecific binding molecules comprising the same. Single-chain Variable Domain fragments are made by linking Light and/or Heavy chain Variable Domain by using a short linking peptide. Bird *et al.* (1988) (“*Single-Chain Antigen-Binding Proteins*,” Science 242:423-426) describes example of linking peptides which bridge approximately 3.5 nm between the carboxy terminus of one Variable Domain and the amino terminus of the other Variable Domain. Linkers of other sequences have been designed and used (Bird *et al.* (1988) “*Single-Chain Antigen-Binding Proteins*,” Science 242:423-426). Linkers can in turn be modified for additional functions, such as attachment of drugs or attachment to solid supports. The single-chain variants can be produced either recombinantly or synthetically. For synthetic production of scFv, an automated synthesizer can be used. For recombinant production of scFv, a suitable plasmid containing polynucleotide

that encodes the scFv can be introduced into a suitable host cell, either eukaryotic, such as yeast, plant, insect or mammalian cells, or prokaryotic, such as *E. coli*. Polynucleotides encoding the scFv of interest can be made by routine manipulations such as ligation of polynucleotides. The resultant scFv can be isolated using standard protein purification techniques known in the art.

[0057] The invention also particularly encompasses humanized variants of the anti-PD-1 antibodies of the invention and multispecific binding molecules comprising the same. The term “**humanized**” antibody refers to a chimeric molecule, generally prepared using recombinant techniques, having an antigen-binding site of an immunoglobulin from a non-human species and a remaining immunoglobulin structure of the molecule that is based upon the structure and /or sequence of a human immunoglobulin. The anti-human PD-1 antibodies of the present invention include humanized, chimeric or caninized variants of antibodies PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15. The polynucleotide sequence of the variable domains of such antibodies may be used for genetic manipulation to generate such derivatives and to improve the affinity, or other characteristics of such antibodies. The general principle in humanizing an antibody involves retaining the basic sequence of the antigen-binding portion of the antibody, while swapping the non-human remainder of the antibody with human antibody sequences. There are four general steps to humanize a monoclonal antibody. These are: (1) determining the nucleotide and predicted amino acid sequence of the starting antibody light and heavy variable domains (2) designing the humanized antibody or caninized antibody, *i.e.*, deciding which antibody framework region to use during the humanizing or canonizing process (3) the actual humanizing or caninizing methodologies/techniques and (4) the transfection and expression of the humanized antibody. See, for example, U.S. Patents Nos. 4,816,567; 5,807,715; 5,866,692; and 6,331,415.

[0058] The antigen-binding site may comprise either a complete Variable Domain fused to a Constant Domain or only the complementarity determining regions (CDRs) of such Variable Domain grafted to appropriate framework regions. Antigen-binding sites may be wild-type or modified by one or more amino acid substitutions. This eliminates the constant region as an immunogen in human individuals, but the possibility of an immune response to the foreign variable domain remains (LoBuglio, A.F. *et al.* (1989) “*Mouse/Human Chimeric Monoclonal*

*Antibody In Man: Kinetics And Immune Response*,” Proc. Natl. Acad. Sci. (U.S.A.) 86:4220-4224). Another approach focuses not only on providing human-derived constant regions, but modifying the variable domains as well so as to reshape them as closely as possible to human form. It is known that the variable domains of both heavy and light chains contain three complementarity determining regions (CDRs) which vary in response to the antigens in question and determine binding capability, flanked by four framework regions (FRs) which are relatively conserved in a given species and which putatively provide a scaffolding for the CDRs. When non-human antibodies are prepared with respect to a particular antigen, the variable domains can be “reshaped” or “humanized” by grafting CDRs derived from non-human antibody on the FRs present in the human antibody to be modified. Application of this approach to various antibodies has been reported by Sato, K. *et al.* (1993) Cancer Res 53:851-856; Riechmann, L. *et al.* (1988) “*Reshaping Human Antibodies for Therapy*,” Nature 332:323-327; Verhoeven, M. *et al.* (1988) “*Reshaping Human Antibodies: Grafting An Antilysozyme Activity*,” Science 239:1534-1536; Kettleborough, C. A. *et al.* (1991) “*Humanization Of A Mouse Monoclonal Antibody By CDR-Grafting: The Importance Of Framework Residues On Loop Conformation*,” Protein Engineering 4:773-3783; Maeda, H. *et al.* (1991) “*Construction Of Reshaped Human Antibodies With HIV-Neutralizing Activity*,” Human Antibodies Hybridoma 2:124-134; Gorman, S. D. *et al.* (1991) “*Reshaping A Therapeutic CD4 Antibody*,” Proc. Natl. Acad. Sci. (U.S.A.) 88:4181-4185; Tempest, P.R. *et al.* (1991) “*Reshaping A Human Monoclonal Antibody To Inhibit Human Respiratory Syncytial Virus Infection in vivo*,” Bio/Technology 9:266-271; Co, M. S. *et al.* (1991) “*Humanized Antibodies For Antiviral Therapy*,” Proc. Natl. Acad. Sci. (U.S.A.) 88:2869-2873; Carter, P. *et al.* (1992) “*Humanization Of An Anti-p185her2 Antibody For Human Cancer Therapy*,” Proc. Natl. Acad. Sci. (U.S.A.) 89:4285-4289; and Co, M.S. *et al.* (1992) “*Chimeric And Humanized Antibodies With Specificity For The CD33 Antigen*,” J. Immunol. 148:1149-1154. In some embodiments, humanized antibodies preserve all CDR sequences (for example, a humanized mouse antibody which contains all six CDRs from the mouse antibodies). In other embodiments, humanized antibodies have one or more CDRs (one, two, three, four, five, or six) which differ in sequence relative to the original antibody.

**[0059]** A number of “humanized” antibody molecules comprising an antigen-binding site derived from a non-human immunoglobulin have been described, including chimeric antibodies having rodent or modified rodent Variable Domain and their associated complementarity determining regions (CDRs) fused to human Constant Domains (see, for

example, Winter *et al.* (1991) “*Man-made Antibodies*,” *Nature* 349:293-299; Lobuglio *et al.* (1989) “*Mouse/Human Chimeric Monoclonal Antibody In Man: Kinetics And Immune Response*,” *Proc. Natl. Acad. Sci. (U.S.A.)* 86:4220-4224 (1989), Shaw *et al.* (1987) “*Characterization Of A Mouse/Human Chimeric Monoclonal Antibody (17-1A) To A Colon Cancer Tumor-Associated Antigen*,” *J. Immunol.* 138:4534-4538, and Brown *et al.* (1987) “*Tumor-Specific Genetically Engineered Murine/Human Chimeric Monoclonal Antibody*,” *Cancer Res.* 47:3577-3583). Other references describe rodent CDRs grafted into a human supporting framework region (FR) prior to fusion with an appropriate human antibody Constant Domain (see, for example, Riechmann, L. *et al.* (1988) “*Reshaping Human Antibodies for Therapy*,” *Nature* 332:323-327; Verhoeyen, M. *et al.* (1988) “*Reshaping Human Antibodies: Grafting An Antilysozyme Activity*,” *Science* 239:1534-1536; and Jones *et al.* (1986) “*Replacing The Complementarity-Determining Regions In A Human Antibody With Those From A Mouse*,” *Nature* 321:522-525). Another reference describes rodent CDRs supported by recombinantly veneered rodent framework regions. See, for example, European Patent Publication No. 519,596. These “humanized” molecules are designed to minimize unwanted immunological response towards rodent anti-human antibody molecules, which limits the duration and effectiveness of therapeutic applications of those moieties in human recipients. Other methods of humanizing antibodies that may also be utilized are disclosed by Daugherty *et al.* (1991) “*Polymerase Chain Reaction Facilitates The Cloning, CDR-Grafting, And Rapid Expression Of A Murine Monoclonal Antibody Directed Against The CD18 Component Of Leukocyte Integrins*,” *Nucl. Acids Res.* 19:2471-2476 and in U.S. Patents Nos. 6,180,377; 6,054,297; 5,997,867; and 5,866,692.

## II. Fcγ Receptors (FcγRs)

[0060] The CH2 and CH3 Domains of the two heavy chains interact to form the **Fc Region**, which is a domain that is recognized by cellular **Fc Receptors**, including but not limited to Fc gamma Receptors (**FcγRs**). As used herein, the term “Fc Region” is used to define a C-terminal region of an IgG heavy chain. The amino acid sequence of the CH2-CH3 Domain of an exemplary human IgG1 is (**SEQ ID NO:1**):

|            |            |            |            |            |            |
|------------|------------|------------|------------|------------|------------|
| 231        | 240        | 250        | 260        | 270        | 280        |
| APELLGGPSV | FLFPPKPKDT | LMISRTPEVT | CVVVDVSHED | PEVKFNWYVD |            |
|            | 290        | 300        | 310        | 320        | 330        |
|            | GVEVHNAKTK | PREEQYNSTY | RVVSVLTVLH | QDWLNGKEYK | CKVSNKALPA |

340                      350                      360                      370                      380  
 PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLTCLVK GFYPSDIAVE  
 390                      400                      410                      420                      430  
 WESNGQPENN YKTTTPVLDS DGSFFLYSKL TVDKSRWQQG NVFSCSVMHE  
 440                      447  
 ALHNHYTQKS LSLSPGX

as numbered by the EU index as set forth in Kabat, wherein, **X** is a lysine (K) or is absent.

**[0061]** The amino acid sequence of the CH2-CH3 Domain of an exemplary human IgG2 is (SEQ ID NO:2):

231                      240                      250                      260                      270                      280  
 APPVA-GPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVQFNWYVD  
 290                      300                      310                      320                      330  
 GVEVHNAKTK PREEQFNSTF RVVSVLTVVH QDWLNGKEYK CKVSNKGLPA  
 340                      350                      360                      370                      380  
 PIEKTISKTK GQPREPQVYT LPPSREEMTK NQVSLTCLVK GFYPSDISVE  
 390                      400                      410                      420                      430  
 WESNGQPENN YKTTTPMLDS DGSFFLYSKL TVDKSRWQQG NVFSCSVMHE  
 440                      447  
 ALHNHYTQKS LSLSPGX

as numbered by the EU index as set forth in Kabat, wherein, **X** is a lysine (K) or is absent.

**[0062]** The amino acid sequence of the CH2-CH3 Domain of an exemplary human IgG3 is (SEQ ID NO:3):

231                      240                      250                      260                      270                      280  
 APELLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVQFKWYVD  
 290                      300                      310                      320                      330  
 GVEVHNAKTK PREEQYNSTF RVVSVLTVLH QDWLNGKEYK CKVSNKALPA  
 340                      350                      360                      370                      380  
 PIEKTISKTK GQPREPQVYT LPPSREEMTK NQVSLTCLVK GFYPSDIAVE  
 390                      400                      410                      420                      430  
 WESSGQPENN YNTTPMLDS DGSFFLYSKL TVDKSRWQQG NIFSCSVMHE  
 440                      447  
 ALHNRFTQKS LSLSPGX

as numbered by the EU index as set forth in Kabat, wherein, **X** is a lysine (K) or is absent.

**[0063]** The amino acid sequence of the CH2-CH3 Domain of an exemplary human IgG4 is (SEQ ID NO:4):

```

231      240      250      260      270      280
APEFLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSQED PEVQFNWYVD

      290      300      310      320      330
GVEVHNAKTK PREEQFNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKGLPS

      340      350      360      370      380
SIEKTISKAK GQPREPQVYT LPPSQEEMTK NQVSLTCLVK GFYPSDIAVE

      390      400      410      420      430
WESNGQPENN YKTTTPVLDS DGSFFLYSRL TVDKSRWQEG NVFSCSVMHE

      440      447
ALHNHYTQKS LSLSLGX

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as numbered by the EU index as set forth in Kabat, wherein, **X** is a lysine (K) or is absent.

**[0064]** Throughout the present specification, the numbering of the residues in the constant region of an IgG heavy chain is that of the EU index as in Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5<sup>th</sup> Ed. Public Health Service, NH1, MD (1991) (“Kabat”), expressly incorporated herein by references. The term “EU index as in Kabat” refers to the numbering of the human IgG1 EU antibody. Amino acids from the Variable Domains of the mature heavy and light chains of immunoglobulins are designated by the position of an amino acid in the chain. Kabat described numerous amino acid sequences for antibodies, identified an amino acid consensus sequence for each subgroup, and assigned a residue number to each amino acid, and the CDRs are identified as defined by Kabat (it will be understood that CDR<sub>H1</sub> as defined by Chothia, C. & Lesk, A. M. ((1987) “*Canonical structures for the hypervariable regions of immunoglobulins*,” J. Mol. Biol. 196:901-917) begins five residues earlier). Kabat’s numbering scheme is extendible to antibodies not included in his compendium by aligning the antibody in question with one of the consensus sequences in Kabat by reference to conserved amino acids. This method for assigning residue numbers has become standard in the field and readily identifies amino acids at equivalent positions in different antibodies, including chimeric or humanized variants. For example, an amino acid at position 50 of a human antibody light chain occupies the equivalent position to an amino acid at position 50 of a mouse antibody light chain.

**[0065]** Polymorphisms have been observed at a number of different positions within antibody constant regions (*e.g.*, CH1 positions, including but not limited to positions 192, 193, and 214; Fc positions, including but not limited to positions 270, 272, 312, 315, 356, and 358 as numbered by the EU index as set forth in Kabat), and thus slight differences between the presented sequence and sequences in the prior art can exist. Polymorphic forms of human immunoglobulins have been well-characterized. At present, 18 Gm allotypes are known: G1m (1, 2, 3, 17) or G1m (a, x, f, z), G2m (23) or G2m (n), G3m (5, 6, 10, 11, 13, 14, 15, 16, 21, 24, 26, 27, 28) or G3m (b1, c3, b3, b0, b3, b4, s, t, g1, c5, u, v, g5) (Lefranc, *et al.*, “*The Human IgG Subclasses: Molecular Analysis Of Structure, Function And Regulation.*” Pergamon, Oxford, pp. 43-78 (1990); Lefranc, G. *et al.*, 1979, Hum. Genet.: 50, 199-211). It is specifically contemplated that the antibodies of the present invention may be incorporate any allotype, isoallotype, or haplotype of any immunoglobulin gene, and are not limited to the allotype, isoallotype or haplotype of the sequences provided herein. Furthermore, in some expression systems the C-terminal amino acid residue (bolded above) of the CH3 Domain may be post-translationally removed. Accordingly, the C-terminal residue of the CH3 Domain is an optional amino acid residue in the PD-1-binding molecules of the invention. Specifically encompassed by the instant invention are PD-1-binding molecules lacking the C-terminal residue of the CH3 Domain. Also specifically encompassed by the instant invention are such constructs comprising the C-terminal lysine residue of the CH3 Domain.

**[0066]** Activating and inhibitory signals are transduced through the ligation of an Fc region to a cellular Fc gamma Receptor (FcγR). The ability of such ligation to result in diametrically opposing functions results from structural differences among the different FcγRs. Two distinct domains within the cytoplasmic signaling domains of the receptor called immunoreceptor tyrosine-based activation motifs (ITAMs) and immunoreceptor tyrosine-based inhibitory motifs (ITIMS) account for the different responses. The recruitment of different cytoplasmic enzymes to these structures dictates the outcome of the FcγR-mediated cellular responses. ITAM-containing FcγR complexes include FcγRI, FcγRIIA, FcγRIIIA, whereas ITIM-containing complexes only include FcγRIIB. Human neutrophils express the FcγRIIA gene. FcγRIIA clustering via immune complexes or specific antibody cross-linking serves to aggregate ITAMs along with receptor-associated kinases which facilitate ITAM phosphorylation. ITAM phosphorylation serves as a docking site for Syk kinase, activation of which results in activation of downstream substrates (*e.g.*, PI<sub>3</sub>K). Cellular activation leads to release of proinflammatory mediators. The FcγRIIB gene is expressed on B lymphocytes; its

extracellular domain is 96% identical to FcγRIIA and binds IgG complexes in an indistinguishable manner. The presence of an ITIM in the cytoplasmic domain of FcγRIIB defines this inhibitory subclass of FcγR. Recently the molecular basis of this inhibition was established. When co-ligated along with an activating FcγR, the ITIM in FcγRIIB becomes phosphorylated and attracts the SH2 domain of the inositol polyphosphate 5'-phosphatase (SHIP), which hydrolyzes phosphoinositol messengers released as a consequence of ITAM-containing FcγR-mediated tyrosine kinase activation, consequently preventing the influx of intracellular Ca<sup>++</sup>. Thus cross-linking of FcγRIIB dampens the activating response to FcγR ligation and inhibits cellular responsiveness. B-cell activation, B-cell proliferation and antibody secretion is thus aborted.

### III. Bispecific Antibodies, Multispecific Diabodies and DART® Diabodies

[0067] The ability of an antibody to bind an epitope of an antigen depends upon the presence and amino acid sequence of the antibody's VL and VH Domains. Interaction of an antibody light chain and an antibody heavy chain and, in particular, interaction of its VL and VH Domains forms one of the two epitope-binding sites of a natural antibody. Natural antibodies are capable of binding to only one epitope species (*i.e.*, they are monospecific), although they can bind multiple copies of that species (*i.e.*, exhibiting bivalency or multivalency).

[0068] The binding domains of the present invention bind to epitopes in an “**immunospecific**” manner. As used herein, an antibody, diabody or other epitope-binding molecule is said to “**immunospecifically**” bind a region of another molecule (*i.e.*, an epitope) if it reacts or associates more frequently, more rapidly, with greater duration and/or with greater affinity with that epitope relative to alternative epitopes. For example, an antibody that immunospecifically binds to a viral epitope is an antibody that binds this viral epitope with greater affinity, avidity, more readily, and/or with greater duration than it immunospecifically binds to other viral epitopes or non-viral epitopes. It is also understood by reading this definition that, for example, an antibody (or moiety or epitope) that immunospecifically binds to a first target may or may not specifically or preferentially bind to a second target. As such, “immunospecific binding” does not necessarily require (although it can include) exclusive binding. Generally, but not necessarily, reference to binding means “specific” binding. Two molecules are said to be capable of binding to one another in a “**physiospecific**” manner, if such binding exhibits the specificity with which receptors bind to their respective ligands.

**[0069]** The functionality of antibodies can be enhanced by generating multispecific antibody-based molecules that can simultaneously bind two separate and distinct antigens (or different epitopes of the same antigen) and/or by generating antibody-based molecule having higher valency (*i.e.*, more than two binding sites) for the same epitope and/or antigen.

**[0070]** In order to provide molecules having greater capability than natural antibodies, a wide variety of recombinant bispecific antibody formats have been developed (see, *e.g.*, PCT Publication Nos. WO 2008/003116, WO 2009/132876, WO 2008/003103, WO 2007/146968, WO 2009/018386, WO 2012/009544, WO 2013/070565), most of which use linker peptides either to fuse a further epitope-binding fragment (*e.g.*, an scFv, VL, VH, *etc.*) to, or within the antibody core (IgA, IgD, IgE, IgG or IgM), or to fuse multiple epitope-binding fragments (*e.g.*, two Fab fragments or scFvs). Alternative formats use linker peptides to fuse an epitope-binding fragment (*e.g.*, an scFv, VL, VH, *etc.*) to an a dimerization domain such as the CH2-CH3 Domain or alternative polypeptides (WO 2005/070966, WO 2006/107786A WO 2006/107617A, WO 2007/046893). Typically, such approaches involve compromises and trade-offs. For example, PCT Publications Nos. WO 2013/174873, WO 2011/133886 and WO 2010/136172 disclose that the use of linkers may cause problems in therapeutic settings, and teaches a trispecific antibody in which the CL and CH1 Domains are switched from their respective natural positions and the VL and VH Domains have been diversified (WO 2008/027236; WO 2010/108127) to allow them to bind to more than one antigen. Thus, the molecules disclosed in these documents trade binding specificity for the ability to bind additional antigen species. PCT Publications Nos. WO 2013/163427 and WO 2013/119903 disclose modifying the CH2 Domain to contain a fusion protein adduct comprising a binding domain. The document notes that the CH2 Domain likely plays only a minimal role in mediating effector function. PCT Publications Nos. WO 2010/028797, WO2010028796 and WO 2010/028795 disclose recombinant antibodies whose Fc Regions have been replaced with additional VL and VH Domains, so as to form trivalent binding molecules. PCT Publications Nos. WO 2003/025018 and WO2003012069 disclose recombinant diabodies whose individual chains contain scFv Domains. PCT Publications No. WO 2013/006544 discloses multivalent Fab molecules that are synthesized as a single polypeptide chain and then subjected to proteolysis to yield heterodimeric structures. Thus, the molecules disclosed in these documents trade all or some of the capability of mediating effector function for the ability to bind additional antigen species. PCT Publications Nos. WO 2014/022540, WO 2013/003652, WO 2012/162583, WO 2012/156430, WO 2011/086091, WO 2008/024188, WO 2007/024715,

WO 2007/075270, WO 1998/002463, WO 1992/022583 and WO 1991/003493 disclose adding additional binding domains or functional groups to an antibody or an antibody portion (*e.g.*, adding a diabody to the antibody's light chain, or adding additional VL and VH Domains to the antibody's light and heavy chains, or adding a heterologous fusion protein or chaining multiple Fab Domains to one another). Thus, the molecules disclosed in these documents trade native antibody structure for the ability to bind additional antigen species.

**[0071]** The art has additionally noted the capability to produce diabodies that differ from such natural antibodies in being capable of binding two or more different epitope species (*i.e.*, exhibiting bispecificity or multispecificity in addition to bivalency or multivalency) (see, *e.g.*, Holliger *et al.* (1993) “*Diabodies’: Small Bivalent And Bispecific Antibody Fragments*,” Proc. Natl. Acad. Sci. (U.S.A.) 90:6444-6448; US 2004/0058400 (Hollinger *et al.*); US 2004/0220388 / WO 02/02781 (Mertens *et al.*); Alt *et al.* (1999) FEBS Lett. 454(1-2):90-94; Lu, D. *et al.* (2005) “*A Fully Human Recombinant IgG-Like Bispecific Antibody To Both The Epidermal Growth Factor Receptor And The Insulin-Like Growth Factor Receptor For Enhanced Antitumor Activity*,” J. Biol. Chem. 280(20):19665-19672; WO 02/02781 (Mertens *et al.*); Olafsen, T. *et al.* (2004) “*Covalent Disulfide-Linked Anti-CEA Diabody Allows Site-Specific Conjugation And Radiolabeling For Tumor Targeting Applications*,” Protein Eng. Des. Sel. 17(1):21-27; Wu, A. *et al.* (2001) “*Multimerization Of A Chimeric Anti-CD20 Single Chain Fv-Fv Fusion Protein Is Mediated Through Variable Domain Exchange*,” Protein Engineering 14(2):1025-1033; Asano *et al.* (2004) “*A Diabody For Cancer Immunotherapy And Its Functional Enhancement By Fusion Of Human Fc Domain*,” Abstract 3P-683, J. Biochem. 76(8):992; Takemura, S. *et al.* (2000) “*Construction Of A Diabody (Small Recombinant Bispecific Antibody) Using A Refolding System*,” Protein Eng. 13(8):583-588; Baeuerle, P.A. *et al.* (2009) “*Bispecific T-Cell Engaging Antibodies For Cancer Therapy*,” Cancer Res. 69(12):4941-4944).

**[0072]** The design of a diabody is based on the antibody derivative known as a single-chain Variable Domain fragment (**scFv**). Such molecules are made by linking Light and/ or Heavy chain Variable Domains by using a short linking peptide. Bird *et al.* (1988) (“*Single-Chain Antigen-Binding Proteins*,” Science 242:423-426) describes example of linking peptides which bridge approximately 3.5 nm between the carboxy terminus of one Variable Domain and the amino terminus of the other Variable Domain. Linkers of other sequences have been designed and used (Bird *et al.* (1988) “*Single-Chain Antigen-Binding Proteins*,” Science 242:423-426).

Linkers can in turn be modified for additional functions, such as attachment of drugs or attachment to solid supports. The single-chain variants can be produced either recombinantly or synthetically. For synthetic production of scFv, an automated synthesizer can be used. For recombinant production of scFv, a suitable plasmid containing polynucleotide that encodes the scFv can be introduced into a suitable host cell, either eukaryotic, such as yeast, plant, insect or mammalian cells, or prokaryotic, such as *E. coli*. Polynucleotides encoding the scFv of interest can be made by routine manipulations such as ligation of polynucleotides. The resultant scFv can be isolated using standard protein purification techniques known in the art.

**[0073]** The provision of non-monospecific diabodies provides a significant advantage over antibodies, including but not limited to, the capacity to co-ligate and co-localize cells that express different epitopes. Bispecific diabodies thus have wide-ranging applications including therapy and immunodiagnosis. Bispecificity allows for great flexibility in the design and engineering of the diabody in various applications, providing enhanced avidity to multimeric antigens, the cross-linking of differing antigens, and directed targeting to specific cell types relying on the presence of both target antigens. Due to their increased valency, low dissociation rates and rapid clearance from the circulation (for diabodies of small size, at or below ~50 kDa), diabody molecules known in the art have also shown particular use in the field of tumor imaging (Fitzgerald *et al.* (1997) "*Improved Tumour Targeting By Disulphide Stabilized Diabodies Expressed In Pichia pastoris*," Protein Eng. 10:1221).

**[0074]** The bispecificity of diabodies has led to their use for co-ligating differing cells, for example, the cross-linking of cytotoxic T-cells to tumor cells (Staerz *et al.* (1985) "*Hybrid Antibodies Can Target Sites For Attack By T Cells*," Nature 314:628-631, and Holliger *et al.* (1996) "*Specific Killing Of Lymphoma Cells By Cytotoxic T-Cells Mediated By A Bispecific Diabody*," Protein Eng. 9:299-305; Marvin *et al.* (2005) "*Recombinant Approaches To IgG-Like Bispecific Antibodies*," Acta Pharmacol. Sin. 26:649-658). Alternatively, or additionally, bispecific diabodies can be used to co-ligate receptors on the surface of different cells or on a single cell. Co-ligation of different cells and/or receptors is useful to modulation effector functions and/or immune cell signaling. Multispecific molecules (*e.g.*, bispecific diabodies) comprising epitope-binding sites may be directed to a surface determinant of any immune cell such as B7-H3 (CD276), B7-H4 (VTCN1), BTLA (CD272), CD3, CD8, CD16, CD27, CD32, CD40, CD40L, CD47, CD64, CD70 (CD27L), CD80 (B7-1), CD86 (B7-2), CD94 (KLRD1), CD137 (4-1BB), CD137L (4-1BBL), CD226, CTLA-4 (CD152), Galectin-9, GITR, GITRL,

HHLA2, ICOS (CD278), ICOSL (CD275), Killer Activation Receptor (KIR), LAG-3 (CD223), LIGHT (TNFSF14, CD258), MHC class I or II, NKG2a, NKG2d, OX40 (CD134), OX40L (CD134L), PD1H, PD-1 (CD279), PD-L1 (B7-H1, CD274), PD-L2 (B7-CD, CD273), PVR (NECL5, CD155), SIRPa, TCR, TIGIT, TIM-3 (HAVCR2), and/or VISTA (PD-1H), which are expressed on T lymphocytes, Natural Killer (NK) cells, Antigen-presenting cells or other mononuclear cell. In particular, epitope-binding sites directed to a cell surface receptor that is involved in regulating an immune checkpoint (or the ligand thereof) are useful in the generation of bispecific or multispecific binding molecules which antagonize or block the inhibitory signaling of immune checkpoint molecules and thereby stimulate, upregulate or enhance, immune responses in a subject. Molecules involved in regulating immune checkpoints include, but are not limited to B7-H3, B7-H4, BTLA, CD40, CD40L, CD47, CD70, CD80, CD86, CD94, CD137, CD137L, CD226, CTLA-4, Galectin-9, GITR, GITRL, HHLA2, ICOS, ICOSL, KIR, LAG-3, LIGHT, MHC class I or II, NKG2a, NKG2d, OX40, OX40L, PD1H, PD-1, PD-L1, PD-L2, PVR, SIRPa, TCR, TIGIT, TIM-3 and/or VISTA.

**[0075]** However, the above advantages come at a salient cost. The formation of such non-monospecific diabodies requires the successful assembly of two or more distinct and different polypeptides (*i.e.*, such formation requires that the diabodies be formed through the heterodimerization of different polypeptide chain species). This fact is in contrast to monospecific diabodies, which are formed through the homodimerization of identical polypeptide chains. Because at least two dissimilar polypeptides (*i.e.*, two polypeptide species) must be provided in order to form a non-monospecific diabody, and because homodimerization of such polypeptides leads to inactive molecules (Takemura, S. *et al.* (2000) “*Construction Of A Diabody (Small Recombinant Bispecific Antibody) Using A Refolding System*,” Protein Eng. 13(8):583-588), the production of such polypeptides must be accomplished in such a way as to prevent covalent bonding between polypeptides of the same species (*i.e.*, so as to prevent homodimerization) (Takemura, S. *et al.* (2000) “*Construction Of A Diabody (Small Recombinant Bispecific Antibody) Using A Refolding System*,” Protein Eng. 13(8):583-588). The art has therefore taught the non-covalent association of such polypeptides (see, *e.g.*, Olafsen *et al.* (2004) “*Covalent Disulfide-Linked Anti-CEA Diabody Allows Site-Specific Conjugation And Radiolabeling For Tumor Targeting Applications*,” Prot. Engr. Des. Sel. 17:21-27; Asano *et al.* (2004) “*A Diabody For Cancer Immunotherapy And Its Functional Enhancement By Fusion Of Human Fc Domain*,” Abstract 3P-683, J. Biochem. 76(8):992; Takemura, S. *et al.* (2000) “*Construction Of A Diabody (Small Recombinant Bispecific*

*Antibody) Using A Refolding System,” Protein Eng. 13(8):583-588; Lu, D. et al. (2005) “A Fully Human Recombinant IgG-Like Bispecific Antibody To Both The Epidermal Growth Factor Receptor And The Insulin-Like Growth Factor Receptor For Enhanced Antitumor Activity,” J. Biol. Chem. 280(20):19665-19672).*

[0076] However, the art has recognized that bispecific diabodies composed of non-covalently associated polypeptides are unstable and readily dissociate into non-functional monomers (see, *e.g.*, Lu, D. et al. (2005) “A Fully Human Recombinant IgG-Like Bispecific Antibody To Both The Epidermal Growth Factor Receptor And The Insulin-Like Growth Factor Receptor For Enhanced Antitumor Activity,” J. Biol. Chem. 280(20):19665-19672).

[0077] In the face of this challenge, the art has succeeded in developing stable, covalently bonded heterodimeric non-monospecific diabodies, termed **DART® (Dual Affinity Re-Targeting Reagents)** diabodies; see, *e.g.*, United States Patent Publications No. 2013-0295121; 2010-0174053 and 2009-0060910; European Patent Publication No. EP 2714079; EP 2601216; EP 2376109; EP 2158221 and PCT Publications No. WO 2012/162068; WO 2012/018687; WO 2010/080538; and Sloan, D.D. et al. (2015) “Targeting HIV Reservoir in Infected CD4 T Cells by Dual-Affinity Re-targeting Molecules (DARTs) that Bind HIV Envelope and Recruit Cytotoxic T Cells,” PLoS Pathog. 11(11):e1005233. doi: 10.1371/journal.ppat.1005233; Al Hussaini, M. et al. (2015) “Targeting CD123 In AML Using A T-Cell Directed Dual-Affinity Re-Targeting (DART®) Platform,” Blood pii: blood-2014-05-575704; Chichili, G.R. et al. (2015) “A CD3xCD123 Bispecific DART For Redirecting Host T Cells To Myelogenous Leukemia: Preclinical Activity And Safety In Nonhuman Primates,” Sci. Transl. Med. 7(289):289ra82; Moore, P.A. et al. (2011) “Application Of Dual Affinity Retargeting Molecules To Achieve Optimal Redirected T-Cell Killing Of B-Cell Lymphoma,” Blood 117(17):4542-4551; Veri, M.C. et al. (2010) “Therapeutic Control Of B Cell Activation Via Recruitment Of Fcγ Receptor IIb (CD32B) Inhibitory Function With A Novel Bispecific Antibody Scaffold,” Arthritis Rheum. 62(7):1933-1943; Johnson, S. et al. (2010) “Effector Cell Recruitment With Novel Fv-Based Dual-Affinity Re-Targeting Protein Leads To Potent Tumor Cytolysis And in vivo B-Cell Depletion,” J. Mol. Biol. 399(3):436-449). Such diabodies comprise two or more covalently complexed polypeptides and involve engineering one or more cysteine residues into each of the employed polypeptide species that permit disulfide bonds to form and thereby covalently bond two polypeptide chains. For example, the addition of a cysteine residue to the C-terminus of such constructs has been shown to allow

disulfide bonding between the polypeptide chains, stabilizing the resulting heterodimer without interfering with the binding characteristics of the bivalent molecule.

**[0078]** Each of the two polypeptides of the simplest bispecific **DART®** diabody comprises three domains. The first polypeptide comprises (in the N-terminal to C-terminal direction): (i) a First Domain that comprises a binding region of a Light Chain Variable Domain of a first immunoglobulin (VL1), (ii) a Second Domain that comprises a binding region of a Heavy Chain Variable Domain of a second immunoglobulin (VH2), and (iii) a Third Domain that contains a cysteine residue (or a cysteine-containing domain) and a Heterodimer-Promoting Domain that serves to promote heterodimerization with the second polypeptide of the diabody and to covalently bond the diabody's first and second polypeptides to one another. The second polypeptide contains (in the N-terminal to C-terminal direction): (i) a First Domain that comprises a binding region of a Light Chain Variable Domain of the second immunoglobulin (VL2), (ii) a Second Domain that comprises a binding region of a Heavy Chain Variable Domain of the first immunoglobulin (VH1), and (iii) a Third Domain that contains a cysteine residue (or a cysteine-containing domain) and a complementary Heterodimer-Promoting Domain that complexes with the Heterodimer-Promoting Domain of the first polypeptide chain in order to promote heterodimerization with the first polypeptide chain. The cysteine residue (or a cysteine-containing domain) of the third domain of the second polypeptide chain serves to promote the covalent bonding of the second polypeptide chain to the first polypeptide chain of the diabody. Such molecules are stable, potent and have the ability to simultaneously bind two or more antigens. In one embodiment, the Third Domains of the first and second polypeptides each contain a cysteine residue, which serves to bind the polypeptides together via a disulfide bond. **Figure 1** provides a schematic of such a diabody, which utilizes E-coil/K-coil Heterodimer-Promoting domains and a cysteine containing linker for covalent bonding. As provided in **Figure 2** and **Figures 3A-3C**, one or both of the polypeptides may additionally possess the sequence of a CH2-CH3 Domain, such that complexing between the two diabody polypeptides forms an Fc Region that is capable of binding to the Fc receptor of cells (such as B lymphocytes, dendritic cells, natural killer cells, macrophages, neutrophils, eosinophils, basophils and mast cells). As provided in more detail below, the CH2 and/or CH3 Domains of such polypeptide chains need not be identical in sequence, and advantageously are modified to foster complexing between the two polypeptide chains.

**[0079]** Many variations of such molecules have been described (see, *e.g.*, United States Patent Publications No. 2015/0175697; 2014/0255407; 2014/0099318; 2013/0295121; 2010/0174053 and 2009/0060910; European Patent Publication No. EP 2714079; EP 2601216; EP 2376109; EP 2158221 and PCT Publications No. WO 2012/162068; WO 2012/018687; WO 2010/080538). These Fc Region-containing **DART®** diabodies may comprise two pairs of polypeptide chains. The first polypeptide chain comprises (in the N-terminal to C-terminal direction): (i) a First Domain that comprises a binding region of a Light Chain Variable Domain of a first immunoglobulin (VL1), (ii) a Second Domain that comprises a binding region of a Heavy Chain Variable Domain of a second immunoglobulin (VH2), (iii) a Third Domain that contains a cysteine residue (or a cysteine-containing domain) and serves to promote heterodimerization with the second polypeptide of the diabody and to covalently bond the diabody's first and second polypeptides to one another, and (iv) a CH2-CH3 Domain. The second polypeptide contains (in the N-terminal to C-terminal direction): (i) a First Domain that comprises a binding region of a Light Chain Variable Domain of the second immunoglobulin (VL2), (ii) a Second Domain that comprises a binding region of a Heavy Chain Variable Domain of the first immunoglobulin (VH1), and (iii) ) a Third Domain that contains a cysteine residue (or a cysteine-containing domain) and a Heterodimer-Promoting Domain that promotes heterodimerization with the first polypeptide chain. Here two first polypeptides complex with each other to form an Fc Region. **Figures 3A-3C** provide schematics of three variations of such diabodies utilizing different Heterodimer-Promoting Domains.

**[0080]** Other Fc-Region-containing **DART®** diabodies may comprise three polypeptide chains. The first polypeptide of such **DART®** diabodies contains three domains: (i) a VL1-containing Domain, (ii) a VH2-containing Domain and (iii) a Domain containing a CH2-CH3 sequence. The second polypeptide of such **DART®** diabodies contains: (i) a VL2-containing Domain, (ii) a VH1-containing Domain and (iii) a Domain that promotes heterodimerization and covalent bonding with the diabody's first polypeptide chain. The third polypeptide of such **DART®** diabodies comprises a CH2-CH3 sequence. Thus, the first and second polypeptide chains of such **DART®** diabodies associate together to form a VL1/VH1 binding site that is capable of binding to the epitope, as well as a VL2/VH2 binding site that is capable of binding to the second epitope. Such more complex **DART®** molecules also possess cysteine-containing domains which function to form a covalently bonded complex. Thus, the first and second polypeptides are bonded to one another through a disulfide bond involving cysteine residues in their respective Third Domains. Notably, the first and third polypeptide chains

complex with one another to form an Fc Region that is stabilized via a disulfide bond. **Figures 4A-4B** provide schematics of such diabodies comprising three polypeptide chains.

**[0081]** Still other Fc-Region-containing DART® diabodies may comprise five polypeptide chains which may comprise the binding regions from the Light and Heavy Chain Variable Domains of up to three different immunoglobulins (referred to as VL1/VH1, VL2/VH2 and VL3/VH3). For example, the first polypeptide chain of such diabodies may contain: (i) a VH1-containing domain, (ii) a CH1-containing domain, and (iii) a Domain containing a CH2-CH3 sequence. The second and fifth polypeptide chains of such diabodies may contain: (i) a VL1-containing domain, and (ii) a CL-containing domain. The third polypeptide chain of such diabodies may contain: (i) a VH1-containing domain, (ii) a CH1-containing domain, (iii) a Domain containing a CH2-CH3 sequence, (iv) a VL2-containing Domain, (v) a VH3-containing Domain and (vi) a Heterodimer-Promoting Domain, where the Heterodimer-Promoting Domains promote the dimerization of the third chain with the fourth chain. The fourth polypeptide of such diabodies may contain: (i) a VL3-containing Domain, (ii) a VH2-containing Domain and (iii) a Domain that promotes heterodimerization and covalent bonding with the diabody's third polypeptide chain. Here the first and third polypeptides complex with each other to form an Fc Region. Such more complex DART® molecules also possess cysteine-containing domains which function to form a covalently bonded complex, such that each polypeptide chain is bonded to at least one additional polypeptide chain through a disulfide bond involving cysteine residues. Preferably, such domains are ordered in the N-terminal to C-terminal direction. **Figure 5** provides schematics of such diabodies comprising five polypeptide chains.

**[0082]** Alternative constructs are known in the art for applications where a tetravalent molecule is desirable but an Fc is not required including, but not limited to, tetravalent tandem antibodies, also referred to as "**TandAbs**" (see, *e.g.* United States Patent Publications Nos. 2005-0079170, 2007-0031436, 2010-0099853, 2011-020667 2013-0189263; European Patent Publication Nos. EP 1078004, EP 2371866, EP 2361936 and EP 1293514; PCT Publications Nos. WO 1999/057150, WO 2003/025018, and WO 2013/013700) which are formed by the homo-dimerization of two identical chains each possessing a VH1, VL2, VH2, and VL2 Domain.

**[0083]** Recently, trivalent structures incorporating two diabody-type binding domains and one non-diabody-type domain and an Fc Region have been described (see, *e.g.*, PCT

Application No: PCT/US15/33076, titled “Tri-Specific Binding Molecules and Methods of Use Thereof,” filed May 29, 2015; and PCT/US15/33081, titled “Tri-Specific Binding Molecules That Specifically Bind to Multiple Cancer Antigens and Methods of Use Thereof,” filed May 29, 2015). Such trivalent molecules may be utilized to generate monospecific, bispecific or trispecific molecules. **Figures 6A-6F** provide schematics of such trivalent molecules comprising 3 or 4 polypeptide chains.

#### IV. The Anti-Human PD-1-Binding Molecules of the Present Invention

**[0084]** The preferred PD-1-binding molecules of the present invention include antibodies, diabodies, BiTEs, *etc.* and are capable of binding to a continuous or discontinuous (*e.g.*, conformational) portion (**epitope**) of human PD-1 (CD279). The PD-1-binding molecules of the present invention will preferably also exhibit the ability to bind to PD-1 molecules of one or more non-human species, in particular, primate species (and especially a primate species, such as cynomolgus monkey). A representative human PD-1 polypeptide (NCBI Sequence NP\_005009.2; including a 20 amino acid residue signal sequence (shown underlined) and the 268 amino acid residue mature protein) has the amino acid sequence (**SEQ ID NO:68**):

MQIPQAPWPV VWAVLQLGWR PGWFLDSPDR PWNPTTFSPA LLVVTEGDNA  
TFTCSFSNTS ESFVLNWYRM SPSNQTDKLA AFPEDRSQPG QDCRFRTVL  
PNGRDFHMSV VRARRNDSGT YLCGAISLAP KAQIKESLRA ELRVTERRAE  
VPTAHPSPSP RPAGQFQTLV VGVVGGLLGS LVLLVWVLAV ICSRAARGTI  
GARRTGQPLK EDPSAVPVFS VDYGELDFQW REKTPEPPVP CVPEQTEYAT  
IVFPSGMGTS SPARRGSADG PRSAQPLRPE DGHCSWPL

**[0085]** In certain embodiments the anti-human PD-1-binding molecules of the invention are characterized by any (one or more) of the following criteria:

- (1) specifically binds human PD-1 as endogenously expressed on the surface of a stimulated human T-cell;
- (2) specifically binds human PD-1 with an equilibrium binding constant ( $K_D$ ) of 40 nM or less;
- (3) specifically binds human PD-1 with an equilibrium binding constant ( $K_D$ ) of 5 nM or less;
- (4) specifically binds human PD-1 with an on rate ( $k_a$ ) of  $1.5 \times 10^4 \text{ M}^{-1}\text{min}^{-1}$  or more;
- (5) specifically binds human PD-1 with an on rate ( $k_a$ ) of  $90.0 \times 10^4 \text{ M}^{-1}\text{min}^{-1}$  or more;
- (6) specifically binds human PD-1 with an off rate ( $k_d$ ) of  $7 \times 10^{-4} \text{ min}^{-1}$  or less;

- (7) specifically binds human PD-1 with an off rate ( $k_d$ ) of  $2 \times 10^{-4} \text{ min}^{-1}$  or less;
- (8) specifically binds non-human primate PD-1 (*e.g.*, PD-1 of cynomolgus monkey);
- (9) inhibits (*i.e.*, blocks or interferes with) the binding/the inhibitory activity) of PD-1 ligand (PD-L1/PD-L2) to PD-1;
- (10) stimulates an immune response; and/or
- (11) synergizes with an anti-human LAG-3 antibody to stimulate an antigen specific T-cell response.

**[0086]** As used here the term “antigen specific T-cell response” refers to responses by a T-cell that result from stimulation of the T-cell with the antigen for which the T-cell is specific. Non-limiting examples of responses by a T-cell upon antigen specific stimulation include proliferation and cytokine production (*e.g.*, TNF- $\alpha$ , IFN- $\gamma$  production). The ability of a molecule to stimulate an antigen specific T-cell response may be determined, for example, using the *Staphylococcus aureus* Enterotoxin type B antigen (“SEB”)-stimulated PBMC assay described herein.

**[0087]** The preferred anti-human PD-1-binding molecules of the present invention possess the VH and/or VL Domains of murine anti-human PD-1 monoclonal antibodies “PD-1 mAb 1,” “PD-1 mAb 2,” “PD-1 mAb 3,” “PD-1 mAb 4,” “PD-1 mAb 5,” “PD-1 mAb 6,” “PD-1 mAb 7,” “PD-1 mAb 8,” “PD-1 mAb 9,” “PD-1 mAb 10,” “PD-1 mAb 11,” “PD-1 mAb 12,” “PD-1 mAb 13,” “PD-1 mAb 14,” or “PD-1 mAb 15,” and more preferably possess 1, 2 or all 3 of the CDR<sub>HS</sub> of the VH Domain and/or 1, 2 or all 3 of the CDR<sub>LS</sub> of the VL Domain of such anti-human PD-1 monoclonal antibodies. Such preferred anti-human PD-1-binding molecules include bispecific (or multispecific) antibodies, chimeric or humanized antibodies, BiTcs, diabodies, *etc.*, and such binding molecules having variant Fc Regions.

**[0088]** The invention particularly relates to PD-1-binding molecules comprising a PD-1 binding domain that possess:

- (A) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 1;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 1;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 1 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 1;
- (4) the VH Domain of hPD-1 mAb 1 VH1;
- (5) the VL Domain of hPD-1 mAb 1 VL1;

- (6) the VH and VL Domains of hPD-1 mAb 1;
- (B) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 2;
- (2) the three CDR<sub>LS</sub> of the VL Domain of the PD-1 mAb 2;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 2 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 2;
- (4) the VH Domain of hPD-1 mAb 2 VH1;
- (5) the VL Domain of hPD-1 mAb 2 VL1;
- (6) the VH and VL Domains of hPD-1 mAb 2;
- (C) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 3;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 3;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 3 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 3;
- (D) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 4;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 4;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 4 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 4;
- (E) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 5;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 5;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 5 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 5;
- (F) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 6;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 6;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 6 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 6;
- (G) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 7;
- (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 7, or hPD-1 mAb 7 VL2, or hPD-1 mAb 7 VL3;
- (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 7 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 7, or hPD-1 mAb 7 VL2, hPD-1 mAb 7 VL3;
- (4) the VH Domain of hPD-1 mAb 7 VH1, or hPD-1 mAb 7 VH2;
- (5) the VL Domain of hPD-1 mAb 7 VL1, or hPD-1 mAb 7 VL2, or hPD-1 mAb 7 VL 3;

- (6) the VH and VL Domains of the hPD-1 mAb 7(1.1), or hPD-1 mAb 7(1.2), or hPD-1 mAb 7(1.3), or hPD-1 mAb 7(2.1), or hPD-1 mAb 7(2.2), or hPD-1 mAb 7(2.3);
- (H) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 8;  
(2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 8;  
(3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 8 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 8;
- (I) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 9, or hPD-1 mAb 9 VH2;  
(2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 9, or hPD-1 mAb 9 VL2;  
(3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 9, or hPD-1 mAb 9 VH2 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 9, or hPD-1 mAb 9 VL2;  
(4) the VH Domain of hPD-1 mAb 9 VH1, or hPD-1 mAb 9 VH2;  
(5) the VL Domain of hPD-1 mAb 9 VL1, or hPD-1 mAb 9 VL2;  
(6) the VH and VL Domains of the hPD-1 mAb 9(1.1), or hPD-1 mAb 9(1.2), or hPD-1 mAb 9(2.1), or hPD-1 mAb 9(2.2);
- (J) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 10;  
(2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 10;  
(3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 10 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 10;
- (K) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 11;  
(2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 11;  
(3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 11 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 11;
- (L) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 12;  
(2) the three CDR<sub>LS</sub> of the VL Domain of the PD-1 mAb 12;  
(3) the three CDR<sub>HS</sub> of the VH Domain of the PD-1 mAb 12 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 12;
- (M) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 13;  
(2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 13;  
(3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 13 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 13;

- (N) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 14;  
 (2) the three CDR<sub>LS</sub> of the VL Domain of the PD-1 mAb 14;  
 (3) the three CDR<sub>HS</sub> of the VH Domain of the PD-1 mAb 14 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 14;
- (O) (1) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 15;  
 (2) the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 15;  
 (3) the three CDR<sub>HS</sub> of the VH Domain of PD-1 mAb 15 and the three CDR<sub>LS</sub> of the VL Domain of PD-1 mAb 15;  
 (4) the VH Domain of hPD-1 mAb 15 VH1;  
 (5) the VL Domain of hPD-1 mAb 15 VL1;  
 (6) the VH and VL Domains of hPD-1 mAb 15;

or

that binds, or competes for binding with, the same epitope as PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15.

#### A. The Anti-Human PD-1 Antibody PD-1 mAb 1

##### 1. Murine Anti-Human PD-1 Antibody PD-1 mAb 1

[0089] The amino acid sequence of the VH Domain of PD-1 mAb 1 (SEQ ID NO:69) is shown below (CDR<sub>H</sub> residues are shown underlined).

DVQLQESGPG RVKPSQSLSL TCTVTGFSIT NDYAWNWIRQ FPGNKLEWMG  
HITYSGSTSY NPSLKSRISI TRDTSKNHFF LQLSSVTPED TATYYCARDY  
GSGYPYTLDY WGQGTSVTVS S

CDR<sub>H1</sub> of PD-1 mAb 1 (SEQ ID NO:71): NDYAWN

CDR<sub>H2</sub> of PD-1 mAb 1 (SEQ ID NO:72): HITYSGSTSYNPSLKS

CDR<sub>H3</sub> of PD-1 mAb 1 (SEQ ID NO:73): DYGSGYPYTLDY

[0090] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 1 is SEQ ID NO:70 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

cagatccagt gatgtgcagc ttcaggagtc gggacctggc cgggtgaaac  
 cttctcagtc tctgtccctc acctgcactg tctactggctt ctcaatcacc  
aatgattatg cctggaactg gatccgacag tttccaggaa acaaaactgga  
 gtggatgggc cacataacct acagtggcag cactagctac aacccatctc  
tcaaaagtcg aatctctatc actcgggaca catccaagaa ccacttcttc  
 ctgcagttga gttctgtgac tcctgaggac acagccacat attactgtgc

aagagattac ggtagtggct acccctatac tttggactac tgggggtcaag  
gtacctcagt caccgtctcc tcc

[0091] The amino acid sequence of the VL Domain of PD-1 mAb 1 (SEQ ID NO:74) is shown below (CDRL residues are shown underlined):

QIVLTQSPAL MSASPGKVT MTCSATSIVS YVYWYQQKPG SSPQPWIILT  
SNLASGVPAR FSGSGSGTSY SLTISSMEAE DAATYYCQQW SDNPYTFGGG  
TKLEIK

CDRL1 of PD-1 mAb 1 (SEQ ID NO:76): **SATSIVSYVY**

CDRL2 of PD-1 mAb 1 (SEQ ID NO:77): **LTSNLAS**

CDRL3 of PD-1 mAb 1 (SEQ ID NO:78): **QQWSDNPYT**

[0092] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 1 is SEQ ID NO:75 (nucleotides encoding the CDRL residues are shown underlined):

caaattgttc tcaccagtc tccagcactc atgtctgcat ctccagggga  
gaaggtcacc atgacctgca gtgccacctc aattgtaagt tacgtttact  
ggtaccagca gaagcctgga tcttcccccc aacctggat ttatctcaca  
tccaacctgg cttctggagt cctgtctcgc ttcagtggca gtgggtctgg  
gacctcttac tctctcacia tcagcagcat ggaggctgaa gatgctgcca  
cttattactg ccagcagtgg agtgataacc cgtacacgtt cggagggggg  
accaagctgg aaataaaa

## 2. Humanization of the Anti-Human PD-1 Antibody PD-1 mAb 1 to Form "hPD-1 mAb 1"

[0093] The above-described murine anti-human PD-1 antibody PD-1 mAb 1 was humanized and further deimmunized when antigenic epitopes were identified in order to demonstrate the capability of humanizing an anti-human PD-1 antibody so as to decrease its antigenicity upon administration to a human recipient. The humanization yielded one humanized VH Domain, designated herein as "hPD-1 mAb 1 VH1," and one humanized VL Domain designated herein as "hPD-1 mAb 1 VL1." Accordingly, an antibody comprising the humanized VL Domains paired with the humanized VH Domain is referred to as "hPD-1 mAb 1."

[0094] The amino acid sequence of the VH Domain of hPD-1 mAb 1 VH1 (SEQ ID NO:79) is shown below (CDRH residues are shown underlined):

DVQLQESGPG LVKPSQTLST TCTVSGFSIS NDYAWNWIRQ PPGKGLEWIG  
HITYSGSTSY NPSLKSRLLTI TRDTSKNQFV LTMTNMDPVD TATYYCARDY  
SGYPYTLDY WGQGT TVTVS S

[0095] An exemplary polynucleotide that encodes hPD-1 mAb 1 VH1 is **SEQ ID NO:80** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gacgtacagc tccaggaaag tggcccaggt ctggtgaagc catcccagac  
 actgagcctg acttgcaccg tgagtggcct ctccatctca aatgactacg  
cctggaattg gattaggcag cctcccggta aagggctgga gtggatcggc  
cacatcacat acagcggctc cacatcatat aatcccagtc tgaagagccg  
 tcttaccatt actcgcgaca ctagtaagaa ccagtttggt ctgaccatga  
 ccaacatgga ccctgtggat actgcaacat actattgtgc tcgagattat  
ggttctggtt acccttatac actcgactac tggggacagg gaaccactgt  
 gaccgtgagc tcc

[0096] The amino acid sequence of the VL Domain of hPD-1 mAb 1 VL1 (**SEQ ID NO:81**) is shown below (CDR<sub>H</sub> residues are shown underlined):

EIVLTQSPAT LSVSPGEKVT ITCSATSIVS YVYWYQQKPG QAPQPLIYLT  
SNLASGIPAR FSGSGSGTDF TLTISSEAE DAATYYCQQW SDNPYTFGGG  
 TKVEIK

[0097] An exemplary polynucleotide that encodes hPD-1 mAb 1 VL1 is **SEQ ID NO:82** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaaatcgttc tgaccagag cccagcaacc ctgtctgtct cccccggaga  
 aaaggtcacc attacttgct ctgctacttc tatcgtgtcc tacgtgtact  
 ggtatcagca gaagcccggc caggctcccc agccattgat atatctgacc  
agcaacctgg cttctggat cccagctcgt ttttccggta gcgggtccgg  
 gactgatttc actttgacta tcagctctct ggaggcagaa gacgccgcca  
 cctattattg tcaacagtgg tcagacaatc catacacttt tggcgggtggc  
 accaaagtcg aaataaag

## B. The Anti-Human PD-1 Antibody PD-1 mAb 2

### 1. Murine Anti-Human PD-1 Antibody PD-1 mAb 2

[0098] The amino acid sequence of the VH Domain of PD-1 mAb 2 (**SEQ ID NO:83**) is shown below (CDR<sub>H</sub> residues are shown underlined).

DVQLVESGGG LVQPGGSRKL SCAASGFVFS SFGMHWVRQA PEKGLEWVAY  
ISSGMSISY ADTVKGRFTV TRDNAKNTLF LQMTSLRSED TAIYYCASLS  
DYFDYWGQGT TLTVSS

CDR<sub>H1</sub> of PD-1 mAb 2 (**SEQ ID NO:85**): SFGMH

CDR<sub>H2</sub> of PD-1 mAb 2 (**SEQ ID NO:86**): YISSGMSISYADTVKG

CDR<sub>H3</sub> of PD-1 mAb 2 (**SEQ ID NO:87**): LSDYFDY

[0099] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 2 is **SEQ ID NO:84** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gatgtgcagc tcgtggagtc tgggggaggc ttagtgcagc ctggagggtc  
 ccggaactc tcctgtgcag cctctggatt cgttttcagt agctttggaa  
tgcactgggt tcgtcaggct ccagagaagg ggctggagtg ggtcgcatac  
atcagtagtg gcagtatgag catttcctat gcagacacag tgaagggccg  
 attcaccgtc accagagaca atgccaaagaa caccctgttc ctgcaaatga  
 ccagtctaag gtctgaggac acggccatctt attactgtgc atccctgagt  
gactactttg actactgggg ccaaggcacc actctcacag tctcctcc

[00100] The amino acid sequence of the VL Domain of PD-1 mAb 2 (**SEQ ID NO:88**) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVMSQTPLS LPVSLGDQAS ISCRSSQSLV HSTGNTYLHW YLQKPGQSPK  
 LLIYRVSNRF SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV FFCSQTTHVP  
WTFGGGTKLE IK

CDR<sub>L</sub>1 of PD-1 mAb 2 (**SEQ ID NO:90**): **RSSQSLVHSTGNTYLH**

CDR<sub>L</sub>2 of PD-1 mAb 2 (**SEQ ID NO:91**): **RVS**NRFS

CDR<sub>L</sub>3 of PD-1 mAb 2 (**SEQ ID NO:92**): **SQTTHVPWT**

[00101] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 2 is **SEQ ID NO:89** (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatgttgtga tgtcccaaac tccactctcc ctgcctgtca gtcttggaga  
 tcaagcctcc atctcttgca gatctagtca gaggccttgtt cacagtactg  
gaaacaccta tttacattgg tacctgcaga agccaggcca gtctccaaag  
 ctcttgatct acaggggtttc taaccgattt tctgggggtcc ccgacagggt  
 cagtggcagt ggatcaggga cagatttcac actcaagatc agtagagtgg  
 aggctgagga tctgggagtt tttttctgct ctcaaactac acatgttccg  
tggacgttcg gtggaggcac caagctggaa atcaaa

## 2. Humanization of the Anti-Human PD-1 Antibody PD-1 mAb 2 to Form “hPD-1 mAb 2”

[00102] The above-described murine anti-human PD-1 antibody PD-1 mAb 2 was humanized and further deimmunized when antigenic epitopes were identified in order to demonstrate the capability of humanizing an anti-human PD-1 antibody so as to decrease its antigenicity upon administration to a human recipient. The humanization yielded one humanized VH Domain, designated herein as “**hPD-1 mAb 2 VH1**,” and one humanized VL Domains designated herein as “**hPD-1 mAb 1 VL1**.” Accordingly, any antibody comprising

the humanized VL Domains paired with the humanized VH Domain is referred to as “hPD-1 mAb 2.”

**[00103]** The amino acid sequence of the VH Domain of hPD-1 mAb 2 VH1 (SEQ ID NO:93) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVQLVESGGG LVQPGGSLRL SCAASGFVFS SFGMHWVRQA PGKGLEWVAY  
ISSGMSISY ADTVKGRFTI SRDNAKNTLY LQMNSLRTEG TALYYCASLS  
DYFDYWGQGT TTVSS

**[00104]** An exemplary polynucleotide that encodes hPD-1 mAb 2 VH1 is SEQ ID NO:94 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgcaat tggttgagag tgggtggtggc ctggtgcagc caggtggaag  
tctgcggttg tctgtgcag caagcggatt tgtgttcagc tcttttggga  
tgcattgggt gcgccaggct cccggcaagg gtctcgagtg ggtagcatac  
atctccagcg ggtccatgtc tattagttat gccgacacag tgaaaggcag  
gtttactatc tcccgtgaca atgcaaaaaa cacactgtac ctgcaaatga  
atagcctgcg caccgaggac accgccttgt actactgcgc ttccctgtct  
gattacttcg actactgggg tcagggcaca actgtgacag tttcttcc

**[00105]** The amino acid sequence of the VL Domain of hPD-1 mAb 2 VL1 (SEQ ID NO:95) is shown below (CDR<sub>H</sub> residues are shown underlined):

DVMTQSPLS LPVTLGQPAS ISCRSSQSLV HSTGNTYLHW YLQKPGQSPQ  
LLIYRVSNRF SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCSQTTHVP  
WTFGQGTKLE IK

**[00106]** An exemplary polynucleotide that encodes hPD-1 mAb 2 VL1 is SEQ ID NO:96 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gacgttgatga tgacacagtc accactgagt ctgccagtta ccttgggcca  
gccagccagt atttcttgtc ggagttcaca gagtctggta cattccacag  
gaaatacata tctccattgg tacctgcaaa aaccagggca gagccccag  
ctgctgattt atagagtgtc taatcgattt tctggcgtgc cagatcggtt  
cagcggcagc ggttctggca ctgatttcac actgaaaatc tctaggggtg  
aggcagagga cgtaggcggt tactactgta gtcagaccac ccatgtaccc  
tggacttttg gccaaaggtag taagctggaa atcaag

### C. Murine Anti-Human PD-1 Antibody PD-1 mAb 3

**[00107]** The amino acid sequence of the VH Domain of PD-1 mAb 3 (SEQ ID NO:97) is shown below (CDR<sub>H</sub> residues are shown underlined).

QVQLQQSGAE LVRPGASVTL SCKASGYTFT DYVMHWVKQT PVHGLEWIGT  
IDPETGGTAY NQKFKGKAIL TADKSSNTAY MELRSLTSED SAVYYFTREK  
ITTIVEGTYW YFDVWGTGTT VTVSS

CDR<sub>H</sub>1 of PD-1 mAb 3 (SEQ ID NO:99): DYVMH  
 CDR<sub>H</sub>2 of PD-1 mAb 3 (SEQ ID NO:100): TIDPETGGTAYNQKFKG  
 CDR<sub>H</sub>3 of PD-1 mAb 3 (SEQ ID NO:101): EKITTIVEGTYWYFDV

[00108] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 3 is SEQ ID NO:98 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

caggttcaac tgcaacagtc tggggctgag ctggtgaggc ctggggcttc  
 agtgacgctg tcctgcaagg cttcgggcta cacatttact gactatgtaa  
tgcactgggt gaagcagaca cctgtgcatg gcctggaatg gattggaact  
attgatacctg aaactggtgg tactgcctac aatcagaagt tcaagggcaa  
 ggccatactg actgcagaca agtcctccaa cacagcctac atggagctcc  
 gcagcctgac atctgaggac tctgccgtct attactttac aagagagaag  
attactacga tagtagaggg gacatactgg tacttcgatg tctggggcac  
 agggaccacg gtcaccgtct cctca

[00109] The amino acid sequence of the VL Domain of PD-1 mAb 3 (SEQ ID NO:102) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVLLTQTPLS LPVSLGDQAS ISCRSSQNIV HSNGDTYLEW YLQKPGQSPK  
 LLIYKVSNRF SGVPDRFGSGS GSGTDFTLKI SRVEAEDLGV YYCFQGSHLP  
YTFGGGKLE IK

CDR<sub>L</sub>1 of PD-1 mAb 3 (SEQ ID NO:104): RSSQNIVHSNGDTYLE  
 CDR<sub>L</sub>2 of PD-1 mAb 3 (SEQ ID NO:105): KVSNRFS  
 CDR<sub>L</sub>3 of PD-1 mAb 3 (SEQ ID NO:106): FQGSHPYT

[00110] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 3 is SEQ ID NO:103 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatgttttgc tgacccaaac tccactctcc ctgcctgtca gtcttggaga  
 tcaagcctcc atctcttgca gatctagtca gaacattgta catagtaatg  
gagacaccta tttggaatgg tacctgcaga aaccaggcca gtctccaaag  
 ctctgatct ataaagtttc caaccgattt tctggggctcc cagacagggtt  
 cagtggcagt gggtcaggga cagattttac actcaaaatc agcagagtgg  
 aggctgagga tctgggagtt tattactgct ttcaaggttc acatcttccg  
tacacgttcg gaggggggac caagctggaa ataaaa

#### D. Murine Anti-Human PD-1 Antibody PD-1 mAb 4

[00111] The amino acid sequence of the VH Domain of PD-1 mAb 4 (SEQ ID NO:107) is shown below (CDR<sub>H</sub> residues are shown underlined).

DVQLVESGGG LVQPGGSRKL SCAASGFVFS SFGMHWVRQA PEKGLEWVAY  
ISSGMSISY ADTVKGRFTV TRDNAKNTLF LQMTSLRSED TAIYYCASLT  
DYFDYWGQGT TLTVSS

CDR<sub>H</sub>1 of PD-1 mAb 4 (SEQ ID NO:109): SFGMH

CDR<sub>H</sub>2 of PD-1 mAb 4 (SEQ ID NO:110): YISSGMSISYADTVKG

CDR<sub>H</sub>3 of PD-1 mAb 4 (SEQ ID NO:111): LTDYFDY

[00112] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 4 is SEQ ID NO:108 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gatgtgcagc tcgtggagtc tgggggagggc ttagtgcagc ctggagggtc  
 ccggaaactc tctgtgcag cctctggatt cgttttcagt agctttggaa  
tgcactgggt tcgtcaggct ccagagaagg ggctggagtg ggtcgcatat  
attagtagtg gcagtatgag tatttcctat gcagacacag tgaagggccg  
 attcaccgtc accagagaca atgccaagaa caccctgttc ctgcaaatga  
 ccagtctaag gtctgaggac acggccattt attactgtgc atccctgact  
gactactttg actactgggg ccaaggcacc actctcacag tctcctca

[00113] The amino acid sequence of the VL Domain of PD-1 mAb 4 (SEQ ID NO:112) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVMSQTPLS LPVSLGDQAS ISRSSQSLV HSTGNTYFW YLQKPGQSPK  
 LLIYRVSNRF SGVPDRFGSGS GSGTDFTLKI SRVEAEDLGV YFCSQTTHVP  
WTFGGGTKLE IK

CDR<sub>L</sub>1 of PD-1 mAb 4 (SEQ ID NO:114): RSSQSLVHSTGNTYFW

CDR<sub>L</sub>2 of PD-1 mAb 4 (SEQ ID NO:115): RVSNRFS

CDR<sub>L</sub>3 of PD-1 mAb 4 (SEQ ID NO:116): SQTTHVPWT

[00114] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 4 is SEQ ID NO:113 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatgttgatga tgtcccaaac tccactctcc ctgcctgtca gtcttgaggaga  
 tcaagcctcc atctcctgca gatctagtc gagccttggt cacagtactg  
gaaacaccta tttccattgg tacctgcaga agccaggcca gtctccaaag  
 ctctgatct acagggtttc taaccgattt tctgggggtcc ccgacagggt  
 cagtggcagt ggatcaggga cagatttcac actcaagatc agcagagtgg  
 aggctgagga tctgggaggt tatttctgct ctcaaaactac acatgttccg  
tggacgttcg gtggaggcac caagctggaa atcaaa

**E. Murine Anti-Human PD-1 Antibody PD-1 mAb 5**

[00115] The amino acid sequence of the VH Domain of PD-1 mAb 5 (SEQ ID NO:117) is shown below (CDR<sub>H</sub> residues are shown underlined).

QVQLQQPGVE LVRPGASVKL SCKASGYSFT AYWMNWMKQR PGQGLEWIGV  
IHPSDSETWL NQKFKDKATL TVDKSSSTAY MQLISPTSED SAVYYCAREH  
YGSSPFAYWG QGTLVTVSA

CDR<sub>H1</sub> of PD-1 mAb 5 (SEQ ID NO:119): AYWMN

CDR<sub>H2</sub> of PD-1 mAb 5 (SEQ ID NO:120): VIHPSDSETWLNNQKFKD

CDR<sub>H3</sub> of PD-1 mAb 5 (SEQ ID NO:121): EHYGSSPFAY

[00116] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 5 is SEQ ID NO:118 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

caggtccaac tgcagcagcc tggggttgaa ctggtgaggc ctggagcttc  
 agtgaagctg tcttgcaagg cttctggcta ctcttcacc gcctactgga  
tgaactggat gaaacagagg cctggacaag gccttgagtg gattggcgtg  
attcatcctt ccgatagtga aacttgggta aatcagaagt tcaaggacaa  
 ggccacattg actgtagaca aatcctccag cacagcctac atgcaactca  
 tcagcccgac atctgaggac tctgcggtct attactgtgc aagagagcac  
tacggtagta gcccgtttgc ttactggggc caagggactc tggtcactgt  
 ctctgca

[00117] The amino acid sequence of the VL Domain of PD-1 mAb 5 (SEQ ID NO:122) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVLTQSPAS LAVSLGQRAT ISCRRANESVD NYGMSFMNWF QQKPGQPPKL  
 LIYAAASNQGS GVPARFSGSG SGTDFSLNIH PMEEDDTAMY FCQQSKEVPY  
TFGGGTKLEI K

CDR<sub>L1</sub> of PD-1 mAb 5 (SEQ ID NO:124): RANESVDNYGMSFMN

CDR<sub>L2</sub> of PD-1 mAb 5 (SEQ ID NO:125): AASNQGS

CDR<sub>L3</sub> of PD-1 mAb 5 (SEQ ID NO:126): QQSKEVPYT

[00118] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 5 is SEQ ID NO:123 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattgtgc tgaccaatc tccagcttct ttggctgtgt ctctagggca  
 gagggccacc atctcctgca gagccaacga aagtgttgat aattatggca  
tgagttttat gaactgggtc caacagaaac caggacagcc acccaaactc  
 ctcatctatg ctgcatccaa ccaaggatcc ggggtccctg ccaggtttag  
 tggcagtggg tctgggacag atttcagcct caacatccat cctatggagg

aggatgatac tgcaatgtat ttctgt cagc aaagtaagga ggttccgtac  
acgttcggag gggggaccaa gctggaaata aaa

#### F. Murine Anti-Human PD-1 Antibody PD-1 mAb 6

[00119] The amino acid sequence of the VH Domain of PD-1 mAb 6 (SEQ ID NO:127) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVKLVESGGG LVNPGGSLKL SCAASGFTFS SYGMSWVRQT PEKRLEWVAT  
ISGGGSDTYYPDSVKGRFTI SRDNAKNNLY LQMSSLRSED TALYYCARQK  
ATTWFAYWGQ GTLVTVST

CDR<sub>H1</sub> of PD-1 mAb 6 (SEQ ID NO:129): SYGMS

CDR<sub>H2</sub> of PD-1 mAb 6 (SEQ ID NO:130): TISGGGSDTYYPDSVKG

CDR<sub>H3</sub> of PD-1 mAb 6 (SEQ ID NO:131): QKATTWFAY

[00120] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 6 is SEQ ID NO:128 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaaatcgtac tcaccagtc acctgcaacc ctttctctga gccccggtga  
 acgtgccact ctcagctgca gagcaagtga gagtgtggac aattacggca  
tgtccttcat gaactggttt cagcagaagc ctgggcagcc acctaagctg  
 ctcattccacg ccgcctctaa ccgcggatct ggggtgcctt cacgtttttc  
 tggatcagga agtggcactg acttcaccct tacaatcagc tctctggagc  
 cagaggactt tgccgtctat ttctgc cagc aatctaaaga ggtgccctat  
acttttggtg gcgggaccaa ggttgagatc aaa

[00121] The amino acid sequence of the VL Domain of PD-1 mAb 6 (SEQ ID NO:132) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVLTQSPAS LAVSLGQRAT ISCRRASESVD NYGISFMNWF QQKPGQPPKL  
 LIYPASNQGS GVPARFSGSG SGTDFSLNIH PMEEDDAAMY FCQQSKEVPW  
TFGGGTKLEI K

CDR<sub>L1</sub> of PD-1 mAb 6 (SEQ ID NO:134): RASESVDNYGISFMN

CDR<sub>L2</sub> of PD-1 mAb 6 (SEQ ID NO:135): PASNQGS

CDR<sub>L3</sub> of PD-1 mAb 6 (SEQ ID NO:136): QQSKEVPWT

[00122] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 6 is SEQ ID NO:133 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattgtgc tgaccaatc tcagcttct ttggctgtgt ctctagggca  
 gagggccacc atctcctgca gagccagcga aagtgttgat aattatggca  
ttagtttttat gaactggttc caacagaaac caggacagcc acccaaactc  
 ctcattctat c ctgcatccaa ccaaggatcc ggggtccctg ccaggtttag

tggcagtggg tctgggacag acttcagcct caacatccat cctatggagg  
 aggatgatgc tgcaatgtat ttctgtcagc aaagtaagga ggttccgtgg  
acgttcgggtg gaggcaccaa gctggaaatc aaa

## G. The Anti-Human PD-1 Antibody PD-1 mAb 7

### 1. Murine Anti-Human PD-1 Antibody PD-1 mAb 7

[00123] The amino acid sequence of the VH Domain of PD-1 mAb 7 (SEQ ID NO:137) is shown below (CDR<sub>H</sub> residues are shown underlined).

QVQLQQPGAE LVRPGASVKL SCKASGYSFT SYWMNWVKQR PGQGLEWIGV  
IHPSDSETWL DQKFKDKATL TVDKSSTTAY MQLISPTSED SAVYYCAREH  
YGTSPFAYWG QGTLVTVSS

CDR<sub>H</sub>1 of PD-1 mAb 7 (SEQ ID NO:139): SYWMN

CDR<sub>H</sub>2 of PD-1 mAb 7 (SEQ ID NO:140): VIHPSDSETWLDQKFKD

CDR<sub>H</sub>3 of PD-1 mAb 7 (SEQ ID NO:141): EHYGTSPFAY

[00124] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 7 is SEQ ID NO:138 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaggtccaac tgcagcagcc tggggctgaa ctggtgaggc ctggagcttc  
 agtgaagctg tcttgcaagg cttctggcta ctcttcacc agctactgga  
tgaactgggt gaagcagagg cctggacaag gccttgagtg gattggcgtg  
attcatcctt ccgatagtga aacttggta gatcagaagt tcaaggacaa  
 ggccacattg actgtagaca aatcctccac cacagcctac atgcaactca  
 tcagcccgac atctgaggac tctgcggtct attactgtgc aagggagcac  
tacggtacta gcccgtttgc ttactggggc caagggactc tggtcactgt  
 gtcttcc

[00125] The amino acid sequence of the VL Domain of PD-1 mAb 7 (SEQ ID NO:142) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVLTQSPAS LAVSLGQRAT ISCRRANESVD NYGMSFMNWF QQKPGQPPKL  
 LIHAAASNQGS GVPARFSGSG FGTDFSLNIH PMEEDDAAMY FCQQSKEVPY  
TFGGGTKLEI K

CDR<sub>L</sub>1 of PD-1 mAb 7 (SEQ ID NO:144): RANESVDNYGMSFMN

CDR<sub>L</sub>2 of PD-1 mAb 7 (SEQ ID NO:145): AASNQGS

CDR<sub>L</sub>3 of PD-1 mAb 7 (SEQ ID NO:146): QQSKEVPYT

[00126] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 7 is **SEQ ID NO:143** (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattgtgc tgaccaatc tccagcttct ttggctgtgt ctctagggca  
gagggccacc atctcctgca gagccaacga aagtgttgat aattatggca  
tgagttttat gaactggttc caacagaaac caggacagcc acccaaactc  
ctcatccatg ctgcatccaa ccaaggatcc ggggtccctg ccaggtttag  
tggcagtggg tttgggacag acttcagcct caacatccat cctatggagg  
aggatgatgc tgcaatgtat ttctgtcagc aaagtaagga ggttccgtac  
acgttcggag gggggaccaa gctggaaata aaa

## 2. Humanization of the Anti-Human PD-1 Antibody PD-1 mAb 7 to Form “hPD-1 mAb 7”

[00127] The above-described murine anti-human PD-1 antibody PD-1 mAb 7 was humanized and further deimmunized when antigenic epitopes were identified in order to demonstrate the capability of humanizing an anti-human PD-1 antibody so as to decrease its antigenicity upon administration to a human recipient. The humanization yielded two humanized VH Domains, designated herein as “hPD-1 mAb 7 VH1,” and “hPD-1 mAb 7 VH2,” and three humanized VL Domains designated herein as “hPD-1 mAb 7 VL1,” “hPD-1 mAb 7 VL2,” and “hPD-1 mAb 7 VL3.” Any of the humanized VL Domains may be paired with either of the humanized VH Domains. Accordingly, any antibody comprising one of the humanized VL Domains paired with the humanized VH Domain is referred to generically as “hPD-1 mAb 7,” and particular combinations of humanized VH/VL Domains are referred to by reference to the specific VH/VL Domains, for example a humanized antibody comprising hPD-1 mAb 7 VH1 and hPD-1 mAb 1 VL2 is specifically referred to as “hPD-1 mAb 7(1.2).”

[00128] The amino acid sequence of the VH Domain of hPD-1 mAb 7 VH1 (**SEQ ID NO:147**) is shown below (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV  
IHPDSETWL DQKFKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREEH  
YGTSPFAYWG QGTLVTVSS

[00129] An exemplary polynucleotide that encodes hPD-1 mAb 7 VH1 is **SEQ ID NO:148** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

caagttcaat tggtagagag cggggcagag gtgaagaaac ccggcgccag  
tgtaagggtg tcttgcaaag ccagcggta cagctttaca agctattgga  
tgaattgggt gcgtcaagca ccagggcagg gtctggaatg gattggggtg  
atacatcctt ctgacagcga aacatgggtg gaccagaaat ttaaagatcg  
tgtgacaatt acagtcgata agtccacaag cactgcttac atggaactct  
ccagcttgcg gtccgaggac accgctgtgt attattgcgc cagaggagcac

tacggcacat caccttttgc atactggggc caggaactc tcgtaaccgt  
atcctcc

[00130] The amino acid sequence of the VH Domain of hPD-1 mAb 7 VH2 (SEQ ID NO:149) is shown below (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWAGV  
IHPDSETWL DQKFKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREH  
YGTSPFAYWG QGTLVTVSS

[00131] An exemplary polynucleotide that encodes hPD-1 mAb 7 VH2 is SEQ ID NO:150 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

caagttcaat tggtagacagag cggggcagag gtgaagaaac ccggcgccag  
tgtaaggtg tcctgcaaag ccagcgggta cagctttaca agctattgga  
tgaattgggt gcgtcaagca ccagggcagg gtctggaatg ggctggggtg  
atacatcctt ctgacagcga aacatgggtg gaccagaaat ttaaagatcg  
tgtgacaatt acagtcgata agtcacaaag cactgcttac atggaactct  
ccagcttgcg gtccgaggac accgctgtgt attattgcgc cagagagcac  
tacggcacat caccttttgc atactggggc caggaactc tcgtaaccgt  
atcctcc

[00132] The amino acid sequence of the VL Domain of hPD-1 mAb 7 VL1 (SEQ ID NO:151) is shown below (CDR<sub>H</sub> residues are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRANESVD NYGMSFMNWF QOKPGQPPKL  
LIHAASNQGS GVPSRFGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY  
TFGGGTKVEI K

[00133] An exemplary polynucleotide that encodes hPD-1 mAb 7 VL1 is SEQ ID NO:152 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaaatcgtac tcaccagtc acctgcaacc ctttctctga gccccggtga  
acgtgccact ctcagctgca gagcaaatga gagtgtggac aattacggca  
tgtccttcat gaactgggtt cagcagaagc ctgggcagcc acctaagctg  
ctcatccacg ccgcctctaa ccagggatct ggggtgcctt cacgtttttc  
tggatcagga agtggcactg acttcacct tacaatcagc tctctggagc  
cagaggactt tgccgtctat ttctgccagc aatctaaaga ggtgccctat  
acttttgggtg gcgggaccaa gggtgagatc aaa

[00134] The amino acid sequence of the VL Domain of hPD-1 mAb 7 VL2 (SEQ ID NO:153) is shown below (CDR<sub>H</sub> residues are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL  
LIHAASNQGS GVPSRFGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY  
TFGGGTKVEI K

**[00135]** An exemplary polynucleotide that encodes hPD-1 mAb 7 VL2 is **SEQ ID NO:154** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaaatcgtac tcacccagtc acctgcaacc ctttctctga gccccgggtga  
acgtgccact ctcagctgca a gagcaagtga gagtgtggac aattacggca  
tgtccttcat gaactgggtt cagcagaagc ctgggcagcc acctaaagctg  
ctcatccacg ccgcctctaa ccagggatct ggggtgcctt cacgtttttc  
tggatcagga agtggcactg acttcaccct tacaatcagc tctctggagc  
cagaggactt tgccgtctat ttctgc cagc aatctaaaga ggtgccctat  
acttttgggtg gcgggaccaa ggttgagatc aaa

**[00136]** The amino acid sequence of the VL Domain of hPD-1 mAb 7 VL3 (**SEQ ID NO:155**) is shown below (CDR<sub>H</sub> residues are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL  
LIHAASNRGS GVPSRFSGSG SGTDFLTIS SLEPEDFAVY FCQQSKEVPY  
TFGGGTKVEI K

**[00137]** An exemplary polynucleotide that encodes hPD-1 mAb 7 VL3 is **SEQ ID NO:156** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaaatcgtac tcacccagtc acctgcaacc ctttctctga gccccgggtga  
acgtgccact ctcagctgca a gagcaagtga gagtgtggac aattacggca  
tgtccttcat gaactgggtt cagcagaagc ctgggcagcc acctaaagctg  
ctcatccacg ccgcctctaa ccgcggatct ggggtgcctt cacgtttttc  
tggatcagga agtggcactg acttcaccct tacaatcagc tctctggagc  
cagaggactt tgccgtctat ttctgc cagc aatctaaaga ggtgccctat  
acttttgggtg gcgggaccaa ggttgagatc aaa

**[00138]** The CDR<sub>L1</sub> of the VL Domain of both hPD-1 mAb 7 VL2 and hPD-1 mAb 7 VL3 comprises an asparagine to serine amino acid substitution and has the amino acid sequence: RASESVDNYGMSFMN ((**SEQ ID NO:157**), the substituted serine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the PD-1 mAb 7 CDR<sub>L1</sub> Domains described above.

**[00139]** In addition, the CDR<sub>L2</sub> of the VL Domain of hPD-1 mAb 7 VL3 comprises a glutamine to arginine amino acid substitution and has the amino acid sequence: AASNRGS ((**SEQ ID NO:158**), the substituted arginine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the PD-1 mAb 7 CDR<sub>L2</sub> Domains described above.

**H. Murine Anti-Human PD-1 Antibody PD-1 mAb 8**

[00140] The amino acid sequence of the VH Domain of PD-1 mAb 8 (SEQ ID NO:159) is shown below (CDR<sub>H</sub> residues are shown underlined).

EGQLQQSGPE LVKPGASVKI SCKASGYTFT DYYMNWVKQN HGKSLEWIGD  
INPKNGDTHY NQKFKGEATL TVDKSSTTAY MELRSLTSED SAVYYCASDF  
DYWGQGTTLT VSS

CDR<sub>H1</sub> of PD-1 mAb 8 (SEQ ID NO:161): DYYMN

CDR<sub>H2</sub> of PD-1 mAb 8 (SEQ ID NO:162): DINPKNGDTHYNQKFKG

CDR<sub>H3</sub> of PD-1 mAb 8 (SEQ ID NO:163): DFDY

[00141] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 8 is SEQ ID NO:160 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gagggccagc tgcaacaatc tggacctgag ctggtgaagc ctggggccttc  
 agtgaagata tcctgtaagg cttctggata cacgttcact gactactaca  
tgaactgggt gaagcagaac catggaaaga gccttgagtg gattggagat  
attaatccta aaaatggtga cactcactac aaccagaagt tcaagggcga  
 ggccacattg actgtagaca agtcctccac cacagcctac atggagctcc  
 gcagcctgac atctgaggac tctgcagtct attactgtgc gagcgatttt  
gactactggg gccaaaggcac cactctcaca gtctcctcc

[00142] The amino acid sequence of the VL Domain of PD-1 mAb 8 (SEQ ID NO:164) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVMTQTPLS LPVGLGDQAS ISCRSSQTLV YSNGNTYLNW FLQKPGQSPK  
 LLIYKVSNRF SGVPDRFSGS GSGTDFTLKI SRVEAEDLGV YFCSQSTHVP  
FTFGSGTKLE IK

CDR<sub>L1</sub> of PD-1 mAb 8 (SEQ ID NO:166): RSSQTLVYSNGNTYLN

CDR<sub>L2</sub> of PD-1 mAb 8 (SEQ ID NO:167): KVSNRFS

CDR<sub>L3</sub> of PD-1 mAb 8 (SEQ ID NO:168): SQSTHVPFT

[00143] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 8 is SEQ ID NO:165 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatgttgtga tgacccaaac tccactctcc ctgcctgtcg gtcttgaggaga  
 tcaagcctcc atctcttgca gatctagtca gacccttgta tatagtaatg  
gaaacaccta tttaaatttggt ttcctgcaga agccaggcca gtctccaaag  
 ctcttgatct acaaaagtttc caaccgattt tctgggggtcc cagacagggt  
 cagtggcagt ggatcaggga cagatttcac actcaagatc agcagagtgg  
 aggctgagga tctgggagtt tatttctgct ctcaaagtac acatgttcca  
ttcacgttcg gctcggggac aaagtgggaa ataaaa

# I. The Anti-Human PD-1 Antibody PD-1 mAb 9

## 1. Murine Anti-Human PD-1 Antibody PD-1 mAb 9

[00144] The amino acid sequence of the VH Domain of PD-1 mAb 9 (SEQ ID NO:169) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVMLVESGGG LVKPGGSLKL SCAASGFTFS SYLVSWVRQT PEKRLEWVAT  
ISGGGGNTYY SDSVKGRFTI SRDNAKNTLY LQISSLRSED TALYYCARYG  
FDGAWFAYWG QGTLVTVSS

CDR<sub>H1</sub> of PD-1 mAb 9 (SEQ ID NO:171): SYLVS

CDR<sub>H2</sub> of PD-1 mAb 9 (SEQ ID NO:172): TISGGGGNTYYSDSVKG

CDR<sub>H3</sub> of PD-1 mAb 9 (SEQ ID NO:173): YGFDGAWFAY

[00145] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 9 is SEQ ID NO:170 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgatgc tgggtggagtc tgggggagggc ttagtgaagc ctggaggggc  
cctgaaactc tcctgtgcag cctctggatt cactttcagt agttatctttg  
tgtcttgggt tcgccagact ccggagaaga ggctggagtg ggtcgcaacc  
attagtgggtg gtgggtggtaa cacctactat tcagacagtg tgaagggtc  
attcaccatc tccagagaca atgccaagaa caccctgtac ctgcaaatca  
gcagtctgag gtctgaggac acggccttgt attactgtgc aaggtatgggt  
ttcgacggcg cctggtttgc ttactggggc caagggactc tggtcactgt  
ctcttcc

[00146] The amino acid sequence of the VL Domain of PD-1 mAb 9 (SEQ ID NO:174) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIQMTQSPAS LSASVGDIVT ITCRASENIY SYLAWYQQKQ EKSPQLLVYN  
AKTLAAGVPS RFSGSGSGTQ FSLTINSLQP EDFGNYYCQH HYAVPWTFGG  
GTRLEIT

CDR<sub>L1</sub> of PD-1 mAb 9 (SEQ ID NO:176): RASENIYSYLA

CDR<sub>L2</sub> of PD-1 mAb 9 (SEQ ID NO:177): NAKTLAA

CDR<sub>L3</sub> of PD-1 mAb 9 (SEQ ID NO:178): QHHYAVPWT

[00147] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 9 is SEQ ID NO:175 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacatccaga tgactcagtc tccagcctcc ctatctgcat ctgtggggaga  
tattgtcacc atcacatgtc c gagcaagtga gaatatttac agttatttag  
catgggtatca gcagaaacag gaaaaatctc ctcagctcct ggtctataaat  
gcaaaaacct tggcagcagg tgtgccatca aggttcagtg gcagtggatc

aggcacacag ttttctctga ccatcaacag cctgcagcct gaagattttg  
 ggaattatta ctgtcagcat cattatgctg ttccgtggac gttcgggtgga  
 ggcaccagac tggaaatcac a

## 2. Humanization of the Anti-Human PD-1 Antibody PD-1 mAb 9 to Form “hPD-1 mAb 9”

[00148] The above-described murine anti-human PD-1 antibody PD-1 mAb 9 was humanized and further deimmunized when antigenic epitopes were identified in order to demonstrate the capability of humanizing an anti-human PD-1 antibody so as to decrease its antigenicity upon administration to a human recipient. The humanization yielded two humanized VH Domains, designated herein as “hPD-1 mAb 9 VH1,” and “hPD-1 mAb 9 VH2,” and two humanized VL Domains designated herein as “hPD-1 mAb 9 VL1,” and “hPD-1 mAb 9 VL2.” Any of the humanized VL Domains may be paired with the humanized VH Domains. Accordingly, any antibody comprising one of the humanized VL Domains paired with the humanized VH Domain is referred to generically as “hPD-1 mAb 9,” and particular combinations of humanized VH/VL Domains are referred to by reference to the specific VH/VL Domains, for example a humanized antibody comprising hPD-1 mAb 9 VH1 and hPD-1 mAb 9 VL2 is specifically referred to as “hPD-1 mAb 9(1.2).”

[00149] The amino acid sequence of the VH Domain of hPD-1 mAb 9 VH1 (SEQ ID NO:179) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVQLVESGGG LVRPGGSLKL SCAASGFTFS SYLVSWVRQA PGKGLEWVAT  
ISGGGGNTYY SDSVKGRFTI SRDNAKNSLY LQMNSLRAED TATYYCARYG  
FDGAWFAYWG QGTLVTVSS

[00150] An exemplary polynucleotide that encodes hPD-1 mAb 9 VH1 is SEQ ID NO:180 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaggtgcagc tgggtggaaag tggggggcggc ctggtgcgac ccggggggaag  
 tctgaaactg tctgtgtcag catcaggatt tactttttca tcttatctcg  
tgtcttgggt aagacaagca cccggaaaag gcttggaatg ggtggccact  
atctccggtg gaggtggcaa cacctactat agcgacagtg tcaaggggaag  
 atttaccatc agtcgcgaca acgctaagaa tagcctgtac ctccagatga  
 actccctgcg cgccgaggac accgccacct attactgtgc acgctatgga  
tttgacggcg catggtttgc ctactgggga cagggcacat tggtaacctg  
 tagctcc

[00151] The amino acid sequence of the VH Domain of hPD-1 mAb 9 VH2 (SEQ ID NO:181) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVQLVESGGG LARPGGSLKL SCAASGFTFS SYLVGWVRQA PGKGLEWTAT  
ISGGGGNTYY SDSVKGRFTI SRDNAKNSLY LQMNSARAED TATYYCARYG  
FDGAWFAYWG QGTLVTVSS

[00152] An exemplary polynucleotide that encodes hPD-1 mAb 9 VH2 is SEQ ID NO:182 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaggtgcagc tgggtggaaag tggggggcggc ctggcgcgac ccggggggaag  
tctgaaactg tcctgtgcag catcaggatt tactttttca tcttatctcg  
tgggctgggt aagacaagca cccggaaaag gcttggaatg gacggccact  
atctccggtg gaggtggcaa cacctactat agcgacagt tcaagggaag  
atttaccatc agtcgcgaca acgctaagaa tagcctgtac ctccagatga  
actccgcacg cgccgaggac accgccacct attactgtgc acgctatgga  
tttgacggcg catggtttgc ctactgggga cagggcacat tggtaaccgt  
tagctcc

[00153] The CDR<sub>H1</sub> of the VH Domain of hPD-1 mAb 9 VH2 comprises a serine to glycine amino acid substitution and has the amino acid sequence: SYLVG ((SEQ ID NO:183), the substituted glycine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the PD-1 mAb 9 CDR<sub>H1</sub> Domains described above.

[00154] The amino acid sequence of the VL Domain of hPD-1 mAb 9 VL1 (SEQ ID NO:184) is shown below (CDR<sub>H</sub> residues are shown underlined):

DIQMTQSPSS LSASVGDRVT ITCRASENIY SYLAWYQQKP GKAPKLLIYN  
AKTLAAGVPS RFSGSGSGTD FTLTISSLQP EDFATYYCQH HYAVPWTFGQ  
GTKLEIK

[00155] An exemplary polynucleotide that encodes hPD-1 mAb 9 VL1 is SEQ ID NO:185 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gacattcaga tgactcagtc tcccagcagt ctgtccgcat ccgtggggga  
tcgggtcacc atcacctgcc gtgcctcaga aaacatctat tcatacctcg  
cctgggtatca acagaaacct ggtaaagccc caaaattgct catttacaaac  
gccaagaccc tcgcagctgg cgtgccaaagt aggttctcag gcagcggctc  
agggacagat ttcaccctca ccatatcctc actgcagccc gaggattttg  
ccacttacta ctgccagcat cattacgcag tgcctggac cttcggacaa  
ggcactaagc tcgagatcaa a

[00156] The amino acid sequence of the VL Domain of hPD-1 mAb 9 VL2 (SEQ ID NO:186) is shown below (CDR<sub>H</sub> residues are shown underlined):

DIQMTQSPSS LSASVGDRVIT ITCRASENIY NYLAWYQQKP GKAPKLLIYD  
AKTLAAGVPS RFSGSGSGTD FTLTISSLQP EDFATYYCQH HYAVPWTFGQ  
 GTKLEIK

[00157] An exemplary polynucleotide that encodes hPD-1 mAb 9 VL2 is SEQ ID NO:187 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gacattcaga tgactcagtc tcccagcagt ctgtccgcat ccgtggggga  
 tcgggtcacc atcacctgcc gtgcctcaga aaacatctat aactacctcg  
cctggtatca acagaaacct ggtaaagccc caaaattgct catttacgac  
gccaagaccc tcgcagctgg cgtgccaaagt aggttctcag gcagcggctc  
 agggacagat ttcacctca ccatactctc actgcagccc gaggattttg  
 ccacttacta ctgccagcat cattacgcag tgccctggac cttcggacaa  
 ggcactaagc tcgagatcaa a

[00158] The CDR<sub>L1</sub> of the VL Domain of hPD-1 mAb 9 VL2 comprises a serine to asparagine amino acid substitution and has the amino acid sequence: RASENIYNYLA (SEQ ID NO:188), the substituted asparagine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the PD-1 mAb 9 CDR<sub>L1</sub> Domains described above.

[00159] The CDR<sub>L2</sub> of the VL Domain of hPD-1 mAb 9 VL2 comprises an asparagine to aspartate amino acid substitution and has the amino acid sequence: DAKTLAA ((SEQ ID NO:189), the substituted aspartate is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the PD-1 mAb 7 CDR<sub>L2</sub> Domains described above.

## J. Murine Anti-Human PD-1 Antibody PD-1 mAb 10

[00160] The amino acid sequence of the VH Domain of PD-1 mAb 10 (SEQ ID NO:190) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVILVESGGG LVKPGGSLKL SCAASGFTFS NYLMSWVRQT PEKRLEWVAS  
ISGGGSNIYY PDSVKGRFTI SRDNAKNTLY LQMNSLRSED TALYYCARQE  
LAFDYWGQGT TLTVSS

CDR<sub>H1</sub> of PD-1 mAb 10 (SEQ ID NO:192): NYLMS

CDR<sub>H2</sub> of PD-1 mAb 10 (SEQ ID NO:193): SISGGGSNIYYPDSVKG

CDR<sub>H3</sub> of PD-1 mAb 10 (SEQ ID NO:194): QELAFDY

[00161] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 10 is **SEQ ID NO:191** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgatac tgggtggagtc tggggggaggc ttagtgaagc ctggagggtc  
 cctgaaactc tcctgtgcag cctctggatt cactttcagt aactatctca  
tgtcttgggt tcgccagact ccggagaaga ggctggagtg ggtcgcaagt  
attagtgggtg gtggtagtaa tatctactat ccagacagtg tgaagggtcg  
 attcaccata tccagggaca atgccaaagaa caccctgtac ctgcaaatga  
 acagtctgag gtctgaggac acggccttgt attactgtgc aagacaagaa  
ctggcttttg actactgggg ccaaggcacc actctcacag tctcctcc

[00162] The amino acid sequence of the VL Domain of PD-1 mAb 10 (**SEQ ID NO:195**) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIQMTQTSS LSASLGDRVT ISCRTSQDIS NFLNWYQQKP DGTIKLLIYY  
TSRLHSGVPS RFGSGSGTD YSLTISNLEQ EDIATYFCQQ GSTLPWTFGG  
 GTKLEII

CDR<sub>L</sub>1 of PD-1 mAb 10 (**SEQ ID NO:197**): RTSQDISNFLN

CDR<sub>L</sub>2 of PD-1 mAb 10 (**SEQ ID NO:198**): YTSRLHS

CDR<sub>L</sub>3 of PD-1 mAb 10 (**SEQ ID NO:199**): QQGSTLPWT

[00163] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 10 is **SEQ ID NO:196** (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatatccaga tgacacagac tacatcctcc ctgtctgcct ctctgggaga  
 cagagtcacc atcagttgca ggacaagtca ggacattagc aatttttttaa  
actgggtatca gcagaaacca gatggaacta ttaaactcct gatctacttac  
acatcaagat tacactcagg agtcccatca aggttcagtg gcagtgggtc  
 tggaaacagat tattctctca ccattagcaa cctggagcaa gaagatattg  
 ccacttactt ttgccaacag ggtagtacgc ttccgtggac gttcgggtgga  
 ggcaccaagc tggaaatcat a

#### K. Murine Anti-Human PD-1 Antibody PD-1 mAb 11

[00164] The amino acid sequence of the VH Domain of PD-1 mAb 11 (**SEQ ID NO:200**) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVQLQQSGTV LARPGASVKM SCKTSGYTFT GYWMHWVKQR PGQGLKWMGA  
IYPGNSDTHY NQKFKGKAKL TAVTSASTAY MELSSLTNEQ SAIYYCTTGT  
YSYFDVWGTG TTVTVSS

CDR<sub>H</sub>1 of PD-1 mAb 11 (**SEQ ID NO:202**): GYWMH

CDR<sub>H</sub>2 of PD-1 mAb 11 (**SEQ ID NO:203**): AIYPGNSDTHYNQKFKG

CDR<sub>H</sub>3 of PD-1 mAb 11 (**SEQ ID NO:204**): GTYSYFDV

[00165] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 11 is **SEQ ID NO:201** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaggttcagc tccagcagtc tgggactgtg ctggcaaggc ctggggccttc  
 agtgaagatg tcttgcaaga cttctggcta cacatttacc ggctactgga  
tgcactgggt aaaacagagg cctggacagg gtctgaaatg gatgggggct  
atttatcctg gaaatagtga tactcactac aaccagaagt tcaagggcaa  
 ggccaaactg actgcagtca catccgccag cactgcctac atggagctca  
 gcagcctgac aaatgaggac tctgcatct attactgtac tactgggacc  
tactcgtact tcgatgtctg gggcacaggg accacggtca ccgtctctc a

[00166] The amino acid sequence of the VL Domain of PD-1 mAb 11 (**SEQ ID NO:205**) is shown below (CDR<sub>L</sub> residues are shown underlined):

DILLTQSPAI LSVSPGERVS FSCRASQSIG TSIHWYQHRT NGSPRLLIKY  
ASESISGIPS RFSGSGSGTD FTLINSINSVES EDIADYYCQQ SNSWLTFGAG  
 TKLELK

CDR<sub>L</sub>1 of PD-1 mAb 11 (**SEQ ID NO:207**): RASQSIGTSIH

CDR<sub>L</sub>2 of PD-1 mAb 11 (**SEQ ID NO:208**): YASESIS

CDR<sub>L</sub>3 of PD-1 mAb 11 (**SEQ ID NO:209**): QQSNSWLT

[00167] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 11 is **SEQ ID NO:206** (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacatcttgc tgactcagtc tccagccatc ctgtctgtga gtccaggaga  
 aagagtcagt ttctcctgca gggccagtca gagcattggc acaagcatac  
actgggtatca gcacagaaca aatgggttctc caaggcttct cataaagttat  
gcttctgagt ctatctctgg gatcccttcc aggttttagtg gcagtggatc  
 agggactgat tttactctta gcatcaacag tgtggagtct gaagatattg  
 cagattatta ctgtcaacaa agtaatagct ggctcacgtt cggtgctggg  
 accaagctgg agctgaaa

## L. Murine Anti-Human PD-1 Antibody PD-1 mAb 12

[00168] The amino acid sequence of the VH Domain of PD-1 mAb 12 (**SEQ ID NO:210**) is shown below (CDR<sub>H</sub> residues are shown underlined).

QGHLLQSGAE LVRPGASVTL SCKASGFTFT DYEMHWVKQT PVHGLEWIGT  
IDPETGGTAY NQKFKGKAIL TVDKSSTTTY MELRSLTSED SAVFYCSRER  
ITTVVEGAYW YFDVWGTGTT VTSS

CDR<sub>H</sub>1 of PD-1 mAb 12 (**SEQ ID NO:212**): DYEMH

CDR<sub>H</sub>2 of PD-1 mAb 12 (**SEQ ID NO:213**): TIDPETGGTAYNQKFKG

CDR<sub>H</sub>3 of PD-1 mAb 12 (**SEQ ID NO:214**): ERITTVVEGAYWYFDV

[00169] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 12 is **SEQ ID NO:211** (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

cagggtcacc tgcagcagtc tggggctgag ctggtgaggc ctggggccttc  
 agtgacgctg tcttgcaagg cttcgggctt cacatttact gactatgaga  
tgcactgggt gaaacagaca cctgtgcatg gcctggaatg gattgggact  
attgatacctg aaactggtgg tactgcctac aatcagaagt tcaagggcaa  
 ggccatactg acagtagaca aatcttccac tacaacctac atggagctcc  
 gcagcctgac atctgaggac tctgccgtct tttattgttc aagagagagg  
attactacgg ttgttgaggg ggcatactgg tacttcgatg tctggggcac  
 agggaccacg gtcaccgtct cctca

[00170] The amino acid sequence of the VL Domain of PD-1 mAb 4 (**SEQ ID NO:215**) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVLMTQTPLS LPVSLGDQAS ISCRSSQNIV HSNGNTYLEW YLQKPGQSPK  
 LLICKKVSTRF SGVPDRFGSGS GSGTDFTLKI SRVEAEDLGV YYCFQGSHVP  
YTFGGGKLE IK

CDR<sub>L</sub>1 of PD-1 mAb 12 (**SEQ ID NO:217**): RSSQNIVHSNGNTYLE

CDR<sub>L</sub>2 of PD-1 mAb 12 (**SEQ ID NO:218**): KVSTRFS

CDR<sub>L</sub>3 of PD-1 mAb 12 (**SEQ ID NO:219**): FQGSHPYT

[00171] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 12 is **SEQ ID NO:216** (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gatgttttga tgaccagac tccactctcc ctgcctgtca gtcttgagga  
 tcaagcctcc atctcttgca gatctagtca gaacattgta catagtaatg  
gaaacaccta ttagaatgg tacctgcaga aaccaggcca gtctccaaag  
 ctctgatct gcaaaagtttc caccgattt tctggggtcc cagacagggt  
 cagtggcagt ggatcaggga cagatttcac actcaagatc agcagagtgg  
 aggctgagga tctgggagtt tattattgct ttcaaggttc acatgttccg  
tacacgttcg gaggggggac caagctggaa ataaaa

## M. Murine Anti-Human PD-1 Antibody PD-1 mAb 13

[00172] The amino acid sequence of the VH Domain of PD-1 mAb 13 (**SEQ ID NO:220**) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVMLVESGGG LVKPGGSLKL SCAASGFTFS SHTMSWVRQT PEKRLEWVAT  
ISGGGSNIYY PDSVKGRFTI SRDNAKNTLY LQMSSLRSED TALYYCARQA  
YYGNYWYFDV WGTGTTVTVS S

CDR<sub>H</sub>1 of PD-1 mAb 13 (**SEQ ID NO:222**): SHTMS

CDR<sub>H</sub>2 of PD-1 mAb 13 (**SEQ ID NO:223**): TISGGGSNIYYPDSVKG

CDR<sub>H</sub>3 of PD-1 mAb 13 (SEQ ID NO:224): QAYYGNYWYFDV

[00173] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 13 is SEQ ID NO:221 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgatgc tgggtggagtc tggggggaggc ttagtgaagc ctggagggtc  
cctgaaactc tcctgtgcag cctctggatt cactttcagt agccatacca  
tgtcttgggt tcgccagact ccggagaaga ggctggagtg ggtcgcaacc  
attagtgggtg gtggttctaa tatctactat ccagacagtg tgaagggtcg  
attcaccatc tccagagaca atgccaagaa caccctgtac ctgcaaatga  
gcagtctgag gtctgaggac acggccttgt attactgtgc aagacaagct  
tactacggta attactggta cttcgatgtc tggggcacag ggaccacggg  
caccgtctcc tcc

[00174] The amino acid sequence of the VL Domain of PD-1 mAb 13 (SEQ ID NO:225) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIQMTQSPAT QSASLGESVT ITCLASQTIG TWLAWYQQKP GKSPQLLIYA  
ATSLADGVPS RFSGSGSGTK FSFKISLQA EDFVSYYCQQ LDSIPWTFGG  
GTKLEIK

CDR<sub>L</sub>1 of PD-1 mAb 13 (SEQ ID NO:227): LASQTIGTWLA

CDR<sub>L</sub>2 of PD-1 mAb 13 (SEQ ID NO:228): AATSLAD

CDR<sub>L</sub>3 of PD-1 mAb 13 (SEQ ID NO:229): QQLD SIPWT

[00175] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 13 is SEQ ID NO:226 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattcaga tgaccagtc tcctgccacc cagtctgcat ctctgggaga  
aagtgtcacc atcacgtgc c tggcaagtca gaccattggt acatgggttag  
catgggtatca gcagaaacca gggaaatctc ctcagctcct gatattatgct  
gcaaccagct tggcagatgg ggtcccatca aggttcagtg gtagtggatc  
tggcacaaaa ttttctttca agatcagcag cctacaggct gaagattttg  
taagttatta ctgtcaacaa cttgacagta ttccgtggac gttcgggtgga  
ggcaccaagc tggaaatcaa a

#### N. Murine Anti-Human PD-1 Antibody PD-1 mAb 14

[00176] The amino acid sequence of the VH Domain of PD-1 mAb 14 (SEQ ID NO:230) is shown below (CDR<sub>H</sub> residues are shown underlined).

QVQLQQPGAE LVKPGASVKM SCKASGYNFI SYWITWVKQR PGQGLQWIGN  
IYPGTDGTTY NEKFKSKATL TVDTSSSTAY MHL SRLTSED SAVYYCATGL  
HWYFDVWGTG TTVTVSS

CDR<sub>H</sub>1 of PD-1 mAb 14 (SEQ ID NO:232): SYWIT

CDR<sub>H</sub>2 of PD-1 mAb 14 (SEQ ID NO:233): NIYPGTDGTTYNEKFKS

CDR<sub>H</sub>3 of PD-1 mAb 14 (SEQ ID NO:234): GLHWYFDV

[00177] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 14 is SEQ ID NO:231 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

cagggtccaac tgcagcagcc tgggggctgag cttgtgaagc ctgggggcttc  
 agtgaagatg tcttgcaagg cttctggcta caacttcac agctactgga  
taacctgggt gaaacagagg cctggacaag gccttcagtg gattggaaaat  
atttatcctg gtactgatgg tactacctac aatgagaagt tcaagagcaa  
 ggccacactg actgtagaca catcctccag cacagcctac atgcacctca  
 gtcgcctgac atctgaggac tctgcggtct attactgtgc aactgggcta  
cactggtact tcgatgtctg gggcacaggg accacggtca cegtctctc c

[00178] The amino acid sequence of the VL Domain of PD-1 mAb 14 (SEQ ID NO:235) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVMTQSQKF MSTSVGDRVS VTCKASQSVG TNVAWYQQKP GQSPKALIYS  
ASSRFSGVDP RFTGSGSGTD FTLTISNVQS EDLAEYFCQQ YNSYPYTFGG  
 GTKLEIK

CDR<sub>L</sub>1 of PD-1 mAb 14 (SEQ ID NO:237): KASQSVGTNVA

CDR<sub>L</sub>2 of PD-1 mAb 14 (SEQ ID NO:238): SASSRFS

CDR<sub>L</sub>3 of PD-1 mAb 14 (SEQ ID NO:239): QQYNSYPYT

[00179] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 14 is SEQ ID NO:236 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattgtga tgacccagtc tcaaaaattc atgtccacat cagtaggaga  
 cagggtcagt gtcacctgca aggccagtc gagtgtgggt actaatgtag  
cctgggtatca acagaagccc ggtcaatctc ctaaagcact gatttacttcg  
gcatcctccc gattcagtgg cgtccctgat cgcttcacag gcagtggatc  
 tgggacagat ttcactctca ccatcagtaa tgtgcagtct gaagacttgg  
 cagagtattt ctgtcagcaa tataacagct atccgtacac gttcggaggg  
 gggaccaagc tggaaataaa a

## O. The Anti-Human PD-1 Antibody PD-1 mAb 15

### 1. Murine Anti-Human PD-1 Antibody PD-1 mAb 15

[00180] The amino acid sequence of the VH Domain of PD-1 mAb 15 (SEQ ID NO:240) is shown below (CDR<sub>H</sub> residues are shown underlined).

EVMLVESGGG LVKPGGSLKL SCAASGFIFS SYLISWVRQT PEKRLEWVAA  
ISGGGADTTY ADSVKGRFTI SRDNAKNTLY LQMSSLRSED TALYYCTRRG  
TYAMDYWGQG TSVTVSS

CDR<sub>H</sub>1 of PD-1 mAb 15 (SEQ ID NO:242): SYLIS  
 CDR<sub>H</sub>2 of PD-1 mAb 15 (SEQ ID NO:243): AISGGGADTTYADSVKG  
 CDR<sub>H</sub>3 of PD-1 mAb 15 (SEQ ID NO:244): RGTYAMDY

[00181] An exemplary polynucleotide that encodes the VH Domain of PD-1 mAb 15 is SEQ ID NO:241 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgatgc tgggtggagtc tggggggaggc ttagtgaagc ctggagggtc  
 cctgaaactc tcctgtgcag cctctggatt cattttcagt agctatctca  
tctcttgggt tcgccagact ccggagaaga ggctggagtg ggtcgctgcc  
attagtgggtg gtgggtgctga cacctactat gccgacagtg tgaagggtcg  
 attcaccatc tccagagaca atgccaaaga caccctgtat ctgcaaatga  
 gcagtctgag gtctgaggac acggccttat attactgtac aagacgaggg  
acctatgcta tggactactg ggggtcaagga acctcagtca ccgtctctc c

[00182] The amino acid sequence of the VL Domain of PD-1 mAb 15 (SEQ ID NO:245) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIQMTQSPAS QSASLGESVT ITCLASQTIG TWLAWYQQKP GKSPQLLIYA  
ATSLADGVPS RFSGSGSGTK FSKISSLQA EDFVNYYCQQ LYSIPWTFGG  
 GTKLEIK

CDR<sub>L</sub>1 of PD-1 mAb 15 (SEQ ID NO:247): LASQTIGTWLA  
 CDR<sub>L</sub>2 of PD-1 mAb 15 (SEQ ID NO:248): AATSLAD  
 CDR<sub>L</sub>3 of PD-1 mAb 15 (SEQ ID NO:249): QQLYSIPWT

[00183] An exemplary polynucleotide that encodes the VL Domain of PD-1 mAb 15 is SEQ ID NO:246 (nucleotides encoding the CDR<sub>L</sub> residues are shown underlined):

gacattcaga tgaccagtc tcccgcctcc cagtctgcat ctctgggaga  
 aagtgtcacc atcacatgc tggcaagtca gaccattggt acatgggttag  
catgggtatca gcagaaacca gggaaatctc ctgagctcct gatttatgct  
gcaaccagct tggcagatgg ggtcccatca aggttcagtg gtagtggatc  
 tggcacaaaa ttttctttca agatcagcag cctacaggct gaagattttg  
 taaattatta ctgtcaacaa ctttacagta ttccgtggac gttcgggtgga  
 ggcaccaagc tggaaatcaa a

## 2. Humanization of the Anti-Human PD-1 Antibody PD-1 mAb 15 to Form "hPD-1 mAb 15"

[00184] The above-described murine anti-human PD-1 antibody PD-1 mAb 15 was humanized and further deimmunized when antigenic epitopes were identified in order to demonstrate the capability of humanizing an anti-human PD-1 antibody so as to decrease its antigenicity upon administration to a human recipient. The humanization yielded one

humanized VH Domain, designated herein as “hPD-1 mAb 2 VH1,” and one humanized VL Domains designated herein as “hPD-1 mAb 1 VL1.” An antibody comprising the humanized VL Domain paired with the humanized VH Domain is referred to as “hPD-1 mAb 15.”

[00185] The amino acid sequence of the VH Domain of hPD-1 mAb 15 VH1 (SEQ ID NO:250) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVQLVESGGG LVRPGGSLRL SCAASGFTFS SYLISWVRQA PGKGLEWVAA  
ISGGGADTTY ADSVKGRFTI SRDNAKNSLY LQMNSLRAED TATYYCARRG  
TYAMDYWGQG TLVTVSS

[00186] An exemplary polynucleotide that encodes hPD-1 mAb 15 VH1 is SEQ ID NO:251 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gaagtgcacac tgggtgaaag tggcggcggg ctggtgcggc caggtgggttc  
 actcagactg tcttgtgcag cttcaggctt tacattctcc tcttatctta  
tctcttgggt gcgccaagcc ccaggtaagg gccttgaatg ggtcgccgcc  
attagtgggg gtggtgccga tacatattat gccgacagcg tcaagggacg  
 tttcaccatc agcagggaca acgccaagaa tagcctttac ctgcagatga  
 actcacttag agctgaagac accgctactt attactgtgc ccggcgcggg  
acttacgcta tggactattg gggccagggc accttgggtca ctgtctcatc c

[00187] The amino acid sequence of the VH Domain of hPD-1 mAb 15 VL1 (SEQ ID NO:252) is shown below (CDR<sub>H</sub> residues are shown underlined):

DIQMTQSPSS LSASVGDRVT ITCLASQTIG TWLAWYQQKP GKAPKLLIYA  
ATSLADGVPS RFSGSGSGTD FTFTISSLQP EDFATYYCQQ LYSIPWTFGQ  
 GTKLEIK

[00188] An exemplary polynucleotide that encodes hPD-1 mAb 15 VL1 is SEQ ID NO:253 (nucleotides encoding the CDR<sub>H</sub> residues are shown underlined):

gatatccaga tgaccagtc tcccagctct ctcagtgcaa gcgtaggcga  
 ccgtgtgacc atcacctgtc tggccagtca gaccattgga acctggctcg  
cctgggtatca gcagaaacct ggcaaggccc ctaagctgct gatttacgcc  
gccacctccc tcgcagatgg agtgccctcc cgatttagcg ggtccgggtc  
 cggcaccgac ttcacattca caatcagcag cctccagccc gaggatttcg  
 ctacatacta ctgtcaacag ctctactcca ttccatggac ctttggtcag  
 ggtactaaac tggagatcaa a

## V. Anti-Human PD-1 Antibodies PD-1 mAb 1-15, and Their Derivatives Having an Engineered Fc Region

[00189] In traditional immune function, the interaction of antibody-antigen complexes with cells of the immune system results in a wide array of responses, ranging from effector functions such as antibody dependent cytotoxicity, mast cell degranulation, and phagocytosis to

immunomodulatory signals such as regulating lymphocyte proliferation and antibody secretion. All of these interactions are initiated through the binding of the Fc Region of antibodies or immune complexes to specialized cell surface receptors on hematopoietic cells. The diversity of cellular responses triggered by antibodies and immune complexes results from the structural heterogeneity of the three Fc receptors: Fc $\gamma$ RI (CD64), Fc $\gamma$ RII (CD32), and Fc $\gamma$ RIII (CD16). Fc $\gamma$ RI (CD64), Fc $\gamma$ RIIA (CD32A) and Fc $\gamma$ RIII (CD16) are activating (*i.e.*, immune system enhancing) receptors; Fc $\gamma$ RIIB (CD32B) is an inhibiting (*i.e.*, immune system dampening) receptor. In addition, interaction with the neonatal Fc Receptor (FcRn) mediates the recycling of IgG molecules from the endosome to the cell surface and release into the blood. The amino acid sequence of exemplary wild-type IgG1 (**SEQ ID NO:1**), IgG2 (**SEQ ID NO:2**), IgG3 (**SEQ ID NO:3**), and IgG4 (**SEQ ID NO:4**) are presented above.

**[00190]** Modification of the Fc Region normally leads to an altered phenotype, for example altered serum half-life, altered stability, altered susceptibility to cellular enzymes or altered effector function. It may be desirable to modify an antibody or other binding molecule of the present invention with respect to effector function, for example, so as to enhance the effectiveness of such molecule in treating cancer. Reduction or elimination of effector function is desirable in certain cases, for example in the case of antibodies whose mechanism of action involves blocking or antagonism, but not killing of the cells bearing a target antigen. Increased effector function is generally desirable when directed to undesirable cells, such as tumor and foreign cells, where the Fc $\gamma$ Rs are expressed at low levels, for example, tumor-specific B cells with low levels of Fc $\gamma$ RIIB (*e.g.*, non-Hodgkins lymphoma, CLL, and Burkitt's lymphoma). In said embodiments, molecules of the invention with conferred or altered effector function activity are useful for the treatment and/or prevention of a disease, disorder or infection where an enhanced efficacy of effector function activity is desired.

**[00191]** In certain embodiments, the PD-1-binding molecules of the present invention comprise an Fc Region that possesses one or more modifications (*e.g.*, substitutions, deletions, or insertions) to the sequence of amino acids of a wild-type Fc Region (*e.g.*, **SEQ ID NO:1**), which reduce the affinity and avidity of the Fc Region and, thus, the molecule of the invention, for one or more Fc $\gamma$ R receptors. In other embodiments, the molecules of the invention comprise an Fc Region that possesses one or more modifications to the amino acids of the wild-type Fc Region, which increase the affinity and avidity of the Fc Region and, thus, the molecule of the invention, for one or more Fc $\gamma$ R receptors. In other embodiments, the molecules

comprise a variant Fc Region wherein said variant confers or mediates increased antibody dependent cell mediated cytotoxicity (ADCC) activity and/or an increased binding to FcγRIIA, relative to a molecule comprising no Fc Region or comprising a wild-type Fc Region. In alternate embodiments, the molecules comprise a variant Fc Region wherein said variant confers or mediates decreased ADCC activity (or other effector function) and/or an increased binding to FcγRIIB, relative to a molecule comprising no Fc Region or comprising a wild-type Fc Region. In some embodiments, the invention encompasses PD-1-binding molecules comprising a variant Fc Region, which variant Fc Region does not show a detectable binding to any FcγR, relative to a comparable molecule comprising the wild-type Fc Region. In other embodiments, the invention encompasses PD-1-binding molecules comprising a variant Fc Region, which variant Fc Region only binds a single FcγR, preferably one of FcγRIIA, FcγRIIB, or FcγRIIA. Any such increased affinity and/or avidity is preferably assessed by measuring *in vitro* the extent of detectable binding to the FcγR or FcγR-related activity in cells that express low levels of the FcγR when binding activity of the parent molecule (without the modified Fc Region) cannot be detected in the cells, or in cells which express non-FcγR receptor target antigens at a density of 30,000 to 20,000 molecules/cell, at a density of 20,000 to 10,000 molecules/cell, at a density of 10,000 to 5,000 molecules/cell, at a density of 5,000 to 1,000 molecules/cell, at a density of 1,000 to 200 molecules/cell or at a density of 200 molecules/cell or less (but at least 10, 50, 100 or 150 molecules/cell).

**[00192]** The PD-1-binding molecules of the present invention may comprise a variant Fc Region having altered affinities for an activating and/or inhibitory Fcγ receptor. In one embodiment, the PD-1-binding molecule comprises a variant Fc Region that has increased affinity for FcγRIIB and decreased affinity for FcγRIIA and/or FcγRIIA, relative to a comparable molecule with a wild-type Fc Region. In another embodiment, the PD-1-binding molecule of the present invention comprise a variant Fc Region, which has decreased affinity for FcγRIIB and increased affinity for FcγRIIA and/or FcγRIIA, relative to a comparable molecule with a wild-type Fc Region. In yet another embodiment, the PD-1-binding molecules of the present invention comprise a variant Fc Region that has decreased affinity for FcγRIIB and decreased affinity for FcγRIIA and/or FcγRIIA, relative to a comparable molecule with a wild-type Fc Region. In still another embodiment, the PD-1-binding molecules of the present invention comprise a variant Fc Region, which has unchanged affinity for FcγRIIB and decreased (or increased) affinity for FcγRIIA and/or FcγRIIA, relative to a comparable molecule with a wild-type Fc Region.

**[00193]** In certain embodiments, the PD-1-binding molecules of the present invention comprise a variant Fc Region having an altered affinity for FcγRIIIA and/or FcγRIIA such that the immunoglobulin has an enhanced effector function. Non-limiting examples of effector cell functions include antibody dependent cell mediated cytotoxicity, antibody dependent phagocytosis, phagocytosis, opsonization, opsonophagocytosis, cell binding, rosetting, C1q binding, and complement dependent cell mediated cytotoxicity.

**[00194]** In a preferred embodiment, the alteration in affinity or effector function is at least 2-fold, preferably at least 4-fold, at least 5-fold, at least 6-fold, at least 7-fold, at least 8-fold, at least 9-fold, at least 10-fold, at least 50-fold, or at least 100-fold, relative to a comparable molecule comprising a wild-type Fc Region. In other embodiments of the invention, the variant Fc Region immunospecifically binds one or more FcRs with at least 65%, preferably at least 70%, 75%, 80%, 85%, 90%, 95%, 100%, 125%, 150%, 175%, 200%, 225%, or 250% greater affinity relative to a molecule comprising a wild-type Fc Region. Such measurements can be in vivo or in vitro assays, and in a preferred embodiment are in vitro assays such as ELISA or surface plasmon resonance assays.

**[00195]** In different embodiments, the PD-1-binding molecules of the present invention comprise a variant Fc Region wherein said variant agonizes at least one activity of an FcγR receptor, or antagonizes at least one activity of an FcγR receptor. In a preferred embodiment, the molecules comprise a variant that antagonizes one or more activities of FcγRIIB, for example, B-cell receptor-mediated signaling, activation of B-cells, B-cell proliferation, antibody production, intracellular calcium influx of B cells, cell cycle progression, FcγRIIB-mediated inhibition of FcεRI signaling, phosphorylation of FcγRIIB, SHIP recruitment, SHIP phosphorylation and association with Shc, or activity of one or more downstream molecules (*e.g.*, MAP kinase, JNK, p38, or Akt) in the FcγRIIB signal transduction pathway. In another embodiment, the PD-1-binding molecules of the present invention comprise a variant that agonizes one or more activities of FcεRI, for example, mast cell activation, calcium mobilization, degranulation, cytokine production, or serotonin release.

**[00196]** In certain embodiments, the molecules comprise an Fc Region comprising regions from two or more IgG isotypes (*e.g.*, IgG1, IgG2, IgG3 and IgG4). As used herein, an Fc Region is said to be of a particular IgG isotype if its amino acid sequence is most homologous to that isotype relative to other IgG isotypes. The various IgG isotypes exhibit differing physical and functional properties including serum half-life, complement fixation, FcγR

binding affinities and effector function activities (*e.g.*, ADCC, CDC, *etc.*) due to differences in the amino acid sequences of their hinge and/or Fc Regions, for example as described in Flesch and Neppert (1999) *J. Clin. Lab. Anal.* 14:141-156; Chappel *et al.* (1993) *J. Biol. Chem.* 33:25124-25131; Chappel *et al.* (1991) *Proc. Natl. Acad. Sci. (U.S.A.)* 88:9036-9040; or Brüggemann *et al.* (1987) *J. Exp. Med* 166:1351-1361. This type of variant Fc Region may be used alone, or in combination with an amino acid modification, to affect Fc-mediated effector function and/or binding activity. In combination, the amino acid modification and IgG hinge/Fc Region may display similar functionality (*e.g.*, increased affinity for FcγRIIA) and may act additively or, more preferably, synergistically to modify the effector functionality in the molecule of the invention, relative to a molecule of the invention comprising a wild-type Fc Region. In other embodiments, the amino acid modification and IgG Fc Region may display opposite functionality (*e.g.*, increased and decreased affinity for FcγRIIA, respectively) and may act to selectively temper or reduce a specific functionality in the molecule of the invention, relative to a molecule of the invention not comprising an Fc Region or comprising a wild-type Fc Region of the same isotype.

**[00197]** In a preferred specific embodiment, the PD-1-binding molecules of the present invention comprise a variant Fc Region, wherein said variant Fc Region comprises at least one amino acid modification relative to a wild-type Fc Region, such that said molecule has an altered affinity for an FcR, provided that said variant Fc Region does not have a substitution at positions that make a direct contact with FcγR based on crystallographic and structural analysis of Fc-FcR interactions such as those disclosed by Sondermann *et al.* (2000) *Nature* 406:267-73. Examples of positions within the Fc Region that make a direct contact with FcγR are amino acid residues 234-239, amino acid residues 265-269 (B/C loop), amino acid residues 297-299 (C'/E loop), and amino acid residues 327-332 (F/G loop). In some embodiments, the molecules of the invention comprise variant Fc Regions comprise modification of at least one residue that does not make a direct contact with an FcγR based on structural and crystallographic analysis, *e.g.*, is not within the Fc-FcγR binding site.

**[00198]** Variant Fc Regions are well known in the art, and any known variant Fc Region may be used in the present invention to confer or modify the effector function exhibited by a molecule of the invention comprising an Fc Region (or portion thereof) as functionally assayed, *e.g.*, in an NK dependent or macrophage dependent assay. For example, Fc Region variants identified as altering effector function are disclosed in PCT Publications No. WO 04/063351;

WO 06/088494; WO 07/024249; WO 06/113665; WO 07/021841; WO 07/106707; and WO 2008/140603, and any suitable variant disclosed therein may be used in the present molecules.

**[00199]** In certain embodiments, the PD-1-binding molecules of the present invention comprise a variant Fc Region, having one or more amino acid modifications in one or more regions, which modification(s) alter (relative to a wild-type Fc Region) the **Ratio of Affinities** of the variant Fc Region to an activating FcγR (such as FcγRIIA or FcγRIIIA) relative to an inhibiting FcγR (such as FcγRIIB):

$$\text{Ratio of Affinities} = \frac{\text{Wild-Type to Variant Change in Affinity to Fc}\gamma\text{R}_{\text{Activating}}}{\text{Wild-Type to Variant Change in Affinity to Fc}\gamma\text{R}_{\text{Inhibiting}}}$$

**[00200]** Particularly preferred are PD-1-binding molecules of the present invention that possess a variant Fc Region (relative to the wild-type Fc Region) in which the variant Fc Region has a Ratio of Affinities greater than 1. Such molecules have particular use in providing a therapeutic or prophylactic treatment of a disease, disorder, or infection, or the amelioration of a symptom thereof, where an enhanced efficacy of effector cell function (*e.g.*, ADCC) mediated by FcγR is desired, *e.g.*, cancer or infectious disease. In contrast, a variant Fc Region having a Ratio of Affinities less than 1 mediates decreased efficacy of effector cell function. **Table 1** lists exemplary single, double, triple, quadruple and quintuple mutations by whether their Ratio of Affinities is greater than or less than 1.

| Table 1                                                               |               |                      |                              |                                    |
|-----------------------------------------------------------------------|---------------|----------------------|------------------------------|------------------------------------|
| Exemplary Single and Multiple Mutations Listed by Ratio of Affinities |               |                      |                              |                                    |
| Single                                                                | Double        | Triple               | Quadruple                    | Quintuple                          |
| Ratio of Affinities > 1                                               |               |                      |                              |                                    |
| F243L                                                                 | F243L & R292P | F243L, P247L & N421K | L234F, F243L, R292P & Y300L  | L235V, F243L, R292P, Y300L & P396L |
| D270E                                                                 | F243L & Y300L | F243L, R292P & Y300L | L235I, F243L, R292P & Y300L  | L235P, F243L, R292P, Y300L & P396L |
| R292G                                                                 | F243L & P396L | F243L, R292P & V305I | L235Q, F243L, R292P & Y300L  | F243L, R292P, V305I, Y300L & P396L |
| R292P                                                                 | D270E & P396L | F243L, R292P & P396L | F243L, P247L, D270E & N421K  |                                    |
|                                                                       | R292P & Y300L | F243L, Y300L & P396L | F243L, R255L, D270E & P396L  |                                    |
|                                                                       | R292P & V305I | P247L, D270E & N421K | F243L, D270E, G316D & R416G  |                                    |
|                                                                       | R292P & P396L | R255L, D270E & P396L | F243L, D270E, K392T & P396L  |                                    |
|                                                                       | Y300L & P396L | D270E, G316D & R416G | F243L, D270E, P396L & Q419H  |                                    |
|                                                                       | P396L & Q419H | D270E, K392T & P396L | F243L, R292P, Y300L, & P396L |                                    |
|                                                                       |               | D270E, P396L & Q419H | F243L, R292P, V305I & P396L  |                                    |
|                                                                       |               | V284M, R292L & K370N | P247L, D270E, Y300L & N421K  |                                    |
|                                                                       |               | R292P, Y300L & P396L | R255L, D270E, R292G & P396L  |                                    |
|                                                                       |               |                      | R255L, D270E, Y300L & P396L  |                                    |
|                                                                       |               |                      | D270E, G316D, P396L & R416G  |                                    |
| Ratio of Affinities < 1                                               |               |                      |                              |                                    |
| Y300L                                                                 | F243L & P396L | F243L, R292P & V305I |                              |                                    |
| P396L                                                                 | P247L & N421K |                      |                              |                                    |
|                                                                       | R255L & P396L |                      |                              |                                    |
|                                                                       | R292P & V305I |                      |                              |                                    |
|                                                                       | K392T & P396L |                      |                              |                                    |
|                                                                       | P396L & Q419H |                      |                              |                                    |

**[00201]** In a specific embodiment, in variant Fc Regions, any amino acid modifications (e.g., substitutions) at any of positions 235, 240, 241, 243, 244, 247, 262, 263, 269, 298, 328, or 330

and preferably one or more of the following residues: A240, I240, L241, L243, H244, N298, I328 or V330. In a different specific embodiment, in variant Fc Regions, any amino acid modifications (*e.g.*, substitutions) at any of positions 268, 269, 270, 272, 276, 278, 283, 285, 286, 289, 292, 293, 301, 303, 305, 307, 309, 331, 333, 334, 335, 337, 338, 340, 360, 373, 376, 416, 419, 430, 434, 435, 437, 438 or 439 and preferably one or more of the following residues: H280, Q280, Y280, G290, S290, T290, Y290, N294, K295, P296, D298, N298, P298, V298, I300 or L300.

**[00202]** In a preferred embodiment, in variant Fc Regions that bind an FcγR with an altered affinity, any amino acid modifications (*e.g.*, substitutions) at any of positions 255, 256, 258, 267, 268, 269, 270, 272, 276, 278, 280, 283, 285, 286, 289, 290, 292, 293, 294, 295, 296, 298, 300, 301, 303, 305, 307, 309, 312, 320, 322, 326, 329, 330, 332, 331, 333, 334, 335, 337, 338, 339, 340, 359, 360, 373, 376, 416, 419, 430, 434, 435, 437, 438 or 439. Preferably, the variant Fc Region has any of the following residues: A256, N268, Q272, D286, Q286, S286, A290, S290, A298, M301, A312, E320, M320, Q320, R320, E322, A326, D326, E326, N326, S326, K330, T339, A333, A334, E334, H334, L334, M334, Q334, V334, K335, Q335, A359, A360 or A430.

**[00203]** In a different embodiment, in variant Fc Regions that bind an FcγR (via its Fc Region) with a reduced affinity, any amino acid modifications (*e.g.*, substitutions) at any of positions 252, 254, 265, 268, 269, 270, 278, 289, 292, 293, 294, 295, 296, 298, 300, 301, 303, 322, 324, 327, 329, 333, 335, 338, 340, 373, 376, 382, 388, 389, 414, 416, 419, 434, 435, 437, 438 or 439.

**[00204]** In a different embodiment, in variant Fc Regions that bind an FcγR (via its Fc Region) with an enhanced affinity, any amino acid modifications (*e.g.*, substitutions) at any of positions 280, 283, 285, 286, 290, 294, 295, 298, 300, 301, 305, 307, 309, 312, 315, 331, 333, 334, 337, 340, 360, 378, 398 or 430. In a different embodiment, in variant Fc Regions that binds FcγRIIA with an enhanced affinity, any of the following residues: A255, A256, A258, A267, A268, N268, A272, Q272, A276, A280, A283, A285, A286, D286, Q286, S286, A290, S290, M301, E320, M320, Q320, R320, E322, A326, D326, E326, S326, K330, A331, Q335, A337 or A430.

**[00205]** Preferred variants include one or more modifications at any of positions: 228, 230, 231, 232, 233, 234, 235, 239, 240, 241, 243, 244, 245, 247, 262, 263, 264, 265, 266, 271, 273, 275, 281, 284, 291, 296, 297, 298, 299, 302, 304, 305, 313, 323, 325, 326, 328, 330 or 332.

**[00206]** Particularly preferred variants include one or more modifications selected from groups A-AI:

|    |                                                                                                                   |
|----|-------------------------------------------------------------------------------------------------------------------|
| A  | 228E, 228K, 228Y or 228G;                                                                                         |
| B  | 230A, 230E, 230Y or 230G;                                                                                         |
| C  | 231E, 231K, 231Y, 231P or 231G;                                                                                   |
| D  | 232E, 232K, 232Y, 232G;                                                                                           |
| E  | 233D;                                                                                                             |
| F  | 234I or 234F;                                                                                                     |
| G  | 235D, 235Q, 235P, 235I or 235V;                                                                                   |
| H  | 239D, 239E, 239N or 239Q;                                                                                         |
| I  | 240A, 240I, 240M or 240T;                                                                                         |
| J  | 243R, 243, 243Y, 243L, 243Q, 243W, 243H or 243I;                                                                  |
| K  | 244H;                                                                                                             |
| L  | 245A;                                                                                                             |
| M  | 247G, 247V or 247L;                                                                                               |
| N  | 262A, 262E, 262I, 262T, 262E or 262F;                                                                             |
| O  | 263A, 263I, 263M or 263T;                                                                                         |
| P  | 264F, 264E, 264R, 264I, 264A, 264T or 264W;                                                                       |
| Q  | 265F, 265Y, 265H, 265I, 265L, 265T, 265V, 265N or 265Q;                                                           |
| R  | 266A, 266I, 266M or 266T;                                                                                         |
| S  | 271D, 271E, 271N, 271Q, 271K, 271R, 271S, 271T, 271H, 271A, 271V, 271L, 271I, 271F, 271M, 271Y, 271W or 271G;     |
| T  | 273I;                                                                                                             |
| U  | 275L or 275W;                                                                                                     |
| V  | 281D, 281K, 281Y or 281P;                                                                                         |
| W  | 284E, 284N, 284T, 284L, 284Y or 284M;                                                                             |
| X  | 291D, 291E, 291Q, 291T, 291H, 291I or 291G;                                                                       |
| Y  | 299A, 299D, 299E, 299F, 299G, 299H, 299I, 299K, 299L, 299M, 299N, 299P, 299Q, 299R, 299S, 299V, 299W or 299Y;     |
| Z  | 302I;                                                                                                             |
| AA | 304D, 304N, 304T, 304H or 304L                                                                                    |
| AB | 305I;                                                                                                             |
| AC | 313F;                                                                                                             |
| AD | 323I;                                                                                                             |
| AE | 325A, 325D, 325E, 325G, 325H, 325I, 325L, 325K, 325R, 325S, 325F, 325M, 325T, 325V, 325Y, 325W or 325P;           |
| AF | 328D, 328Q, 328K, 328R, 328S, 328T, 328V, 328I, 328Y, 328W, 328P, 328G, 328A, 328E, 328F, 328H, 328M or 328N;     |
| AG | 330L, 330Y, 330I or 330V;                                                                                         |
| AH | 332A, 332D, 332E, 332H, 332N, 332Q, 332T, 332K, 332R, 332S, 332V, 332L, 332F, 332M, 332W, 332P, 332G or 332Y; and |
| AI | 336E, 336K or 336Y                                                                                                |

[00207] Still more particularly preferred variants include one or more modifications selected from Groups 1-105:

| Group | Variant                                       | Group | Variant                                                       |
|-------|-----------------------------------------------|-------|---------------------------------------------------------------|
| 1     | A330L / I332E                                 | 54    | S239D / D265L / N297D / I332E                                 |
| 2     | D265F / N297E / I332E                         | 55    | S239D / D265T / N297D / I332E                                 |
| 3     | D265Y / N297D / I332E                         | 56    | S239D / D265V / N297D / I332E                                 |
| 4     | D265Y / N297D / T299L / I332E                 | 57    | S239D / D265Y / N297D / I332E                                 |
| 5     | F241E / F243Q / V262T / V264F                 | 58    | S239D / I332D                                                 |
| 6     | F241E / F243Q / V262T / V264E / I332E         | 59    | S239D / I332E                                                 |
| 7     | F241E / F243R / V262E / V264R                 | 60    | S239D / I332E / A330I                                         |
| 8     | F241E / F243R / V262E / V264R / I332E         | 61    | S239D / I332N                                                 |
| 9     | F241E / F243Y / V262T / V264R                 | 62    | S239D / I332Q                                                 |
| 10    | F241E / F243Y / V262T / V264R / I332E         | 63    | S239D / N297D / I332E                                         |
| 11    | F241L / F243L / V262I / V264I                 | 64    | S239D / N297D / I332E / A330Y                                 |
| 12    | F241L / V262I                                 | 65    | S239D / N297D / I332E / A330Y / F241S / F243H / V262T / V264T |
| 13    | F241R / F243Q / V262T / V264R                 | 66    | S239D / N297D / I332E / K326E                                 |
| 14    | F241R / F243Q / V262T / V264R / I332E         | 67    | S239D / N297D / I332E / L235D                                 |
| 15    | F241W / F243W / V262A / V264A                 | 68    | S239D / S298A / I332E                                         |
| 16    | F241Y / F243Y / V262T / V264T                 | 69    | S239D / V264I / A330L / I332E                                 |
| 17    | F241Y / F243Y / V262T / V264T / N297D / I332E | 70    | S239D / V264I / I332E                                         |
| 18    | F243L / V262I / V264W                         | 71    | S239D / V264I / S298A / I332E                                 |
| 19    | P243L / V264I                                 | 72    | S239E / D265N                                                 |
| 20    | L328D / I332E                                 | 73    | S239E / D265Q                                                 |
| 21    | L328E / I332E                                 | 74    | S239E / I332D                                                 |
| 22    | L328H / I332E                                 | 75    | S239E / I332E                                                 |
| 23    | L328I / I332E                                 | 76    | S239E / I332N                                                 |
| 24    | L328M / I332E                                 | 77    | S239E / I332Q                                                 |
| 25    | L328N / I332E                                 | 78    | S239E / N297D / I332E                                         |
| 26    | L328Q / I332E                                 | 79    | S239E / V264I / A330Y / I332 E                                |
| 27    | L328T / I332E                                 | 80    | S239E / V264I / I332 E                                        |
| 28    | L328V / I332E                                 | 81    | S239E / V264I / S298A / A330Y / I332E                         |
| 29    | N297D / A330Y / I332E                         | 82    | S239N / A330L / I332E                                         |
| 30    | N297D / I332E                                 | 83    | S239N / A330Y / I332E                                         |
| 31    | N297D / I332E / S239D / A330L                 | 84    | S239N / I332D                                                 |
| 32    | N297D / S298A / A330Y / I 332E                | 85    | S239N / I332E                                                 |
| 33    | N297D / T299L / I332E                         | 86    | S239N / I332N                                                 |
| 34    | N297D / T299F / I332E / N297D / T299H / I332E | 87    | S239N / I332Q                                                 |
| 35    | N297D / T299I / I332E                         | 88    | S239N1S298A / I332E                                           |

| Group | Variant                       | Group | Variant               |
|-------|-------------------------------|-------|-----------------------|
| 36    | N297D / T299L / I332E         | 89    | S239Q / I332D         |
| 37    | N297D / T299V / I332E         | 90    | S239Q / I332E         |
| 38    | N297E / I332E                 | 91    | S239Q / I332N         |
| 39    | N297S / I332E                 | 92    | S239Q / I332Q         |
| 40    | P230A / E233D / I332E         | 93    | S239Q / V264I / I332E |
| 41    | P244H / P245A / P247V         | 94    | S298A / I332E         |
| 42    | S239D / A330L / I332E         | 95    | V264E / N297D / I332E |
| 43    | S239D / A330Y / I332E         | 96    | V264I / A330L / I332E |
| 44    | S239D / A330Y / I332E / K326E | 97    | V264I / A330Y / I332E |
| 45    | S239D / A330Y / I332E / K326T | 98    | V264I / I332E         |
| 46    | S239D / A330Y / I332E / L234I | 99    | V264I / S298A / I332E |
| 47    | S239D / A330Y / I332E / L235D | 100   | Y296D / N297D / I332E |
| 48    | S239D / A330Y / I332E / V240I | 101   | Y296E / N297D / I332E |
| 49    | S239D / A330Y / I332E / V264T | 102   | Y296H / N297D / I332E |
| 50    | S239D / A330Y / I332E / V266I | 103   | Y296N / N297D / I332E |
| 51    | S239D / D265F / N297D / I332E | 104   | Y296Q / N297I / I332E |
| 52    | S239D / D265H / N297D / I332E | 105   | Y296T / N297D / I332E |
| 53    | S239D / D265I / N297D / I332E |       |                       |

**[00208]** In one embodiment, a PD-1-binding molecule of the invention will comprise a variant Fc Region having at least one modification in the Fc Region. In certain embodiments, the variant Fc Region comprises at least one substitution selected from the group consisting of L235V, F243L, R292P, Y300L, V305I, and P396L.

**[00209]** In a specific embodiment, the variant Fc Region comprises:

- (A) at least one substitution selected from the group consisting of F243L, R292P, Y300L, V305I, and P396L;
- (B) at least two substitutions selected from the group consisting of:
  - (1) F243L and P396L;
  - (2) F243L and R292P; and
  - (3) R292P and V305I;
- (C) at least three substitutions selected from the group consisting of:
  - (1) F243L, R292P and Y300L;
  - (2) F243L, R292P and V305I;
  - (3) F243L, R292P and P396L; and
  - (4) R292P, V305I and P396L;
- (D) at least four substitutions selected from the group consisting of:
  - (1) F243L, R292P, Y300L and P396L; and
  - (2) F243L, R292P, V305I and P396L; or

- (E) at least the five substitutions selected from the group consisting of:
- (1) F243L, R292P, Y300L, V305I and P396L; and
  - (2) L235V, F243L, R292P, Y300L and P396L.

**[00210]** In another specific embodiment, the variant Fc Region comprises substitutions of:

- (A) F243L, R292P, and Y300L;
- (B) L235V, F243L, R292P, Y300L, and P396L; or
- (C) F243L, R292P, Y300L, V305I, and P396L.

**[00211]** In one embodiment, a PD-1-binding molecule of the invention comprises a variant Fc Region that exhibits decreased (or substantially no) binding to FcγRIA (CD64), FcγRIIA (CD32A), FcγRIIB (CD32B), FcγRIIIA (CD16a) or FcγRIIIB (CD16b) (relative to the binding exhibited by the wild-type IgG1 Fc Region (**SEQ ID NO:1**)). In one embodiment, a PD-1-binding molecule of the invention will comprise a variant Fc Region that exhibits reduced (or substantially no) binding to an FcγR (*e.g.*, FcγRIIIA) and reduced (or substantially no) ADCC effector function. In certain embodiments, the variant Fc Region comprises at least one substitution selected from the group consisting of L234A, L235A, D265A, N297Q, and N297G. In a specific embodiment, the variant Fc Region comprises the substitution of L234A; L235A; L234A and L235A; D265A; N297Q, or N297G.

**[00212]** A preferred IgG1 sequence for the CH2 and CH3 Domains of the PD-1-binding molecules of the invention will have the L234A/L235A substitutions (**SEQ ID NO:5**):

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APEAAAGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVKFNWYVD
GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA
PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLTCLVK GFYPSDIAVE
WESNGQPENN YKTTTPVLDS DGSFFLYSKL TVDKSRWQQG NVFSCSVMHE
ALHNHYTQKS LSLSPGX
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wherein, **X** is a lysine (K) or is absent.

**[00213]** In a different embodiment, a PD-1-binding molecule of the invention comprises an Fc Region which inherently exhibits decreased (or substantially no) binding to FcγRIIIA (CD16a) and/or reduced effector function (relative to the binding exhibited by the wild-type IgG1 Fc Region (**SEQ ID NO:1**)). In a specific embodiment, a PD-1-binding molecule of the present invention comprises an IgG2 Fc Region (**SEQ ID NO:2**) or an IgG4 Fc Region (**SEQ ID NO:4**). When an IgG4 Fc Region is utilized, the instant invention also encompasses the introduction of a stabilizing mutation, such as the IgG4 hinge region S228P substitution (see, *e.g.*,

**SEQ ID NO:13:** ESKYGPPCPPCP, (Lu *et al.*, (2008) “*The Effect Of A Point Mutation On The Stability Of IgG4 As Monitored By Analytical Ultracentrifugation*,” J. Pharmaceutical Sciences 97:960-969) to reduce the incidence of strand exchange. Other stabilizing mutations known in the art may be introduced into an IgG4 Fc Region (Peters, P *et al.*, (2012) “*Engineering an Improved IgG4 Molecule with Reduced Disulfide Bond Heterogeneity and Increased Fab Domain Thermal Stability*,” J. Biol. Chem., 287:24525-24533; PCT Patent Publication No: WO 2008/145142).

**[00214]** In other embodiments, the invention encompasses the use of any variant Fc Region known in the art, such as those disclosed in Jefferis, B.J. *et al.* (2002) “*Interaction Sites On Human IgG-Fc For FcγR: Current Models*,” Immunol. Lett. 82:57-65; Presta, L.G. *et al.* (2002) “*Engineering Therapeutic Antibodies For Improved Function*,” Biochem. Soc. Trans. 30:487-90; Idusogie, E.E. *et al.* (2001) “*Engineered Antibodies With Increased Activity To Recruit Complement*,” J. Immunol. 166:2571-75; Shields, R.L. *et al.* (2001) “*High Resolution Mapping Of The Binding Site On Human IgG1 For FcγRI, FcγRII, FcγRIII, And FcγRn And Design Of IgG1 Variants With Improved Binding To The FcγR*,” J. Biol. Chem. 276:6591-6604; Idusogie, E.E. *et al.* (2000) “*Mapping Of The C1q Binding Site On Rituxan, A Chimeric Antibody With A Human IgG Fc*,” J. Immunol. 164:4178-84; Reddy, M.P. *et al.* (2000) “*Elimination Of Fc Receptor-Dependent Effector Functions Of A Modified IgG4 Monoclonal Antibody To Human CD4*,” J. Immunol. 164:1925-1933; Xu, D. *et al.* (2000) “*In Vitro Characterization of Five Humanized OKT3 Effector Function Variant Antibodies*,” Cell. Immunol. 200:16-26; Armour, K.L. *et al.* (1999) “*Recombinant human IgG Molecules Lacking FcγR Binding And Monocyte Triggering Activities*,” Eur. J. Immunol. 29:2613-24; Jefferis, R. *et al.* (1996) “*Modulation Of Fc(γ)R And Human Complement Activation By IgG3-Core Oligosaccharide Interactions*,” Immunol. Lett. 54:101-04; Lund, J. *et al.* (1996) “*Multiple Interactions Of IgG With Its Core Oligosaccharide Can Modulate Recognition By Complement And Human FcγR I And Influence The Synthesis Of Its Oligosaccharide Chains*,” J. Immunol. 157:4963-4969; Hutchins *et al.* (1995) “*Improved Biodistribution, Tumor Targeting, And Reduced Immunogenicity In Mice With A Gamma 4 Variant Of Campath-1H*,” Proc. Natl. Acad. Sci. (U.S.A.) 92:11980-84; Jefferis, R. *et al.* (1995) “*Recognition Sites On Human IgG For Fcγ Receptors: The Role Of Glycosylation*,” Immunol. Lett. 44:111-17; Lund, J. *et al.* (1995) “*Oligosaccharide-Protein Interactions In IgG Can Modulate Recognition By Fcγ Receptors*,” FASEB J. 9:115-19; Alegre, M.L. *et al.* (1994) “*A Non-Activating "Humanized" Anti-CD3 Monoclonal*

*Antibody Retains Immunosuppressive Properties In Vivo*,” Transplantation 57:1537-1543; Lund *et al.* (1992) “*Multiple Binding Sites On The CH2 Domain Of IgG For Mouse Fc Gamma R11*,” Mol. Immunol. 29:53-59; Lund *et al.* (1991) “*Human Fc Gamma RI And Fc Gamma RII Interact With Distinct But Overlapping Sites On Human IgG*,” J. Immunol. 147:2657-2662; Duncan, A.R. *et al.* (1988) “*Localization Of The Binding Site For The Human High-Affinity Fc Receptor On IgG*,” Nature 332:563-564; US Patent Nos. 5,624,821; 5,885,573; 6,194,551; 7,276,586; and 7,317,091; and PCT Publications WO 00/42072 and PCT WO 99/58572.

**[00215]** In some embodiments, the molecules of the invention further comprise one or more glycosylation sites, so that one or more carbohydrate moieties are covalently attached to the molecule. Preferably, the molecules of the invention with one or more glycosylation sites and/or one or more modifications in the Fc Region confer or have an enhanced antibody mediated effector function, *e.g.*, enhanced ADCC activity, compared to the unmodified antibody. In some embodiments, the invention further comprises molecules comprising one or more modifications of amino acids that are directly or indirectly known to interact with a carbohydrate moiety of the Fc Region, including but not limited to amino acids at positions 241, 243, 244, 245, 249, 256, 258, 260, 262, 264, 265, 296, 299, and 301. Amino acids that directly or indirectly interact with a carbohydrate moiety of an Fc Region are known in the art, *see, e.g.*, Jefferis *et al.*, 1995 *Immunology Letters*, 44: 111-7, which is incorporated herein by reference in its entirety.

**[00216]** In another embodiment, the invention encompasses molecules that have been modified by introducing one or more glycosylation sites into one or more sites of the molecules, preferably without altering the functionality of the molecules, *e.g.*, binding activity to target antigen or FcγR. Glycosylation sites may be introduced into the variable and/or constant region of the molecules of the invention. As used herein, “glycosylation sites” include any specific amino acid sequence in an antibody to which an oligosaccharide (*i.e.*, carbohydrates containing two or more simple sugars linked together) will specifically and covalently attach. Oligosaccharide side chains are typically linked to the backbone of an antibody via either N- or O-linkages. N-linked glycosylation refers to the attachment of an oligosaccharide moiety to the side chain of an asparagine residue. O-linked glycosylation refers to the attachment of an oligosaccharide moiety to a hydroxyamino acid, *e.g.*, serine, threonine. The molecules of the invention may comprise one or more glycosylation sites, including N-linked and O-linked glycosylation sites. Any glycosylation site for N-linked or O-linked glycosylation known in

the art may be used in accordance with the instant invention. An exemplary N-linked glycosylation site that is useful in accordance with the methods of the present invention is the amino acid sequence: Asn-X-Thr/Ser, wherein X may be any amino acid and Thr/Ser indicates a threonine or a serine. Such a site or sites may be introduced into a molecule of the invention using methods well known in the art to which this invention pertains (see for example, *IN VITRO* MUTAGENESIS, RECOMBINANT DNA: A SHORT COURSE, J. D. Watson, *et al.* W.H. Freeman and Company, New York, 1983, chapter 8, pp. 106-116, which is incorporated herein by reference in its entirety). An exemplary method for introducing a glycosylation site into a molecule of the invention may comprise: modifying or mutating an amino acid sequence of the molecule so that the desired Asn-X-Thr/Ser sequence is obtained.

**[00217]** In some embodiments, the invention encompasses methods of modifying the carbohydrate content of a molecule of the invention by adding or deleting a glycosylation site. Methods for modifying the carbohydrate content of antibodies (and molecules comprising antibody domains, *e.g.*, Fc Region) are well known in the art and encompassed within the invention, *see, e.g.*, U.S. Patent No. 6,218,149; EP 0 359 096 B1; U.S. Publication No. US 2002/0028486; WO 03/035835; U.S. Publication No. 2003/0115614; U.S. Patent No. 6,218,149; U.S. Patent No. 6,472,511; all of which are incorporated herein by reference in their entirety. In other embodiments, the invention encompasses methods of modifying the carbohydrate content of a molecule of the invention by deleting one or more endogenous carbohydrate moieties of the molecule. In a specific embodiment, the invention encompasses shifting the glycosylation site of the Fc Region of an antibody, by modifying positions adjacent to 297. In a specific embodiment, the invention encompasses modifying position 296 so that position 296 and not position 297 is glycosylated.

**[00218]** Effector function can also be modified by techniques such as by introducing one or more cysteine residues into the Fc Region, thereby allowing interchain disulfide bond formation in this region to occur, resulting in the generation of a homodimeric antibody that may have improved internalization capability and/or increased complement-mediated cell killing and ADCC (Caron, P.C. *et al.* (1992) “*Engineered Humanized Dimeric Forms Of IgG Are More Effective Antibodies*,” J. Exp. Med. 176:1191-1195; Shopes, B. (1992) “*A Genetically Engineered Human IgG Mutant With Enhanced Cytolytic Activity*,” J. Immunol. 148(9):2918-2922. Homodimeric antibodies with enhanced antitumor activity may also be prepared using heterobifunctional cross-linkers as described in Wolff, E.A. *et al.* (1993)

*“Monoclonal Antibody Homodimers: Enhanced Antitumor Activity In Nude Mice,”* Cancer Research 53:2560-2565. Alternatively, an antibody can be engineered which has dual Fc Regions and may thereby have enhanced complement lysis and ADCC capabilities (Stevenson, G.T. *et al.* (1989) *“A Chimeric Antibody With Dual Fc Regions (bisFabFc) Prepared By Manipulations At The IgG Hinge,”* Anti-Cancer Drug Design 3:219-230).

**[00219]** The serum half-life of the molecules of the present invention comprising Fc Regions may be increased by increasing the binding affinity of the Fc Region for FcRn. The term “half-life” as used herein means a pharmacokinetic property of a molecule that is a measure of the mean survival time of the molecules following their administration. Half-life can be expressed as the time required to eliminate fifty percent (50%) of a known quantity of the molecule from a subject’s body (*e.g.*, human patient or other mammal) or a specific compartment thereof, for example, as measured in serum, *i.e.*, circulating half-life, or in other tissues. In general, an increase in half-life results in an increase in mean residence time (MRT) in circulation for the molecule administered.

**[00220]** In some embodiments, the PD-1-binding molecules of the present invention comprise a variant Fc Region, wherein said variant Fc Region comprises at least one amino acid modification relative to a wild-type Fc Region, such that said molecule has an increased half-life (relative to a wild-type Fc Region).

**[00221]** In some embodiments, the PD-1-binding molecules of the present invention comprise a variant Fc Region, wherein said variant Fc Region comprises a half-live extending amino acid substitution at one or more positions selected from the group consisting of 238, 250, 252, 254, 256, 257, 256, 265, 272, 286, 288, 303, 305, 307, 308, 309, 311, 312, 317, 340, 356, 360, 362, 376, 378, 380, 382, 413, 424, 428, 433, 434, 435, and 436. Numerous specific mutations capable of increasing the half-life of an Fc Region-containing molecule are known in the art and include, for example M252Y, S254T, T256E, and combinations thereof. For example, see the mutations described in U.S. Patent Nos. 6,277,375, 7,083,784; 7,217,797, 8,088,376; U.S. Publication Nos. 2002/0147311; 2007/0148164; and International Publication Nos. WO 98/23289; WO 2009/058492; and WO 2010/033279, which are herein incorporated by reference in their entireties. Fc Region-containing molecules with enhanced half-life also include those with substitutions at two or more of Fc Region residues 250, 252, 254, 256, 257, 288, 307, 308, 309, 311, 378, 428, 433, 434, 435 and 436. In particular, two or more

substitutions selected from: T250Q, M252Y, S254T, T256E, K288D, T307Q, V308P, A378V, M428L, N434A, H435K, and Y436I.

**[00222]** In a specific embodiment, the variant Fc Region comprises substitutions of:

- (A) M252Y, S254T and T256E;
- (B) M252Y and S254T;
- (C) M252Y and T256E;
- (D) T250Q and M428L;
- (E) T307Q and N434A;
- (F) A378V and N434A;
- (G) N434A and Y436I;
- (H) V308P and N434A; or
- (I) K288D and H435K.

**[00223]** The instant invention further encompasses variant Fc Regions comprising:

- (A) one or more mutations which alter effector function and/or FcγR; and
- (B) one or more mutations which extend serum half-life.

## **VI. Bispecific Anti-Human PD-1-Binding Molecules**

**[00224]** One embodiment of the present invention relates to bispecific binding molecules that are capable of binding to a “**first epitope**” and a “**second epitope**,” wherein the first epitope is an epitope of human PD-1 and the second epitope is the same or a different epitope of PD-1, or is an epitope of another molecule that is present on the surface of an immune cell (such as a T lymphocyte) and is involved in regulating an immune checkpoint. In one embodiment, the second epitope is an epitope of B7-H3, B7-H4, BTLA, CD3, CD8, CD16, CD27, CD32, CD40, CD40L, CD47, CD64, CD70, CD80, CD86, CD94, CD137, CD137L, CD226, CTLA-4, Galectin-9, GITR, GITRL, HHLA2, ICOS, ICOSL, KIR, LAG-3, LIGHT, MHC class I or II, NKG2a, NKG2d, OX40, OX40L, PD1H, PD-1, PD-L1, PD-L2, PVR, SIRPa, TCR, TIGIT, TIM-3 or VISTA. In one embodiment, the second epitope not an epitope of PD-1. In a specific embodiment, the second epitope is CD137, CTLA-4, LAG-3, OX40, TIGIT, or TIM-3. In certain embodiments, a bispecific molecule comprises more than two epitope binding sites. Such bispecific molecules may bind two or more different epitopes of LAG-3 and at least one epitope of a molecule that is not LAG-3.

**[00225]** The instant invention encompasses bispecific antibodies capable of simultaneously binding to PD-1 and the second epitope (*e.g.* B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*). In some embodiments, the bispecific antibody capable of simultaneously binding to PD-1 and the second epitope is produced using any of the methods described in PCT Publication Nos. WO 1998/002463, WO 2005/070966, WO 2006/107786 WO 2007/024715, WO 2007/075270, WO 2006/107617, WO 2007/046893, WO 2007/146968, WO 2008/003103, WO 2008/003116, WO 2008/027236, WO 2008/024188, WO 2009/132876, WO 2009/018386, WO 2010/028797, WO2010028796, WO 2010/028795, WO 2010/108127, WO 2010/136172, WO 2011/086091, WO 2011/133886, WO 2012/009544, WO 2013/003652, WO 2013/070565, WO 2012/162583, WO 2012/156430, WO 2013/174873, and WO 2014/022540, each of which is hereby incorporated herein by reference in its entirety.

#### **A. Bispecific Diabodies Lacking Fc Regions**

**[00226]** One embodiment of the present invention relates to bispecific diabodies that comprise, and most preferably are composed of, a first polypeptide chain and a second polypeptide chain, whose sequences permit the polypeptide chains to covalently bind to each other to form a covalently associated diabody that is capable of simultaneously binding to a first epitope and a second epitope, such epitopes not being identical to one another. Such bispecific diabodies thus comprise “VL1” / “VH1” domains that are capable of binding to the first epitope and “VL2” / “VH2” domains that are capable of binding to the second epitope. The notation “VL1” and “VH1” denote respectively, the Variable Light Chain Domain and Variable Heavy Chain Domain that bind the “first” epitope of such bispecific diabody. Similarly, the notation “VL2” and “VH2” denote respectively, the Variable Light Chain Domain and Variable Heavy Chain Domain that bind the “second” epitope of such bispecific diabody. It is irrelevant whether a particular epitope is designated as the first vs. the second epitope; such notation having relevance only with respect to the presence and orientation of domains of the polypeptide chains of the binding molecules of the present invention. In one embodiment, one of such epitopes is an epitope of PD-1 and the other of such epitopes is not an epitope of PD-1 (for example, an epitope of B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

**[00227]** The VL Domain of the first polypeptide chain interacts with the VH Domain of the second polypeptide chain to form a first functional antigen-binding site that is specific for a

first antigen (*i.e.*, either PD-1 or an antigen that contains the second epitope). Likewise, the VL Domain of the second polypeptide chain interacts with the VH Domain of the first polypeptide chain in order to form a second functional antigen-binding site that is specific for a second antigen (*i.e.*, either an antigen that contains the second epitope or PD-1). Thus, the selection of the VL and VH Domains of the first and second polypeptide chains is coordinated, such that the two polypeptide chains of the diabody collectively comprise VL and VH Domains capable of binding to both an epitope of PD-1 and to the second epitope (*i.e.*, they comprise VL<sub>PD-1</sub>/VH<sub>PD-1</sub> and VL<sub>2</sub>/VH<sub>2</sub>, wherein PD-1 is the “first” epitope, or VL<sub>1</sub>/VH<sub>1</sub> and VL<sub>PD-1</sub>/VH<sub>PD-1</sub>, wherein PD-1 is the “second” epitope).

**[00228]** The first polypeptide chain of an embodiment of such bispecific diabodies comprises, in the N-terminal to C-terminal direction, an N-terminus, the VL<sub>1</sub> Domain of a monoclonal antibody capable of binding to either the first or second epitope (*i.e.*, either VL<sub>PD-1</sub> or VL<sub>Epitope 2</sub>), a first intervening spacer peptide (Linker 1), a VH<sub>2</sub> Domain of a monoclonal antibody capable of binding to either the second epitope (if such first polypeptide chain contains VL<sub>PD-1</sub>) or the first epitope (if such first polypeptide chain contains VL<sub>Epitope 2</sub>), a second intervening spacer peptide (Linker 2) optionally containing a cysteine residue, a Heterodimer-Promoting Domain and a C-terminus (**Figure 1**).

**[00229]** The second polypeptide chain of this embodiment of bispecific diabodies comprises, in the N-terminal to C-terminal direction, an N-terminus, a VL<sub>2</sub> Domain of a monoclonal antibody capable of binding to either PD-1 or the second epitope (*i.e.*, either VL<sub>PD-1</sub> or VL<sub>Epitope 2</sub>, and being the VL Domain not selected for inclusion in the first polypeptide chain of the diabody), an intervening linker peptide (Linker 1), a VH<sub>1</sub> Domain of a monoclonal antibody capable of binding to either the second epitope (if such second polypeptide chain contains VL<sub>PD-1</sub>) or to PD-1 (if such second polypeptide chain contains VL<sub>Epitope 2</sub>), a second intervening spacer peptide (Linker 2) optionally containing a cysteine residue, a Heterodimer-Promoting Domain, and a C-terminus (**Figure 1**).

**[00230]** Most preferably, the length of the intervening linker peptide (*e.g.*, Linker 1) that separates such VL and VH Domains is selected to substantially or completely prevent the VL and VH Domains of the polypeptide chain from binding to one another. Thus the VL and VH Domains of the first polypeptide chain are substantially or completely incapable of binding to one another. Likewise, the VL and VH Domains of the second polypeptide chain are

substantially or completely incapable of binding to one another. A preferred intervening spacer peptide (Linker 1) has the sequence (**SEQ ID NO:14**): GGGSGGGG.

**[00231]** The length and composition of the second intervening linker peptide (Linker 2) is selected based on the choice of heterodimer-promoting domains. Typically, the second intervening linker peptide (Linker 2) will comprise 3-20 amino acid residues. In particular, where the heterodimer-promoting domains do not comprise a cysteine residue a cysteine-containing second intervening linker peptide (Linker 2) is utilized. A cysteine-containing second intervening spacer peptide (Linker 2) will contain 1, 2, 3 or more cysteines. A preferred cysteine-containing spacer peptide (Linker 2) has the sequence is **SEQ ID NO:15**: GGCGGG. Alternatively, Linker 2 does not comprise a cysteine (*e.g.*, GGG, GGGS (**SEQ ID NO:29**), LGGGSG (**SEQ ID NO:261**), GGGSGGGSGGG (**SEQ ID NO:262**), ASTKG (**SEQ ID NO:30**), LEPKSS (**SEQ ID NO:33**), APSSS (**SEQ ID NO:34**), *etc.*) and a Cysteine-Containing Heterodimer-Promoting Domain, as described below is used. Optionally, both a cysteine-containing Linker 2 and a cysteine-containing Heterodimer-Promoting Domain are used.

**[00232]** The Heterodimer-Promoting Domains may be GVEPKSC (**SEQ ID NO:16**) or VEPKSC (**SEQ ID NO:17**) or AEPKSC (**SEQ ID NO:18**) on one polypeptide chain and GFNRGEC (**SEQ ID NO:19**) or FNRGEC (**SEQ ID NO:20**) on the other polypeptide chain (US2007/0004909).

**[00233]** More preferably, however, the Heterodimer-Promoting Domains of such diabodies are formed from one, two, three or four tandemly repeated coil domains of opposing charge that comprise a sequence of at least six, at least seven or at least eight amino acid residues such that the Heterodimer-Promoting Domain possesses a net charge (Apostolovic, B. *et al.* (2008) “*pH-Sensitivity of the E3/K3 Heterodimeric Coiled Coil*,” *Biomacromolecules* 9:3173–3180; Arndt, K.M. *et al.* (2001) “*Helix-stabilized Fv (hsFv) Antibody Fragments: Substituting the Constant Domains of a Fab Fragment for a Heterodimeric Coiled-coil Domain*,” *J. Molec. Biol.* 312:221-228; Arndt, K.M. *et al.* (2002) “*Comparison of In Vivo Selection and Rational Design of Heterodimeric Coiled Coils*,” *Structure* 10:1235-1248; Boucher, C. *et al.* (2010) “*Protein Detection By Western Blot Via Coiled–Coil Interactions*,” *Analytical Biochemistry* 399:138-140; Cachia, P.J. *et al.* (2004) “*Synthetic Peptide Vaccine Development: Measurement Of Polyclonal Antibody Affinity And Cross-Reactivity Using A New Peptide Capture And Release System For Surface Plasmon Resonance Spectroscopy*,” *J. Mol.*

Recognit. 17:540-557; De Crescenzo, G.D. *et al.* (2003) “*Real-Time Monitoring of the Interactions of Two-Stranded de novo Designed Coiled-Coils: Effect of Chain Length on the Kinetic and Thermodynamic Constants of Binding*,” Biochemistry 42:1754-1763; Fernandez-Rodriguez, J. *et al.* (2012) “*Induced Heterodimerization And Purification Of Two Target Proteins By A Synthetic Coiled-Coil Tag*,” Protein Science 21:511-519; Ghosh, T.S. *et al.* (2009) “*End-To-End And End-To-Middle Interhelical Interactions: New Classes Of Interacting Helix Pairs In Protein Structures*,” Acta Crystallographica D65:1032-1041; Grigoryan, G. *et al.* (2008) “*Structural Specificity In Coiled-Coil Interactions*,” Curr. Opin. Struc. Biol. 18:477-483; Litowski, J.R. *et al.* (2002) “*Designing Heterodimeric Two-Stranded  $\alpha$ -Helical Coiled-Coils: The Effects Of Hydrophobicity And  $\alpha$ -Helical Propensity On Protein Folding, Stability, And Specificity*,” J. Biol. Chem. 277:37272-37279; Steinkruger, J.D. *et al.* (2012) “*The d'-d'-d' Vertical Triad is Less Discriminating Than the  $\alpha'$ - $\alpha'$ - $\alpha'$  Vertical Triad in the Antiparallel Coiled-coil Dimer Motif*,” J. Amer. Chem. Soc. 134(5):2626-2633; Straussman, R. *et al.* (2007) “*Kinking the Coiled Coil – Negatively Charged Residues at the Coiled-coil Interface*,” J. Molec. Biol. 366:1232-1242; Tripet, B. *et al.* (2002) “*Kinetic Analysis of the Interactions between Troponin C and the C-terminal Troponin I Regulatory Region and Validation of a New Peptide Delivery/Capture System used for Surface Plasmon Resonance*,” J. Molec. Biol. 323:345-362; Woolfson, D.N. (2005) “*The Design Of Coiled-Coil Structures And Assemblies*,” Adv. Prot. Chem. 70:79-112; Zeng, Y. *et al.* (2008) “*A Ligand-Pseudoreceptor System Based On de novo Designed Peptides For The Generation Of Adenoviral Vectors With Altered Tropism*,” J. Gene Med. 10:355-367).

**[00234]** Such repeated coil domains may be exact repeats or may have substitutions. For example, the coil domain of the Heterodimer-Promoting Domain of the first polypeptide chain may comprise a sequence of eight amino acid residues selected to confer a negative charge to such Heterodimer-Promoting Domain, and the coil domain of the Heterodimer-Promoting Domain of the second polypeptide chain may comprise a sequence of eight amino acid residues selected to confer a positive charge to such Heterodimer-Promoting Domain. It is immaterial which coil is provided to the first or second polypeptide chains, provided that a coil of opposite charge is used for the other polypeptide chain. The positively charged amino acid may be lysine, arginine, histidine, *etc.* and/or the negatively charged amino acid may be glutamic acid, aspartic acid, *etc.* The positively charged amino acid is preferably lysine and/or the negatively charged amino acid is preferably glutamic acid. It is possible for only a single Heterodimer-Promoting Domain to be employed (since such domain will inhibit homodimerization and

thereby promote heterodimerization), however, it is preferred for both the first and second polypeptide chains of the diabodies of the present invention to contain Heterodimer-Promoting Domains.

[00235] In a preferred embodiment, one of the Heterodimer-Promoting Domains will comprise four tandem “E-coil” helical domains (SEQ ID NO:21: EVAALEK-EVAALEK-EVAALEK-EVAALEK), whose glutamate residues will form a negative charge at pH 7, while the other of the Heterodimer-Promoting Domains will comprise four tandem “K-coil” domains (SEQ ID NO:22: KVAALKE-KVAALKE-KVAALKE-KVAALKE), whose lysine residues will form a positive charge at pH 7. The presence of such charged domains promotes association between the first and second polypeptides, and thus fosters heterodimer formation. Especially preferred is a Heterodimer-Promoting Domain in which one of the four tandem “E-coil” helical domains of SEQ ID NO:21 has been modified to contain a cysteine residue: EVAACEK-EVAALEK-EVAALEK-EVAALEK (SEQ ID NO:23). Likewise, especially preferred is a Heterodimer-Promoting Domain in which one of the four tandem “K-coil” helical domains of SEQ ID NO:22 has been modified to contain a cysteine residue: KVAACKE-KVAALKE-KVAALKE-KVAALKE (SEQ ID NO:24).

[00236] As disclosed in WO 2012/018687, in order to improve the *in vivo* pharmacokinetic properties of diabodies, a diabody may be modified to contain a polypeptide portion of a serum-binding protein at one or more of the termini of the diabody. Most preferably, such polypeptide portion of a serum-binding protein will be installed at the C-terminus of the diabody. Albumin is the most abundant protein in plasma and has a half-life of 19 days in humans. Albumin possesses several small molecule binding sites that permit it to non-covalently bind to other proteins and thereby extend their serum half-lives. The Albumin-Binding Domain 3 (ABD3) of protein G of Streptococcus strain G148 consists of 46 amino acid residues forming a stable three-helix bundle and has broad albumin-binding specificity (Johansson, M.U. *et al.* (2002) “Structure, Specificity, And Mode Of Interaction For Bacterial Albumin-Binding Modules,” J. Biol. Chem. 277(10):8114-8120. Thus, a particularly preferred polypeptide portion of a serum-binding protein for improving the *in vivo* pharmacokinetic properties of a diabody is the Albumin-Binding Domain (ABD) from streptococcal protein G, and more preferably, the Albumin-Binding Domain 3 (ABD3) of protein G of *Streptococcus dysgalactiae* strain G148 (SEQ ID NO:25): LAEAKVLANR ELDKYGVSDY YKNLIDNAKS AEGVKALIDE ILAALP.

**[00237]** As disclosed in WO 2012/162068 (herein incorporated by reference), “deimmunized” variants of **SEQ ID NO:25** have the ability to attenuate or eliminate MHC class II binding. Based on combinational mutation results, the following combinations of substitutions are considered to be preferred substitutions for forming such a deimmunized ABD: 66D/70S +71A; 66S/70S +71A; 66S/70S +79A; 64A/65A/71A; 64A/65A/71A+66S; 64A/65A/71A+66D; 64A/65A/71A+66E; 64A/65A/79A+66S; 64A/65A/79A+66D; 64A/65A/79A+66E. Variant ABDs having the modifications L64A, I65A and D79A or the modifications N66S, T70S and D79A. Variant deimmunized ABD having the amino acid sequence:

LAEAKVLNLR ELDKYGVSDY YKNLID<sub>66</sub>NAKS<sub>70</sub> A<sub>71</sub>EGVKALIDE ILAALP (**SEQ ID NO:26**),

or the amino acid sequence:

LAEAKVLNLR ELDKYGVSDY YKNA<sub>64</sub>A<sub>65</sub>NNAKT VEGVKALIAA<sub>79E</sub> ILAALP (**SEQ ID NO:27**),

or the amino acid sequence:

LAEAKVLNLR ELDKYGVSDY YKNLIS<sub>66</sub>NAKS<sub>70</sub> VEGVKALIAA<sub>79E</sub> ILAALP (**SEQ ID NO:28**),

are particularly preferred as such deimmunized ABD exhibit substantially wild-type binding while providing attenuated MHC class II binding. Thus, the first polypeptide chain of such a diabody having an ABD contains a peptide linker preferably positioned C-terminally to the E-coil (or K-coil) Domain of such polypeptide chain so as to intervene between the E-coil (or K-coil) Domain and the ABD (which is preferably a deimmunized ABD). A preferred sequence for such a peptide linker is **SEQ ID NO:29**: GGGS.

## **B. Bispecific Diabodies Containing Fc Regions**

**[00238]** One embodiment of the present invention relates to bispecific diabodies comprising an Fc Region capable of simultaneously binding to PD-1 and a second epitope (*e.g.* B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-1, PD-L1, TCR, TIM-3, *etc.*). The addition of an IgG CH2-CH3 Domain to one or both of the diabody polypeptide chains, such that the complexing of the diabody chains results in the formation of an Fc Region, increases the biological half-life and/or alters the valency of the diabody. Incorporating an IgG CH2-CH3 Domains onto both of the diabody polypeptides will permit a two-chain bispecific Fc-Region-containing diabody to form (**Figure 2**).

[00239] Alternatively, incorporating an IgG CH2-CH3 Domains onto only one of the diabody polypeptides will permit a more complex four-chain bispecific Fc Region-containing diabody to form (**Figures 3A-3C**). **Figure 3C** shows a representative four-chain diabody possessing the Constant Light (CL) Domain and the Constant Heavy CH1 Domain, however fragments of such domains as well as other polypeptides may alternatively be employed (see, e.g., **Figures 3A and 3B**, United States Patent Publications No. 2013-0295121; 2010-0174053 and 2009-0060910; European Patent Publication No. EP 2714079; EP 2601216; EP 2376109; EP 2158221 and PCT Publications No. WO 2012/162068; WO 2012/018687; WO 2010/080538). Thus, for example, in lieu of the CH1 Domain, one may employ a peptide having the amino acid sequence GVEPKSC (**SEQ ID NO:16**) VEPKSC (**SEQ ID NO:17**), or AEPKSC (**SEQ ID NO:18**), derived from the hinge domain of a human IgG, and in lieu of the CL Domain, one may employ the C-terminal 6 amino acids of the human kappa light chain, GFNRGEC (**SEQ ID NO:19**) or FNRGEC (**SEQ ID NO:20**). A representative peptide containing four-chain diabody is shown in **Figure 3A**. Alternatively, or in addition, one may employ a peptide comprising tandem coil domains of opposing charge such as the “E-coil” helical domains (**SEQ ID NO:21**: EVAALEK-EVAALEK-EVAALEK-EVAALEK or **SEQ ID NO:23**: EVAALEK-EVAALEK-EVAALEK-EVAALEK); and the “K-coil” domains (**SEQ ID NO:22**: KVAALKE-KVAALKE-KVAALKE-KVAALKE or **SEQ ID NO:24**: KVAACKE-KVAALKE-KVAALKE-KVAALKE). A representative coil domain containing four-chain diabody is shown in **Figure 3B**.

[00240] The Fc Region-containing diabody molecules of the present invention generally include additional intervening linker peptides (Linkers). Typically, the additional Linkers will comprise 3-20 amino acid residues. Additional or alternative linkers that may be employed in the Fc Region-containing diabody molecules of the present invention include: GGGS (**SEQ ID NO:29**), LGGGSG (**SEQ ID NO:261**), GGGSGGGSGGG (**SEQ ID NO:262**), ASTKG (**SEQ ID NO:30**), DKTHTCPPCP (**SEQ ID NO:31**), EPKSCDKTHTCPPCP (**SEQ ID NO:32**), LEPKSS (**SEQ ID NO:33**), APSSS (**SEQ ID NO:34**), and APSSSPME (**SEQ ID NO:35**), LEPKSADKTHTCPPC **SEQ ID NO:36**), GGC, and GGG. **SEQ ID NO:33** may be used in lieu of GGG or GGC for ease of cloning. Additionally, the amino acids GGG, or **SEQ ID NO:33** may be immediately followed by **SEQ ID NO:31** to form the alternate linkers: GGSDKTHTCPPCP (**SEQ ID NO:263**); and LEPKSSDKTHTCPPCP (**SEQ ID NO:37**). Fc Region-containing diabody molecule of the present invention may incorporate an IgG hinge

region in addition to or in place of a linker. Exemplary hinge regions include: EPKSCDKTHTCPPCP (SEQ ID NO:32) from IgG1, ERKCCVECPPCP (SEQ ID NO:11) from IgG2, ESKYGPPCPSCP (SEQ ID NO:12) from IgG4, and ESKYGPPCPPCP (SEQ ID NO:13) an IgG4 hinge variant comprising a stabilizing substitute to reduce strand exchange.

[00241] As provided in **Figure 3A-3C**, diabodies of the invention may comprise four different chains. The first and third polypeptide chains of such a diabody contain three domains: (i) a VL1-containing Domain, (ii) a VH2-containing Domain, (iii) Heterodimer-Promoting Domain and (iv) a Domain containing a CH2-CH3 sequence. The second and fourth polypeptide chains contain: (i) a VL2-containing Domain, (ii) a VH1-containing Domain and (iii) a Heterodimer-Promoting Domain, where the Heterodimer-Promoting Domains promote the dimerization of the first/third polypeptide chains with the second/fourth polypeptide chains. The VL and/or VH Domains of the third and fourth polypeptide chains, and VL and/or VH Domains of the first and second polypeptide chains may be the same or different so as to permit tetravalent binding that is either monospecific, bispecific or tetraspecific. The notation “**VL3**” and “**VH3**” denote respectively, the Variable Light Chain Domain and Variable Heavy Chain Domain that bind the “third” epitope of such diabody. Similarly, the notation “**VL4**” and “**VH4**” denote respectively, the Variable Light Chain Domain and Variable Heavy Chain Domain that bind the “fourth” epitope of such diabody. The general structure of the polypeptide chains of a representative four-chain Fc Region-containing diabodies of invention is provided in **Table 2**:

| <b>Table 2</b> |                       |                                           |
|----------------|-----------------------|-------------------------------------------|
| Bispecific     | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH         |
|                | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH2-CH3-COOH |
|                | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH2-CH3-COOH |
|                | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH         |
| Tetraspecific  | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH         |
|                | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH2-CH3-COOH |
|                | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VL3-VH4-HPD-CH2-CH3-COOH |
|                | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL4-VH3-HPD-COOH         |

HPD = Heterodimer-Promoting Domain

[00242] In a specific embodiment, diabodies of the present invention are bispecific, tetravalent (*i.e.*, possess four epitope-binding sites), Fc-containing diabodies (**Figures 3A-3C**)

that are composed of four total polypeptide chains. The bispecific, tetravalent, Fc-containing diabodies of the invention comprise two epitope-binding sites immunospecific for PD-1 (which may be capable of binding to the same epitope of PD-1 or to different epitopes of PD-1), and two epitope-binding sites specific for a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

**[00243]** In a further embodiment, the bispecific Fc Region-containing diabodies may comprise three polypeptide chains. The first polypeptide of such a diabody contains three domains: (i) a VL1-containing Domain, (ii) a VH2-containing Domain and (iii) a Domain containing a CH2-CH3 sequence. The second polypeptide of such diabodies contains: (i) a VL2-containing Domain, (ii) a VH1-containing Domain and (iii) a Domain that promotes heterodimerization and covalent bonding with the diabody's first polypeptide chain. The third polypeptide of such diabodies comprises a CH2-CH3 sequence. Thus, the first and second polypeptide chains of such diabodies associate together to form a VL1/VH1 binding site that is capable of binding to the first epitope, as well as a VL2/VH2 binding site that is capable of binding to the second epitope. The first and second polypeptides are bonded to one another through a disulfide bond involving cysteine residues in their respective Third Domains. Notably, the first and third polypeptide chains complex with one another to form an Fc Region that is stabilized via a disulfide bond. Such diabodies have enhanced potency. **Figures 4A and 4B** illustrate the structures of such diabodies. Such Fc-Region-containing bispecific diabodies may have either of two orientations (**Table 3**):

| <b>Table 3</b>     |                       |                                                                     |
|--------------------|-----------------------|---------------------------------------------------------------------|
| First Orientation  | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -CH <sub>2</sub> -CH <sub>3</sub> -COOH             |
|                    | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH <sub>2</sub> -CH <sub>3</sub> -COOH |
|                    | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH                                   |
| Second Orientation | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -CH <sub>2</sub> -CH <sub>3</sub> -COOH             |
|                    | 1 <sup>st</sup> Chain | NH <sub>2</sub> -CH <sub>2</sub> -CH <sub>3</sub> -VL1-VH2-HPD-COOH |
|                    | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH                                   |

HPD = Heterodimer-Promoting Domain

**[00244]** In a specific embodiment, diabodies of the present invention are bispecific, bivalent (*i.e.*, possess two epitope-binding sites), Fc-containing diabodies (**Figures 4A-4B**) that are composed of three total polypeptide chains. The bispecific, bivalent Fc-containing diabodies

of the invention comprise one epitope-binding site immunospecific for PD-1, and one epitope-binding site specific for a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

**[00245]** In a further embodiment, the bispecific Fc Region-containing diabodies may comprise a total of five polypeptide chains. In a particular embodiment, two of said five polypeptide chains have the same amino acid sequence. The first polypeptide chain of such diabodies contains: (i) a VH1-containing domain, (ii) a CH1-containing domain, and (iii) a Domain containing a CH2-CH3 sequence. The first polypeptide chain may be the heavy chain of an antibody that contains a VH1 and a heavy chain constant region. The second and fifth polypeptide chains of such diabodies contain: (i) a VL1-containing domain, and (ii) a CL-containing domain. The second and/or fifth polypeptide chains of such diabodies may be light chains of an antibody that contains a VL1 complementary to the VH1 of the first/third polypeptide chain. The first, second and/or fifth polypeptide chains may be isolated from naturally occurring antibodies. Alternatively, they may be constructed recombinantly. The third polypeptide chain of such diabodies contains: (i) a VH1-containing domain, (ii) a CH1-containing domain, (iii) a Domain containing a CH2-CH3 sequence, (iv) a VL2-containing Domain, (v) a VH3-containing Domain and (vi) a Heterodimer-Promoting Domain, where the Heterodimer-Promoting Domains promote the dimerization of the third chain with the fourth chain. The fourth polypeptide of such diabodies contains: (i) a VL3-containing Domain, (ii) a VH2-containing Domain and (iii) a Domain that promotes heterodimerization and covalent bonding with the diabody's third polypeptide chain.

**[00246]** Thus, the first and second, and the third and fifth, polypeptide chains of such diabodies associate together to form two VL1/VH1 binding sites capable of binding a first epitope. The third and fourth polypeptide chains of such diabodies associate together to form a VL2/VH2 binding site that is capable of binding to a second epitope, as well as a VL3/VH3 binding site that is capable of binding to a third epitope. The first and third polypeptides are bonded to one another through a disulfide bond involving cysteine residues in their respective constant regions. Notably, the first and third polypeptide chains complex with one another to form an Fc Region. Such diabodies have enhanced potency. **Figure 5** illustrates the structure of such diabodies. It will be understood that the VL1/VH1, VL2/VH2, and VL3/VH3 Domains may be the same or different so as to permit binding that is monospecific, bispecific or trispecific. However, as provided herein, these domains are preferably selected so as to bind

PD-1 and a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

**[00247]** The VL and VH Domains of the polypeptide chains are selected so as to form VL/VH binding sites specific for a desired epitope. The VL/VH binding sites formed by the association of the polypeptide chains may be the same or different so as to permit tetravalent binding that is monospecific, bispecific, trispecific or tetraspecific. In particular, the VL and VH Domains maybe selected such that a bispecific diabody may comprise two binding sites for a first epitope and two binding sites for a second epitope, or three binding sites for a first epitope and one binding site for a second epitope, or two binding sites for a first epitope, one binding site for a second epitope and one binding site for a third epitope (as depicted in **Figure 5**). The general structure of the polypeptide chains of representative five-chain Fc Region-containing diabodies of invention is provided in **Table 4**:

| <b>Table 4</b>      |                       |                                                   |
|---------------------|-----------------------|---------------------------------------------------|
| Bispecific (2x2)    | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-COOH             |
|                     | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-VL2-VH2-HPD-COOH |
|                     | 5 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL2-VH2-HPD-COOH                 |
| Bispecific (3x1)    | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-COOH             |
|                     | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-VL1-VH2-HPD-COOH |
|                     | 5 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH                 |
| Trispecific (2x1x1) | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-COOH             |
|                     | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VH1-CH1-CH2-CH3-VL2-VH3-HPD-COOH |
|                     | 5 <sup>nd</sup> Chain | NH <sub>2</sub> -VL1-CL-COOH                      |
|                     | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL3-VH2-HPD-COOH                 |

HPD = Heterodimer-Promoting Domain

**[00248]** In a specific embodiment, diabodies of the present invention are bispecific, tetravalent (*i.e.*, possess four epitope-binding sites), Fc-containing diabodies that are composed of five total polypeptide chains having two binding sites for a first epitope and two binding sites for a second epitope. In one embodiment, the bispecific, tetravalent, Fc-containing

diabodies of the invention comprise two epitope-binding sites immunospecific for PD-1 (which may be capable of binding to the same epitope of PD-1 or to different epitopes of PD-1), and two epitope-binding sites specific for a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*). In another embodiment, the bispecific, tetravalent, Fc-containing diabodies of the invention comprise three epitope-binding sites immunospecific for PD-1 which may be capable of binding to the same epitope of PD-1 or to different epitopes of PD-1), and one epitope-binding sites specific for a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*). In another embodiment, the bispecific, tetravalent, Fc-containing diabodies of the invention comprise one epitope-binding sites immunospecific for PD-1, and three epitope-binding sites specific for a second epitope (*e.g.*, B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

### C. Bispecific Trivalent Binding Molecules Containing Fc Regions

**[00249]** A further embodiment of the present invention relates to bispecific, trivalent binding molecules, comprising an Fc Region, and being capable of simultaneously binding to a first epitope, a second epitope and a third epitope, wherein at least one of such epitopes is not identical to another. Such bispecific diabodies thus comprise “VL1” / “VH1” domains that are capable of binding to the first epitope, “VL2” / “VH2” domains that are capable of binding to the second epitope and “VL3” / “VH3” domains that are capable of binding to the third epitope. In one embodiment, one or two of such epitopes is an epitope of PD-1 and another (or the other) of such epitopes is not an epitope of PD-1 (for example, an epitope of B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-1, PD-L1, TCR, TIM-3, *etc.*). Such bispecific trivalent binding molecules comprise three epitope-binding sites, two of which are diabody-type binding domains, which provide binding Site A and binding Site B, and one of which is a non-diabody-type binding domain, which provides binding Site C (see, *e.g.*, **Figures 6A-6F**, and PCT Application No: PCT/US15/33081; and PCT/US15/33076).

**[00250]** Typically, the trivalent binding molecules of the present invention will comprise four different polypeptide chains (see **Figures 6A-6B**), however, the molecules may comprise fewer or greater numbers of polypeptide chains, for example by fusing such polypeptide chains to one another (*e.g.*, via a peptide bond) or by dividing such polypeptide chains to form

additional polypeptide chains, or by associating fewer or additional polypeptide chains via disulfide bonds. **Figures 6B-6F** illustrate this aspect of the present invention by schematically depicting such molecules having three polypeptide chains. As provided in **Figures 6A-6F**, the trivalent binding molecules of the present invention may have alternative orientations in which the diabody-type binding domains are N-terminal (**Figures 6A, 6C and 6D**) or C-terminal (**Figures 6B, 6E and 6F**) to an Fc Region.

**[00251]** In certain embodiments, the first polypeptide chain of such trivalent binding molecules of the present invention contains: (i) a **VL1-containing Domain**, (ii) a **VH2-containing Domain**, (iii) a Heterodimer-Promoting Domain, and (iv) a Domain containing a CH2-CH3 sequence. The VL1 and VL2 Domains are located N-terminal or C-terminal to the CH2-CH3-containing domain as presented in **Table 5 (Figures 6A and 6B)**. The second polypeptide chain of such embodiments contains: (i) a VL2-containing Domain, (ii) a VH1-containing Domain, and (iii) a Heterodimer-Promoting Domain. The third polypeptide chain of such embodiments contains: (i) a VH3-containing Domain, (ii) a CH1-containing Domain and (iii) a Domain containing a CH2-CH3 sequence. The third polypeptide chain may be the heavy chain of an antibody that contains a VH3 and a heavy chain constant region. The fourth polypeptide of such embodiments contains: (i) a VL3-containing Domain and (ii) a CL-containing Domain. The fourth polypeptide chains may be a light chain of an antibody that contains a VL3 complementary to the VH3 of the third polypeptide chain. The third or fourth polypeptide chains may be isolated from naturally occurring antibodies. Alternatively, they may be constructed recombinantly, synthetically or by other means.

**[00252]** The Variable Light Chain Domain of the first and second polypeptide chains are separated from the Variable Heavy Chain Domains of such polypeptide chains by an intervening spacer linker having a length that is too short to permit their VL1/VH2 (or their VL2/VH1) domains to associate together to form epitope-binding site capable of binding to either the first or second epitope. A preferred intervening spacer peptide (Linker 1) for this purpose has the sequence (**SEQ ID NO:14**): GGGSGGGG. Other Domains of the trivalent binding molecules may be separated by one or more intervening spacer peptides, optionally comprising a cysteine residue. Exemplary linkers useful for the generation of trivalent binding molecules are provided herein and are also provided in PCT Application Nos: PCT/US15/33081; and PCT/US15/33076. Thus, the first and second polypeptide chains of such trivalent binding molecules associate together to form a VL1/VH1 binding site capable of

binding a first epitope, as well as a VL2/VH2 binding site that is capable of binding to a second epitope. The third and fourth polypeptide chains of such trivalent binding molecules associate together to form a VL3/VH3 binding site that is capable of binding to a third epitope. It will be understood that the VL1/VH1, VL2/VH2, and VL3/VH3 Domains may be the same or different so as to permit binding that is monospecific, bispecific or trispecific.

**[00253]** As described above, the trivalent binding molecules of the present invention may comprise three polypeptides. Trivalent binding molecules comprising three polypeptide chains may be obtained by linking the domains of the fourth polypeptide N-terminal to the VH3-containing Domain of the third polypeptide. Alternatively, a third polypeptide chain of a trivalent binding molecule of the invention containing the following three domains is utilized: (i) a VL3-containing Domain, (ii) a VH3-containing Domain, and (iii) a Domain containing a CH2-CH3 sequence, wherein the VL3 and VH3 are spaced apart from one another by an intervening spacer peptide that is sufficiently long (at least 9 or more amino acid residues) so as to allow the association of these domains to form an epitope-binding site.

**[00254]** It will be understood that the VL1/VH1, VL2/VH2, and VL3/VH3 Domains may be the same or different so as to permit binding that is monospecific, bispecific or trispecific. However, as provided herein, these domains are preferably selected so as to bind PD-1 and a second epitope (or a second and third epitope) (preferably, such epitopes are epitopes of B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3 MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*).

**[00255]** In particular, the VL and VH Domains may be selected such that a trivalent binding molecule comprises two binding sites for a first epitope and one binding sites for a second epitope, or one binding site for a first epitope and two binding sites for a second epitope, or one binding site for a first epitope, one binding site for a second epitope and one binding site for a third epitope. The general structure of the polypeptide chains of representative trivalent binding molecules of invention is provided in **Figures 6A-6F** and in **Table 5**:

| Table 5                                    |                       |                                            |
|--------------------------------------------|-----------------------|--------------------------------------------|
| Four Chain<br>1 <sup>st</sup> Orientation  | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH          |
|                                            | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH2-CH3-COOH  |
|                                            | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VH3-CH1-CH2-CH3-COOH      |
|                                            | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL3-CL-COOH               |
| Four Chain<br>2 <sup>nd</sup> Orientation  | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH          |
|                                            | 1 <sup>st</sup> Chain | NH <sub>2</sub> -CH2-CH3--VL1-VH2-HPD COOH |
|                                            | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VH3-CH1-CH2-CH3-COOH      |
|                                            | 4 <sup>th</sup> Chain | NH <sub>2</sub> -VL3-CL-COOH               |
| Three Chain<br>1 <sup>st</sup> Orientation | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH          |
|                                            | 1 <sup>st</sup> Chain | NH <sub>2</sub> -VL1-VH2-HPD-CH2-CH3-COOH  |
|                                            | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VL3-VH3-HPD-CH2-CH3-COOH  |
| Three Chain<br>2 <sup>nd</sup> Orientation | 2 <sup>nd</sup> Chain | NH <sub>2</sub> -VL2-VH1-HPD-COOH          |
|                                            | 1 <sup>st</sup> Chain | NH <sub>2</sub> -CH2-CH3-VL1-VH2-HPD COOH  |
|                                            | 3 <sup>rd</sup> Chain | NH <sub>2</sub> -VL3-VH3-HPD-CH2-CH3-COOH  |

HPD = Heterodimer-Promoting Domain

**[00256]** One embodiment of the present invention relates to bispecific trivalent binding molecules that comprise two epitope-binding sites for PD-1 and one epitope-binding site for the second epitope present on a molecule other than PD-1 (*e.g.* B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*). The two epitope-binding sites for PD-1 may bind the same epitope or different epitopes. Another embodiment of the present invention relates to bispecific trivalent binding molecules that comprise, one epitope-binding site for PD-1 and two epitope-binding sites that bind a second antigen present on a molecule other than PD-1 (*e.g.* B7-H3, B7-H4, BTLA, CD40, CD80, CD86, CD137, CTLA-4, ICOS, KIR, LAG-3, MHC class I or II, OX40, PD-L1, TCR, TIM-3, *etc.*). The two epitope-binding sites for the second antigen may bind the same epitope or different epitopes of the antigen (*e.g.*, the same or different epitopes of LAG-3). As provided above, such bispecific trivalent binding molecules may comprise three or four polypeptide chains.

## VII. Constant Domains and Fc Regions

[00257] Provided herein are antibody Constant Domains useful in the generation of the PD-1-binding molecules (*e.g.*, antibodies, diabodies, trivalent binding molecules, *etc.*) of the invention.

[00258] A preferred CL Domain is a human IgG CL Kappa Domain. The amino acid sequence of an exemplary human CL Kappa Domain is (SEQ ID NO:8):

```
RTVAAPSVFI FPPSDEQLKS GTASVCLLN NFYPREAKVQ WKVDNALQSG
NSQESVTEQD SKDSTYSLSS TLTLKADYE KHKVYACEVT HQGLSSPVTK
SFNRGEC
```

[00259] Alternatively, an exemplary CL Domain is a human IgG CL Lambda Domain. The amino acid sequence of an exemplary human CL Kappa Domain is (SEQ ID NO:9):

```
QPKAAPSVTL FPPSSEELQA NKATLVCLIS DFYPGAVTVA WKADSSPVKA
GVETTPSKQS NNKYAASSYL SLTPEQWKSH RSYSCQVTHE GSTVEKTVAP
TECS
```

[00260] As provided herein, the PD-1-binding molecules of the invention may comprise an Fc Region. The Fc Region of such molecules of the invention may be of any isotype (*e.g.*, IgG1, IgG2, IgG3, or IgG4). The PD-1-binding molecules of the invention may further comprise a CH1 Domain and/or a hinge region. When present, the CH1 Domain and/or hinge region may be of any isotype (*e.g.*, IgG1, IgG2, IgG3, or IgG4), and is preferably of the same isotype as the desired Fc Region.

[00261] An exemplary CH1 Domain is a human IgG1 CH1 Domain. The amino acid sequence of an exemplary human IgG1 CH1 Domain is (SEQ ID NO:10):

```
ASTKGPSVFP LAPSSKSTSG GTAALGCLVK DYFPEPVTVS WNSGALTSGV
HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT YICNVNHKPS NTKVDKRV
```

[00262] An exemplary CH1 Domain is a human IgG2 CH1 Domain. The amino acid sequence of an exemplary human IgG2 CH1 Domain is (SEQ ID NO:257):

```
ASTKGPSVFP LAPCSRSTSE STAALGCLVK DYFPEPVTVS WNSGALTSGV
HTFPAVLQSS GLYSLSSVVT VPSSNFGTQT YTCNVDHKPS NTKVDKTV
```

[00263] An exemplary CH1 Domain is a human IgG4 CH1 Domain. The amino acid sequence of an exemplary human IgG4 CH1 Domain is (SEQ ID NO:254):

```
ASTKGPSVFP LAPCSRSTSE STAALGCLVK DYFPEPVTVS WNSGALTSGV
HTFPAVLQSS GLYSLSSVVT VPSSSLGTKT YTCNVDHKPS NTKVDKRV
```

[00264] One exemplary hinge region is a human IgG1 hinge region. The amino acid sequence of an exemplary human IgG1 hinge region is (SEQ ID NO:32): EPKSCDKTHTCPPCP .

[00265] Another exemplary hinge region is a human IgG2 hinge region. The amino acid sequence of an exemplary human IgG2 hinge region is (SEQ ID NO:11): ERKCCVECPPCP .

[00266] Another exemplary hinge region is a human IgG4 hinge region. The amino acid sequence of an exemplary human IgG4 hinge region is (SEQ ID NO:12): ESKYGPPCPSCP . As described herein, an IgG4 hinge region may comprise a stabilizing mutation such as the S228P substitution. The amino acid sequence of an exemplary stabilized IgG4 hinge region is (SEQ ID NO:13): ESKYGPPCPPCP .

[00267] The Fc Region of the Fc Region-containing molecules (*e.g.*, antibodies, diabodies, and trivalent molecules) of the present invention may be either a complete Fc Region (*e.g.*, a complete IgG Fc Region) or only a fragment of an Fc Region. Optionally, the Fc Region of the Fc Region-containing molecules of the present invention lacks the C-terminal lysine amino acid residue. In particular, the Fc Region of the Fc Region-containing molecules of the present invention may be an engineered variant Fc Region. Although the Fc Region of the bispecific Fc Region-containing molecules of the present invention may possess the ability to bind to one or more Fc receptors (*e.g.*, FcγR(s)), more preferably such variant Fc Region have altered binding to FcγRIA (CD64), FcγRIIA (CD32A), FcγRIIB (CD32B), FcγRIIIA (CD16a) or FcγRIIIB (CD16b) (relative to the binding exhibited by a wild-type Fc Region) or will have substantially reduced or no ability to bind to inhibitory receptor(s). Thus, the Fc Region of the Fc Region-containing molecules of the present invention may include some or all of the CH2 Domain and/or some or all of the CH3 Domain of a complete Fc Region, or may comprise a variant CH2 and/or a variant CH3 sequence (that may include, for example, one or more insertions and/or one or more deletions with respect to the CH2 or CH3 domains of a complete Fc Region). Such Fc Regions may comprise non-Fc polypeptide portions, or may comprise portions of non-naturally complete Fc Regions, or may comprise non-naturally occurring orientations of CH2 and/or CH3 Domains (such as, for example, two CH2 domains or two CH3 domains, or in the N-terminal to C-terminal direction, a CH3 Domain linked to a CH2 Domain, *etc.*).

[00268] Fc Region modifications identified as altering effector function are known in the art, including modifications that increase binding to activating receptors (*e.g.*, FcγRIIA (CD16A)

and reduce binding to inhibitory receptors (*e.g.*, FcγRIIB (CD32B) (see, *e.g.*, Stavenhagen, J.B. *et al.* (2007) “Fc Optimization Of Therapeutic Antibodies Enhances Their Ability To Kill Tumor Cells In Vitro And Controls Tumor Expansion In Vivo Via Low-Affinity Activating Fcγ Receptors,” *Cancer Res.* 57(18):8882-8890). Exemplary variants of human IgG1 Fc Regions with reduced binding to CD32B and/or increased binding to CD16A contain F243L, R292P, Y300L, V305I or P296L substitutions. These amino acid substitutions may be present in a human IgG1 Fc Region in any combination or sub-combination. In one embodiment, the human IgG1 Fc Region variant contains a F243L, R292P and Y300L substitution. In another embodiment, the human IgG1 Fc Region variant contains F243L, R292P, Y300L, V305I and P296L substitutions.

**[00269]** In particular, it is preferred for the Fc Regions of the polypeptide chains of the Fc Region-containing molecules of the present invention to exhibit decreased (or substantially no) binding to FcγRIA (CD64), FcγRIIA (CD32A), FcγRIIB (CD32B), FcγRIIIA (CD16a) or FcγRIIIB (CD16b) (relative to the binding exhibited by the wild-type IgG1 Fc Region (**SEQ ID NO:1**)). Variant Fc Regions and mutant forms capable of mediating such altered binding are described above. In a specific embodiment, the Fc Region-containing molecules of the present invention comprise an IgG Fc Region that exhibits reduced ADCC effector function. In a preferred embodiment the CH2-CH3 Domain of the first and/or third polypeptide chains of such Fc Region-containing molecules include any 1, 2, or 3, of the substitutions: L234A, L235A, N297Q, and N297G. In another embodiment, the human IgG Fc Region variant contains an N297Q substitution, an N297G substitution, L234A and L235A substitutions or a D265A substitution, as these mutations abolish FcR binding. Alternatively, a CH2-CH3 Domain of an Fc region which inherently exhibits decreased (or substantially no) binding to FcγRIIIA (CD16a) and/or reduced effector function (relative to the binding exhibited by the wild-type IgG1 Fc Region (**SEQ ID NO:1**)) is utilized. In a specific embodiment, the Fc Region-containing molecules of the present invention comprise an IgG2 Fc Region (**SEQ ID NO:2**) or an IgG4 Fc Region (**SEQ ID:NO:4**). When an IgG4 Fc Region is utilized, the instant invention also encompasses the introduction of a stabilizing mutation, such as the hinge region S228P substitution described above (see, *e.g.*, **SEQ ID NO:13**). Since the N297G, N297Q, L234A, L235A and D265A substitutions abolish effector function, in circumstances in which effector function is desired, these substitutions would preferably not be employed.

[00270] In particular, it is preferred for the Fc Regions of the polypeptide chains of the Fc Region-containing molecules of the present invention to exhibit increased serum half-life (relative to the half-life exhibited by the corresponding wild-type Fc). Variant Fc Regions and mutant forms exhibiting extended serum half-life are described above. In a preferred embodiment the CH2-CH3 Domain of the first and/or third polypeptide chains of such Fc Region-containing molecules include any 1, 2, or 3, of the substitutions: M252Y, S254T and T256E. The invention further encompasses Fc Region-containing molecules of the present invention comprising variant Fc Regions comprising:

- (A) one or more mutations which alter effector function and/or FcγR; and
- (B) one or more mutations which extend serum half-life.

[00271] A preferred IgG1 sequence for the CH2 and CH3 Domains of the Fc Region-containing molecules of the present invention will comprise the substitutions L234A/L235A/M252Y/S254T/T256E (**SEQ ID NO:258**):

APEAAGGPSV FLFPPKPKDT LYITREPEVT CVVVDVSHED PEVKFNWYVD  
 GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA  
 PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLTCLVK GFYPSDIAVE  
 WESNGQPENN YKTTTPVLDS DGSFFLYSKL TVDKSRWQQG NVFSCSV MHE  
 ALHNHYTQKS LSLSPGX

wherein, X is a lysine (K) or is absent.

[00272] A preferred IgG4 sequence for the CH2 and CH3 Domains of the Fc Region-containing molecules of the present invention will comprise the M252Y/S254T/T256E substitutions (**SEQ ID NO:259**):

APEFLGGPSV FLFPPKPKDT LYITREPEVT CVVVDVSQED PEVQFNWYVD  
 GVEVHNAKTK PREEQFNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKGLPS  
 SIEKTISKAK GQPREPQVYT LPPSQEEMTK NQVSLTCLVK GFYPSDIAVE  
 WESNGQPENN YKTTTPVLDS DGSFFLYSRL TVDKSRWQEG NVFSCSV MHE  
 ALHNHYTQKS LSLSLGX

wherein, X is a lysine (K) or is absent.

[00273] For diabodies and trivalent binding molecules whose first and third polypeptide chains are not identical), it is desirable to reduce or prevent homodimerization from occurring between the CH2-CH3 Domains of two first polypeptide chains or between the CH2-CH3 Domains of two third polypeptide chains. The CH2 and/or CH3 Domains of such polypeptide chains need not be identical in sequence, and advantageously are modified to foster complexing between the two polypeptide chains. For example, an amino acid substitution (preferably a substitution with an amino acid comprising a bulky side group forming a “knob”, *e.g.*,

tryptophan) can be introduced into the CH2 or CH3 Domain such that steric interference will prevent interaction with a similarly mutated domain and will obligate the mutated domain to pair with a domain into which a complementary, or accommodating mutation has been engineered, *i.e.*, “the hole” (*e.g.*, a substitution with glycine). Such sets of mutations can be engineered into any pair of polypeptides comprising CH2-CH3 Domains that forms an Fc Region. Methods of protein engineering to favor heterodimerization over homodimerization are well known in the art, in particular with respect to the engineering of immunoglobulin-like molecules, and are encompassed herein (see *e.g.*, Ridgway *et al.* (1996) “‘Knobs-Into-Holes’ Engineering Of Antibody CH3 Domains For Heavy Chain Heterodimerization,” *Protein Engr.* 9:617-621, Atwell *et al.* (1997) “Stable Heterodimers From Remodeling The Domain Interface Of A Homodimer Using A Phage Display Library,” *J. Mol. Biol.* 270: 26-35, and Xie *et al.* (2005) “A New Format Of Bispecific Antibody: Highly Efficient Heterodimerization, Expression And Tumor Cell Lysis,” *J. Immunol. Methods* 296:95-101; each of which is hereby incorporated herein by reference in its entirety). Preferably the “knob” is engineered into the CH2-CH3 Domains of the first polypeptide chain and the “hole” is engineered into the CH2-CH3 Domains of the third polypeptide chain of diabodies comprising three polypeptide chains. Thus, the “knob” will help in preventing the first polypeptide chain from homodimerizing via its CH2 and/or CH3 Domains. As the third polypeptide chain preferably contains the “hole” substitution it will heterodimerize with the first polypeptide chain as well as homodimerize with itself. This strategy may be utilized for diabodies and trivalent binding molecules comprising three, four or five chains as detailed above, where the “knob” is engineered into the CH2-CH3 Domains of the first polypeptide chain and the “hole” is engineered into the CH2-CH3 Domains the third polypeptide chain.

**[00274]** A preferred knob is created by modifying an IgG Fc Region to contain the modification T366W. A preferred hole is created by modifying an IgG Fc Region to contain the modification T366S, L368A and Y407V. To aid in purifying the hole-bearing third polypeptide chain homodimer from the final bispecific heterodimeric Fc Region-containing molecule, the protein A binding site of the hole-bearing CH2 and CH3 Domains of the third polypeptide chain is preferably mutated by amino acid substitution at position 435 (H435R). Thus, the hole-bearing third polypeptide chain homodimer will not bind to protein A, whereas the bispecific heterodimer will retain its ability to bind protein A via the protein A binding site on the first polypeptide chain. In an alternative embodiment, the hole-bearing third polypeptide chain may incorporate amino acid substitutions at positions 434 and 435 (N434A/N435K).

[00275] A preferred IgG1 amino acid sequence for the CH2 and CH3 Domains of the first polypeptide chain of an Fc Region-containing molecule of the present invention will have the “knob-bearing” sequence (SEQ ID NO:6):

APEAAGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVKFNWYVD  
 GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA  
 PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLWCLVK GFYPSDIAVE  
 WESNGQPENN YKTTTPVLDS DGSFFLYSKL TVDKSRWQQG NVFSCSVMHE  
 ALHNHYTQKS LSLSPGX

wherein, **X** is a lysine (K) or is absent.

[00276] A preferred IgG1 amino acid sequence for the CH2 and CH3 Domains of the second polypeptide chain of an Fc Region-containing molecule of the present invention having two polypeptide chains (or the third polypeptide chain of an Fc Region-containing molecule having three, four, or five polypeptide chains) will have the “hole-bearing” sequence (SEQ ID NO:7):

APEAAGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVKFNWYVD  
 GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA  
 PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLSCAVK GFYPSDIAVE  
 WESNGQPENN YKTTTPVLDS DGSFFLYVSKL TVDKSRWQQG NVFSCSVMHE  
 ALHNRYTQKS LSLSPGX

wherein, **X** is a lysine (K) or is absent.

[00277] As will be noted, the CH2-CH3 Domains of SEQ ID NO:6, and SEQ ID NO:7 include a substitution at position 234 with alanine and 235 with alanine, and thus form an Fc Region exhibit decreased (or substantially no) binding to FcγRIA (CD64), FcγRIIA (CD32A), FcγRIIB (CD32B), FcγRIIA (CD16a) or FcγRIIB (CD16b) (relative to the binding exhibited by the wild-type Fc Region (SEQ ID NO:1). The invention also encompasses such CH2-CH3 Domains, which comprise alternative and/or additional substitutions which modify effector function and/or FcγR binding activity of the Fc region. The invention also encompasses such CH2-CH3 Domains, which further comprise one or more half-live extending amino acid substitutions. In particular, the invention encompasses such hole-bearing and such knob-bearing CH2-CH3 Domains which further comprise the M252Y/S254T/T256E.

[00278] It is preferred that the first polypeptide chain will have a “knob-bearing” CH2-CH3 sequence, such as that of SEQ ID NO:6. However, as will be recognized, a “hole-bearing” CH2-CH3 Domain (*e.g.*, SEQ ID NO:7) could be employed in the first polypeptide chain, in which case, a “knob-bearing” CH2-CH3 Domain (*e.g.*, SEQ ID NO:6) would be employed in the second polypeptide chain of an Fc Region-containing molecule of the present invention

having two polypeptide chains (or in the third polypeptide chain of an Fc Region-containing molecule having three, four, or five polypeptide chains).

**[00279]** As detailed above the invention encompasses Fc Region-containing molecules (*e.g.*, antibodies and Fc Region-containing diabodies) having wild type CH2 and CH3 Domains, or having CH2 and CH3 Domains comprising combinations of the substitutions described above. An exemplary amino acid sequence of an IgG1 CH2-CH3 Domain encompassing such variations is (**SEQ ID NO:260**):

```
APEX1X2GGPSV FLFPPKPKDT LX3IX4RX5PEVT CVVVDVSHED PEVKFNWYVD
GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK CKVSNKALPA
PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLX6CX7VK GFYPSDIAVE
WESNGQPENN YKTTTPVLDS DGSFFLX8SKL TVDKSRWQQG NVFSCSVMHE
ALHX9X10YTQKS LSLSPGX11
```

wherein:

- (a) X<sub>1</sub> and X<sub>2</sub> are both L (wild type), or are both A (decreased FcγR binding);
- (b) X<sub>3</sub>, X<sub>4</sub>, and X<sub>5</sub> respectively are M, S and T (wild type), or are Y, T and E (extended half-life),
- (c) X<sub>6</sub>, X<sub>7</sub>, and X<sub>8</sub> respectively are: T, L and Y (wild type), or are W, L and Y (knob), or S, A and V (hole);
- (d) X<sub>9</sub> and X<sub>10</sub> respectively are N and H (wild type), or are N and R (no protein A binding), or A and K (no protein A binding); and
- (e) X<sub>11</sub> is K or is absent.

**[00280]** In other embodiments, the invention encompasses PD-1-binding molecules comprising CH2 and/or CH3 Domains that have been engineered to favor heterodimerization over homodimerization using mutations known in the art, such as those disclosed in PCT Publication No. WO 2007/110205; WO 2011/143545; WO 2012/058768; WO 2013/06867, all of which are incorporated herein by reference in their entirety.

## VIII. PD-1 x LAG-3 Bispecific Binding Molecules

**[00281]** The present invention particularly relates to PD-1 x LAG-3 bispecific binding molecules (*e.g.*, bispecific antibodies, bispecific diabodies, *etc.*) comprising an epitope-binding fragment of an anti-PD-1 antibody, and preferably one of the novel anti-human PD-1 antibodies provided herein, and an epitope-binding fragment of an anti-human LAG-3 antibody, preferably one of the novel anti-human LAG-3 antibodies provided herein. The preferred PD-1 x LAG-3 bispecific binding molecules of the present invention possess epitope-binding fragments of antibodies that enable them to be able to coordinately bind to two different epitopes: an epitope of PD-1 and an epitope of LAG-3, so as to attenuate the inhibitory

activities of such molecules. As used herein, such attenuation refers to a decrease of at least 20%, a decrease of at least 50%, a decrease of at least 80%, or a decrease of at least 90% in detectable PD-1 and/or LAG-3 inhibitory activity, or the complete elimination of detectable PD-1 and/or LAG-3 inhibitory activity. Selection of the epitope-binding fragments (*e.g.*, VL and VH Domains) of the anti-human PD-1 antibody and anti-LAG-3 antibody is coordinated such that the polypeptides chains that make up such PD-1 x LAG-3 bispecific binding molecules assemble to form at least one functional antigen binding site that is specific for the first antigen (*i.e.*, either PD-1 or LAG-3) and at least one functional antigen binding site that is specific for the second antigen (*i.e.*, either PD-1 or LAG-3, depending upon the identity of the first antigen).

**[00282]** In a particular embodiment, a PD-1 x LAG-3 bispecific binding molecule of the instant invention is a bispecific diabody, which preferably comprises two, three, four, or five polypeptide chains as described herein. In another particular embodiment, a PD-1 x LAG-3 bispecific binding molecule of the instant invention is a bispecific antibody, which preferably comprises two, three, or four polypeptide chains as described herein (also see, *e.g.*, WO 2007/024715; WO2007/110205; WO 2009/080251; WO 2009/080254; WO 2009/089004; WO 2011/069104; WO 2011/117329; WO 2011/131746; WO 2011/133886; WO 2011/143545; WO 2012/023053; WO 2013/060867, all of which descriptions are incorporated herein by reference in their entirety).

#### **A. Anti-Human LAG-3 Antibodies**

**[00283]** Exemplary antibodies that are immunospecific for human LAG-3 are provided below. Additional desired antibodies may be made by isolating antibody-secreting hybridomas elicited using LAG-3 or a peptide fragment thereof, or by screening recombinant antibody libraries for binding to LAG-3 or a peptide fragment thereof. Human LAG-3 (including a 28 amino acid residue signal sequence (shown underlined) and the 497 amino acid residue mature protein) has the amino acid sequence (**SEQ ID NO:38**):

MWEAQFLGLL FLQPLWVAPV KPLQPGAEVP VVWAQEGAPA QLPCSPTIPL  
 QDLSLLRRAG VTWQHQPDSG PPAAAPGHPL APGPHPAAPS SWGPRPRRYT  
 VLSVGPGGLR SGRLPLQPRV QLDERGRQRG DFSLWLRPAR RADAGEYRAA  
 VHLRDRALSC RLRLRLGQAS MTASPPGSLR ASDWVILNCS FSRPDRPASV  
 HWFRNRGQGR VPVRESPHHH LAESFLFLPQ VSPMDSGPWG CILTYRDGFN  
 VSIMYNLTVL GLEPPTPLTV YAGAGSRVGL PCRLPAGVGT RSFLTAKWTP  
 PGGGPDLLVT GDNGDFTLRL EDVSQAQAGT YTCHIHLEQ QLNATVTLAI

ITVTPKSFSGS PGSLGKLLCE VTPVSGQERF VSSSLDTPSQ RSFSGPWLEA  
 QEAQLLSQPW QCQLYQGERL LGAAVYFTEL SSPGAQRSGR APGALPAGHL  
 LLFLILGVLS LLLLVGTGAFG FHLWRRQWRP RRFSALEQGI HPPQAQSKIE  
 ELEQEPEPEP EPEPEPEPEP EPEQL

## 1. LAG-3 mAb A

[00284] The anti-human LAG-3 antibody BMS-986016 (25F7; Medarex/BMS), designated herein as “**LAG-3 mAb A**,” and variants thereof have been described (see, *e.g.*, WO 2014/008218). The amino acid sequence of the Heavy Chain Variable Domain of **LAG-3 mAb A** has the amino acid sequence (**SEQ ID NO:39**) (CDRs are shown underlined):

QVQLQQWGAG LLKPSETLSL TCAVYGGSF DYYWNWIRQP PGKGLEWIGE  
INHNGNTNSN PSLKSRVTLS LDTSKNQFSL KLRSVTAADT AVYYCAFGYS  
DYEYNWFDPW GQGTLLTVSS

[00285] The amino acid sequence of the Light Chain Variable Domain of **LAG-3 mAb A** has the amino acid sequence (**SEQ ID NO:40**) (CDRs are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRASQSI SYLAWYQQKP GQAPRLLIYD  
ASNRTGIPA RFGSGSGTD FTLTISSLEP EDFAVYYCQQ RSNWPLTFGQ  
 GTNLEIK

[00286] Additional murine anti-human LAG-3 antibodies possessing unique binding characteristics have recently been identified (see, United States Patent Application No. 62/172,277). Preferred PD-1 x LAG-3 bispecific binding molecules of the present invention comprise the epitope-binding fragments of the anti-human LAG-3 antibody **LAG-3 mAb 1** or **LAG-3 mAb 6**, antibodies, which bind a novel epitope and do not compete with BMS-986016 for LAG-3 binding. Particularly preferred, are PD-1 x LAG-3 bispecific binding molecules of the present invention which possess a humanized VH and/or VL Domains of LAG-3 mAb 1 or LAG-3 mAb 6.

## 2. LAG-1 mAb 1

[00287] The amino acid sequence of the VH Domain of LAG-3 mAb 1 (**SEQ ID NO:41**) is shown below (CDR<sub>H</sub> residues are shown underlined).

QIQLVQSGPE LKKPGETVKI SCKASGYTFR NYGMNWVKQA PGKVLKWMGW  
INTYTGESTY ADDFEGRFAF SLGTSASTAY LQINILKNED TATYFCARES  
LYDYYSMDYW GQGTSVTVSS

CDR<sub>H</sub>1 of LAG-3 mAb 1 (**SEQ ID NO:42**): RNYGMN

CDR<sub>H</sub>2 of LAG-3 mAb 1 (**SEQ ID NO43**): WINTYTGESTYADDFEG

CDR<sub>H</sub>3 of LAG-3 mAb 1 (SEQ ID NO:44): ESLYDYYSMDY

[00288] The amino acid sequence of the VL Domain of LAG-3 mAb 1 (SEQ ID NO:45) is shown below (CDR<sub>L</sub> residues are shown underlined):

DVVVTQTPLT LSVTIGQPAS ISCKKSSQSLL HSDGKTYLNW LLQRPQGQSPE  
RLIYLVSELD SGVPDRFTGS GSGTDFTLKI SRVEAEDLGV YYCWQGTTHFP  
YTFGGGTKLE IK

CDR<sub>L</sub>1 of LAG-3 mAb 1 (SEQ ID NO:46): KSSQSLLHSDGKTYLN

CDR<sub>L</sub>2 of LAG-3 mAb 1 (SEQ ID NO:47): LVSELDS

CDR<sub>L</sub>3 of LAG-3 mAb 1 (SEQ ID NO:48): WQGTTHFPYT

[00289] Two exemplary humanized VH Domains of LAG-3 mAb 1 designated herein as “hLAG-3 mAb 1 VH1,” and “hLAG-3 mAb 1 VH2,” and four exemplary humanized VL Domains of LAG-3 mAb 1 “hLAG-3 mAb 1 VL1,” “hLAG-3 mAb 1 VL2,” “hLAG-3 mAb 1 VL3,” and “hLAG-3 mAb 1 VL4,” are provided below. Any of the humanized VL Domains may be paired with any of the humanized VH Domains to generate a LAG-3 binding domain. Accordingly, any antibody comprising one of the humanized VL Domains paired with the humanized VH Domain is referred to generically as “hLAG-3 mAb 1,” and particular combinations of humanized VH/VL Domains are referred to by reference to the specific VH/VL Domains, for example a humanized antibody comprising hLAG-3 mAb 1 VH1 and hLAG-3 mAb 1 VL2 is specifically referred to as “hLAG-3 mAb 1(1.2).”

[00290] The amino acid sequence of the VH Domain of hLAG-3 mAb 1 VH1 (SEQ ID NO:49) is shown below (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGAE VKKPGASVKV SCKASGYTFT NYGMNWVRQA PGQGLEWMGW  
INTYTGESTY ADDFEGRFVF SMDTSASTAY LQISLKAED TAVYYCARES  
LYDYYSMDYW GQGTTVTVSS

[00291] The amino acid sequence of the VH Domain of hLAG-3 mAb 1 VH2 (SEQ ID NO:50) is shown below (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGAE VKKPGASVKV SCKASGYTFT NYGMNWVRQA PGQGLEWMGW  
INTYTGESTY ADDFEGRFVF SMDTSASTAY LQISLKAED TAVYFCARES  
LYDYYSMDYW GQGTTVTVSS

[00292] The amino acid sequence of the VL Domain of hLAG-3 mAb 1 VL1 (SEQ ID NO:51) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVMTQTPLS LSVTPGQPAS ISCKKSSQSLL HSDGKTYLNW LLQKPGQSPE

RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
YTFGGGTKVE IK

[00293] The amino acid sequence of the VL Domain of hLAG-3 mAb 1 VL2 (SEQ ID NO:52) is shown below (CDRL residues are shown underlined):

DIVMTQTPLS LSVTPGQPAS ISCKKSSQSLL HSDGKTYLNW LLQRPQGSPPE  
 RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
YTFGGGTKVE IK

[00294] The amino acid sequence of the VL Domain of hLAG-3 mAb 1 VL3 (SEQ ID NO:53) is shown below (CDRL residues are shown underlined):

DIVMTQTPLS LSVTPGQPAS ISCKKSSQSLL HSDGKTYLNW LLQKPGQPPE  
 RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
YTFGGGTKVE IK

[00295] The amino acid sequence of the VL Domain of hLAG-3 mAb 1 VL4 (SEQ ID NO:54) is shown below (CDRL residues are shown underlined):

DIVMTQTPLS LSVTPGQPAS ISCKKSSQSLL HSDAKTYLNW LLQKPGQPPE  
 RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
YTFGGGTKVE IK

[00296] The CDR<sub>L1</sub> of the VL Domain of hLAG-3 mAb 1 VL4 comprises an glycine to alanine amino acid substitution and has the amino acid sequence: KSSQSLLHSDAKTYLN (SEQ ID NO:55), the substituted alanine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the LAG-3 mAb 1 CDR<sub>L1</sub> Domains described above.

### 3. LAG-3 mAb 6

[00297] The amino acid sequence of the VH Domain of LAG-3 mAb 6 (SEQ ID NO:56) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVLLQQSGPE LVKPGASVKI PCKASGYTFT DYNMDWVKQS HGESLEWIGD  
INPDNGVTIY NQKFEGKATL TVDKSSSTAY MELRSLTSED TAVYYCAREEA  
DYFYFDYWGQ GTTLTVSS

CDR<sub>H1</sub> of LAG-3 mAb 6 (SEQ ID NO:57): DYNMD

CDR<sub>H2</sub> of LAG-3 mAb 6 (SEQ ID NO:58): DINPDNGVTIYNQKFEG

CDR<sub>H3</sub> of LAG-3 mAb 6 (SEQ ID NO:59): EADYFYFDY

[00298] The amino acid sequence of the VL Domain of LAG-3 mAb 6 (SEQ ID NO:60) is shown below (CDR residues are shown underlined):

DIVMTQSHRF MSTSVGDRVS ITCKASQDVS SVVAWYQQKP GQSPKLLIFS  
ASYRYTGVPD RFTGSGSGTD FTFTISSVQA ADLAVYYCQQ HYSTPWTFGG  
 GTKLEIK

CDR<sub>L1</sub> of LAG-3 mAb 6 (SEQ ID NO:61): KASQDVSSVVA

CDR<sub>L2</sub> of LAG-3 mAb 6 (SEQ ID NO:62): SASRYT

CDR<sub>L3</sub> of LAG-3 mAb 6 (SEQ ID NO:63): HYSTPWT

[00299] Two exemplary humanized VH Domains of LAG-3 mAb 6 designated herein as “hLAG-3 mAb 6 VH1,” and “hLAG-3 mAb 6 VH2,” and two exemplary humanized VL Domains of LAG-3 mAb 6 “hLAG-3 mAb 1 VL1,” and “hLAG-3 mAb 1 VL2,” are provided below. Any of the humanized VL Domains may be paired with any of the humanized VH Domains to generate a LAG-3 binding domain. Accordingly, any antibody comprising one of the humanized VL Domains paired with the humanized VH Domain is referred to generically as “hLAG-3 mAb 6,” and particular combinations of humanized VH/VL Domains are referred to by reference to the specific VH/VL Domains, for example a humanized antibody comprising hLAG-3 mAb 6 VH1 and hLAG-3 mAb 6 VL2 is specifically referred to as “hLAG-3 mAb 6(1.2).”

[00300] The amino acid sequence of the VH Domain of hLAG-3 mAb 6 VH1 (SEQ ID NO:294) is shown below (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGAE VKKPGASVKV SCKASGYTFT DYNMDWVRQA PGQGLEWMGD  
INPDNGVTIY NQKFEGRVTM TTDSTSTAY MELRSLRSDD TAVYYCAREEA  
DYFYFDYWGQ GTTLTVSS

[00301] An amino acid sequence of the VH Domain of hLAG-3 mAb 6 VH2 (SEQ ID NO:295) is shown below (CDR<sub>H</sub> residues are shown underlined):

EVQLVESGGG LVKPGGSLRL SCAASGFTFS DYNMDWVRQA PGKGLEWVSD  
INPDNGVTIY NQKFEGRFTI SRDNAKNSLY LQMNSLRAED TAVYYCAREEA  
DYFYFDYWGQ GTTLTVSS

[00302] The amino acid sequence of the VL Domain of hLAG-3 mAb 6 VL1 (SEQ ID NO:296) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIQMTQSPSS LSASVGDRVT ITCRASQDVS SVVAWYQQKP GKAPKLLIYS  
ASYRYTGVPD RFSGSGSGTD FTLTISLQP EDFATYYCQQ HYSTPWTFGG  
 GTKLEIK

[00303] The amino acid sequence of the VL Domain of hLAG-3 mAb 6 VL2 (SEQ ID NO:297) is shown below (CDR<sub>L</sub> residues are shown underlined):

DIVMTQSPSS LSASVGDRVT ITCRASQDVS SVVAWYQQKP GKAPKLLIYS  
ASYRYTGVDP RFGSGSGSTD FTFTISSLQP EDIAVYYCQQ HYSTPWTFGG  
 GTKLEIK

[00304] The CDR<sub>L1</sub> of the VL Domain of hLAG-3 mAb 6 VL1 and VL2 comprises a lysine to arginine amino acid substitution and has the amino acid sequence: RASQDVSSVVA (SEQ ID NO:298), the substituted arginine is shown underlined). It is contemplated that a similar substitution may be incorporated into any of the LAG-3 mAb 6 CDR<sub>L1</sub> Domains described above.

## B. Exemplary Four Chain Fc Region-Containing Diabodies Having E/K-Coils

[00305] Four exemplary PD-1 X LAG-3 bispecific, four chain Fc Region-containing diabodies comprising E/K-coil Heterodimer-Promoting Domains (designated “**DART A**,” “**DART B**,” “**DART C**,” and “**DART I**”) were generated. The structure of these Fc Region-containing diabodies is detailed below. These exemplary PD-1 x LAG-3 diabodies are intended to illustrate, but in no way limit, the scope of the invention.

### 1. DART A

[00306] DART A is a bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, a variant IgG4 Fc Region engineered for extended half-life, and cysteine-containing E/K-coil Heterodimer-Promoting Domains. The first and third polypeptide chains of DART A comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (SEQ ID NO:54); an intervening linker peptide (**Linker 1**: GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (SEQ ID NO:147); a cysteine-containing intervening linker peptide (**Linker 2**: GGCGGG (SEQ ID NO:15)); a cysteine-containing Heterodimer-Promoting (E-coil) Domain (EVAACEK-EVAALEK-EVAALEK-EVAALEK (SEQ ID NO:23)); a stabilized IgG4 hinge region (SEQ ID NO:13); a variant IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (SEQ ID NO:259); and a C-terminus.

[00307] The amino acid sequence of the first and third polypeptide chains of DART A is a variant of SEQ ID NO:267:

DIVMTQTPLS LSVTPGQPAS ISCKSSQSLL HSDX<sub>1</sub>KTYLNL LLQKPGQPPE  
 RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
 YTFGGGTKVE IKGGSGGGG QVQLVQSGAE VKKPGASVKV SCKASGYSFT  
 SYWMNWVRQA PGQGLEWIGV IHPDSETWL DQKFKDRVTI TVDKSTSTAY  
 MELSSLRSED TAVYYCAREH YGTSPFAYWG QGTLVTVSSG GCGGGEVAAC  
 EKEVAALEKE VAALEKEVAA LEKESKYGPP CPPCPAPEFL GGPSVFLFPP  
 KPKDTLX<sub>2</sub>IX<sub>3</sub>R X<sub>4</sub>PEVTCVVVD VSQEDPEVQF NWYVDGVEVH NAKTKPREEQ  
 FNSTYRVVSV LTVLHQDWLN GKEYKCKVSN KGLPSSIEKT ISKAKGQPRE  
 PQVYTLPPSQ EEMTKNQVSL TCLVKGFYPS DIAVEWESNG QPENNYKTTP  
 PVLDSGGSFF LYSRLTVDKS RWQEGNVFSC SVMHEALHNH YTQKSLSLSL  
 G

wherein X<sub>1</sub>, X<sub>2</sub>, X<sub>3</sub> and X<sub>4</sub> are independently selected, and wherein X<sub>1</sub> is A or G; X<sub>2</sub> is Y or M; X<sub>3</sub> is T or S; and X<sub>4</sub> is E or T.

**[00308]** The amino acid sequences of the first and third polypeptide chains of DART A is **SEQ ID NO:267**, wherein X<sub>1</sub> is A; X<sub>2</sub> is Y; X<sub>3</sub> is T; and X<sub>4</sub> is E.

**[00309]** The second and fourth polypeptide chains of DART A comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1: GGGSGGGG (SEQ ID NO:14)**); a VH Domain of a monoclonal antibody capable of binding LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); a cysteine-containing intervening linker peptide (**Linker 2: GGC GGG (SEQ ID NO:15)**); a cysteine-containing Heterodimer-Promoting (K-coil) Domain (KVAACKE-KVAALKE-KVAALKE-KVAALKE (**SEQ ID NO:24**); and a C-terminus.

**[00310]** The amino acid sequence of the second and fourth polypeptide chains of DART A is (**SEQ ID NO:268**):

EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL  
 LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY  
 TFGGGTKVEI KGGSGGGGQ VQLVQSGAEV KKPASGVKVS CKASGYTFTN  
 YGMNWVRQAP GQGLEWMGWI NTYTGESTYA DDFEGRFVFS MDTASASTAYL  
 QISSLKAEDT AVYYCARESL YDYYSM DYWG QGTTVTVSSG GCGGGKVAAC  
 KEKVAALKEK VAALKEKVAA LKE

## 2. DART B

**[00311]** DART B is identical to DART A, except that the first and third polypeptide chains of DART B comprise the VL Domain of hLAG-3 mAb 1 VL3 (**SEQ ID NO:53**), which comprises an amino acid substitution in CDR<sub>L1</sub>. Thus, the first and third polypeptide chains of DART B comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain

of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL3) (**SEQ ID NO:53**); an intervening linker peptide (**Linker 1:** GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an intervening linker peptide (**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a cysteine-containing Heterodimer-Promoting (E-coil) Domain (EVAACEK-EVAALEK-EVAALEK-EVAALEK (**SEQ ID NO:23**)); a stabilized IgG4 hinge region (**SEQ ID NO:13**); a variant of IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (**SEQ ID NO:259**); and a C-terminus.

[00312] The amino acid sequence of the first and third polypeptide chains of DART B is **SEQ ID NO:267**, wherein X<sub>1</sub> is G; X<sub>2</sub> is Y; X<sub>3</sub> is T; and X<sub>4</sub> is E.

[00313] The amino acid sequence of the second and fourth polypeptide chains of DART B is **SEQ ID NO:268**.

### 3. DART C

[00314] DART C is identical to DART B, except that the first and third polypeptide chains of DART B comprise a wild type IgG4 CH2-CH3 Domain lacking the C-terminal residue (**SEQ ID NO:4**). Thus, the first and third polypeptide chains of DART C comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL3) (**SEQ ID NO:53**); an intervening linker peptide (**Linker 1:** GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an intervening linker peptide (**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a cysteine-containing Heterodimer-Promoting (E-coil) Domain (EVAACEK-EVAALEK-EVAALEK-EVAALEK (**SEQ ID NO:23**)); a stabilized IgG4 hinge region (**SEQ ID NO:13**); an IgG4 CH2-CH3 Domain lacking the C-terminal residue (**SEQ ID NO:4**); and a C-terminus.

[00315] The amino acid sequence of the first and third polypeptide chains of DART C is **SEQ ID NO:267**, wherein X<sub>1</sub> is G; X<sub>2</sub> is M; X<sub>3</sub> is S; and X<sub>4</sub> is T.

[00316] The amino acid sequence of the second and fourth polypeptide chains of DART C is **SEQ ID NO:268**.

## 4. DART I

[00317] DART I is a bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, a variant IgG4 Fc Region engineered for extended half-life, and cysteine-containing E/K-coil Heterodimer-Promoting Domains. The first and third polypeptide chains of DART I comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 6 VL1) (SEQ ID NO:296); an intervening linker peptide (Linker 1: GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (SEQ ID NO:147); a cysteine-containing intervening linker peptide (Linker 2: GGCGGG (SEQ ID NO:15)); a cysteine-containing Heterodimer-Promoting (E-coil) Domain (EVAACEK-EVAALEK-EVAALEK-EVAALEK (SEQ ID NO:23)); a stabilized IgG4 hinge region (SEQ ID NO:13); a variant IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (SEQ ID NO:259); and a C-terminus.

[00318] The amino acid sequence of the first and third polypeptide chains of DART I is (SEQ ID NO:290):

```
DIQMTQSPSS LSASVGDRVIT ITCRASQDVS SVVAWYQQKP GKAPKLLIYS
ASYRYTGVPF RFSGSGSGTD FTLTISSLQP EDFATYYCQQ HYSTPWTFGG
GTKLEIKGGG SGGGGQVQLV QSGAEVKKPG ASVKVSCAS GYSFTSYWMN
WVRQAPGQGL EWIGVIHPSD SETWLDQKFK DRVTITVDKS TSTAYMELSS
LRSEDTAVYY CAREHYGTSP FAYWGQGLV TVSSGGCGGG EVAACEKEVA
ALEKEVAALE KEVAALEKES KYGPPCPPCP APEFLGGPSV FLFPPKPKDT
LYITREPEVT CVVVDVSQED PEVQFNWYVD GVEVHNAKTK PREEQFNSTY
RVVSVLTVLH QDWLNGKEYK CKVSNKGLPS SIEKTISKAK GQPREPQVYT
LPPSQEEMTK NQVSLTCLVK GFYPSDIAVE WESNGQPENN YKTTTPVLDS
DGSFFLYSRL TVDKSRWQEG NVFSCSV MHE ALHNHYTQKS LSLSLG
```

[00319] The second and fourth polypeptide chains of DART I comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (SEQ ID NO:153); an intervening linker peptide (Linker 1: GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 6 VH1) (SEQ ID NO:294); a cysteine-containing intervening linker peptide (Linker 2: GGCGGG (SEQ ID NO:15)); a cysteine-containing Heterodimer-Promoting (K-coil) Domain (KVAACKE-KVAALKE-KVAALKE-KVAALKE (SEQ ID NO:24); and a C-terminus.

[00320] The amino acid sequence of the second and fourth polypeptide chains of DART I is (SEQ ID NO:291):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGSGGGGQ VQLVQSGAEV KKPGASVKVS CKASGYTFTD
YNMDWVRQAP GQGLEWMGDI NPDNGVTIYN QKFEGRTMT TDTSTSTAYM
ELRSLRSDDT AVYYCAREAD YFYFDYWGQG TTLTVSSGGC GGGKVAACKE
KVAALKEKVA ALKEKVAALK E
```

### C. Exemplary Four Chain Fc Region-Containing Diabodies Having CL/CH1 Domains

[00321] Four exemplary PD-1 X LAG-3 bispecific, four chain Fc Region-containing diabodies comprising CL/CH1 Domains designated “**DART D**,” “**DART E**,” “**DART J**” and “**DART 1**” were generated. The structure of these Fc Region-containing diabodies is detailed below. These exemplary PD-1 x LAG-3 diabodies are intended to illustrate, but in no way limit, the scope of the invention.

#### 1. DART D

[00322] DART D is a bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, CL/CH1 Domains, and a variant IgG4 Fc Region engineered for extended half-life. The first and third polypeptide chains of DART D comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (SEQ ID NO:153); an intervening linker peptide (**Linker 1**: GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (SEQ ID NO:49); an intervening linker peptide (**Linker 2**: LGGGSG (SEQ ID NO:261)); an IgG4 CH1 Domain (SEQ ID NO:254); a stabilized IgG4 hinge region (SEQ ID NO: 13); a variant of an IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (SEQ ID NO:259); and a C-terminus.

[00323] The amino acid sequence of the first and third polypeptide chains of DART D is (SEQ ID NO:269):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGSGGGGQ VQLVQSGAEV KKPGASVKVS CKASGYTFTN
```

```

YGMNWVRQAP  GQGLEWMGWI  NTYTGESTYA  DDFEGRFVFS  MDTASASTAYL
QISSLKAEDT  AVYYCARESL  YDYYSMDYWG  QGTTVTVSSL  GGGSGASTKG
PSVFPLAPCS  RSTSESTAAL  GCLVKDYFPE  PVTVSWNSGA  LTSGVHTFPA
VLQSSGLYSL  SSVVTVPSSS  LGTKYTCNV  DHKPSNTKVD  KRVESKYGPP
CPPCPAPEFL  GGPSVFLFPP  KPKDTLYITR  EPEVTCVVVD  VSQEDPEVQF
NWYVDGVEVH  NAKTKPREEQ  FNSTYRVVSV  LTVLHQDWLN  GKEYKCKVSN
KGLPSSIEKT  ISKAKGQPRE  PQVYTLPPSQ  EEMTKNQVSL  TCLVKGFYPS
DIAVEWESNG  QPENNYKTTP  PVLDSGGSFF  LYSRLTVDKS  RWQEGNVFSC
SVMHEALHNH  YTQKSLSLSL  G

```

**[00324]** The second and fourth polypeptide chains of DART D comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (**SEQ ID NO:54**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an intervening linker peptide (**Linker 2**: LGGGSG (**SEQ ID NO:261**)); a Kappa CL Domain (**SEQ ID NO:8**); and a C-terminus.

**[00325]** The amino acid sequence of the second and fourth polypeptide chains of DART D is (**SEQ ID NO:270**):

```

DIVMTQTPLS  LSVTPGQPAS  ISCKSSQSLL  HSDAKTYLNW  LLQKPGQPPE
RLIYLVSELD  SGVPDRFSGS  GSGTDFTLKI  SRVEAEDVGV  YYCWQGTHFP
YTFGGGKVE  IKGGS GGGG  QVQLVQSGAE  VKKPGASVKV  SCKASGYSFT
SYWMNWVRQA  PGQGLEWIGV  IHPSDSETWL  DQKFKDRVTI  TVDKSTSTAY
MELSSLRSED  TAVYYCAREH  YGTSPFAYWG  QGTLVTVSSL  GGGSGRTVAA
PSVFIFPPSD  EQLKSGTASV  VCLLNNFYPR  EAKVQWKVDN  ALQSGNSQES
VTEQDSKDST  YLSSTLTLS  KADYEKHKVY  ACEVTHQGLS  SPVTKSFNRG
EC

```

## 2. DART E

**[00326]** DART E is another bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, CL/CH1 Domains, and a variant IgG4 Fc Region engineered for extended half-life. The position of the PD-1 and LAG-3 binding sites of DART E is reversed as compared to DART D.

**[00327]** The first and third polypeptide chains of DART E comprise, in the N-terminal to C-terminal direction: an N-terminus, a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (**SEQ ID NO:54**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable

of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an intervening linker peptide (**Linker 2: LGGGSG (SEQ ID NO:261)**); an IgG4 CH1 Domain (**SEQ ID NO:254**); a stabilized IgG4 hinge region (**SEQ ID NO: 13**); a variant of an IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (**SEQ ID NO:259**); and a C-terminus.

**[00328]** The amino acid sequence of the first and third polypeptide chains of DART E is (**SEQ ID NO:271**):

```
DIVMTQTPLS LSVTPGQPAS ISCKSSQSL L HSDAKTYLNW LLQKPGQPPE
RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGT HFP
YTFGGGKVE IKGGGSGGGG QVQLVQSGAE VKKPGASVKV SCKASGYSFT
SYWMNWVRQA PGQGLEWIGV IHPDSETWL DQKFKDRVTI TVDKSTSTAY
MELSSLRSED TAVYYCAREH YGTSPFAYWG QGTLVTVSSL GGGSGASTKG
PSVFPLAPCS RSTSESTAAL GCLVKDYFPE PVTVSWNSGA LTSGVHTFPA
VLQSSGLYSL SSVVTVPSSS LGTKYTCNV DHKPSNTKVD KRVESKYGPP
CPPCPAPEFL GGPSVFLFPP KPKDTLYITR EPEVTCVVVD VSQEDPEVQF
NWYVDGVEVH NAKTKPREEQ FNSTYRVVSV LTVLHQDWLN GKEYKCKVSN
KGLPSSIEKT ISKAKGQPRE PQVYTLPPSQ EEMTKNQVSL TCLVKGFYPS
DIAVEWESNG QPENNYKTTP PVLDSGDSFF LYSRLTVDKS RWQEGNVFSC
SVMHEALHNH YTQKSLSLSL G
```

**[00329]** The second and fourth polypeptide chains of DART E comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1: GGGSGGGG (SEQ ID NO:14)**); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); an intervening linker peptide (**Linker 2: LGGGSG (SEQ ID NO:261)**); a Kappa CL Domain (**SEQ ID NO:8**), and a C-terminus.

**[00330]** The amino acid sequence of the second and fourth polypeptide chains of DART E is (**SEQ ID NO:272**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGKVEI KGGGSGGGGQ VQLVQSGAEV KKPASGVKVS CKASGYTFTN
YGMNWVRQAP GQGLEWMGWI NTYTGESTYA DDFEGRFVFS MDTASASTAYL
QISSLKAEDT AVYYCARESL YDYYSM DYWG QGTTVTVSSL GGGSGRTVAA
PSVFIFPPSD EQLKSGTASV VCLLNNFYPR EAKVQWKVDN ALQSGNSQES
VTEQDSKDST YSLSTLTLS KADYEKHKVY ACEVTHQGLS SPVTKSFNRG
EC
```

### 3. DART J

**[00331]** DART J is a bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, CL/CH1 Domains, and a variant IgG4 Fc Region engineered for extended half-life. The first and third polypeptide chains of DART J comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 6 VL1) (**SEQ ID NO:296**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an intervening linker peptide (**Linker 2**: LGGGSG (**SEQ ID NO:261**)); an IgG4 CH1 Domain (**SEQ ID NO:254**); a stabilized IgG4 hinge region (**SEQ ID NO: 13**); a variant of an IgG4 CH2-CH3 Domain comprising substitutions M252Y/S254T/T256E and lacking the C-terminal residue (**SEQ ID NO:259**); and a C-terminus.

**[00332]** The amino acid sequence of the first and third polypeptide chains of DART J is (**SEQ ID NO:292**):

```
DIQMTQSPSS LSASVGDRVIT ITCRASQDVS SVVAWYQQKP GKAPKLLIYS
ASYRYTGVPV RFGSGSGGTD FTLTISSLQP EDFATYYCQQ HYSTPWTFFG
GTKLEIKGGG SGGGGQVQLV QSGAEVKKPG ASVKVSCKAS GYSFTSYWMN
WVRQAPGQGL EWIGVIHPSD SETWLDQKFK DRVTITVDKS TSTAYMELSS
LRSEDNAVYY CAREHYGTSP FAYWGQGTLV TVSSLGGGSG ASTKGPSVFP
LAPCSRSTSE STAALGCLVK DYFPEPTVTS WNSGALTSGV HTFPAVLQSS
GLYSLSSVVT VPSSSLGTKT YTCNVDPKPS NTKVDKRVES KYGPPCPPCP
APEFLGGPSV FLFPPKPKDT LYITREPEVT CVVDVDSQED PEVQFNWYVD
GVEVHNAKTK PREEQFNSTY RVVSVLTIVLH QDWLNGKEYK CKVSNKGLPS
SIEKTISKAK GQPREPQVYT LPPSQEEMTK NQVSLTCLVK GFYPSDIAVE
WESNGQPENN YKTTTPVLDS DGSFFLYSRL TVDKSRWQEG NVFSCSVMHE
ALHNHYTQKS LSLSLG
```

**[00333]** The second and fourth polypeptide chains of DART J comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 6 VH1) (**SEQ ID NO:294**); an intervening linker peptide (**Linker 2**: LGGGSG (**SEQ ID NO:261**)); a Kappa CL Domain (**SEQ ID NO:8**); and a C-terminus.

**[00334]** The amino acid sequence of the second and fourth polypeptide chains of DART J is (SEQ ID NO:293):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPGASVKVS CKASGYTFTD
YNMDWVRQAP GQGLEWMGDI NPDNGVTIYN QKFEGRTVMT TDTSTSTAYM
ELRSLRSDDT AVYYCAREAD YFYFDYWGQG TTLTVSSLGG GSGRTVAAPS
VFIFPPSDEQ LKSGTASVVC LLNNFYPREA KVQWKVDNAL QSGNSQESVT
EQDSKDSTYS LSSTLTLSKA DYEKHKVYAC EVTHQGLSSP VTKSFNRGEC
```

#### 4. DART 1

**[00335]** DART 1 is a bispecific, four chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, CL/CH1 Domains, and a variant IgG1 Fc Region engineered for reduced FcγR binding. The first and third polypeptide chains of DART 1 comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> PD-1 mAb A VL) (SEQ ID NO:65); an intervening linker peptide (**Linker 1**: GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> LAG-3 mAb A VH1) (SEQ ID NO:39); an intervening linker peptide (**Linker 2**: LGGGSG (SEQ ID NO:261)); an IgG1 CH1 Domain (SEQ ID NO:10); an IgG1 hinge region (SEQ ID NO: 32); a variant of an IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A and lacking the C-terminal residue (SEQ ID NO:5); and a C-terminus.

**[00336]** The amino acid sequence of the first and third polypeptide chains of DART 1 is (SEQ ID NO:284):

```
EIVLTQSPAT LSLSPGERAT LSCRASQSI SYLAWYQQKP GQAPRLLIYD
ASNRATGIPA RFSGSGSGTD FTLTISSLEP EDFAVYYCQQ RSNWPLTFGQ
GTNLEIKGGG SGGGGQVQLV ESGGGVVQPG RSLRLDCKAS GITFSNSGMH
WVRQAPGKGL EWVAWIWYDG SKRYYADSVK GRFTISRDN KNTLFLQMNS
LRAEDTAVYY CATNDDYWGQ GTLTVSSLG GSGASTKGP SVFPLAPSSK
STSGGTAALG CLVKDYFPEP VTVSWNSGAL TSGVHTFPAV LQSSGLYSLS
SVVTPVSSSL GTQTYICNVN HKPSNTKVDK RVEPKSCDKT HTCPCPAPE
AAGGPSVFLF PPKPKDTLYI TREPEVTCVV VDVSHEDPEV KFNWYVDGVE
VHNAKTKPRE EQYNSTYRVV SVLTVLHQDW LNGKEYKCKV SNKALPAPIE
KTISKAKGQP REPQVYTLPP SREEMTKNQV SLTCLVKGFY PSDIAVEWES
NGQPENNYKT TPPVLDSDGS FFLYSKLTVD KSRWQQGNVF SCSVMHEALH
NHYTQKSLSL SPG
```

**[00337]** The second and fourth polypeptide chains of DART 1 comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> LAG-3 mAb A VL) (**SEQ ID NO:40**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> PD-1 mAb A VH) (**SEQ ID NO:64**); an intervening linker peptide (**Linker 2**: LGGGSG (**SEQ ID NO:261**)); a Kappa CL Domain (**SEQ ID NO:8**); and a C-terminus.

**[00338]** The amino acid sequence of the second and fourth polypeptide chains of DART 1 is (**SEQ ID NO:285**):

```
EIVLTQSPAT LSLSPGERAT LSCRASQSVS SYLAWYQQKP GQAPRLLIYD
ASNRATGIPA RFSGSGSGTD FTLTISSLEP EDFAVYYCQQ SSNWPRTFGQ
GTKVEIKGGG SGGGGQVQLQ QWGAGLLKPS ETLSLTCAVY GGSFSDYYWN
WIRQPPGKGL EWIGEINHNG NTNSNPSLKS RVTLSLDTSK NQFSLKLRSV
TAADTAVYYC AFGYSDYEYN WFDPWGQGTI VTVSSLGGGS GRTVAAPSVF
IFPPSDEQLK SGTASVVCLL NNFYPREAKV QWKVDNALQS GNSQESVTEQ
DSKDSTYSLT STLTLKADY EKHKVYACEV THQGLSSPVT KSFNRGEC
```

#### **D. Exemplary Five Chain Fc Region-Containing Diabodies**

**[00339]** Two exemplary PD-1 X LAG-3 bispecific, five chain Fc Region-containing diabodies comprising CL/CH1 Domains and E/K-coil Heterodimer-Promoting Domains designated “**DART F**,” and “**DART G**” were generated. The structure of these Fc Region-containing diabodies is detailed below. These exemplary PD-1 x LAG-3 diabodies are intended to illustrate, but in no way limit, the scope of the invention.

##### **1. DART F**

**[00340]** DART F is a bispecific, five chain, Fc Region-containing diabody having three binding sites specific for PD-1, one binding site specific for LAG-3, CL/CH1 Domains, a variant knob/hole-bearing IgG1 Fc Region engineered for reduced FcγR binding and extended half-life, and E/K-coil Heterodimer-Promoting Domains. The first polypeptide chain of DART F comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an IgG1 CH1 Domain (**SEQ ID NO:10**); an IgG1 hinge region (**SEQ ID NO:32**); a hole-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/M252Y/S254T/T256E/N434A/H435K and lacking the C-terminal residue

(**SEQ ID NO:260**, wherein X<sub>1</sub> is A, X<sub>2</sub> is A; X<sub>3</sub> is Y, X<sub>4</sub> is T, X<sub>5</sub> is E, X<sub>6</sub> is S, X<sub>7</sub> is A, X<sub>8</sub> is V, X<sub>9</sub> is A, X<sub>10</sub> is K, and X<sub>11</sub> is absent); and a C-terminus.

**[00341]** The amino acid sequence of the first polypeptide chain of DART F is (**SEQ ID NO:273**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV
IHPDSEETWL DQKFKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREH
YGTSPFAYWG QGTLVTVSSA STKGPSVFPL APSSKSTSGG TAALGCLVKD
YFPEPVTVSW NSGALTSGVH TFPVLQSSG LYSLSVTVV PSSSLGTQTY
ICNVNHKPSN TKVDKRVEPK SCDKTHTCPP CPAPEAAGGP SVFLFPPKPK
DTLYITREPE VTCVVVDVSH EDPEVKFNWY VDGVEVHNAK TKPREEQYNS
TYRVVSVLTV LHQDWLNGKE YKCKVSNKAL PAPIEKTISK AKGQPREPQV
YTLPPSREEM TKNQVSLSCA VKGFYPSDIA VEWESNGQPE NNYKTTPPVL
DSDGSFFLVS KLTVDKSRWQ QGNVFSCSVN HEALHAKYTQ KSLSLSPG
```

**[00342]** The second and fifth polypeptide chains of DART F comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**), a Kappa CL Domain (**SEQ ID NO:8**), and a C-terminus.

**[00343]** The amino acid sequence of the second and fifth polypeptide chain of DART F is (**SEQ ID NO:274**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGKTKVEI KRTVAAPSVF IFPPSDEQLK SGTASVVCLL NNFYPREAKV
QWKVDNALQS GNSQESVTEQ DSKDSTYSLT STLTLKADY EKHKVYACEV
THQGLSSPVT KSFNRGEC
```

**[00344]** The third polypeptide chain of DART F comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an IgG1 CH1 Domain (**SEQ ID NO:10**); an IgG1 hinge region (**SEQ ID NO:32**); a knob-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/M252Y/S254T/T256E and lacking the C-terminal residue (**SEQ ID NO:260**, wherein X<sub>1</sub> is A, X<sub>2</sub> is A; X<sub>3</sub> is Y, X<sub>4</sub> is T, X<sub>5</sub> is E, X<sub>6</sub> is W, X<sub>7</sub> is L, X<sub>8</sub> is Y, X<sub>9</sub> is N, X<sub>10</sub> is H, and X<sub>11</sub> is absent); an intervening linker peptide (GGGSGGGSGGG (**SEQ ID NO:262**)); a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (**SEQ ID NO:54**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); a cysteine-containing intervening linker peptide

(**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a Heterodimer-Promoting (E-coil) Domain (EVAALEK-EVAALEK-EVAALEK-EVAALEK (**SEQ ID NO:21**)); and a C-terminus.

**[00345]** The amino acid sequence of the third polypeptide chain of DART F is (**SEQ ID NO:275**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV
IHPDSETWL DQKFKDRVIT TVDKSTSTAY MELSSLRSED TAVYYCAREH
YGTSPFAYWG QGTLVTVSSA STKGPSVFPL APSSKSTSGG TAALGCLVKD
YFPEPVTVSW NSGALTSGVH TFPVLQSSG LYSLSVVTV PSSSLGTQTY
ICNVNHKPSN TKVDKRVEPK SCDKTHTCPP CPAPEAAGGP SVFLFPPKPK
DTLYITREPE VTCVVVDVSH EDPEVKFNWY VDGVEVHNAK TKPREEQYNS
TYRVVSVLTV LHQDWLNGKE YKCKVSNKAL PAPIEKTISK AKGQPREPQV
YTLPPSREEM TKNQVSLWCL VKGFYPSDIA VEWESNGQPE NNYKTTTPVL
DSDGSFFLYS KLTVDKSRWQ QGNVFSCSVM HEALHNHYTQ KSLSLSPGGG
GSGGSGGGG IVMTQTPLSL SVTPGQPASI SCKSSQSLH SDAKTYLNWL
LQKPGQPPER LIYLVSELDG GVPDRFSGSG SGTDFTLKIS RVEAEDVGVY
YCWQGTHTFPY TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPGASVKVS
CKASGYSFTS YWMNWVRQAP GQGLEWIGVI HPDSETWLD QKFKDRVITIT
VDKSTSTAYM ELSSLRSED AVYYCAREHY GTSPFAYWGQ GTLVTVSSGG
CGGGEVAALE KEVAALEKEV AALEKEVAAL EK
```

**[00346]** The fourth polypeptide chain of DART F comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1:** GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); a cysteine-containing intervening linker peptide (**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a Heterodimer-Promoting (K-coil) Domain (KVAALKE-KVAALKE-KVAALKE-KVAALKE (**SEQ ID NO:22**)); and a C-terminus.

**[00347]** The amino acid sequence of the fourth polypeptide chains of DART F is (**SEQ ID NO:276**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPGASVKVS CKASGYTFTN
YGMNWVRQAP GQGLEWMGWI NTYTGESTYA DDFEGRFVFS MDTASASTAYL
QISSLKAEDT AVYYCARESL YDYYSM DYWG QGTTVTVSSG GCGGKVAAL
KEKVAALKEK VAALKEKVAA LKE
```

## 2. DART G

**[00348]** DART G is a bispecific, five chain, Fc Region-containing diabody having two binding sites specific for PD-1, two binding sites specific for LAG-3, CL/CH1 Domains, a variant knob/hole-bearing IgG1 Fc Region engineered for reduced FcγR binding and extended half-life, and E/K-coil Heterodimer-Promoting Domains. The first polypeptide chain of DART G comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); an IgG1 CH1 Domain (**SEQ ID NO:10**); an IgG1 hinge region (**SEQ ID NO:32**); a hole-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/M252Y/S254T/T256E/N434A/H435K and lacking the C-terminal residue (**SEQ ID NO:260**, wherein X<sub>1</sub> is A, X<sub>2</sub> is A; X<sub>3</sub> is Y, X<sub>4</sub> is T, X<sub>5</sub> is E, X<sub>6</sub> is S, X<sub>7</sub> is A, X<sub>8</sub> is V, X<sub>9</sub> is A, X<sub>10</sub> is K, and X<sub>11</sub> is absent); and a C-terminus.

**[00349]** The amino acid sequence of the first polypeptide chain of DART G is (**SEQ ID NO:277**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYTFT NYGMNWVRQA PGQGLEWMGW
INTYTGESTY ADDFEGRFVF SMDTSASTAY LQISSLKAED TAVYYCARES
LYDYYSMDYW GQGTTVTVSS ASTKGPSVFP LAPSSKSTSG GTAALGCLVK
DYFPEPVTVS WNSGALTSGV HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT
YICNVNHKPS NTKVDKRVEP KSCDKTHTCP PCPAPEAAGG PSVFLFPPKP
KDTLYITREP EVTCVVVDVS HEDPEVKFNW YVDGVEVHNA KTKPREEQYN
STYRVVSVLT VLHQDWLNGK EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ
VYTLPPSREE MTKNQVSLSC AVKGFYPSDI AVEWESNGQP ENNYKTTTPV
LDS DGSFFLV SKLTVDKSRW QQGNVFSCSV MHEALHAKYT QKSLSLSPG
```

**[00350]** The second and fifth polypeptide chains of DART G comprise, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (**SEQ ID NO:54**), a Kappa CL Domain (**SEQ ID NO:8**), and a C-terminus.

**[00351]** The amino acid sequence of the second and fifth polypeptide chain of DART G is (**SEQ ID NO:278**):

```
DIVMTQTPLS LSVTPGQPAS ISCKSSQSLL HSDAKTYLNW LLQKPGQPPE
RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP
YTFGGGKVE IKRTVAAPSV FIFPPSDEQL KSGTASVCL LNNFYPREAK
VQWKVDNALQ SGNSQESVTE QDSKDSTYSL SSTLTLSKAD YEKHKVYACE
VTHQGLSSPV TKSFNREGC
```

**[00352]** The third polypeptide chain of DART G comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); an IgG1 CH1 Domain (**SEQ ID NO:10**); an IgG1 hinge region (**SEQ ID NO:32**); a knob-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/M252Y/S254T/T256E and lacking the C-terminal residue (**SEQ ID NO:260**, wherein X<sub>1</sub> is A, X<sub>2</sub> is A; X<sub>3</sub> is Y, X<sub>4</sub> is T, X<sub>5</sub> is E, X<sub>6</sub> is W, X<sub>7</sub> is L, X<sub>8</sub> is Y, X<sub>9</sub> is N, X<sub>10</sub> is H, and X<sub>11</sub> is absent); an intervening linker peptide (GGGSGGGSGGG (**SEQ ID NO:262**)); a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); a cysteine-containing intervening linker peptide (**Linker 2**: GGC GGG (**SEQ ID NO:15**)); a Heterodimer-Promoting (E-coil) Domain (EVAALEK-EVAALEK-EVAALEK (**SEQ ID NO:21**)); and a C-terminus.

**[00353]** The amino acid sequence of the third polypeptide chain of DART G is (**SEQ ID NO:279**):

```

QVQLVQSGAE VKKPGASVKV SCKASGYTFT NYGMNWVRQA PGQGLEWMGW
INTYTGESTY ADDFEGRFVF SMDTSASTAY LQISLKAED TAVYYCARES
LYDYYSMDYW GQGTTTVTVSS ASTKGPSVFP LAPSSKSTSG GTAALGCLVK
DYFPEPVTVS WNSGALTSGV HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT
YICNVNHKPS NTKVDKRVEP KSCDKTHTCP PCPAPEAAGG PSVFLFPPKP
KDTLYITREP EVTCVVVDVS HEDPEVKFNW YVDGVEVHNA KTKPREEQYN
STYRVVSVLT VLHQDWLNGK EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ
VYTLPPSREE MTKNQVSLWC LVKGFYPSDI AVEWESNGQP ENNYKTTPPV
LDS DGSFFLY SKLTVDKSRW QQGNVFSCSV MHEALHNHYT QKSLSLSPGG
GGSGGGSGGG EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF
QQKPGQPPKL LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY
FCQQSKEVPY TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPGASVKVS
CKASGYSFTS YWMNWVRQAP GQGLEWIGVI HPDSETWLD QKFKDRVTIT
VDKSTSTAYM ELSSLRSEDV AVYYCAREHY GTSPFAYWGQ GTLVTVSSGG
CGGGEVAALE KEVAALEKEV AALEKEVAAL EK

```

**[00354]** The fourth polypeptide chain of DART G comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1**: GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); a cysteine-containing intervening linker

peptide (**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a Heterodimer-Promoting (K-coil) Domain (KVAALKE-KVAALKE-KVAALKE-KVAALKE (**SEQ ID NO:22**); and a C-terminus.

**[00355]** The amino acid sequence of the fourth polypeptide chains of DART G is (**SEQ ID NO:280**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPGASVKVS CKASGYSFTS
YWMNWVRQAP GQGLEWIGVI HPSDSETWLD QKFKDRVITIT VDKSTSTAYM
ELSSLRSEDV AVYYCAREHY GTSPFAYWGQ GTLVTVSSGG CGGGKVAALK
EKVAALKEKV AALKEKVAAL KE
```

#### **E. Exemplary Three Chain Fc Region-Containing Diabody Having E/K-Coils**

**[00356]** The present invention additionally provides PD-1 X LAG-3 bispecific, three chain Fc Region-containing diabodies comprising E/K-coil Heterodimer-Promoting Domains. An exemplary PD-1 X LAG-3 bispecific, three chain Fc Region-containing diabody comprising E/K-coil Heterodimer-Promoting Domains designated “**DART H**” was generated. The structure of this Fc Region-containing diabodies is detailed below. This exemplary PD-1 x LAG-3 diabody is intended to illustrate, but in no way limit, the scope of the invention.

**[00357]** DART H is a bispecific, three chain, Fc Region-containing diabody having one binding site specific for PD-1, one binding site specific for LAG-3, a variant knob/hole-bearing IgG1 Fc Region engineered for reduced FcγR binding, and E/K-coil Heterodimer-Promoting Domains.

**[00358]** The first polypeptide chain of DART H comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1 (VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); an intervening linker peptide (**Linker 1:** GGGSGGGG (**SEQ ID NO:14**)); a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); a cysteine-containing intervening linker peptide (**Linker 2:** GGCGGG (**SEQ ID NO:15**)); a Heterodimer-Promoting (E-coil) Domain (EVAALEK-EVAALEK-EVAALEK-EVAALEK (**SEQ ID NO:21**)); an intervening linker (**Spacer-Linker 3:** GGGDKTHTCPPCP (**SEQ ID NO:263**)); a knob-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A and having the C-terminal lysine residue (**SEQ ID NO:6**); and a C-terminus.

**[00359]** The amino acid sequence of the first polypeptide chain of DART H is (SEQ ID NO:281):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KGGGSGGGGQ VQLVQSGAEV KKPASVSVKVS CKASGYTFTN
YGMNWVRQAP GQGLEWMGWI NTYTGESTYA DDFEGRFVFS MDTASASTAYL
QISSLKAEDT AVYYCARESL YDYYSM DYWG QGTTVTVSSG GCGGGEVAAL
EKEVAALEKE VAALKEKVAAL LEKGGGDKTH TCPPCPAPEA AGGPSVFLFP
PKPKDTLMIS RTPEVTCVVV DVSHEDPEVK FNWYVDGVEV HNAKTKPREE
QYNSTYRVVS VLTVLHQDWL NGKEYKCKVS NKALPAPIEK TISKAKGQPR
EPQVYTLPPS REEMTKNQVS LWCLVKGFYP SDIAVEWESN GQPENNYKTT
PPVLDSGDSF FLYSKLTVDK SRWQQGNVFS CSVMHEALHN HYTQKSLSL
PGK
```

**[00360]** The second polypeptide chain of DART H comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (SEQ ID NO:54); an intervening linker peptide (**Linker 1:** GGGSGGGG (SEQ ID NO:14)); a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (SEQ ID NO:147); a cysteine-containing intervening linker peptide (**Linker 2:** GGCGGG (SEQ ID NO:15)); a Heterodimer-Promoting (K-coil) Domain (KVAALKE-KVAALKE-KVAALKE-KVAALKE (SEQ ID NO:22)); and a C-terminus.

**[00361]** The amino acid sequence of the second polypeptide chain of DART H is (SEQ ID NO:282):

```
DIVMTQTPLS LSVTPGQPAS ISCKSSQSLH HSDAKTYLNW LLQKPGQPPE
RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTTHFP
YTFGGGTKVE IKGSGGGGQ VQLVQSGAE VKKPASVSVKVS SCKASGYSFT
SYWMNWVRQA PGQGLEWIGV IHPSDSETWL DQKFKDRVTI TVDKSTSTAY
MELSSLRSED TAVYYCAREH YGTSPFAYWG QGTLVTVSSG GCGGGKVAAL
KEKVAALKEK VAALKEKVAAL LKE
```

**[00362]** The third polypeptide chain of DART H comprises, in the N-terminal to C-terminal direction: an N-terminus; a hinge region (DKHTTCPPCP (SEQ ID NO:31)); a hole-bearing IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A and having the C-terminal lysine residue (SEQ ID NO:7); and a C-terminus.

**[00363]** The amino acid sequence of the third polypeptide chain of DART H is (SEQ ID NO:283):

DKTHTCPPCP APEAAGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSHED  
 PEVKFNWYVD GVEVHNAKTK PREEQYNSTY RVVSVLTVLH QDWLNGKEYK  
 CKVSNKALPA PIEKTISKAK GQPREPQVYT LPPSREEMTK NQVSLSCAVK  
 GFYPSPDIAVE WESNGQPENN YKTTTPVLDL DGSFFLVSKL TVDKSRWQQG  
 NVFSCSVME ALHNRYTQKS LSLSPGK

## F. Exemplary Bispecific Antibody

[00364] An exemplary PD-1 X LAG-3 four chain bispecific antibody designated “**BSAB A**” was generated. The structure of this bispecific antibody is detailed below. This exemplary PD-1 x LAG-3 bispecific antibody is intended to illustrate, but in no way limit, the scope of the invention.

[00365] BSAB A is a bispecific antibody having one binding site specific for PD-1, one binding site specific for LAG-3, a variant IgG1 Fc Region engineered to reduce FcγR binding and to foster complexing between the two different heavy chain polypeptides (see, *e.g.*, WO 2011/143545).

[00366] The first polypeptide chain of BSAB A comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding to PD-1 (VH<sub>PD-1</sub> hPD-1 mAb 7 VH1) (**SEQ ID NO:147**); an IgG1 CH1 Domain (**SEQ ID NO:10**); a variant IgG1 hinge region comprising substitutions D221E/P228E (numbered by the EU index as in Kabat and underlined in **SEQ ID NO:286**, below); a variant IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/L368E (underlined in **SEQ ID NO:286**, below) and lacking the C-terminal residue; and a C-terminus.

[00367] The amino acid sequence of the first polypeptide chain of BSAB A is (**SEQ ID NO:286**):

QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV  
 IHPSDSETWL DQKFKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREH  
 YGTSPFAYWG QGTLVTVSSA STKGPSVFPL APSSKSTSGG TAALGCLVKD  
 YFPEPVTVSW NSGALTSGVH TFPVAVLQSSG LYSLSVTVV PSSSLGTQTY  
 ICNVNHKPSN TKVDKRVEPK SEKTHTCPE CPAPEAAGGP SVFLFPPKPK  
 DTLMISRTPE VTCVVVDVSH EDPEVKFNWY VDGVEVHNAK TKPREEQYNS  
 TYRVVSVLTV LHQDWLNGKE YKCKVSNKAL PAPIEKTISK AKGQPREPQV  
 YTLPPSREEM TKNQVSLTCE VKGFYPSPDIA VEWESNGQPE NNYKTTTPVL  
 DSDGSFFLYS KLTVDKSRWQ QGNVFSCSVM HEALHNHYTQ KSLSLSPG

[00368] The second polypeptide chain of BSAB comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to PD-1

(VL<sub>PD-1</sub> hPD-1 mAb 7 VL2) (**SEQ ID NO:153**); a Kappa CL Domain (**SEQ ID NO:8**), and a C-terminus.

**[00369]** The amino acid sequence of the second polypeptide chain of BSAB is (**SEQ ID NO:287**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QQKPGQPPKL
LIHAASNQGS GVPSRFSGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KRTVAAPSVF IFPPSDEQLK SGTASVVCLL NNFYPREAKV
QWKVDNALQS GNSQESVTEQ DSKDSTYSLS STLTLKADY EKHKVYACEV
THQGLSSPVT KSFNRGEC
```

**[00370]** The third polypeptide chain of BSAB A comprises, in the N-terminal to C-terminal direction: an N-terminus; a VH Domain of a monoclonal antibody capable of binding to LAG-3 (VH<sub>LAG-3</sub> hLAG-3 mAb 1 VH1) (**SEQ ID NO:49**); an IgG1 CH1 Domain (**SEQ ID NO:10**); a variant IgG1 hinge region comprising substitutions D221R/P228R (underlined in **SEQ ID NO:288**, below); a variant IgG1 CH2-CH3 Domain comprising substitutions L234A/L235A/L409R (underlined in **SEQ ID NO:288**, below) and lacking the C-terminal residue; and a C-terminus.

**[00371]** The amino acid sequence of the third polypeptide chain of BSAB A is (**SEQ ID NO:288**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYTFT NYGMNWVRQA PGQGLEWMGW
INTYTGESTY ADDFEGRFVF SMDTSASTAY LQISSLKAED TAVYYCARES
LYDYYSMDYW GQGTTVTVSS ASTKGPSVFP LAPSSKSTSG GTAALGCLVK
DYFPEPVTVS WNSGALTSGV HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT
YICNVNHKPS NTKVDKRVEP KSCRKTHTCP RCPAPEAAGG PSVFLFPPKP
KDTLMISRTP EVTCVVVDVS HEDPEVKFNW YVDGVEVHNA KTKPREEQYN
STYRVVSVLT VLHQDWLNGK EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ
VYTLPPSREE MTKNQVSLTC LVKGFYPSDI AVEWESNGQP ENNYKTTTPV
LDSDGSFFLY SRLTVDKSRW QQGNVFSCSV MHEALHNHYT QKSLSLSPG
```

**[00372]** The fourth polypeptide chain of BSAB A comprises, in the N-terminal to C-terminal direction: an N-terminus; a VL Domain of a monoclonal antibody capable of binding to LAG-3 (VL<sub>LAG-3</sub> hLAG-3 mAb 1 VL4) (**SEQ ID NO:54**); a Kappa CL Domain (**SEQ ID NO:8**), and a C-terminus.

**[00373]** The amino acid sequence of the fourth polypeptide chain of BSAB A is (**SEQ ID NO:289**):

DIVMTQTPLS LSVTPGQPAS ISCKSSQSLL HSDAKTYLNW LLQKPGQPPE  
 RLIYLVSELD SGVPDRFSGS GSGTDFTLKI SRVEAEDVGV YYCWQGTHFP  
 YTFGGGKVE IKRTVAAPSV FIFPPSDEQL KSGTASVCL LNNFYPREAK  
 VQWKVDNALQ SGNSQESVTE QDSKDSTYSL SSTLTLSKAD YEKHKVYACE  
 VTHQGLSSPV TKSFNRGEC

## IX. Reference Antibodies

### A. Reference Anti-Human PD-1 Antibodies

[00374] In order to assess and characterize the novel anti-human PD-1-binding molecules of the present invention, the following reference antibodies were employed: nivolumab (also known as 5C4, BMS-936558, ONO-4538, MDX-1106, and marketed as OPDIVO® by Bristol-Myers Squibb), a human IgG4 antibody designated herein as “**PD-1 mAb A**,” and pembrolizumab (formerly known as lambrolizumab, also known as MK-3475, SCH-900475, and marketed as KEYTRUDA® by Merck) a humanized IgG4 antibody designated herein as “**PD-1 mAb B**.”

#### 1. Nivolumab (“PD-1 mAb A”)

[00375] The amino acid sequence of the Heavy Chain Variable Domain of **PD-1 mAb A** has the amino acid sequence (**SEQ ID NO:64**) (CDR<sub>H</sub> residues are shown underlined):

QVQLVESGGG VVQPGRSLRL DCKASGITFS NSGMHWVRQA PGKGLEWVAV  
IWYDGSKRYY ADSVKGRFTI SRDNSKNTLF LQMNSLRAED TAVYYCATND  
DYWGQGLTVT VSS

[00376] The amino acid sequence of the Light Chain Variable Domain of **PD-1 mAb A** has the amino acid sequence (**SEQ ID NO:65**) (CDR<sub>L</sub> residues are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRASQSVS SYLAWYQQKP GQAPRLLIYD  
ASNRATGIPA RFSGSGSGTD FTLTISSLEP EDFAVYYCQQ SSNWPRTFGQ  
 GTKVEIK

#### 2. Pembrolizumab (“PD-1 mAb B”)

[00377] The amino acid sequence of the Heavy Chain Variable Domain of **PD-1 mAb B** has the amino acid sequence (**SEQ ID NO:66**) (CDR<sub>H</sub> residues are shown underlined):

QVQLVQSGVE VKKPGASVKV SCKASGYTFT NYMYWVRQA PGQGLEWMGG  
INPSNGGTNF NEKFKNRVTL TTDSSTTTAY MELKSLQFDD TAVYYCARRRD  
YRFDMGFDYW GQGTTVTVSS

[00378] The amino acid sequence of the Light Chain Variable Domain of **PD-1 mAb B** has the amino acid sequence (**SEQ ID NO:67**) (CDRL residues are shown underlined):

EIVLTQSPAT LSLSPGERAT LSCRASKGVS TSGYSYLHWY QQKPGQAPRL  
 LIYLASYLES GVPARFSGSG SGTDFTLTIS SLEPEDFAVY YCQHSRDLPL  
TFGGGTKVEIK

## X. Methods of Production

[00379] An anti-human PD-1 polypeptide, and other PD-1 agonists, antagonists and modulators can be created from the polynucleotides and/or sequences of the anti-PD-1 antibodies PD-1 mAb 1-15 by methods known in the art, for example, synthetically or recombinantly. One method of producing such peptide agonists, antagonists and modulators involves chemical synthesis of the polypeptide, followed by treatment under oxidizing conditions appropriate to obtain the native conformation, that is, the correct disulfide bond linkages. This can be accomplished using methodologies well known to those skilled in the art (see, *e.g.*, Kelley, R. F. *et al.* (1990) In: GENETIC ENGINEERING PRINCIPLES AND METHODS, Setlow, J.K. Ed., Plenum Press, N.Y., vol. 12, pp 1-19; Stewart, J.M *et al.* (1984) SOLID PHASE PEPTIDE SYNTHESIS, Pierce Chemical Co., Rockford, IL; see also United States Patents Nos. 4,105,603; 3,972,859; 3,842,067; and 3,862,925).

[00380] Polypeptides of the invention may be conveniently prepared using solid phase peptide synthesis (Merrifield, B. (1986) “*Solid Phase Synthesis*,” Science 232(4748):341-347; Houghten, R.A. (1985) “*General Method For The Rapid Solid-Phase Synthesis Of Large Numbers Of Peptides: Specificity Of Antigen-Antibody Interaction At The Level Of Individual Amino Acids*,” Proc. Natl. Acad. Sci. (U.S.A.) 82(15):5131-5135; Ganesan, A. (2006) “*Solid-Phase Synthesis In The Twenty-First Century*,” Mini Rev. Med. Chem. 6(1):3-10).

[00381] In yet another alternative, fully human antibodies having one or more of the CDRs of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15, or which compete with PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15, for binding to human PD-1 or a soluble form thereof may be obtained through the use of commercially available mice that have been engineered to express specific human immunoglobulin proteins. Transgenic animals that are designed to produce a more desirable (*e.g.*, fully human antibodies) or more robust immune response may also be used for generation

of humanized or human antibodies. Examples of such technology are XENOMOUSE™ (Abgenix, Inc., Fremont, CA) and HUMAB-MOUSE® and TC MOUSE™ (both from Medarex, Inc., Princeton, NJ).

**[00382]** In an alternative, antibodies may be made recombinantly and expressed using any method known in the art. Antibodies may be made recombinantly by first isolating the antibodies made from host animals, obtaining the gene sequence, and using the gene sequence to express the antibody recombinantly in host cells (*e.g.*, CHO cells). Another method that may be employed is to express the antibody sequence in plants (*e.g.*, tobacco) or transgenic milk. Suitable methods for expressing antibodies recombinantly in plants or milk have been disclosed (see, for example, Peeters *et al.* (2001) “*Production Of Antibodies And Antibody Fragments In Plants*,” *Vaccine* 19:2756; Lonberg, N. *et al.* (1995) “*Human Antibodies From Transgenic Mice*,” *Int. Rev. Immunol* 13:65-93; and Pollock *et al.* (1999) “*Transgenic Milk As A Method For The Production Of Recombinant Antibodies*,” *J. Immunol Methods* 231:147-157). Suitable methods for making derivatives of antibodies, *e.g.*, humanized, single-chain, *etc.* are known in the art. In another alternative, antibodies may be made recombinantly by phage display technology (see, for example, U.S. Patent Nos. 5,565,332; 5,580,717; 5,733,743; 6,265,150; and Winter, G. *et al.* (1994) “*Making Antibodies By Phage Display Technology*,” *Annu. Rev. Immunol.* 12:433-455).

**[00383]** The antibodies or protein of interest may be subjected to sequencing by Edman degradation, which is well known to those of skill in the art. The peptide information generated from mass spectrometry or Edman degradation can be used to design probes or primers that are used to clone the protein of interest.

**[00384]** An alternative method of cloning the protein of interest is by “panning” using purified PD-1 or portions thereof for cells expressing an antibody or protein of interest that possesses one or more of the CDRs of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15, or of an antibody that competes with PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15, for binding to human PD-1. The “panning” procedure may be conducted by obtaining a cDNA library from tissues or cells that express PD-1, overexpressing the cDNAs in a second cell type, and screening the transfected cells of

the second cell type for a specific binding to PD-1 in the presence or absence of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15. Detailed descriptions of the methods used in cloning mammalian genes coding for cell surface proteins by “panning” can be found in the art (see, for example, Aruffo, A. *et al.* (1987) “*Molecular Cloning Of A CD28 cDNA By A High-Efficiency COS Cell Expression System*,” Proc. Natl. Acad. Sci. (U.S.A.) 84:8573-8577 and Stephan, J. *et al.* (1999) “*Selective Cloning Of Cell Surface Proteins Involved In Organ Development: Epithelial Glycoprotein Is Involved In Normal Epithelial Differentiation*,” Endocrinol. 140:5841-5854).

**[00385]** Vectors containing polynucleotides of interest can be introduced into the host cell by any of a number of appropriate means, including electroporation, transfection employing calcium chloride, rubidium chloride, calcium phosphate, DEAE- dextran, or other substances; microprojectile bombardment; lipofection; and infection (*e.g.*, where the vector is an infectious agent such as vaccinia virus). The choice of introducing vectors or polynucleotides will often depend on features of the host cell.

**[00386]** Any host cell capable of overexpressing heterologous DNAs can be used for the purpose of isolating the genes encoding the antibody, polypeptide or protein of interest. Non-limiting examples of suitable mammalian host cells include but are not limited to COS, HeLa, and CHO cells. Preferably, the host cells express the cDNAs at a level of about 5-fold higher, more preferably 10-fold higher, even more preferably 20-fold higher than that of the corresponding endogenous antibody or protein of interest, if present, in the host cells. Screening the host cells for a specific binding to PD-1 is effected by an immunoassay or FACS. A cell overexpressing the antibody or protein of interest can be identified.

**[00387]** The invention includes polypeptides comprising an amino acid sequence of the antibodies of this invention. The polypeptides of this invention can be made by procedures known in the art. The polypeptides can be produced by proteolytic or other degradation of the antibodies, by recombinant methods (*i.e.*, single or fusion polypeptides) as described above or by chemical synthesis. Polypeptides of the antibodies, especially shorter polypeptides up to about 50 amino acids, are conveniently made by chemical synthesis. Methods of chemical synthesis are known in the art and are commercially available. For example, an anti-human PD-1 polypeptide could be produced by an automated polypeptide synthesizer employing the solid phase method.

**[00388]** The invention includes variants of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15 antibodies and their polypeptide fragments that bind to PD-1, including functionally equivalent antibodies and fusion polypeptides that do not significantly affect the properties of such molecules as well as variants that have enhanced or decreased activity. Modification of polypeptides is routine practice in the art and need not be described in detail herein. Examples of modified polypeptides include polypeptides with conservative substitutions of amino acid residues, one or more deletions or additions of amino acids which do not significantly deleteriously change the functional activity, or use of chemical analogs. Amino acid residues that can be conservatively substituted for one another include but are not limited to: glycine/alanine; serine/threonine; valine/isoleucine/leucine; asparagine/glutamine; aspartic acid/glutamic acid; lysine/arginine; and phenylalanine/tyrosine. These polypeptides also include glycosylated and non-glycosylated polypeptides, as well as polypeptides with other post-translational modifications, such as, for example, glycosylation with different sugars, acetylation, and phosphorylation. Preferably, the amino acid substitutions would be conservative, *i.e.*, the substituted amino acid would possess similar chemical properties as that of the original amino acid. Such conservative substitutions are known in the art, and examples have been provided above. Amino acid modifications can range from changing or modifying one or more amino acids to complete redesign of a region, such as the Variable Domain. Changes in the Variable Domain can alter binding affinity and/or specificity. Other methods of modification include using coupling techniques known in the art, including, but not limited to, enzymatic means, oxidative substitution and chelation. Modifications can be used, for example, for attachment of labels for immunoassay, such as the attachment of radioactive moieties for radioimmunoassay. Modified polypeptides are made using established procedures in the art and can be screened using standard assays known in the art.

**[00389]** The invention encompasses fusion proteins comprising one or more of the polypeptides or PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15 antibodies of this invention. In one embodiment, a fusion polypeptide is provided that comprises a light chain, a heavy chain or both a light and heavy chain. In another embodiment, the fusion polypeptide contains a heterologous immunoglobulin constant region. In another embodiment, the fusion polypeptide

contains a Light Chain Variable Domain and a Heavy Chain Variable Domain of an antibody produced from a publicly-deposited hybridoma. For purposes of this invention, an antibody fusion protein contains one or more polypeptide domains that specifically bind to PD-1 and another amino acid sequence to which it is not attached in the native molecule, for example, a heterologous sequence or a homologous sequence from another region.

## **XI. Uses of the PD-1-Binding Molecules of the Present Invention**

**[00390]** The present invention encompasses compositions, including pharmaceutical compositions, comprising the PD-1-binding molecules of the present invention (*e.g.*, anti-PD-1 antibodies, anti-PD-1 bispecific diabodies, *etc.*), polypeptides derived from such molecules, polynucleotides comprising sequences encoding such molecules or polypeptides, and other agents as described herein.

### **A. Therapeutic Uses**

**[00391]** As discussed above, PD-1 plays an important role in negatively regulating T-cell proliferation, function and homeostasis. Certain of the PD-1-binding molecules of the present invention have the ability to inhibit PD-1 function, and thus reverse the PD-1-mediated immune system inhibition. As such, PD-1 mAb 1, PD-1 mAb 3, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and PD-1 mAb 15, their humanized derivatives, and molecules comprising their PD-1-binding fragments (*e.g.*, bispecific antibodies, bispecific diabodies (including, but not limited to, DART-A, DART-B, DART-C, DART-D, DART-E, DART-F, DART-G, DART-H, DART-I, and DART-J), *etc.*), or that compete for binding with such antibodies, may be used to block PD-1-mediated immune system inhibition, and thereby promote the activation of the immune system.

**[00392]** Such bispecific PD-1-binding molecules of the present invention that bind to PD-1 and another molecule involved in regulating an immune check point present on the cell surface (*e.g.*, LAG-3) augment the immune system by blocking immune system inhibition mediated by PD-1 and such immune check point molecules. Thus, such PD-1-binding molecules of the invention are useful for augmenting an immune response (*e.g.*, the T-cell mediated immune response) of a subject. In particular, such PD-1-binding molecules of the invention and may be used to treat any disease or condition associated with an undesirably suppressed immune

system, including cancer and diseases that are associated with the presence of a pathogen (*e.g.*, a bacterial, fungal, viral or protozoan infection).

**[00393]** The cancers that may be treated by such PD-1-binding molecules of the present invention include cancers characterized by the presence of a cancer cell selected from the group consisting of a cell of: an adrenal gland tumor, an AIDS-associated cancer, an alveolar soft part sarcoma, an astrocytic tumor, bladder cancer, bone cancer, a brain and spinal cord cancer, a metastatic brain tumor, a breast cancer, a carotid body tumors, a cervical cancer, a chondrosarcoma, a chordoma, a chromophobe renal cell carcinoma, a clear cell carcinoma, a colon cancer, a colorectal cancer, a cutaneous benign fibrous histiocytoma, a desmoplastic small round cell tumor, an ependymoma, a Ewing's tumor, an extraskeletal myxoid chondrosarcoma, a fibrogenesis imperfecta ossium, a fibrous dysplasia of the bone, a gallbladder or bile duct cancer, gastric cancer, a gestational trophoblastic disease, a germ cell tumor, a head and neck cancer, hepatocellular carcinoma, an islet cell tumor, a Kaposi's Sarcoma, a kidney cancer, a leukemia, a lipoma/benign lipomatous tumor, a liposarcoma/malignant lipomatous tumor, a liver cancer, a lymphoma, a lung cancer, a medulloblastoma, a melanoma, a meningioma, a multiple endocrine neoplasia, a multiple myeloma, a myelodysplastic syndrome, a neuroblastoma, a neuroendocrine tumors, an ovarian cancer, a pancreatic cancer, a papillary thyroid carcinoma, a parathyroid tumor, a pediatric cancer, a peripheral nerve sheath tumor, a pheochromocytoma, a pituitary tumor, a prostate cancer, a posterior uveal melanoma, a rare hematologic disorder, a renal metastatic cancer, a rhabdoid tumor, a rhabdomyosarcoma, a sarcoma, a skin cancer, a soft-tissue sarcoma, a squamous cell cancer, a stomach cancer, a synovial sarcoma, a testicular cancer, a thymic carcinoma, a thymoma, a thyroid metastatic cancer, and a uterine cancer.

**[00394]** In particular, such PD-1-binding molecules of the present invention may be used in the treatment of colorectal cancer, hepatocellular carcinoma, glioma, kidney cancer, breast cancer, multiple myeloma, bladder cancer, neuroblastoma; sarcoma, non-Hodgkin's lymphoma, non-small cell lung cancer, ovarian cancer, pancreatic cancer and rectal cancer.

**[00395]** Pathogen-associated diseases that may be treated by such PD-1-binding molecules of the present invention include chronic viral, bacterial, fungal and parasitic infections. Chronic infections that may be treated by the PD-1-binding molecules of the present invention include Epstein Barr virus, Hepatitis A Virus (HAV); Hepatitis B Virus (HBV); Hepatitis C Virus (HCV); herpes viruses (*e.g.* HSV-1, HSV-2, HHV-6, CMV), Human Immunodeficiency

Virus (HIV), Vesicular Stomatitis Virus (VSV), *Bacilli*, *Citrobacter*, *Cholera*, *Diphtheria*, *Enterobacter*, *Gonococci*, *Helicobacter pylori*, *Klebsiella*, *Legionella*, *Meningococci*, mycobacteria, *Pseudomonas*, *Pneumonococci*, rickettsia bacteria, *Salmonella*, *Serratia*, *Staphylococci*, *Streptococci*, *Tetanus*, *Aspergillus* (fumigatus, niger, etc.), *Blastomyces dermatitidis*, *Candida* (albicans, krusei, glabrata, tropicalis, etc.), *Cryptococcus neoformans*, Genus *Mucorales* (mucor, absidia, rhizopus), *Sporothrix schenkii*, *Paracoccidioides brasiliensis*, *Coccidioides immitis*, *Histoplasma capsulatum*, *Leptospirosis*, *Borrelia burgdorferi*, helminth parasite (hookworm, tapeworms, flukes, flatworms (e.g. *Schistosomia*), *Giardia lamblia*, *trichinella*, *Dientamoeba Fragilis*, *Trypanosoma brucei*, *Trypanosoma cruzi*, and *Leishmania donovani*.

[00396] Such PD-1-binding molecules of the invention can be combined with other anti-cancer agents, in particular, molecules that specifically bind a cancer antigen (e.g., antibodies, diabodies). Anti-cancer therapies that may be combined with the PD-1-binding molecules of the invention include molecules which specifically bind one more cancer antigens including: **19.9** as found in colon cancer, gastric cancer mucins; **4.2**; **A33** (a colorectal carcinoma antigen; Almqvist, Y. 2006, *Nucl Med Biol.* Nov;33(8):991-998); **ADAM-9** (United States Patent Publication No. 2006/0172350; PCT Publication No. WO 06/084075); **AH6** as found in gastric cancer; **ALCAM** (PCT Publication No. WO 03/093443); **APO-1 (malignant human lymphocyte antigen)** (Trauth *et al.* (1989) "Monoclonal Antibody-Mediated Tumor Regression By Induction Of Apoptosis," *Science* 245:301-304); **B1** (Egloff, A.M. *et al.* 2006, *Cancer Res.* 66(1):6-9); **B7-H3** (Collins, M. *et al.* (2005) "The B7 Family Of Immune-Regulatory Ligands," *Genome Biol.* 6:223.1-223.7). Chapoval, A. *et al.* (2001) "B7-H3: A Costimulatory Molecule For T Cell Activation and IFN- $\gamma$  Production," *Nature Immunol.* 2:269-274; Sun, M. *et al.* (2002) "Characterization of Mouse and Human B7-H3 Genes," *J. Immunol.* 168:6294-6297); **BAGE** (Bodey, B. 2002 *Expert Opin Biol Ther.* 2(6):577-84); **beta-catenin** (Prange W. *et al.* 2003 *J Pathol.* 201(2):250-9); **blood group ALe<sup>b</sup>/Le<sup>y</sup>** as found in colonic adenocarcinoma; **Burkitt's lymphoma antigen-38.13**, **C14** as found in colonic adenocarcinoma; **CA125 (ovarian carcinoma antigen)** (Bast, R.C. Jr. *et al.* 2005 *Int J Gynecol Cancer* 15 Suppl 3:274-81 ; Yu *et al.* (1991) "Coexpression Of Different Antigenic Markers On Moieties That Bear CA 125 Determinants," *Cancer Res.* 51(2):468-475); **Carboxypeptidase M** (United States Patent Publication No. 2006/0166291); **CD5** (Calin, G.A. *et al.* 2006 *Semin Oncol.* 33(2):167-73; **CD19** (Ghetie *et al.* (1994) "Anti-CD19 Inhibits The Growth Of Human B-Cell Tumor Lines In Vitro And Of Daudi Cells In SCID Mice By Inducing

*Cell Cycle Arrest*,” Blood 83:1329-1336; Troussard, X. *et al.* 1998 *Hematol Cell Ther.* 40(4):139-48); **CD20** (Reff *et al.* (1994) “*Depletion Of B Cells In Vivo By A Chimeric Mouse Human Monoclonal Antibody To CD20*,” Blood 83:435-445; Thomas, D.A. *et al.* 2006 *Hematol Oncol Clin North Am.* 20(5):1125-36); **CD22** (Kreitman, R.J. 2006 *AAPS J.* 18;8(3):E532-51); **CD23** (Rosati, S. *et al.* 2005 *Curr Top Microbiol Immunol.* 5;294:91-107); **CD25** (Troussard, X. *et al.* 1998 *Hematol Cell Ther.* 40(4):139-48); **CD27** (Bataille, R. 2006 *Haematologica* 91(9):1234-40); **CD28** (Bataille, R. 2006 *Haematologica* 91(9):1234-40); **CD33** (Sgouros *et al.* (1993) “*Modeling And Dosimetry Of Monoclonal Antibody M195 (Anti-CD33) In Acute Myelogenous Leukemia*,” J. Nucl. Med. 34:422-430); **CD36** (Ge, Y. 2005 *Lab Hematol.* 11(1):31-7); CD40/CD154 (Messmer, D. *et al.* 2005 *Ann N Y Acad Sci.* 1062:51-60); **CD45** (Jurcic, J.G. 2005 *Curr Oncol Rep.* 7(5):339-46); CD56 (Bataille, R. 2006 *Haematologica* 91(9):1234-40); **CD46** (United States Patent No. 7,148,038; PCT Publication No. WO 03/032814); **CD52** (Eketorp, S.S. *et al.* (2014) “*Alemtuzumab (Anti-CD52 Monoclonal Antibody) As Single-Agent Therapy In Patients With Relapsed/Refractory Chronic Lymphocytic Leukaemia (CLL)-A Single Region Experience On Consecutive Patients*,” Ann Hematol. 93(10):1725-1733; Suresh, T. *et al.* (2014) “*New Antibody Approaches To Lymphoma Therapy*,” J. Hematol. Oncol. 7:58; Hoelzer, D. (2013) “*Targeted Therapy With Monoclonal Antibodies In Acute Lymphoblastic Leukemia*,” Curr. Opin. Oncol. 25(6):701-706); **CD56** (Bataille, R. 2006 *Haematologica* 91(9):1234-40); **CD79a/CD79b** (Troussard, X. *et al.* 1998 *Hematol Cell Ther.* 40(4):139-48; Chu, P.G. *et al.* 2001 *Appl Immunohistochem Mol Morphol.* 9(2):97-106); **CD103** (Troussard, X. *et al.* 1998 *Hematol Cell Ther.* 40(4):139-48); **CD317** (Kawai, S. *et al.* (2008) “*Interferon- $\alpha$  Enhances CD317 Expression And The Antitumor Activity Of Anti-CD317 Monoclonal Antibody In Renal Cell Carcinoma Xenograft Models*,” Cancer Science 99(12):2461-2466; Wang, W. *et al.* (2009) *HMI.24 (CD317) Is A Novel Target Against Lung Cancer For Immunotherapy Using Anti-HMI.24 Antibody*,” Cancer Immunology, Immunotherapy 58(6):967-976; Wang, W. *et al.* (2009) “*Chimeric And Humanized Anti-HMI.24 Antibodies Mediate Antibody-Dependent Cellular Cytotoxicity Against Lung Cancer Cells. Lung Cancer*,” 63(1):23-31; Sayeed, A. *et al.* (2013) “*Aberrant Regulation Of The BST2 (Tetherin) Promoter Enhances Cell Proliferation And Apoptosis Evasion In High Grade Breast Cancer Cells*,” PLoS ONE 8(6)e67191, pp. 1-10); **CDK4** (Lee, Y.M. *et al.* 2006 *Cell Cycle* 5(18):2110-4); **CEA** (carcinoembryonic antigen; Foon *et al.* (1995) “*Immune Response To The Carcinoembryonic Antigen In Patients Treated With An Anti-Idiotypic Antibody Vaccine*,” J. Clin. Invest. 96(1):334-42); Mathelin, C. 2006 *Gynecol Obstet Fertil.* 34(7-8):638-46; Tellez-Avila, F.I. *et al.* 2005 *Rev Invest Clin.* 57(6):814-9);

**CEACAM9/CEACAM6** (Zheng, C. *et al.* (2011) “A Novel Anti-CEACAM5 Monoclonal Antibody, CC4, Suppresses Colorectal Tumor Growth and Enhances NK Cells-Mediated Tumor Immunity,” PLoS One 6(6):e21146, pp. 1-11); **CO17-1A** (Ragnhammar *et al.* (1993) “Effect Of Monoclonal Antibody 17-1A And GM-CSF In Patients With Advanced Colorectal Carcinoma - Long-Lasting, Complete Remissions Can Be Induced,” Int. J. Cancer 53:751-758); **CO-43** (blood group Le<sup>b</sup>); **CO-514** (blood group Le<sup>a</sup>) as found in adenocarcinoma; **CTA-1**; **CTLA-4** (Peggs, K.S. *et al.* 2006 *Curr Opin Immunol.* 18(2):206-13); **Cytokeratin 8** (PCT Publication No. WO 03/024191); **D1.1**; **D156-22**; **DR5** (Abdulghani, J. *et al.* (2010) “TRAIL Receptor Signaling And Therapeutics,” Expert Opin. Ther. Targets 14(10):1091-1108; Andera, L. (2009) “Signaling Activated By The Death Receptors Of The TNFR Family,” Biomed. Pap. Med. Fac. Univ. Palacky Olomouc Czech. Repub. 153(3):173-180; Carlo-Stella, C. *et al.* (2007) “Targeting TRAIL Agonistic Receptors for Cancer Therapy,” Clin. Cancer 13(8):2313-2317; Chaudhari, B.R. *et al.* (2006) “Following the TRAIL to Apoptosis,” Immunologic Res. 35(3):249-262); **E1** series (blood group B) as found in pancreatic cancer; **EGFR** (Epidermal Growth Factor Receptor; Adenis, A. *et al.* 2003 *Bull Cancer.* 90 Spec No:S228-32); **Ephrin receptors** (and in particular **EphA2** (United States Patent No. 7,569,672; PCT Publication No. WO 06/084226); **Erb** (ErbB1; ErbB3; ErbB4; Zhou, H. *et al.* 2002 *Oncogene* 21(57):8732-8740; Rimon, E. *et al.* 2004 *Int J Oncol.* 24(5):1325-1338); **GAGE** (GAGE-1; GAGE-2; Akcakanat, A. *et al.* 2006 *Int J Cancer.* 118(1):123-128); **GD2/GD3/GM2** (Livingston, P.O. *et al.* 2005 *Cancer Immunol Immunother.* 54(10):1018-1025); **ganglioside GD2** (GD<sub>2</sub>; Saleh *et al.* (1993) “Generation Of A Human Anti-Idiotypic Antibody That Mimics The GD2 Antigen,” J.Immunol., 151, 3390-3398); **ganglioside GD3** (GD<sub>3</sub>; Shitara *et al.* (1993) “A Mouse/Human Chimeric Anti-(Ganglioside GD3) Antibody With Enhanced Antitumor Activities,” Cancer Immunol. Immunother. 36:373-380); **ganglioside GM2** (GM<sub>2</sub>; Livingston *et al.* (1994) “Improved Survival In Stage III Melanoma Patients With GM2 Antibodies: A Randomized Trial Of Adjuvant Vaccination With GM2 Ganglioside,” J. Clin. Oncol. 12:1036-1044); **ganglioside GM3** (GM<sub>3</sub>; Hoon *et al.* (1993) “Molecular Cloning Of A Human Monoclonal Antibody Reactive To Ganglioside GM3 Antigen On Human Cancers,” Cancer Res. 53:5244-5250); **GICA 19-9** (Herlyn *et al.* (1982) “Monoclonal Antibody Detection Of A Circulating Tumor-Associated Antigen. I. Presence Of Antigen In Sera Of Patients With Colorectal, Gastric, And Pancreatic Carcinoma,” J. Clin. Immunol. 2:135-140); **gp100** (Lotem, M. *et al.* 2006 *J Immunother.* 29(6):616-27); **Gp37** (human leukemia T cell antigen; Bhattacharya-Chatterjee *et al.* (1988) “Idiotypic Vaccines Against Human T Cell Leukemia. II. Generation And Characterization Of A Monoclonal Idiotypic Cascade (Ab1, Ab2, and Ab3),” J. Immunol.

141:1398-1403); **gp75** (melanoma antigen; Vijayasardahl *et al.* (1990) "The Melanoma Antigen Gp75 Is The Human Homologue Of The Mouse B (Brown) Locus Gene Product," J. Exp. Med. 171(4):1375-1380); **gpA33** (Heath, J.K. *et al.* (1997) "The Human A33 Antigen Is A Transmembrane Glycoprotein And A Novel Member Of The Immunoglobulin Superfamily," Proc. Natl. Acad. Sci. (U.S.A.) 94(2):469-474; Ritter, G. *et al.* (1997) "Characterization Of Posttranslational Modifications Of Human A33 Antigen, A Novel Palmitoylated Surface Glycoprotein Of Human Gastrointestinal Epithelium," Biochem. Biophys. Res. Commun. 236(3):682-686; Wong, N.A. *et al.* (2006) "EpCAM and gpA33 Are Markers Of Barrett's Metaplasia," J. Clin. Pathol. 59(3):260-263); **HER2 antigen** (HER2/neu, p185<sup>HER2</sup>; Kumar, Pal S *et al.* 2006 Semin Oncol. 33(4):386-91); **HMFG** (human milk fat globule antigen; WO1995015171); **human papillomavirus-E6/human papillomavirus-E7** (DiMaio, D. *et al.* 2006 Adv Virus Res. 66:125-59; **HMW-MAA** (high molecular weight melanoma antigen; Natali *et al.* (1987) "Immunohistochemical Detection Of Antigen In Human Primary And Metastatic Melanomas By The Monoclonal Antibody 140.240 And Its Possible Prognostic Significance," Cancer 59:55-63; Mittelman *et al.* (1990) "Active Specific Immunotherapy In Patients With Melanoma. A Clinical Trial With Mouse Antiidiotypic Monoclonal Antibodies Elicited With Syngeneic Anti-High-Molecular-Weight-Melanoma-Associated Antigen Monoclonal Antibodies," J. Clin. Invest. 86:2136-2144); **I antigen** (differentiation antigen; Feizi (1985) "Demonstration By Monoclonal Antibodies That Carbohydrate Structures Of Glycoproteins And Glycolipids Are Onco-Developmental Antigens," Nature 314:53-57); **IL13R $\alpha$ 2** (PCT Publication No. WO 2008/146911; Brown, C.E. *et al.* (2013) "Glioma IL13R $\alpha$ 2 Is Associated With Mesenchymal Signature Gene Expression And Poor Patient Prognosis," PLoS One. 18;8(10):e77769; Barderas, R. *et al.* (2012) "High Expression Of IL-13 Receptor A2 In Colorectal Cancer Is Associated With Invasion, Liver Metastasis, And Poor Prognosis," Cancer Res. 72(11):2780-2790; Kasaian, M.T. *et al.* (2011) "IL-13 Antibodies Influence IL-13 Clearance In Humans By Modulating Scavenger Activity Of IL-13R $\alpha$ 2," J. Immunol. 187(1):561-569; Bozinov, O. *et al.* (2010) "Decreasing Expression Of The Interleukin-13 Receptor IL-13R $\alpha$ 2 In Treated Recurrent Malignant Gliomas," Neurol. Med. Chir. (Tokyo) 50(8):617-621; Fujisawa, T. *et al.* (2009) "A novel role of interleukin-13 receptor alpha2 in pancreatic cancer invasion and metastasis," Cancer Res. 69(22):8678-8685); **Integrin  $\beta$ 6** (PCT Publication No. WO 03/087340); **JAM-3** (PCT Publication No. WO 06/084078); **KID3** (PCT Publication No. WO 05/028498); **KID31** (PCT Publication No. WO 06/076584); **KS 1/4 pan-carcinoma antigen** (Perez *et al.* (1989) "Isolation And Characterization Of A cDNA Encoding The Ks1/4 Epithelial Carcinoma Marker," J. Immunol.

142:3662-3667; Möller *et al.* (1991) “*Bi-specific-Monoclonal-Antibody-Directed Lysis Of Ovarian Carcinoma Cells By Activated Human T Lymphocytes*,” *Cancer Immunol. Immunother.* 33(4):210-216; Ragupathi, G. 2005 *Cancer Treat Res.* 123:157-80); **L6** and **L20** (human lung carcinoma antigens; Hellström *et al.* (1986) “*Monoclonal Mouse Antibodies Raised Against Human Lung Carcinoma*,” *Cancer Res.* 46:3917-3923); **LEA**; **LUCA-2** (United States Patent Publication No. 2006/0172349; PCT Publication No. WO 06/083852); **M1:22:25:8**; **M18**; **M39**; **MAGE** (MAGE-1; MAGE-3; (Bodey, B. 2002 *Expert Opin Biol Ther.* 2(6):577-84); **MART** (Kounalakis, N. *et al.* 2005 *Curr Oncol Rep.* 7(5):377-82; **mesothelin** (Chang K, and Pastan I. 1996 “*Molecular cloning of mesothelin, a differentiation antigen present on mesothelium, mesotheliomas, and ovarian cancers*,” *Proc Natl Acad Sci USA* 93:136–40); **MUC-1** (Mathelin, C. 2006 *Gynecol Obstet Fertil.* 34(7-8):638-46); **MUM-1** (Castelli, C. *et al.* 2000 *J Cell Physiol.* 182(3):323-31); **Myl**; **N-acetylglucosaminyltransferase** (Dennis, J.W. 1999 *Biochim Biophys Acta.* 6;1473(1):21-34); **neoglycoprotein**; **NS-10** as found in adenocarcinomas; **OFA-1**; **OFA-2**; **Oncostatin M** (Oncostatin Receptor Beta; United States Patent No. 7,572,896; PCT Publication No. WO 06/084092); **p15** (Gil, J. *et al.* 2006 *Nat Rev Mol Cell Biol.* 7(9):667-77); **p97** (melanoma-associated antigen; Estlin *et al.* (1989) “*Transfected Mouse Melanoma Lines That Express Various Levels Of Human Melanoma-Associated Antigen p97*,” *J. Natl. Cancer Instit.* 81(6):445-454); **PEM** (polymorphic epithelial mucin; Hilkens *et al.* (1992) “*Cell Membrane-Associated Mucins And Their Adhesion-Modulating Property*,” *Trends in Biochem. Sci.* 17:359-363); **PEMA (polymorphic epithelial mucin antigen)**; **PIPA** (United States Patent No. 7,405,061; PCT Publication No. WO 04/043239); **PSA** (prostate-specific antigen; Henttu *et al.* (1989) “*cDNA Coding For The Entire Human Prostate Specific Antigen Shows High Homologies To The Human Tissue Kallikrein Genes*,” *Biochem. Biophys. Res. Comm.* 10(2):903-910; Israeli *et al.* (1993) “*Molecular Cloning Of A Complementary DNA Encoding A Prostate-Specific Membrane Antigen*,” *Cancer Res.* 53:227-230; Cracco, C.M. *et al.* 2005 *Minerva Urol Nefrol.* 57(4):301-11); **PSMA** (prostate-specific membrane antigen; Ragupathi, G. 2005 *Cancer Treat Res.* 123:157-180); **prostatic acid phosphate** (Tailor *et al.* (1990) “*Nucleotide Sequence Of Human Prostatic Acid Phosphatase Determined From A Full-Length cDNA Clone*,” *Nucl. Acids Res.* 18(16):4928); **R<sub>24</sub>** as found in melanoma; **ROR1** (United States Patent No. 5,843,749); **sphingolipids**; **SSEA-1**; **SSEA-3**; **SSEA-4**; **sTn** (Holmberg, L.A. 2001 *Expert Opin Biol Ther.* 1(5):881-91); **T cell receptor derived peptide** from a cutaneous T cell lymphoma (see Edelson (1998) “*Cutaneous T-Cell Lymphoma: A Model For Selective Immunotherapy*,” *Cancer J Sci Am.* 4:62-71); **T<sub>5A7</sub>** found in myeloid cells; **TAG-72**

(Yokota *et al.* (1992) “*Rapid Tumor Penetration Of A Single-Chain Fv And Comparison With Other Immunoglobulin Forms*,” *Cancer Res.* 52:3402-3408); **TL5** (blood group A); **TNF-receptor** (TNF- $\alpha$  receptor, TNF- $\beta$  receptor; **TNF- $\gamma$  receptor** (van Horssen, R. *et al.* 2006 *Oncologist.* 11(4):397-408; Gardnerova, M. *et al.* 2000 *Curr Drug Targets.* 1(4):327-64); **TRA-1-85** (blood group H); **Transferrin Receptor** (United States Patent No. 7,572,895; PCT Publication No. WO 05/121179); **5T4** (TPBG, trophoblast glycoprotein; Boghaert, E.R. *et al.* (2008) “*The Oncofetal Protein, 5T4, Is A Suitable Target For Antibody-Guided Anti-Cancer Chemotherapy With Calicheamicin*,” *Int. J. Oncol.* 32(1):221-234; Eisen, T. *et al.* (2014) “*Naptumomab Estafenatox: Targeted Immunotherapy with a Novel Immunotoxin*,” *Curr. Oncol. Rep.* 16:370, pp. 1-6); **TSTA (tumor-specific transplantation antigen)** such as virally-induced tumor antigens including T-antigen DNA tumor viruses and envelope antigens of RNA tumor viruses, oncofetal antigen-alpha-fetoprotein such as CEA of colon, bladder tumor oncofetal antigen (Hellström *et al.* (1985) “*Monoclonal Antibodies To Cell Surface Antigens Shared By Chemically Induced Mouse Bladder Carcinomas*,” *Cancer. Res.* 45:2210-2188); **VEGF** (Pietrantonio, F. *et al.* (2015) “*Bevacizumab-Based Neoadjuvant Chemotherapy For Colorectal Cancer Liver Metastases: Pitfalls And Helpful Tricks In A Review For Clinicians*,” *Crit. Rev. Oncol. Hematol.* 95(3):272-281; Grabowski, J.P. (2015) “*Current Management Of Ovarian Cancer*,” *Minerva Med.* 106(3):151-156; Field, K.M. (2015) “*Bevacizumab And Glioblastoma: Scientific Review, Newly Reported Updates, And Ongoing Controversies*,” *Cancer* 121(7):997-1007; Suh, D.H. *et al.* (2015) “*Major Clinical Research Advances In Gynecologic Cancer In 2014*,” *J. Gynecol. Oncol.* 26(2):156-167; Liu, K.J. *et al.* (2015) “*Bevacizumab In Combination With Anticancer Drugs For Previously Treated Advanced Non-Small Cell Lung Cancer*,” *Tumour Biol.* 36(3):1323-1327; Di Bartolomeo, M. *et al.* (2015) “*Bevacizumab treatment in the elderly patient with metastatic colorectal cancer*,” *Clin. Interv. Aging* 10:127-133); **VEGF Receptor** (O'Dwyer, P.J. 2006 *Oncologist.* 11(9):992-998); **VEP8**; **VEP9**; **VIM-D5**; and **Y hapten, Le<sup>y</sup>** as found in embryonal carcinoma cells.

**[00397]** In certain embodiments, such anti-PD-1-binding molecules of the invention are used in combination with one or more molecules that specifically bind 5T4, B7H3, CD19, CD20, CD51, CD123, DR5, EGFR, EpCam, GD2, gpA33, HER2, ROR-1, TAG-72, VEGF-A antibody, and/or VEGFR2.

**[00398]** Such PD-1-binding molecules of the invention can be combined with an immunogenic agent such as a tumor vaccine. Such vaccines may comprise purified tumor

antigens (including recombinant proteins, peptides, and carbohydrate molecules), autologous or allogeneic tumor cells. A number of tumor vaccine strategies have been described (see for example, Palena, C., *et al.*, (2006) “*Cancer vaccines: preclinical studies and novel strategies*,” Adv. Cancer Res. 95, 115-145; Mellman, I., *et al.* (2011) “*Cancer immunotherapy comes of age*,” Nature 480, 480–489; Zhang, X. M. *et al.* (2008) “*The anti-tumor immune response induced by a combination of MAGE-3/MAGE-n-derived peptides*,” Oncol. Rep. 20, 245–252; Disis, M. L. *et al.* (2002) “*Generation of T-cell immunity to the HER-2/neu protein after active immunization with HER-2/neu peptide-based vaccines*,” J. Clin. Oncol. 20, 2624–2632; Vermeij, R. *et al.* (2012) “*Potentiation of a p53-SLP vaccine by cyclophosphamide in ovarian cancer: a single-arm phase II study*,” Int. J. Cancer 131, E670–E680). Such PD-1-binding molecules of the invention can be combined with chemotherapeutic regimes. In these instances, it may be possible to reduce the dose of chemotherapeutic reagent administered (Mokyr *et al.* (1998) Cancer Research 58: 5301-5304).

**[00399]** Such PD-1-binding molecules of the invention can be combined with other immunostimulatory molecules such as antibodies which activate host immune responsiveness to provide for increased levels of T-cell activation. In particular, anti-PD-1 antibodies, anti-PD-L1 antibodies and/or an anti-CTLA-4 antibodies have been demonstrated to active the immune system (see, *e.g.*, del Rio, M-L. *et al.* (2005) “*Antibody-Mediated Signaling Through PD-1 Costimulates T Cells And Enhances CD28-Dependent Proliferation*,” Eur. J. Immunol 35:3545-3560; Barber, D. L. *et al.* (2006) “*Restoring function in exhausted CD8 T cells during chronic viral infection*,” Nature 439, 682–687; Iwai, Y. *et al.* (2002) “*Involvement Of PD-L1 On Tumor Cells In The Escape From Host Immune System And Tumor Immunotherapy By PD-L1 Blockade*,” Proc. Natl Acad. Sci. USA 99, 12293–12297; Leach, D. R., *et al.*, (1996) “*Enhancement Of Antitumor Immunity By CTLA-4 Blockade*,” Science 271, 1734-1736). Additional immunostimulatory molecules that may be combined with the PD-1-binding molecules of the invention include antibodies to molecules on the surface of dendritic cells that activate dendritic cell (DC) function and antigen presentation, anti-CD40 antibodies able to substitute for T-cell helper activity, and activating antibodies to T-cell costimulatory molecules such as PD-L1, CTLA-4, OX-40 4-1BB, and ICOS (see, for example, Ito *et al.* (2000) “*Effective Priming Of Cytotoxic T Lymphocyte Precursors By Subcutaneous Administration Of Peptide Antigens In Liposomes Accompanied By Anti-CD40 And Anti-CTLA-4 Antibodies*,” Immunobiology 201:527-40; U.S. Pat. No. 5,811,097; Weinberg *et al.* (2000) “*Engagement of the OX-40 Receptor In Vivo Enhances Antitumor Immunity*,” Immunol

164:2160-2169; Melero *et al.* (1997) “*Monoclonal Antibodies Against The 4-1BB T-Cell Activation Molecule Eradicate Established Tumors*,” *Nature Medicine* 3: 682-685; Hutloff *et al.* (1999) “*ICOS Is An Inducible T-Cell Co-Stimulator Structurally And Functionally Related To CD28*,” *Nature* 397: 263-266; and Moran, A.E. *et al.* (2013) “*The TNFRs OX40, 4-1BB, and CD40 As Targets For Cancer Immunotherapy*,” *Curr Opin Immunol.* 2013 Apr; 25(2): 10.1016/j.coi.2013.01.004), and/or stimulatory Chimeric Antigen Receptors (**CARs**) comprising an antigen binding domain directed against a disease antigen fused to one or more intracellular signaling domains from various costimulatory protein receptors (*e.g.*, CD28, 4-1BB, ICOS, OX40, *etc.*) which serve to stimulate T-cells upon antigen binding (see, for example, Tettamanti, S. *et al.* (2013) “*Targeting Of Acute Myeloid Leukaemia By Cytokine-Induced Killer Cells Redirected With A Novel CD123-Specific Chimeric Antigen Receptor*,” *Br. J. Haematol.* 161:389-401; Gill, S. *et al.* (2014) “*Efficacy Against Human Acute Myeloid Leukemia And Myeloablation Of Normal Hematopoiesis In A Mouse Model Using Chimeric Antigen Receptor-Modified T Cells*,” *Blood* 123(15): 2343-2354; Mardiros, A. *et al.* (2013) “*T Cells Expressing CD123-Specific Chimeric Antigen Receptors Exhibit Specific Cytolytic Effector Functions And Antitumor Effects Against Human Acute Myeloid Leukemia*,” *Blood* 122:3138-3148; Pizzitola, I. *et al.* (2014) “*Chimeric Antigen Receptors Against CD33/CD123 Antigens Efficiently Target Primary Acute Myeloid Leukemia Cells in vivo*,” *Leukemia* doi:10.1038/leu.2014.62).

**[00400]** Such PD-1-binding molecules of the invention can be combined with inhibitory Chimeric Antigen Receptors (**iCARs**) to divert off target immunotherapy responses. iCARs an antigen binding domain directed against a disease antigen fused to one or more intracellular signaling domains from various inhibitory protein receptors (*e.g.*, CTLA-4, PD-1, *etc.*) which serve to constrain T-cell responses upon antigen binding (see, for example, Fedorov V.D. (2013) “*PD-1– and CTLA-4–Based Inhibitory Chimeric Antigen Receptors (iCARs) Divert Off-Target Immunotherapy Responses*,” *Sci. Tranl. Med.* 5:215ra172 doi:10.1126/scitranslmed.3006597.

**[00401]** In particular, such anti-PD-1-binding molecules of the invention are used in combination with an anti-CD137 antibody, an anti-CTLA-4 antibody, an anti-OX40 antibody, an anti-LAG-3 antibody, an anti-PD-L1 antibody, an anti-TIGIT antibody, an anti TIM-3 antibody and/or a cancer vaccine.

## B. Diagnostic and Theranostic Utility

[00402] Certain of the PD-1-binding molecules of the present invention exhibit little or no ability to block binding between PD-1 and the PD-1L ligand. As such, antibodies PD-1 mAb 2 and PD-1 mAb 4, their humanized derivatives, and molecules comprising their PD-1-binding fragments (*e.g.*, bispecific diabodies, *etc.*) or that compete for binding with such antibodies may be detectably labeled (*e.g.*, with radioactive, enzymatic, fluorescent, chemiluminescent, paramagnetic, diamagnetic, or other labelling moieties) and used in the detection of PD-1 in samples or in the imaging of PD-1 on cells. Since such molecules do not affect the biological activity of PD-1, they are particularly useful in methods of determining the extent, location and change in PD-1 expression in subjects (*e.g.*, subjects being treated for cancer associated with the expression or targeting of PD-1).

## XII. Pharmaceutical Compositions

[00403] The compositions of the invention include bulk drug compositions useful in the manufacture of pharmaceutical compositions (*e.g.*, impure or non-sterile compositions) and pharmaceutical compositions (*i.e.*, compositions that are suitable for administration to a subject or patient) that can be used in the preparation of unit dosage forms. Such compositions comprise a prophylactically or therapeutically effective amount of the PD-1-binding molecules of the present invention, or a combination of such agents and a pharmaceutically acceptable carrier. Preferably, compositions of the invention comprise a prophylactically or therapeutically effective amount of the PD-1-binding molecules of the present invention and a pharmaceutically acceptable carrier. The invention particularly encompasses such pharmaceutical compositions in which the PD-1-binding molecule is: a PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15; a humanized PD-1 mAb 1; PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15; a PD-1-binding fragment of any such antibody; or in which the PD-1-binding molecule is a bispecific PD-1 diabody (*e.g.*, a PD-1 x LAG-3 bispecific diabody). Especially encompassed are such molecules that comprise the 3 CDR<sub>LS</sub> and the 3 CDR<sub>HS</sub> of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15 antibody; a humanized PD-1

mAb 1; PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15.

**[00404]** The invention also encompasses such pharmaceutical compositions that additionally include a second therapeutic antibody (*e.g.*, tumor-specific monoclonal antibody) that is specific for a particular cancer antigen, and a pharmaceutically acceptable carrier.

**[00405]** In a specific embodiment, the term “pharmaceutically acceptable” means approved by a regulatory agency of the Federal or a state government or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, and more particularly in humans. The term “carrier” refers to a diluent, adjuvant (*e.g.*, Freund’s adjuvant (complete and incomplete), excipient, or vehicle with which the therapeutic is administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. Water is a preferred carrier when the pharmaceutical composition is administered intravenously. Saline solutions and aqueous dextrose and glycerol solutions can also be employed as liquid carriers, particularly for injectable solutions. Suitable pharmaceutical excipients include starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. The composition, if desired, can also contain minor amounts of wetting or emulsifying agents, or pH buffering agents. These compositions can take the form of solutions, suspensions, emulsion, tablets, pills, capsules, powders, sustained-release formulations and the like.

**[00406]** Generally, the ingredients of compositions of the invention are supplied either separately or mixed together in unit dosage form, for example, as a dry lyophilized powder or water free concentrate in a hermetically sealed container such as an ampoule or sachette indicating the quantity of active agent. Where the composition is to be administered by infusion, it can be dispensed with an infusion bottle containing sterile pharmaceutical grade water or saline. Where the composition is administered by injection, an ampoule of sterile water for injection or saline can be provided so that the ingredients may be mixed prior to administration.

**[00407]** The compositions of the invention can be formulated as neutral or salt forms. Pharmaceutically acceptable salts include, but are not limited to those formed with anions such as those derived from hydrochloric, phosphoric, acetic, oxalic, tartaric acids, *etc.*, and those formed with cations such as those derived from sodium, potassium, ammonium, calcium, ferric hydroxides, isopropylamine, triethylamine, 2-ethylamino ethanol, histidine, procaine, *etc.*

**[00408]** The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with a PD-1-binding molecule of the present invention (and more preferably, a PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15; a humanized PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15 antibody; a PD-1-binding fragment of any such antibody; or in which the PD-1-binding molecule is a bispecific PD-1 diabody (*e.g.*, a PD-1 x LAG-3 bispecific diabody)). Especially encompassed are such molecules that comprise the 3 CDR<sub>LS</sub> and the 3 CDR<sub>HS</sub> of PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, or PD-1 mAb 15, alone or with such pharmaceutically acceptable carrier. Additionally, one or more other prophylactic or therapeutic agents useful for the treatment of a disease can also be included in the pharmaceutical pack or kit. The invention also provides a pharmaceutical pack or kit comprising one or more containers filled with one or more of the ingredients of the pharmaceutical compositions of the invention. Optionally associated with such container(s) can be a notice in the form prescribed by a governmental agency regulating the manufacture, use or sale of pharmaceuticals or biological products, which notice reflects approval by the agency of manufacture, use or sale for human administration.

**[00409]** The present invention provides kits that can be used in the above methods. A kit can comprise any of the PD-1-binding molecules of the present invention. The kit can further comprise one or more other prophylactic and/or therapeutic agents useful for the treatment of cancer, in one or more containers; and/or the kit can further comprise one or more cytotoxic antibodies that bind one or more cancer antigens associated with cancer. In certain embodiments, the other prophylactic or therapeutic agent is a chemotherapeutic. In other embodiments, the prophylactic or therapeutic agent is a biological or hormonal therapeutic.

### XIII. Methods of Administration

[00410] The compositions of the present invention may be provided for the treatment, prophylaxis, and amelioration of one or more symptoms associated with a disease, disorder or infection by administering to a subject an effective amount of a fusion protein or a conjugated molecule of the invention, or a pharmaceutical composition comprising a fusion protein or a conjugated molecule of the invention. In a preferred aspect, such compositions are substantially purified (*i.e.*, substantially free from substances that limit its effect or produce undesired side effects). In a specific embodiment, the subject is an animal, preferably a mammal such as non-primate (*e.g.*, bovine, equine, feline, canine, rodent, *etc.*) or a primate (*e.g.*, monkey such as, a cynomolgus monkey, human, *etc.*). In a preferred embodiment, the subject is a human.

[00411] Various delivery systems are known and can be used to administer the compositions of the invention, *e.g.*, encapsulation in liposomes, microparticles, microcapsules, recombinant cells capable of expressing the antibody or fusion protein, receptor-mediated endocytosis (See, *e.g.*, Wu *et al.* (1987) "Receptor-Mediated In Vitro Gene Transformation By A Soluble DNA Carrier System," J. Biol. Chem. 262:4429-4432), construction of a nucleic acid as part of a retroviral or other vector, *etc.*

[00412] Methods of administering a molecule of the invention include, but are not limited to, parenteral administration (*e.g.*, intradermal, intramuscular, intraperitoneal, intravenous and subcutaneous), epidural, and mucosal (*e.g.*, intranasal and oral routes). In a specific embodiment, the PD-1-binding molecules of the present invention are administered intramuscularly, intravenously, or subcutaneously. The compositions may be administered by any convenient route, for example, by infusion or bolus injection, by absorption through epithelial or mucocutaneous linings (*e.g.*, oral mucosa, rectal and intestinal mucosa, *etc.*) and may be administered together with other biologically active agents. Administration can be systemic or local. In addition, pulmonary administration can also be employed, *e.g.*, by use of an inhaler or nebulizer, and formulation with an aerosolizing agent. See, *e.g.*, U.S. Patent Nos. 6,019,968; 5,985,320; 5,985,309; 5,934,272; 5,874,064; 5,855,913; 5,290,540; and 4,880,078; and PCT Publication Nos. WO 92/19244; WO 97/32572; WO 97/44013; WO 98/31346; and WO 99/66903, each of which is incorporated herein by reference in its entirety.

[00413] The invention also provides that the PD-1-binding molecules of the present invention are packaged in a hermetically sealed container such as an ampoule or sachette

indicating the quantity of the molecule. In one embodiment, such molecules are supplied as a dry sterilized lyophilized powder or water free concentrate in a hermetically sealed container and can be reconstituted, *e.g.*, with water or saline to the appropriate concentration for administration to a subject. Preferably, the PD-1-binding molecules of the present invention are supplied as a dry sterile lyophilized powder in a hermetically sealed container.

[00414] The lyophilized PD-1-binding molecules of the present invention should be stored at between 2°C and 8°C in their original container and the molecules should be administered within 12 hours, preferably within 6 hours, within 5 hours, within 3 hours, or within 1 hour after being reconstituted. In an alternative embodiment, such molecules are supplied in liquid form in a hermetically sealed container indicating the quantity and concentration of the molecule, fusion protein, or conjugated molecule. Preferably, such PD-1-binding molecules when provided in liquid form are supplied in a hermetically sealed container.

[00415] The amount of the composition of the invention which will be effective in the treatment, prevention or amelioration of one or more symptoms associated with a disorder can be determined by standard clinical techniques. The precise dose to be employed in the formulation will also depend on the route of administration, and the seriousness of the condition, and should be decided according to the judgment of the practitioner and each patient's circumstances. Effective doses may be extrapolated from dose-response curves derived from in vitro or animal model test systems.

[00416] As used herein, an “**effective amount**” of a pharmaceutical composition, in one embodiment, is an amount sufficient to effect beneficial or desired results including, without limitation, clinical results such as decreasing symptoms resulting from the disease, attenuating a symptom of infection (*e.g.*, viral load, fever, pain, sepsis, *etc.*) or a symptom of cancer (*e.g.*, the proliferation, of cancer cells, tumor presence, tumor metastases, *etc.*), thereby increasing the quality of life of those suffering from the disease, decreasing the dose of other medications required to treat the disease, enhancing the effect of another medication such as via targeting and/or internalization, delaying the progression of the disease, and/ or prolonging survival of individuals.

[00417] An effective amount can be administered in one or more administrations. For purposes of this invention, an effective amount of drug, compound, or pharmaceutical composition is an amount sufficient to reduce the proliferation of (or the effect of) viral

presence and to reduce and /or delay the development of the viral disease, either directly or indirectly. In some embodiments, an effective amount of a drug, compound, or pharmaceutical composition may or may not be achieved in conjunction with another drug, compound, or pharmaceutical composition. Thus, an “effective amount” may be considered in the context of administering one or more chemotherapeutic agents, and a single agent may be considered to be given in an effective amount if, in conjunction with one or more other agents, a desirable result may be or is achieved. While individual needs vary, determination of optimal ranges of effective amounts of each component is within the skill of the art.

**[00418]** For the PD-1-binding molecules encompassed by the invention, the dosage administered to a patient is preferably determined based upon the body weight (kg) of the recipient subject. For the PD-1-binding molecules encompassed by the invention, the dosage administered to a patient is typically at least about 0.01 µg/kg, at least about 0.05 µg/kg, at least about 0.1 µg/kg, at least about 0.2 µg/kg, at least about 0.5 µg/kg, at least about 1 µg/kg, at least about 2 µg/kg, at least about 5 µg/kg, at least about 10 µg/kg, at least about 20 µg/kg, at least about 50 µg/kg, at least about 0.1 mg/kg, at least about 1 mg/kg, at least about 3 mg/kg, at least about 5 mg/kg, at least about 10 mg/kg, at least about 30 mg/kg, at least about 50 mg/kg, at least about 75 mg/kg, at least about 100 mg/kg, at least about 125 mg/kg, at least about 150 mg/kg or more of the subject's body weight.

**[00419]** The dosage and frequency of administration of a PD-1-binding molecule of the present invention may be reduced or altered by enhancing uptake and tissue penetration of the molecule by modifications such as, for example, lipidation.

**[00420]** The dosage of a PD-1-binding molecule of the invention administered to a patient may be calculated for use as a single agent therapy. Alternatively, the molecule may be used in combination with other therapeutic compositions and the dosage administered to a patient are lower than when said molecules are used as a single agent therapy.

**[00421]** The pharmaceutical compositions of the invention may be administered locally to the area in need of treatment; this may be achieved by, for example, and not by way of limitation, local infusion, by injection, or by means of an implant, said implant being of a porous, non-porous, or gelatinous material, including membranes, such as sialastic membranes, or fibers. Preferably, when administering a molecule of the invention, care must be taken to use materials to which the molecule does not absorb.

[00422] The compositions of the invention can be delivered in a vesicle, in particular a liposome (See Langer (1990) "New Methods Of Drug Delivery," Science 249:1527-1533); Treat *et al.*, in LIPOSOMES IN THE THERAPY OF INFECTIOUS DISEASE AND CANCER, Lopez-Berestein and Fidler (eds.), Liss, New York, pp. 353- 365 (1989); Lopez-Berestein, *ibid.*, pp. 3 17-327).

[00423] The compositions of the invention can be delivered in a controlled-release or sustained-release system. Any technique known to one of skill in the art can be used to produce sustained-release formulations comprising one or more of the PD-1-binding molecule(s) of the invention. See, e.g., U.S. Patent No. 4,526,938; PCT publication WO 91/05548; PCT publication WO 96/20698; Ning *et al.* (1996) "Intratumoral Radioimmunotherapy Of A Human Colon Cancer Xenograft Using A Sustained-Release Gel," Radiotherapy & Oncology 39:179-189, Song *et al.* (1995) "Antibody Mediated Lung Targeting Of Long-Circulating Emulsions," PDA Journal of Pharmaceutical Science & Technology 50:372-397; Cleek *et al.* (1997) "Biodegradable Polymeric Carriers For A bFGF Antibody For Cardiovascular Application," Pro. Int'l. Symp. Control. Rel. Bioact. Mater. 24:853-854; and Lam *et al.* (1997) "Microencapsulation Of Recombinant Humanized Monoclonal Antibody For Local Delivery," Proc. Int'l. Symp. Control Rel. Bioact. Mater. 24:759-760, each of which is incorporated herein by reference in its entirety. In one embodiment, a pump may be used in a controlled-release system (See Langer, *supra*; Sefton, (1987) "Implantable Pumps," CRC Crit. Rev. Biomed. Eng. 14:201-240; Buchwald *et al.* (1980) "Long-Term, Continuous Intravenous Heparin Administration By An Implantable Infusion Pump In Ambulatory Patients With Recurrent Venous Thrombosis," Surgery 88:507-516; and Saudek *et al.* (1989) "A Preliminary Trial Of The Programmable Implantable Medication System For Insulin Delivery," N. Engl. J. Med. 321:574-579). In another embodiment, polymeric materials can be used to achieve controlled-release of the molecules (see e.g., MEDICAL APPLICATIONS OF CONTROLLED RELEASE, Langer and Wise (eds.), CRC Pres., Boca Raton, Florida (1974); CONTROLLED DRUG BIOAVAILABILITY, DRUG PRODUCT DESIGN AND PERFORMANCE, Smolen and Ball (eds.), Wiley, New York (1984); Levy *et al.* (1985) "Inhibition Of Calcification Of Bioprosthetic Heart Valves By Local Controlled-Release Diphosphonate," Science 228:190-192; During *et al.* (1989) "Controlled Release Of Dopamine From A Polymeric Brain Implant: In Vivo Characterization," Ann. Neurol. 25:351-356; Howard *et al.* (1989) "Intracerebral Drug Delivery In Rats With Lesion-Induced Memory Deficits," J. Neurosurg. 7(1):105-112); U.S. Patent No. 5,679,377; U.S. Patent No. 5,916,597; U.S. Patent No. 5,912,015; U.S. Patent No.

5,989,463; U.S. Patent No. 5,128,326; PCT Publication No. WO 99/15154; and PCT Publication No. WO 99/20253). Examples of polymers used in sustained-release formulations include, but are not limited to, poly(2-hydroxy ethyl methacrylate), poly(methyl methacrylate), poly(acrylic acid), poly(ethylene-co-vinyl acetate), poly(methacrylic acid), polyglycolides (PLG), polyanhydrides, poly(N-vinyl pyrrolidone), poly(vinyl alcohol), polyacrylamide, poly(ethylene glycol), polylactides (PLA), poly(lactide-co-glycolides) (PLGA), and polyorthoesters. A controlled-release system can be placed in proximity of the therapeutic target (*e.g.*, the lungs), thus requiring only a fraction of the systemic dose (see, *e.g.*, Goodson, in MEDICAL APPLICATIONS OF CONTROLLED RELEASE, *supra*, vol. 2, pp. 115-138 (1984)). Polymeric compositions useful as controlled-release implants can be used according to Dunn *et al.* (See U.S. 5,945,155). This particular method is based upon the therapeutic effect of the in situ controlled-release of the bioactive material from the polymer system. The implantation can generally occur anywhere within the body of the patient in need of therapeutic treatment. A non-polymeric sustained delivery system can be used, whereby a non-polymeric implant in the body of the subject is used as a drug delivery system. Upon implantation in the body, the organic solvent of the implant will dissipate, disperse, or leach from the composition into surrounding tissue fluid, and the non-polymeric material will gradually coagulate or precipitate to form a solid, microporous matrix (See U.S. 5,888,533).

**[00424]** Controlled-release systems are discussed in the review by Langer (1990, “*New Methods Of Drug Delivery*,” Science 249:1527-1533). Any technique known to one of skill in the art can be used to produce sustained-release formulations comprising one or more therapeutic agents of the invention. See, *e.g.*, U.S. Patent No. 4,526,938; International Publication Nos. WO 91/05548 and WO 96/20698; Ning *et al.* (1996) “*Intratumoral Radioimmunotherapy Of A Human Colon Cancer Xenograft Using A Sustained-Release Gel*,” Radiotherapy & Oncology 39:179-189, Song *et al.* (1995) “*Antibody Mediated Lung Targeting Of Long-Circulating Emulsions*,” PDA Journal of Pharmaceutical Science & Technology 50:372-397; Cleek *et al.* (1997) “*Biodegradable Polymeric Carriers For A bFGF Antibody For Cardiovascular Application*,” Pro. Int’l. Symp. Control. Rel. Bioact. Mater. 24:853-854; and Lam *et al.* (1997) “*Microencapsulation Of Recombinant Humanized Monoclonal Antibody For Local Delivery*,” Proc. Int’l. Symp. Control Rel. Bioact. Mater. 24:759-760, each of which is incorporated herein by reference in its entirety.

[00425] Where the composition of the invention is a nucleic acid encoding a PD-1-binding molecule of the present invention, the nucleic acid can be administered *in vivo* to promote expression of its encoded PD-1-binding molecule by constructing it as part of an appropriate nucleic acid expression vector and administering it so that it becomes intracellular, *e.g.*, by use of a retroviral vector (See U.S. Patent No. 4,980,286), or by direct injection, or by use of microparticle bombardment (*e.g.*, a gene gun; Biolistic, Dupont), or coating with lipids or cell surface receptors or transfecting agents, or by administering it in linkage to a homeobox-like peptide which is known to enter the nucleus (See *e.g.*, Joliot *et al.* (1991) “*Antennapedia Homeobox Peptide Regulates Neural Morphogenesis*,” Proc. Natl. Acad. Sci. (U.S.A.) 88:1864-1868), *etc.* Alternatively, a nucleic acid can be introduced intracellularly and incorporated within host cell DNA for expression by homologous recombination.

[00426] Treatment of a subject with a therapeutically or prophylactically effective amount of a PD-1-binding molecule of the present invention can include a single treatment or, preferably, can include a series of treatments. In a preferred example, a subject is treated with such a diabody one time per week for between about 1 to 10 weeks, preferably between 2 to 8 weeks, more preferably between about 3 to 7 weeks, and even more preferably for about 4, 5, or 6 weeks. The pharmaceutical compositions of the invention can be administered once a day, twice a day, or three times a day. Alternatively, the pharmaceutical compositions can be administered once a week, twice a week, once every two weeks, once a month, once every six weeks, once every two months, twice a year or once per year. It will also be appreciated that the effective dosage of the molecules used for treatment may increase or decrease over the course of a particular treatment.

## Examples

[00427] The following examples illustrate various methods for compositions in the diagnostic or treatment methods of the invention. The examples are intended to illustrate, but in no way limit, the scope of the invention.

### Example 1 Characterization of Anti-Human PD-1 Monoclonal Antibodies

[00428] Fifteen murine monoclonal antibodies were isolated as being capable specifically binding to both human and cynomolgus monkey PD-1, and accorded the designations “PD-1 mAb 1,” “PD-1 mAb 2,” “PD-1 mAb 3,” “PD-1 mAb 4,” “PD-1 mAb 5,” “PD-1 mAb 6,” “PD-1 mAb 7,” “PD-1 mAb 8,” “PD-1 mAb 9,” “PD-1 mAb 10,” “PD-1 mAb 11,” “PD-1

**mAb 12,” “PD-1 mAb 13,” “PD-1 mAb 14,” and “PD-1 mAb 15.”** The CDRs of these antibodies were found to differ and are provided above. Binding to the extracellular domain of human and cynomolgus monkey PD-1 was evaluated as follows, flat bottom maxisorb 96-well plates were coated with soluble human or cynomolgus monkey PD-1 (the extracellular domain of human PD-1 fused to a His tag (shPD-1 His) or to a human Fc Region (shPD-1 hFc), or the extracellular domain of cynomolgus monkey PD-1 fused to a human Fc Region (scyno-PD1 Fc)) each at 0.5 or 1 µg/mL, the plates were washed and incubated with one of the isolated anti-PD-1 antibodies PD-1 mAb 1-15. For these studies the anti-PD-1 antibodies were utilized at 3, 1.0, 0.3333, 0.1111, 0.0370, 0.0123, or 0.0041 µg/mL (three fold serial dilutions). The amount of antibody binding to the immobilized PD-1 (human or cynomolgus monkey) was assessed using a goat anti-mouse IgG-HRP secondary antibody. All samples were analyzed on a plate reader (Victor 2 Wallac, Perkin Elmers). Representative binding curves for soluble human and soluble cynomolgus PD-1 are shown in **Figures 7A-7D** and **Figures 8A-8C**, respectively.

**[00429]** The results of these binding assays (**Figures 7A-7D** and **Figures 8A-8C**) show that all the anti-PD-1 antibodies PD-1 mAb 1-15 bind to both soluble human and soluble cynomolgus monkey PD-1.

**[00430]** In order to further characterize the murine anti-PD-1 antibodies their ability to block binding of soluble human PD-L1 to soluble human PD-1 was assessed in two different assays. In one assay the ability of the antibodies to block the binding of human PD-1 to PD-L1 immobilized on a surface was examined. For this assay each of the anti-PD-1 antibodies PD-1 mAb 1-15, or a reference anti-PD-1 antibody (PD-1 mAb A) was mixed with shPD-1 His fusion protein, (at 2.5 µg/mL) and was separately incubated with biotin labeled soluble human PD-L1 (the extracellular domain of PD-L1 fused to human Fc (sPD-L1)) at 1 µg/mL immobilized on a streptavidin coated plate. For these studies the anti-PD-1 antibodies were utilized at 10, 5.0, 2.5, 1.25, 0.625, 0.3125, or 0.1563 µg/mL (two fold serial dilutions). The amount of shPD-1 His binding to the immobilized sPD-L1 was assessed via the His-Tag using an anti-His-Tag-HRP secondary antibody. All samples were analyzed on a plate reader (Victor 2 Wallac, Perkin Elmers). The results of this experiment are shown in **Figures 9A-9D**.

**[00431]** The results of these inhibition assays (**Figures 9A-9D**) show that the anti-PD- antibodies PD-1 mAb 1, PD-1 mAb 3, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 8, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and

PD-1 mAb 15, were able to block the binding of soluble human PD-L1 to soluble human PD-1 to varying degrees while PD-1 mAb 2 and PD-1 mAb 4 exhibited little to no blocking activity in this assay format.

**[00432]** In the second assay the ability of the murine anti-PD-1 antibodies PD-1 mAb 1-15 to block binding of PD-1 ligand (*i.e.*, human PD-L1 or human PD-L2) to PD-1 expressed on the surface of NSO cells was examined. For this assay each of the anti-PD-1 antibodies PD-1 mAb 1-15, or a reference anti-PD-1 antibody (PD-1 mAb A or PD-1 mAb B) was separately mixed with a biotinylated-soluble human PD-L1 (shPD-L1 fusion protein) or biotinylated-soluble human PD-L2-muIgFc fusion protein (shPD-L2; Ancell Cat# 573-030), each at 0.1  $\mu\text{g}/\text{test}$ , and incubated with NSO cells expressing human PD-1 ( $\sim 250,000$  cells/well) in blocking buffer (FACS + 10% human serum albumin). For these studies the anti-PD-1 antibodies were utilized at 4.0, 1.0,  $2.5 \times 10^{-1}$ ,  $6.25 \times 10^{-2}$ ,  $1.56 \times 10^{-2}$ ,  $3.90 \times 10^{-3}$ ,  $9.76 \times 10^{-4}$ ,  $2.4 \times 10^{-4}$ ,  $0.6 \times 10^{-4}$   $\mu\text{g}/\text{test}$  (four fold serial dilutions). The amount of shPD-L1 (or shPD-L2) binding to the surface of the NSO cells was determined using a PE-conjugated Streptavidin secondary antibody by FACS analysis. The IC<sub>50</sub> values for inhibition of PD-1/PD-L1 binding were determined and the sample mean ( $\square$ ) of at least two experiments are provided (except where indicated) in **Table 6**.

| <b>Table 6</b>            |                                                               |                           |                                                               |
|---------------------------|---------------------------------------------------------------|---------------------------|---------------------------------------------------------------|
| <b>Anti-PD-1 Antibody</b> | <b>IC<sub>50</sub> (<math>\mu\text{g}/\text{test}</math>)</b> | <b>Anti-PD-1 Antibody</b> | <b>IC<sub>50</sub> (<math>\mu\text{g}/\text{test}</math>)</b> |
| PD-1 mAb A                | 0.0044                                                        | PD-1 mAb 8                | 0.6611 ‡                                                      |
| PD-1 mAb B                | 0.0064                                                        | PD-1 mAb 9                | 0.0154                                                        |
| PD-1 mAb 1                | 0.0048                                                        | PD-1 mAb 10               | 0.0057                                                        |
| PD-1 mAb 2                | 0.0110                                                        | PD-1 mAb 11               | 0.0259 ‡                                                      |
| PD-1 mAb 3                | 0.0361 ‡                                                      | PD-1 mAb 12               | 0.0238 ‡                                                      |
| PD-1 mAb 4                | 0.0156 ‡                                                      | PD-1 mAb 13               | 0.0117                                                        |
| PD-1 mAb 5                | 0.0039                                                        | PD-1 mAb 14               | 0.0149 ‡                                                      |
| PD-1 mAb 6                | 0.0051                                                        | PD-1 mAb 15               | 0.0060                                                        |
| PD-1 mAb 7                | 0.0024                                                        |                           |                                                               |

‡ Results from a single experiment

**[00433]** The results of the shPD-L1 inhibition assays (**Table 6**) show that the anti-PD-1 antibodies PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 11, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, and PD-1 mAb 15, were able to block the binding of human PD-L1 to human PD-1 expressed on the surface of NSO cells. In particular, PD-1 mAb 1, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 10, and PD-1 mAb 15 blocked shPD-L1 binding as well as or better than the reference PD-1 antibodies (PD-1 mAb A, PD-1 mAb B), while PD-1 mAb 8 was

essentially non-blocking in this assay format. Both PD-1 mAb 2 and PD-1 mAb 4 were able to block PD-1/PD-L1 binding in this assay format.

**[00434]** Similarly, the anti-PD-1 antibodies PD-1 mAb 1, PD-1 mAb 2, and PD-1 mAb 3, PD-1 mAb 4, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, PD-1 mAb 9, PD-1 mAb 10, PD-1 mAb 12, PD-1 mAb 13, PD-1 mAb 14, were able to block the binding of human PD-L2 to human PD-1 expressed on the surface of NSO cells, while PD-1 mAb 8 was essentially non-blocking in this assay format. In particular, PD-1 mAb 1, PD-1 mAb 5, PD-1 mAb 6, PD-1 mAb 7, and PD-1 mAb 10 blocked shPD-L2 binding as well as, or better than the reference PD-1 antibodies (PD-1 mAb A, PD-1 mAb B). The PD-1 antibodies PD-1 mAb 11 and PD-1 mAb 15 were not tested in this assay. The results for several humanized anti-PD-1 antibodies including hPD-1 mAb 15 are provided below.

### **Example 2** **Humanization and Further Characterization**

**[00435]** The Variable Domains of the anti-PD-1 antibodies PD-1 mAb 1, PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 were humanized, where antigenic epitopes were identified the antibodies were further deimmunized to generate the final humanized Variable Domains. Humanization of PD-1 mAb 1, PD-1 mAb 2, and PD-1 mAb 15 yielded one humanized VH Domain and one humanized VL Domain for each antibody designated herein as “**hPD-1 mAb 1 VH1**,” and “**hPD-1 mAb 1 VL1**,” “**hPD-1 mAb 2 VH1**,” and “**hPD-1 mAb 2 VL1**,” and “**hPD-1 mAb 15 VH1**,” and “**hPD-1 mAb 15 VL1**.” Humanization of PD-1 mAb 7 yielded two humanized VH Domains, designated herein as “**hPD-1 mAb 7 VH1**,” and “**hPD-1 mAb 7 VH2**,” and three humanized VL Domains designated herein as “**hPD-1 mAb 7 VL1**,” “**hPD-1 mAb 7 VL2**,” and “**hPD-1 mAb 7 VL3**.” Humanization of PD-1 mAb 9 yielded two humanized VH Domains, designated herein as “**hPD-1 mAb 9 VH1**,” and “**hPD-1 mAb 9 VH2**,” and two humanized VL Domains designated herein as “**hPD-1 mAb 9 VL1**,” and “**hPD-1 mAb 9 VL2**.” Where multiple humanized Variable Domains were generated the humanized heavy and light chain Variable Domains of a particular anti-PD-1 antibody (*e.g.*, PD-1 mAb 7) may be used in any combination and particular combinations of humanized chains are referred to by reference to the specific VH/VL Domains, for example a humanized antibody comprising hPD-1 mAb 7 VH1 and hPD-1 mAb 7 VL2 is specifically referred to as “**hPD-1 mAb 7(1.2)**.” Full length humanized antibodies were generated with either a human IgG1 constant region comprising the L234A/L235A substitutions (IgG1 (AA)) or a human IgG4 constant region comprising the S228P substitution (IgG4 (P)).

**[00436]** Full length IgG1 humanized antibody heavy chains were constructed as follows: the C-terminus of the humanized VH Domain was fused to the N-terminus of a human IgG1 Constant Region having a variant CH2-CH3 Domain (comprising the L234A/L235A (AA) substitutions) and lacking the C-terminal lysine residue (**SEQ ID NO:255**):

```
ASTKGPSVFP LAPSSKSTSG GTAALGCLVK DYFPEPVTVS WNSGALTSGV
HTFPAVLQSS GLYSLSSVVT VPSSSLGTQT YICNVNHKPS NTKVDKRVEP
KSCDKTHTCP PCPAPEAAGG PSVFLFPPKP KDTLMISRTPEVTCVVVDVDS
HEDPEVKFNW YVDGVEVHNA KTKPREEQYN STYRVVSVLT VLHQDWLNGK
EYKCKVSNKA LPAPIEKTIS KAKGQPREPQ VYTLPPSREE MTKNQVSLTCL
LVKGFYPSDI AVEWESNGQP ENNYKTTTPV LDSDGSFFLY SKLTVDKSRW
QQGNVFSCSV MHEALHNHYT QKSLSLSPG
```

**[00437]** In **SEQ ID NO:255**, amino acid residues 1-98 correspond to the IgG1 CH1 Domain (**SEQ ID NO: 10**), amino acid residues 99-113 correspond to the IgG1 hinge region (**SEQ ID NO: 32**) and amino acid residues 114-329 correspond to the IgG1 CH2-CH3 Domain comprising the L234A/L235A substitutions (underlined) (**SEQ ID NO:5**) but lacking the C-terminal lysine residue.

**[00438]** The amino acid sequence of a heavy chain of an exemplary humanized antibody ((hPD-1 mAb 7(1.2)) having an IgG1 heavy chain constant region comprising the L234A/L235A mutation and lacking the C-terminal lysine residue is (**SEQ ID NO:265**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV
IHPDSETWL DQKFKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREH
YGTSPFAYWG QGTLVTVSSA STKGPSVFPL APSSKSTSGG TAALGCLVKD
YFPEPVTVSW NSGALTSGVH TFP AVLQSSG LYSLSVVTV PSSSLGTQTY
ICNVNHKPSN TKVDKRVEPK SCDKTHTCPP CPAPEAAGGP SVFLFPPKPK
DTLMISRTPE VTCVVVDVSH EDPEVKFNWY VDGVEVHNAK TKPREEQYNS
TYRVVSVLTV LHQDWLNGKE YKCKVSNKAL PAPIEKTISK AKGQPREPQV
YTLPPSREEM TKNQVSLTCL VKGFYPSDIA VEWESNGQPE NNYKTTTPVL
DSDGSFFLYS KLTVDKSRWQ QGNVFSCSV MHEALHNHYT QKSLSLSPG
```

**[00439]** In **SEQ ID NO: 265**, amino acid residues 1-119 correspond to the VH Domain of hPD-1 mAb 7 VH1 (**SEQ ID NO: 147**), amino acid residues 120-217 correspond to the IgG1 CH1 Domain (**SEQ ID NO: 10**), residues 218-232 correspond to the IgG1 hinge region (**SEQ ID NO: 32**) and residues 233-448 correspond to the IgG1 CH2-CH3 Domain comprising the L234A/L235A substitutions (underlined) (**SEQ ID NO:5**) but lacking the C-terminal lysine residue.

**[00440]** Full length IgG4 humanized antibody heavy chains were constructed as follows: the C-terminus of the humanized VH Domain was fused to the N-terminus of a human IgG4 Constant Region having a stabilized hinge region (comprising the S228P substitution) and lacking the C-terminal lysine residue (**SEQ ID NO:256**):

```
ASTKGPSVFP LAPCSRSTSE STAALGCLVK DYFPEPVTVS WNSGALTSGV
HTFPAVLQSS GLYSLSSVVT VPSSSLGTKT YTCNVDPKPS NTKVDKRVES
KYGPPCPPCP APEFLGGPSV FLFPPKPKDT LMISRTPEVT CVVVDVSQED
PEVQFNWYVD GVEVHNAKTK PREEQFNSTY RVVSVLTVLH QDWLNGKEYK
CKVSNKGLPS SIEKTISKAK GQPREPQVYT LPPSQEEMTK NQVSLTCLVK
GFYPSDIAVE WESNGQPENN YKTPPVLDSD DGSFFLYSRL TVDKSRWQEG
NVFSCSVMEH ALHNHYTQKS LSLSLG
```

**[00441]** In **SEQ ID NO:256**, amino acid residues 1-98 correspond to the IgG4 CH1 Domain (**SEQ ID NO:254**), amino acid residues 99-110 correspond to the stabilized IgG4 hinge region comprising the S228P substitutions (underlined) (**SEQ ID NO: 13**) and amino acid residues 111-326 correspond to the IgG4 CH2-CH3 Domain (**SEQ ID NO:4**) but lacking the C-terminal lysine residue.

**[00442]** The amino acid sequence of a heavy chain of an exemplary humanized antibody ((hPD-1 mAb 7(1.2)) having an IgG4 heavy chain constant region comprising a stabilized hinge region having the S228P mutation and lacking the C-terminal lysine residue is (**SEQ ID NO:266**):

```
QVQLVQSGAE VKKPGASVKV SCKASGYSFT SYWMNWVRQA PGQGLEWIGV
IHPDSETWL DQKFVKDRVTI TVDKSTSTAY MELSSLRSED TAVYYCAREH
YGTSPFAYWG QGTLVTVSSA STKGPSVFPL APCSRSTSES TAALGCLVKD
YFPEPVTVSW NSGALTSGVH TFPQAVLQSSG LYSLSVSTV PSSLGTSKTY
TCNVDPKPSN TKVDKRVESK YGPPCPPCPA PEFLLGGPSVF LFPPKPKDTL
MISRTPEVTC VVVDVSQEDP EVQFNWYVDG VEVHNAKTKP REEQFNSTYR
VVSVLTVLHQ DWLNGKEYKC KVSNGKLPSS IEKTISKAKG QPREPQVYTL
PPSQEEMTKN QVSLTCLVKG FYPSDIAVEW ESNGQPENNY KTPPVLDSD
GSFFLYSRLT VDKSRWQEGN VFSCSVMEHA LHNHYTQKSL LSLSLG
```

**[00443]** In **SEQ ID NO:266**, amino acid residues 1-119 correspond to the VH Domain of hPD-1 mAb 7 VH1 (**SEQ ID NO:147**), amino acid residues 120-217 correspond to the IgG4 CH1 Domain (**SEQ ID NO:254**), amino acid residues 218-229 correspond to the stabilized IgG4 hinge region comprising the S228P substitutions (underlined) (**SEQ ID NO:13**) and amino acid residues 230-445 correspond to the IgG4 CH2-CH3 Domain (**SEQ ID NO:4**) but lacking the C-terminal lysine residue.

**[00444]** Full length humanized antibody light chains were constructed as follows: the C-terminus of the humanized VL Domain was fused to the N-terminus of a human light chain kappa region (**SEQ ID NO:8**). The same light chain is paired with the IgG1 (AA) and the IgG4 (P) heavy chains.

**[00445]** The amino acid sequence of a light chain of an exemplary humanized PD-1 antibody (hPD-1 mAb 7(1.2)) having a kappa constant region is (**SEQ ID NO:264**):

```
EIVLTQSPAT LSLSPGERAT LSCRASESVD NYGMSFMNWF QOKPGQPPKL
LIHAASNQGS GVPSRFGSG SGTDFTLTIS SLEPEDFAVY FCQQSKEVPY
TFGGGTKVEI KRTVAAPSVF IFPPSDEQLK SGTASVVCLL NNFYPREAKV
QWKVDNALQS GNSQESVTEQ DSKDSTYSLT STLTLKADY EKHKVYACEV
THQGLSSPVT KSFNRGEC
```

**[00446]** In **SEQ ID NO:264**, amino acid residues 1-111 correspond to the VL Domain of hPD-1 mAb 7 VL2 (**SEQ ID NO:151**), and amino acid residues 112-218 correspond to the light chain kappa constant region (**SEQ ID NO: 8**).

**[00447]** Anti-PD-1 antibodies having alternative Constant Regions, for example Engineered Fc Regions, are readily generated by incorporating different Constant Regions and/or by introducing one or more amino acid substitutions, additions or deletions. For example, where a bispecific antibody is desired knob-bearing and hole-bearing CH2-CH3 domains are used to facilitate heterodimerization. Chimeric anti-PD-1 antibodies comprising the murine Variable Domains and human Constant Regions are generated as described above.

**[00448]** The humanized antibodies (IgG1 (AA) and/or IgG4 (P)) were tested for binding and blocking activity as described in above. The binding to human PD-1 (shPD-1 His, and shPD-1 hFc) and cynomolgus monkey PD-1 (shPD-L1 hFc) of the humanized antibodies was comparable to that of the corresponding murine antibody. In addition, the humanized antibodies retained the ability to block the binding of human PD-L1 to human PD-1 in an ELISA assay.

**[00449]** The binding kinetics of the murine antibodies PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, PD-1 mAb 15, the humanized antibodies hPD-1 mAb 2, hPD-1 mAb 7(1.2), hPD-1 mAb 9(1.1), hPD-1 mAb 15, and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B was investigated using Biacore analysis. The anti-PD-1 antibodies were captured on immobilized Protein A and were incubated with His-tagged soluble human PD-1 (shPD-1-His) or soluble human cynomolgus monkey PD-1 Fc fusion (scyno PD-1 hFc) cleaved to remove

Fc portion, and the kinetics of binding was determined via Biacore analysis. In additional studies the anti-PD-1 antibodies hPD-1 mAb 7(1.2) IgG1 (AA), hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 9(1.1) IgG1 (AA), hPD-1 mAb 9(1.1) IgG4 (P), PD-1 mAb A IgG1 (AA), PD-1 mAb A IgG4 (P), PD-1 mAb B IgG1 (AA), and PD-1 mAb B IgG4 (P), were captured on immobilized F(ab)<sub>2</sub> goat anti-human Fc and the binding kinetics were determined by Biacore analysis as described above. The calculated  $k_a$ ,  $k_d$  and  $K_D$  from these studies are presented in **Table 7**.

| <b>Table 7</b>                                      |                                                    |                                                       |                              |                                                    |                                                       |                              |
|-----------------------------------------------------|----------------------------------------------------|-------------------------------------------------------|------------------------------|----------------------------------------------------|-------------------------------------------------------|------------------------------|
| <b>Protein A Capture</b>                            |                                                    |                                                       |                              |                                                    |                                                       |                              |
| <b>Anti-PD-1 Antibody</b>                           | <b>Human<sup>a</sup></b>                           |                                                       |                              | <b>Cynomolgus Monkey<sup>b</sup></b>               |                                                       |                              |
|                                                     | <b><math>k_a</math> (<math>\times 10^4</math>)</b> | <b><math>k_d</math> (<math>\times 10^{-4}</math>)</b> | <b><math>K_D</math> (nM)</b> | <b><math>k_a</math> (<math>\times 10^4</math>)</b> | <b><math>k_d</math> (<math>\times 10^{-4}</math>)</b> | <b><math>K_D</math> (nM)</b> |
| PD-1 mAb A                                          | 60                                                 | 18                                                    | 3                            | 14                                                 | 9.6                                                   | 6.9                          |
| PD-1 mAb B                                          | 140                                                | 35                                                    | 2.5                          | 37                                                 | 12                                                    | 3.2                          |
| PD-1 mAb 7                                          | 21                                                 | 2.8                                                   | 1.3                          | 17                                                 | 6                                                     | 3.5                          |
| hPD-1 mAb 7(1.2)                                    | 110                                                | 4.3                                                   | 0.39                         | 37                                                 | 6.4                                                   | 1.7                          |
| PD-1 mAb 9                                          | 4.3                                                | 4.2                                                   | 9.8                          | 2.2                                                | 16                                                    | 72.7                         |
| hPD-1 mAb 9(1.1)                                    | 1.8                                                | 6.5                                                   | 36.1                         | 1.5                                                | 11                                                    | 73.3                         |
| PD-1 mAb 15                                         | 4.5                                                | 1.3                                                   | 2.9                          | 2.7                                                | 11                                                    | 40.7                         |
| hPD-1 mAb 15                                        | 2.4                                                | 3.2                                                   | 13.3                         | 2.3                                                | 18                                                    | 78.3                         |
| PD-1 mAb 2                                          | 5.5                                                | 5.6                                                   | 10.2                         | 4.2                                                | 6.0                                                   | 14.3                         |
| hPD-1 mAb 2                                         | 3.2                                                | 1.6                                                   | 5.0                          | 2.3                                                | 3.9                                                   | 17                           |
| <b>F(ab)<sub>2</sub> goat anti-human Fc Capture</b> |                                                    |                                                       |                              |                                                    |                                                       |                              |
| PD-1 mAb A IgG1 (AA)                                | 13                                                 | 8.4                                                   | 6.5                          | 8.1                                                | 4.5                                                   | 5.6                          |
| PD-1 mAb A IgG4 (P)                                 | 13                                                 | 7.9                                                   | 6.1                          | 8.4                                                | 5.0                                                   | 6.0                          |
| PD-1 mAb B IgG1 (AA)                                | 25                                                 | 28                                                    | 11.2                         | 20                                                 | 6.4                                                   | 3.2                          |
| PD-1 mAb B IgG4 (P)                                 | 26                                                 | 25                                                    | 9.6                          | 20                                                 | 7.9                                                   | 4.0                          |
| hPD-1 mAb 7(1.2) IgG1 (AA)                          | 25                                                 | 3.8                                                   | 1.5                          | 16                                                 | 7.8                                                   | 4.9                          |
| hPD-1 mAb 7(1.2) IgG4 (P)                           | 27                                                 | 4.1                                                   | 1.5                          | 17                                                 | 7.8                                                   | 4.6                          |
| hPD-1 mAb 9(1.1) IgG1 (AA)                          | 5.6                                                | 6.1                                                   | 10.9                         | 5.6                                                | 5.2                                                   | 9.3                          |
| hPD-1 mAb 9(1.1) IgG4 (P)                           | 6.1                                                | 5.8                                                   | 9.5                          | 4.9                                                | 7.4                                                   | 15.1                         |

<sup>a</sup>His tagged soluble human PD-1 (shPD-1 His)

<sup>b</sup>soluble cynomolgus monkey PD-1 (scyno PD-1 hFc) cleaved

**[00450]** The results demonstrate that PD-1 mAb 7 and the humanized hPD-1 mAb 7(1.2) exhibit better binding kinetics relative to the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B. PD-1 mAb 2, and hPD-1 mAb 2 exhibit binding kinetics within about two fold of the reference anti-PD-1 antibodies while PD-1 mAb 9, hPD-1 mAb 9(1.1), PD-1 mAb 15, and hPD-1 mAb 15 exhibit binding kinetics within about 2-6 fold of the reference anti-PD-1 antibodies.

**[00451]** The tissue specificity of the anti-human PD-1 antibody PD-1 mAb 7 was investigated. Normal tissue was contacted with PD-1 mAb 7 or with an isotype control (0.313 µg/mL) and the extent of staining was visualized. Bloxall used for endogenous enzyme block to reduce non-specific mucin staining in the colon tissue. As shown in **Figure 10A, Panels i-xii**, PD-1 mAb 7 and the isotype control both failed to label cells of normal colon, liver, lung, pancreas, kidney and heart tissue. In addition, PD-1 mAb 7 and the isotype control failed to stain normal skin (**Figure 10B, Panels i-ii**). In contrast, PD-1 mAb 7 was found to strongly label lymphocytes present in normal tonsil tissue and PDCD1 transfected NSO cells expressing PD-1 (**Figure 10B, Panels iii and v**), while the isotype control failed to label either (**Figure 10B, Panels iv and vi**). The results presented in **Figures 10A-10B** thus indicate that PD-1 mAb 7 was capable of specifically binding to lymphocytes and cells expressing PD-1.

**[00452]** The binding saturation profiles of hPD-1 mAb 2 IgG1 (AA), hPD-1 mAb 7(1.1) IgG1 (AA), hPD-1 mAb 7(1.2) IgG1, (AA), hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 9(1.1) IgG1 (AA), hPD-1 mAb 9(1.1) IgG4 (P), hPD-1 mAb 15 IgG1 (AA), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B was examined. Briefly, each of the anti-PD-1 antibodies, PD-1 mAb 1-15, or the reference anti-PD-1 antibodies (PD-1 mAb A and PD-1 mAb B) was mixed with NSO cells expressing human PD-1 (~250,000 cells/well) in blocking buffer (FACS + 10% human serum albumin). For these studies the anti-PD-1 antibodies were utilized at 50, 12.5, 3.13,  $2.0 \times 10^{-1}$ ,  $4.9 \times 10^{-2}$ ,  $1.2 \times 10^{-2}$ ,  $3.0 \times 10^{-3}$ ,  $1.9 \times 10^{-4}$ ,  $7.6 \times 10^{-4}$ ,  $4.75 \times 10^{-5}$ , or  $1.19 \times 10^{-5}$  µg/test (four fold serial dilutions). The amount of antibody binding to the surface of the NSO cells was determined using goat anti-human-APC secondary antibody by FACS analysis. Representative saturation curves are shown in **Figure 11**. The EC<sub>50</sub> and EC<sub>90</sub> values were determined and the sample mean (SM) and standard deviation (SD σ) from four separate experiments are provided in **Table 8**.

| <b>Table 8</b>             |                           |             |                       |             |
|----------------------------|---------------------------|-------------|-----------------------|-------------|
|                            | <b>Saturation Binding</b> |             |                       |             |
|                            | <b>EC50 (μg/test)</b>     |             | <b>EC90 (μg/test)</b> |             |
| <b>Anti-PD-1 Antibody</b>  | <b>SM</b>                 | <b>SD σ</b> | <b>SM</b>             | <b>SD σ</b> |
| PD-1 mAb A IgG1 (AA)       | 0.1991                    | 0.1309      | 1.4528                | 0.8040      |
| PD-1 mAb A IgG4 (P)        | 0.1581                    | 0.1161      | 1.5464                | 1.7690      |
| PD-1 mAb B IgG1 (AA)       | 0.1347                    | 0.0681      | 1.3917                | 0.9573      |
| PD-1 mAb B IgG4 (P)        | 0.1398                    | 0.0951      | 1.1619                | 1.2681      |
| hPD-1 mAb 2 IgG1 (AA)      | 0.4431                    | 0.1997      | 2.4374                | 1.2637      |
| hPD-1 mAb 7(1.1) IgG1 (AA) | 0.1069                    | 0.0500      | 0.9102                | 0.5476      |
| hPD-1 mAb 7(1.2) IgG1 (AA) | 0.1872                    | 0.1553      | 0.6810                | 0.3226      |
| hPD-1 mAb 7(1.2) IgG4 (P)  | 0.1376                    | 0.0926      | 0.6609                | 0.3437      |
| hPD-1 mAb 9(1.1) IgG1 (AA) | 0.3123                    | 0.2291      | 1.6486                | 0.9117      |
| hPD-1 mAb 9(1.1) IgG4 (P)  | 0.5128                    | 0.2228      | 3.0563                | 0.9437      |
| hPD-1 mAb 15 IgG1 (AA)     | 0.2927                    | 0.1333      | 2.0640                | 0.6096      |

**[00453]** The binding saturation studies demonstrate that the humanized versions of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 have favorable profile for binding to cell surface PD-1. In particular, humanized PD-1 mAb 7 (hPD-1 mAb 7(1.1), and hPD-1 mAb 7(1.2) having either an IgG1 (AA) or an IgG4 (P) Fc Region) have the lowest EC90 values of all the antibodies examined.

**[00454]** In order to further characterize the humanized anti-PD-1 antibodies hPD-1 mAb 2 IgG1 (AA), hPD-1 mAb 7(1.1) IgG1 (AA), hPD-1 mAb 7(1.2) IgG1, (AA), hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 9(1.1) IgG1 (AA), hPD-1 mAb 9(1.1) IgG4 (P), and hPD-1 mAb 15 IgG1 (AA), their ability to block binding of human PD-L1 (shPD-L1) and human PD-L2 (shPD-L2) to PD-1 expressed on the surface of NSO cells was examined. These assays were performed essentially as described above. Representative curves for inhibition of sPD-L1 and sPD-L2 binding to PD-1 expressed on NSO cells are shown in **Figures 12A** and **12B**, respectively. The IC50 and IC90 values were determined and the sample mean (SM) and standard deviation (SD σ) from three separate experiments are provided in **Table 9**.

| Table 9                    |                |        |                |        |                |        |                |        |
|----------------------------|----------------|--------|----------------|--------|----------------|--------|----------------|--------|
|                            | sPD-L1         |        |                |        | sPD-L2         |        |                |        |
|                            | IC50 (μg/test) |        | IC90 (μg/test) |        | IC50 (μg/test) |        | IC90 (μg/test) |        |
| Anti-PD-1 Antibody         | SM             | SD σ   | SM             | SD σ   | SM             | SD σ   | SM             | SD σ   |
| PD-1 mAb A IgG1 (AA)       | 0.0203         | 0.0089 | 0.2985         | 0.3279 | 0.0414         | 0.0124 | 0.1601         | 0.066  |
| PD-1 mAb A IgG4 (P)        | 0.0156         | 0.0096 | 0.0776         | 0.0208 | 0.0280         | 0.0070 | 0.1594         | 0.1153 |
| PD-1 mAb B IgG1 (AA)       | 0.0148         | 0.0008 | 0.1034         | 0.0100 | 0.0280         | 0.0059 | 0.1190         | 0.060  |
| PD-1 mAb B IgG4 (P)        | 0.0143         | 0.0013 | 0.0798         | 0.0239 | 0.0280         | 0.0055 | 0.0924         | 0.0065 |
| hPD-1 mAb 2 IgG1 (AA)      | 0.0578         | 0.0124 | 0.2480         | 0.050  | 0.1294         | 0.0143 | 0.3813         | 0.0656 |
| hPD-1 mAb 7(1.1) IgG1 (AA) | 0.0166         | 0.0032 | 0.0674         | 0.0041 | 0.0283         | 0.0147 | 0.0886         | 0.0166 |
| hPD-1 mAb 7(1.2) IgG1 (AA) | 0.0118         | 0.0027 | 0.0678         | 0.0031 | 0.0212         | 0.0031 | 0.0672         | 0.0043 |
| hPD-1 mAb 7(1.2) IgG4 (P)  | 0.0103         | 0.0023 | 0.0520         | 0.0033 | 0.0213         | 0.0019 | 0.0616         | 0.0063 |
| hPD-1 mAb 9(1.1) IgG1 (AA) | 0.0593         | 0.0036 | 0.3238         | 0.0508 | 0.4002         | 0.5000 | 0.4573         | 0.1805 |
| hPD-1 mAb 9(1.1) IgG4 (P)  | 0.0460         | 0.0118 | 0.2461         | 0.0513 | 0.1105         | 0.0146 | 0.2914         | 0.0526 |
| hPD-1 mAb 15 IgG1 (AA)     | 0.0440         | 0.0092 | 0.2068         | 0.035  | 0.0945         | 0.0022 | 0.3093         | 0.0588 |

[00455] The ligand binding inhibition studies demonstrate that the humanized versions of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 are able to inhibit the binding of sPD-L1 and sPD-L2 to PD-1 on the cell surface. In particular, humanized PD-1 mAb 7 (hPD-1 mAb 7(1.1), and hPD-1 mAb 7(1.2)) have the lowest IC90 values of all the antibodies examined.

### Example 3

#### Blockade of the PD-1/PD-L1 Checkpoint by Humanized Anti-Human PD-1 Antibodies

[00456] The ability of hPD-1 mAb 2 IgG1 (AA), hPD-1 mAb 7(1.1) IgG1 (AA), hPD-1 mAb 7(1.2) IgG1, (AA), hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 9(1.1) IgG1 (AA), hPD-1 mAb 9(1.1) IgG4 (P), hPD-1 mAb 15 IgG1 (AA), and the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B to antagonize the PD-1/PD-L1 axis (*i.e.*, block the PD-1/PD-L1 interaction and prevent down-regulation of T-cell responses) was examined in a Jurkat-luc-NFAT / CHO-PD-L1 luciferase reporter assay. Briefly, CHO cells expressing PD-L1 (CHO/PD-L1) were plated at 40,000/well in 100 μL of culture medium (RPMI + 10% FBS + 100 μg/mL

Hygromycine B + 100 µg/mL G418) and incubated overnight. The next day the media was removed and MNFAT-luc2/PD-1 Jurkat cells (Promega) at 50,000 cells/well in 40 µL in assay buffer (RPMI + 2% FBS), and the anti-PD-1 antibodies PD-1 mAb 1-15, or a reference anti-PD-1 antibodies (PD-1 mAb A and PD-1 mAb B) (0-25 µg/mL; eight 2.5 fold serial dilutions in assay buffer) were added to each well and incubated for 6 hours at 37°C followed by a 5-10 minutes incubated at ambient temperature. 80 µL of BioGlo Substrate (Promega) was then added to each well and the plate was incubated for an additional 5-10 minutes at ambient temperature, the luminescence was measured in a Victor Plate Reader. Representative saturation curves are shown in **Figure 13**. The EC50 and EC90 values were determined and the sample mean (SM) and standard deviation (SD  $\sigma$ ) from four separate experiments are provided in **Table 10**.

| <b>Table 10</b>            |                           |                               |                       |                               |
|----------------------------|---------------------------|-------------------------------|-----------------------|-------------------------------|
| <b>Anti-PD-1 Antibody</b>  | <b>Reporter Signaling</b> |                               |                       |                               |
|                            | <b>EC50 (µg/test)</b>     |                               | <b>EC90 (µg/test)</b> |                               |
|                            | <b>SM</b>                 | <b>SD <math>\sigma</math></b> | <b>SM</b>             | <b>SD <math>\sigma</math></b> |
| PD-1 mAb A IgG1 (AA)       | 0.2549                    | 0.0480                        | 2.4474                | 1.2228                        |
| PD-1 mAb A IgG4 (P)        | 0.2049                    | 0.0719                        | 2.5535                | 1.2139                        |
| PD-1 mAb B IgG1 (AA)       | 0.2119                    | 0.1781                        | 2.2036                | 2.0118                        |
| PD-1 mAb B IgG4 (P)        | 0.1142                    | 0.0323                        | 0.9418                | 0.2863                        |
| hPD-1 mAb 2 IgG1 (AA)      | 0.3539                    | 0.0983                        | 3.8975                | 2.0054                        |
| hPD-1 mAb 7(1.1) IgG1 (AA) | 0.1080                    | 0.0386                        | 1.1992                | 0.5103                        |
| hPD-1 mAb 7(1.2) IgG1 (AA) | 0.0944                    | 0.0153                        | 0.6452                | 0.2615                        |
| hPD-1 mAb 7(1.2) IgG4 (P)  | 0.0965                    | 0.0169                        | 0.6885                | .01858                        |
| hPD-1 mAb 9 IgG1 (AA)      | 0.2835                    | 0.0530                        | 2.9968                | 0.8866                        |
| hPD-1 mAb 9 IgG4 (P)       | 0.3154                    | 0.0872                        | 5.0940                | 4.0496                        |
| hPD-1 mAb 15 IgG1 (AA)     | 0.2585                    | 0.0592                        | 3.3138                | 1.0532                        |

**[00457]** The reporter signaling studies demonstrate that the humanized versions of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 can block the PD-1/PD-L1 axis and will prevent down-regulation of T-cell responses. In particular, humanized PD-1 mAb 7 (hPD-1 mAb 7(1.1), and hPD-1 mAb 7(1.2) having either an IgG1 (AA) or an IgG4 (P) Fc Region) have the lowest EC50/EC90 values.

#### **Example 4**

##### **Functional Activity of Anti-Human PD-1 Antibodies**

**[00458]** *Staphylococcus aureus* enterotoxin type B (SEB) is a microbial superantigen capable of activating a large proportion of T-cells (5-30%) in SEB-responsive donors. SEB binds to MHC II outside the peptide binding groove and thus is MHC II dependent, but unrestricted and TCR mediated. SEB-stimulation of T-cells results in oligoclonal T-cell proliferation and cytokine production (although donor variability may be observed and some donors will not respond). Within 48 hours of SEB-stimulation PMBCs upregulate PD-1 and LAG-3 with a further enhancement seen at day 5, post-secondary culture in 96-well plate with SEB-stimulation. Upregulation of the immune check point proteins PD-1 and LAG-3 following SEB-stimulation of PBMCs limits cytokine release upon restimulation. The ability of anti-PD-1 antibodies alone and in combination with anti-LAG-3 antibodies to enhance cytokine release through checkpoint inhibition was examined.

**[00459]** Briefly, PBMCs were purified using the Ficoll-Paque Plus (GE Healthcare) density gradient centrifugation method according to manufacturer's instructions from whole blood obtained under informed consent from healthy donors (Biological Specialty Corporation) and T cells were then purified using the Dynabeads® Untouched Human T Cells Kit (Life Technologies) according to manufacturer's instructions. Purified PBMCs were cultured in RPMI-media + 10% heat inactivated FBS + 1% Penicillin/Streptomycin in T-25 bulk flasks for 2-3 days alone or with SEB (Sigma-Aldrich) at 0.1 ng/mL (primary stimulation). At the end of the first round of SEB-stimulation, PBMCs were washed twice with PBS and immediately plated in 96-well tissue culture plates at a concentration of  $1-5 \times 10^5$  cells/well in media alone, media with a control or an anti-PD-1 antibody, media with SEB at 0.1 ng/mL (secondary stimulation) and no antibody, or media with SEB and a control IgG or an anti-PD-1 antibody +/- an anti-LAG-3 mAb, and cultured for an additional 2-3 days. At the end of the second stimulation, supernatants were harvested to measure cytokine secretion using human DuoSet ELISA Kits for IFN $\gamma$ , TNF $\alpha$ , IL-10, and IL-4 (R&D Systems) according to the manufacturer's instructions.

**[00460]** The ability of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 alone, or in combination with the unique anti-LAG-3 antibody LAG-3 mAb 1 to enhance cytokine release through checkpoint inhibition was examined. These studies also included one or more of the following reference anti-PD-1 antibodies: PD-1 mAb A; PD-1 mAb B; and LAG-3 mAb

A, alone or in combination. **Figure 14** shows the IFN $\gamma$  secretion profiles from SEB-stimulated (0.1 ng/mL) PBMCs from a representative responding donor (D:38941), treated with: no antibody; isotype control antibody; PD-1 mAb 7 and/or LAG-3 mAb 7; PD-1 mAb 9 and/or LAG-3 mAb 1; PD-1 mAb 15 and/or LAG-3 mAb 1; PD-1 mAb 2 and/or LAG-3 mAb 1; or the reference anti-PD-1 antibodies PD-1 mAb B and/or LAG-3 mAb A (antibodies were used at 10  $\mu$ g/mL).

**[00461]** In additional studies the ability of the humanized versions of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 (comprising a human IgG1 (AA) or a human IgG4 (P) Fc Region) as well as the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B to enhance cytokine release through checkpoint inhibition was examined. For these studies the antibodies were utilized at 0.625, 2.5, and 10  $\mu$ g/mL. **Figures 15A-15B** shows the IFN $\gamma$  (**Figure 15A**) and TNF $\alpha$  (**Figure 15B**), secretion profiles from SEB-stimulated (0.2 ng/mL) PBMCs from a representative responding donor (D:57709), treated with no antibody or one of the following antibodies: isotype control; hPD-1 mAb 2 IgG1 (AA); hPD-1 mAb 7(1.2) IgG1 (AA); hPD-1 mAb 7(1.2) IgG4 (P); hPD-1 mAb 9(1.1) IgG1 (AA); hPD-1 mAb 9(1.1) IgG4 (P); hPD-1 mAb 15 IgG1 (AA); or the reference anti-PD-1 antibodies PD-1 mAb A IgG1 (AA), PD-1 mAb A IgG4 (P), PD-1 mAb B IgG1 (AA), PD-1 mAb B IgG4 (P). The total pg/mg of IFN $\gamma$  in samples treated with SEB+Ab were determined for the samples treated with the anti-PD-1 antibodies at 0.625, 2.5 and 10  $\mu$ g/mL and the sample mean (SM) and standard deviation (SD  $\sigma$ ) from 3 different responding donors (except where noted) are provided in **Table 11**. The ratio of IFN $\gamma$  secreted in sample treated with the humanized versions of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 (comprising a human IgG1 (AA) or a human IgG4 (P) Fc Region) over the reference anti-PD-1 antibodies PD-1 mAb A and PD-1 mAb B (*i.e.*, humanized anti-PD-1/PD-1 mAb A, and humanized anti-PD-1/PD-1 mAb B) is presented in **Table 12** and **Table 13**, respectively.

| <b>Table 11</b>                               |                                                 |                               |                |                               |               |                               |
|-----------------------------------------------|-------------------------------------------------|-------------------------------|----------------|-------------------------------|---------------|-------------------------------|
|                                               | <b>IFN<math>\gamma</math> Secretion (pg/mL)</b> |                               |                |                               |               |                               |
| <b><math>\mu</math>g/mL anti-PD1 antibody</b> | 0.625 $\mu$ g/mL                                |                               | 2.5 $\mu$ g/mL |                               | 10 $\mu$ g/mL |                               |
| <b>anti-PD-1 Antibody</b>                     | <b>SM</b>                                       | <b>SD <math>\sigma</math></b> | <b>SM</b>      | <b>SD <math>\sigma</math></b> | <b>SM</b>     | <b>SD <math>\sigma</math></b> |
| PD-1 mAb A IgG1 (AA)                          | 221.18                                          | 110.89                        | 341.13         | 247.93                        | 347.46        | 144.72                        |
| PD-1 mAb A IgG4 (P)                           | 281.36                                          | 132.65                        | 495.15         | 190.57                        | 399.41        | 117.56                        |
| PD-1 mAb B IgG1 (AA)                          | 366.69                                          | 196.64                        | 387.682        | 215.51                        | 387.32        | 282.81                        |
| PD-1 mAb B IgG4 (P)                           | 348.40                                          | 185.96                        | 433.382        | 163.23                        | 551.68        | 125.08                        |
| hPD-1 mAb 7(1.2) IgG1 (AA)                    | 302.05                                          | 185.71                        | 610.70         | 209.77                        | 414.63        | 272.65                        |
| hPD-1 mAb 7(1.2) IgG4 (P)                     | 384.57‡                                         | 323.79‡                       | 411.40         | 398.59                        | 370.06        | 108.12                        |
| hPD-1 mAb 9(1.1) IgG1 (AA)                    | 340.81                                          | 207.76                        | 442.598        | 303.70                        | 655.29        | 567.91                        |
| hPD-1 mAb 9(1.1) IgG4 (P)                     | 309.82                                          | 130.30                        | 468.62         | 350.15                        | 424.35        | 288.95                        |
| hPD-1 mAb 15 IgG1 (AA)                        | 360.00                                          | 274.28                        | 373.32         | 160.25                        | 541.83        | 444.22                        |
| hPD-1 mAb 2 IgG1 (AA)                         | 275.88                                          | 135.23                        | 372.73         | 53.53                         | 496.70        | 235.37                        |
| Control IgG                                   | 137.14                                          | 76.61                         | 100.65         | 48.67                         | 138.10        | 120.81                        |
| No Antibody                                   | 120.05                                          | 73.90                         | 120.05         | 73.90                         | 109.46        | 85.18                         |

‡ Results from two responding donors

| <b>Table 12</b>                               |                                                                          |                               |                |                               |               |                               |
|-----------------------------------------------|--------------------------------------------------------------------------|-------------------------------|----------------|-------------------------------|---------------|-------------------------------|
|                                               | <b>Ratio IFN<math>\gamma</math> Secretion (New Anti-PD-1/PD-1 mAb A)</b> |                               |                |                               |               |                               |
| <b><math>\mu</math>g/mL anti-PD1 antibody</b> | 0.625 $\mu$ g/mL                                                         |                               | 2.5 $\mu$ g/mL |                               | 10 $\mu$ g/mL |                               |
| <b>anti-PD-1 Antibody</b>                     | <b>SM</b>                                                                | <b>SD <math>\sigma</math></b> | <b>SM</b>      | <b>SD <math>\sigma</math></b> | <b>SM</b>     | <b>SD <math>\sigma</math></b> |
| PD-1 mAb A IgG1 (AA)                          | 1.00                                                                     | 0.00                          | 1.00           | 0.00                          | 1.00          | 0.00                          |
| PD-1 mAb A IgG4 (P)                           | 1.00                                                                     | 0.00                          | 1.00           | 0.00                          | 1.00          | 0.00                          |
| PD-1 mAb B IgG1 (AA)                          | 1.77                                                                     | 0.92                          | 1.28           | 0.36                          | 1.07          | 0.42                          |
| PD-1 mAb B IgG4 (P)                           | 1.23                                                                     | 0.16                          | 0.92           | 0.27                          | 1.40          | 0.12                          |
| hPD-1 mAb 7(1.2) IgG1 (AA)                    | 1.36                                                                     | 0.37                          | 2.46           | 1.85                          | 1.17          | 0.41                          |
| hPD-1 mAb 7(1.2) IgG4 (P)                     | 1.20‡                                                                    | 0.35‡                         | 0.79           | 0.54                          | 0.95          | 0.22                          |
| hPD-1 mAb 9(1.1) IgG1 (AA)                    | 1.48                                                                     | 0.19                          | 1.46           | 0.71                          | 1.70          | 0.84                          |
| hPD-1 mAb 9(1.1) IgG4 (P)                     | 1.13                                                                     | 0.13                          | 0.91           | 0.42                          | 1.02          | 0.46                          |
| hPD-1 mAb 15 IgG1 (AA)                        | 1.50                                                                     | 0.39                          | 1.51           | 1.23                          | 1.48          | 0.71                          |
| hPD-1 mAb 2 IgG1 (AA)                         | 1.32                                                                     | 0.53                          | 1.48           | 0.86                          | 1.42          | 0.12                          |
| Control IgG                                   | 0.63                                                                     | 0.2                           | 0.33           | 0.08                          | 0.39          | 0.24                          |
| No Antibody                                   | 0.54                                                                     | 0.12                          | 0.39           | 0.14                          | 0.31          | 0.17                          |

‡ Results from two responding donors

| <b>Table 13</b>                               |                                                                          |                               |                |                               |               |                               |
|-----------------------------------------------|--------------------------------------------------------------------------|-------------------------------|----------------|-------------------------------|---------------|-------------------------------|
|                                               | <b>Ratio IFN<math>\gamma</math> Secretion (New Anti-PD-1/PD-1 mAb B)</b> |                               |                |                               |               |                               |
| <b><math>\mu</math>g/mL anti-PD1 antibody</b> | 0.625 $\mu$ g/mL                                                         |                               | 2.5 $\mu$ g/mL |                               | 10 $\mu$ g/mL |                               |
| <b>anti-PD-1 Antibody</b>                     | <b>SM</b>                                                                | <b>SD <math>\sigma</math></b> | <b>SM</b>      | <b>SD <math>\sigma</math></b> | <b>SM</b>     | <b>SD <math>\sigma</math></b> |
| PD-1 mAb A IgG1 (AA)                          | 0.37                                                                     | 0.37                          | 0.82           | 0.20                          | 1.06          | 0.48                          |
| PD-1 mAb A IgG4 (P)                           | 0.82                                                                     | 0.12                          | 1.16           | 0.38                          | 0.72          | 0.07                          |
| PD-1 mAb B IgG1 (AA)                          | 1.0                                                                      | 0.00                          | 1.0            | 0.00                          | 1.0           | 0.00                          |
| PD-1 mAb B IgG4 (P)                           | 1.0                                                                      | 0.00                          | 1.0            | 0.00                          | 1.0           | 0.00                          |
| hPD-1 mAb 7(1.2) IgG1 (AA)                    | 0.84                                                                     | 0.22                          | 1.77           | 0.81                          | 1.11          | 0.07                          |
| hPD-1 mAb 7(1.2) IgG4 (P)                     | 0.91 $\ddagger$                                                          | 0.26 $\ddagger$               | 0.83           | 0.50                          | 0.68          | 0.17                          |
| hPD-1 mAb 9(1.1) IgG1 (AA)                    | 1.04                                                                     | 0.59                          | 1.12           | 0.29                          | 1.60          | 0.42                          |
| hPD-1 mAb 9(1.1) IgG4 (P)                     | 0.92                                                                     | 0.09                          | 0.99           | 0.36                          | 0.75          | 0.39                          |
| hPD-1 mAb 15 IgG1 (AA)                        | 1.01                                                                     | 0.48                          | 1.07           | 0.57                          | 1.34          | 0.15                          |
| hPD-1 mAb 2 IgG1 (AA)                         | 0.78                                                                     | 0.12                          | 1.10           | 0.38                          | 1.46          | 0.53                          |
| Control IgG                                   | 0.39                                                                     | 0.08                          | 0.27           | 0.08                          | 0.34          | 0.13                          |
| No Antibody                                   | 0.34                                                                     | 0.11                          | 0.31           | 0.03                          | 0.28          | 0.08                          |

$\ddagger$  Results from two responding donors

**[00462]** The results of these studies demonstrate that the PD-1 antibodies PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, and PD-1 mAb 15 dramatically enhanced IFN $\gamma$  (**Figures 14** and **15A**, and **Tables 11-13**), and TNF $\alpha$  (**Figure 15B**) production from SEB-stimulated PBMCs upon restimulation. In addition, the combination of anti-PD-1 antibodies with anti-LAG-3 antibodies resulted in a further enhancement of cytokine release (**Figure 14**) from SEB-stimulated PBMCs upon restimulation. In particular, the combination of PD-1 mAb 2, PD-1 mAb 7, PD-1 mAb 9, or PD-1 mAb 15 with the unique anti-LAG-3 antibody LAG-3 mAb 1 provided the largest enhancement.

#### **Example 5** **PD-1 x LAG-3 Bispecific Molecules Binding Studies**

**[00463]** A number of PD-1 x LAG-3 bispecific molecules were generated, including Fc Region-containing diabodies comprising three, four, and five chains and a bispecific antibody. Four diabodies having four chains and comprising E/K-coil Heterodimer-Promoting Domains were generated and accorded the designations “**DART A**,” “**DART B**,” “**DART C**,” and “**DART I**.” Four diabodies having four chains and comprising CH1/CL Domains were generated and accorded the designations “**DART D**,” “**DART E**,” “**DART J**,” and “**DART 1**.” Two diabodies having five chains and comprising E/K-coil Heterodimer-Promoting Domains and CH1/CL Domains were generated and accorded the designations “**DART F**,” and “**DART G**.” One diabody having three chains and comprising E/K-coil Heterodimer-Promoting Domains was generated and accorded the designation “**DART H**.” One bispecific antibody having four chains was generated and accorded the designation “**BSAB A**.” The

structure and amino acid sequences of these PD-1 x LAG-3 bispecific molecules are provided above and are summarized in **Table 14** below.

| <b>Table 14</b> |                                       |                       |               |                                                                                                |                                            |
|-----------------|---------------------------------------|-----------------------|---------------|------------------------------------------------------------------------------------------------|--------------------------------------------|
| <b>Name</b>     | <b>Parental mAbs</b>                  | <b>Fc<sup>‡</sup></b> | <b>Chains</b> | <b>SEQ ID NOs:</b>                                                                             | <b>Other Components</b>                    |
| DART A          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG4<br>(YTE)         | 4             | 267 (X <sub>1</sub> =A;<br>X <sub>2</sub> =Y; X <sub>3</sub> =T;<br>X <sub>4</sub> =E) and 268 | E/K-Coils; see<br>Figure 3B                |
| DART B          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.3) | IgG4<br>(YTE)         | 4             | 267 (X <sub>1</sub> =G;<br>X <sub>2</sub> =Y; X <sub>3</sub> =T;<br>X <sub>4</sub> =E) and 268 | E/K-Coils; see<br>Figure 3B                |
| DART C          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.3) | IgG4                  | 4             | 267 (X <sub>1</sub> =G;<br>X <sub>2</sub> =M; X <sub>3</sub> =S;<br>X <sub>4</sub> =T) and 268 | E/K-Coils; see<br>Figure 3B                |
| DART D          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG4<br>(YTE)         | 4             | 269 and 270                                                                                    | CL/CH1; see<br>Figure 3C                   |
| DART E          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG4<br>(YTE)         | 4             | 271 and 272                                                                                    | CL/CH1; see<br>Figure 3C                   |
| DART F          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG1<br>(AA/<br>YTE)  | 5             | 273, 274, 275,<br>and 276                                                                      | CL/CH1 and E/K-<br>Coils; see Figure<br>5  |
| DART G          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG1<br>(AA/<br>YTE)  | 5             | 277, 278, 279,<br>and 280                                                                      | CL/CH1 and E/K-<br>Coils; see Figure<br>5  |
| DART H          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG1<br>(AA)          | 3             | 281, 282, and<br>283                                                                           | E/K Coils; See<br>Figure 4A                |
| DART I          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 6(1.1) | IgG4<br>(YTE)         | 4             | 290 and 291                                                                                    | E/K-Coils; see<br>Figure 3B                |
| DART J          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 6(1.1) | IgG4<br>(YTE)         | 4             | 292 and 293                                                                                    | CL/CH1; see<br>Figure 3C                   |
| DART 1          | PD-1 mAb A<br>LAG-3 mAb A             | IgG1<br>(AA)          | 4             | 284 and 285                                                                                    | CL/CH1; see<br>Figure 3C                   |
| BSAB A          | hPD-1 mAb 7(1.2)<br>hLAG-3 mAb 1(1.4) | IgG1<br>(AA)          | 4             | 286, 287, 288,<br>and 289                                                                      | mAb with charge<br>engineered Fc<br>Region |

‡ Molecules incorporating IgG4 Fc regions also incorporate a stabilized IgG4 hinge region.

**[00464]** Additional PD-1 x LAG-3 bispecific molecules comprising alternative PD-1 and/or LAG-3 epitope-binding sites may be readily generated by incorporating different VH and VL Domains. Similarly, molecules binding an antigen other than LAG-3 may be generated by incorporating the VH and VL having the desired specificity.

**[00465]** The binding saturation profiles of the PD-1 x LAG-3 bispecific diabody constructs: DART A, DART B, DART D, DART E, DART F, DART G, DART H, DART I, and DART

1; the anti-PD-1 antibodies: hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 7(1.2) IgG1 (AA), PD-1 mAb A IgG1 (AA) and PD-1 mAb A IgG4 (P); and the anti-LAG-3 antibodies: hLAG-3 mAb 1(1.4) IgG4 (P), LAG-3 mAb A IgG4 (P), hLAG-3 mAb 1(1.4) IgG1 (AA), and LAG-3 mAb A IgG1 (AA) were examined essentially as described above. The PD-1 x LAG-3 bispecific diabody constructs were tested for both PD-1 and LAG-3 binding, while the anti-PD-1 and anti-LAG-3 antibodies were only tested for binding to their respective antigens. For these studies NSO cells expressing PD-1 or LAG-3 were utilized. The diabodies and antibodies were utilized (170.0-0.013  $\mu$ M or 85.0-0.0021  $\mu$ M (four fold serial dilutions). The EC<sub>50</sub> and EC<sub>90</sub> values were determined and are presented in **Tables 15-16**. The sample mean (SM) and standard deviation (SD  $\sigma$ ) are provided where 2 or more separate experiments were performed.

| <b>Table 15</b>            |                                            |                               |                                            |                               |
|----------------------------|--------------------------------------------|-------------------------------|--------------------------------------------|-------------------------------|
| <b>Molecule</b>            | <b>Saturation Binding PD-1</b>             |                               |                                            |                               |
|                            | <b>EC<sub>50</sub> (<math>\mu</math>M)</b> |                               | <b>EC<sub>90</sub> (<math>\mu</math>M)</b> |                               |
|                            | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> |
| DART A                     | 1.9297                                     | 0.4324                        | 9.6027                                     | 0.4801                        |
| DART B                     | 1.7640 <sup>§</sup>                        |                               | 12.2700 <sup>§</sup>                       |                               |
| DART D                     | 2.2267                                     | 0.4140                        | 10.9313                                    | 2.6351                        |
| DART E                     | 3.2180                                     | 0.5742                        | 23.840                                     | 3.2385                        |
| DART F                     | 1.4320 <sup>§</sup>                        |                               | 14.5800 <sup>§</sup>                       |                               |
| DART G                     | 1.1488                                     | 0.6227                        | 3.4220                                     | 2.4600                        |
| DART H                     | 4.5310 <sup>§</sup>                        |                               | 22.6600 <sup>§</sup>                       |                               |
| DART I                     | 1.3232                                     | 0.4890                        | 7.8135                                     | 4.0821                        |
| DART 1                     | 2.1329                                     | 1.4850                        | 13.8113                                    | 9.0256                        |
| hPD-1 mAb 7(1.2) IgG4 (P)  | 1.2083                                     | 0.8112                        | 3.9340                                     | 1.8746                        |
| PD-1 mAb A IgG4 (P)        | 2.3470                                     | 1.2362                        | 22.7770                                    | 15.0690                       |
| hPD-1 mAb 7(1.2) IgG1 (AA) | 1.0879                                     | 0.3958                        | 7.4153                                     | 3.0794                        |
| PD-1 mAb A IgG1 (AA)       | 1.6733                                     | 0.5464                        | 9.9543                                     | 6.6569                        |

§ results from a single experiment

| <b>Table 16</b>             |                                 |             |                     |             |
|-----------------------------|---------------------------------|-------------|---------------------|-------------|
| <b>Molecule</b>             | <b>Saturation Binding LAG-3</b> |             |                     |             |
|                             | <b>EC50 (μM)</b>                |             | <b>EC90 (μM)</b>    |             |
|                             | <b>SM</b>                       | <b>SD σ</b> | <b>SM</b>           | <b>SD σ</b> |
| DART A                      | 0.8402                          | 0.2231      | 4.4448              | 2.4770      |
| DART B                      | 1.0750 <sup>§</sup>             |             | 9.8580 <sup>§</sup> |             |
| DART D                      | 0.8985                          | 0.5326      | 5.7967              | 4.7329      |
| DART E                      | 0.9250                          | 0.8075      | 5.6450              | 5.6809      |
| DART F                      | 5.0090                          | 0.5770      | 19.3350             | 4.7447      |
| DART G                      | 0.9396                          | 0.3045      | 8.5507              | 4.7448      |
| DART H                      | 2.3840 <sup>§</sup>             |             | 9.7810              | 4.2412      |
| DART I                      | 0.5321                          | 0.0547      | 4.198               | 3.2188      |
| DART 1                      | 20.0233                         | 2.1454      | 115.97              | 15.2425     |
| hLAG-3 mAb 1(1.4) IgG4 (P)  | 1.0057                          | 0.1969      | 5.1360              | 4.7904      |
| LAG-3 mAb A IgG4 (P)        | 0.5968                          | 0.1376      | 2.0833              | 0.3244      |
| hLAG-3 mAb 1(1.4) IgG1 (AA) | 0.6069                          | 0.3430      | 3.6373              | 2.4762      |
| LAG-3 mAb A IgG1 (AA)       | 0.4523                          | 0.1660      | 2.0187              | 0.7035      |

§ results from a single experiment

**[00466]** The binding saturation studies demonstrate that the PD-1 x LAG-3 bispecific diabody constructs retain binding to PD-1 and have binding profiles that are similar to the binding profiles of the parental anti-PD-1 antibodies. Similarly, the PD-1 x LAG-3 bispecific diabody constructs retain binding to LAG-3 and, with the exception of DART 1, have binding profiles that are similar to the binding profiles of the parental anti-LAG-3 antibodies.

#### **Example 6** **PD-1 x LAG-3 Bispecific Molecules Inhibition Studies**

**[00467]** The ability of the PD-1 x LAG-3 bispecific molecules: DART A, DART B, DART D, DART E, DART F, DART G, DART H, DART I, DART 1 and BSAB A; and the anti-PD-1 antibodies: hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 7(1.2) IgG1 (AA), PD-1 mAb A IgG1 (AA) and PD-1 mAb A IgG4 (P), to block binding of human PD-L1 (shPD-L1) and human PD-L2 (shPD-L2) to PD-1 expressed on the surface of NSO cells was examined essentially as described above. The diabodies and antibodies were utilized at 33.75-0.002 μM or 107.5-0.0001 μM (four fold serial dilutions).

**[00468]** The IC<sub>50</sub> and IC<sub>90</sub> values were determined and are presented in **Table 17**. The sample mean (SM) and standard deviation (SD σ) are provided where 2 or more separate experiments were performed.

| Table 17                        |                           |             |                 |             |                           |             |                 |             |
|---------------------------------|---------------------------|-------------|-----------------|-------------|---------------------------|-------------|-----------------|-------------|
| Molecule                        | block sPD-L1/PD-1 binding |             |                 |             | block sPD-L2/PD-1 binding |             |                 |             |
|                                 | IC50 ( $\mu$ M)           |             | IC90 ( $\mu$ M) |             | IC50 ( $\mu$ M)           |             | IC90 ( $\mu$ M) |             |
|                                 | SM                        | SD $\sigma$ | SM              | SD $\sigma$ | SM                        | SD $\sigma$ | SM              | SD $\sigma$ |
| DART A                          | 0.9645                    | 0.1485      | 5.6312          | 1.5247      | 1.6273                    | 0.4285      | 6.9335          | 3.9849      |
| DART B                          | 1.1515                    | 0.0007      | 4.8615          | 0.2199      | 2.1150                    | 0.3154      | 7.9550          | 0.0933      |
| DART D                          | 1.5548                    | 0.1692      | 7.8950          | 2.5135      | 3.1255                    | 0.5869      | 9.2973          | 5.5426      |
| DART E                          | 1.6533                    | 0.3307      | 7.8470          | 1.1642      | 2.9460                    | 0.7736      | 6.6135          | 0.0177      |
| DART F                          | 0.5697                    | 0.1729      | 2.0360          | 0.1174      | 0.8389                    | 0.0846      | 1.7995          | 0.2171      |
| DART G                          | 1.6013                    | 0.3581      | 8.1953          | 1.5708      | 2.5540                    | 0.7891      | 7.4810          | 0.2333      |
| DART H                          | 3.3950                    | 0.1018      | 18.640          | 9.5742      | 6.2065                    | 3.6847      | 29.395          | 3.8679      |
| DART I                          | 0.8363                    | 0.1302      | 5.3115          | 0.3125      | 1.286                     | 0.3125      | 6.2485          | 1.3951      |
| DART 1                          | 1.7467                    | 0.3097      | 5.4533          | 1.0214      | 2.8355                    | 1.8250      | 7.2735          | 3.9831      |
| BSAB A                          | 2.1590                    | 0.3097      | 11.075          | 0.8132      | 4.8775                    | 0.5438      | 15.580          | 1.3294      |
| hPD-1 mAb<br>7(1.2) IgG4 (P)    | 0.5186                    | 0.1668      | 3.8050          | 1.2227      | 1.0425                    | 0.2563      | 3.4880          | 0.5459      |
| PD-1 mAb A<br>IgG4 (P)          | 0.9209                    | 0.3256      | 4.3023          | 0.7069      | 1.3859                    | 0.3882      | 5.1675          | 0.2943      |
| hPD-1 mAb<br>7(1.2)<br>IgG1(AA) | 0.7320                    | 0.2337      | 3.2048          | 1.1479      | 0.9769                    | 0.2893      | 2.8437          | 1.4801      |
| PD-1 mAb A<br>IgG1 (AA)         | 1.0765                    | 0.2393      | 5.2775          | 0.9933      | 1.9510                    | 0.8814      | 5.0880          | 1.3831      |

**[00469]** The ligand binding inhibition studies demonstrate that the PD-1  $\times$  LAG-3 bispecific diabody constructs retain the ability to inhibit the binding of sPD-L1 and sPD-L2 to PD-1 on the cell surface.

**[00470]** In addition, the ability of the PD-1  $\times$  LAG-3 bispecific molecules: DART A, DART B, DART D, DART E, DART F, DART G, DART H, DART I, DART 1 and BSAB A; and the anti-LAG-3 antibodies: hLAG-3 mAb 1(1.4) IgG4 (P), LAG-3 mAb A IgG4 (P), hLAG-3 mAb 1(1.4) IgG1 (AA), and LAG-3 mAb A IgG1 (AA), to block binding of human LAG-3 to native MHC class II on the surface of Daudi cells was examined. Briefly, each PD-1  $\times$  LAG-3 bispecific molecule and control anti-LAG-3 antibody was mixed with a biotinylated-soluble human LAG-3-Fc fusion protein (shLAG-3), (at 0.5  $\mu$ g/ml) and were separately incubated with MHC II-positive Daudi cells ( $2.5 \times 10^6$  cells). The amount of LAG-3 binding to the surface of the Daudi cells was determined using a PE-conjugated Streptavidin secondary antibody by FACS analysis. The diabodies and antibodies were utilized at 27.5-0.026  $\mu$ M (two fold serial dilutions) or 107.5-0.0001  $\mu$ M (four fold serial dilutions), or 35-0.002  $\mu$ M (four fold serial dilutions).

[00471] The IC<sub>50</sub> and IC<sub>90</sub> values were determined and are presented in **Table 18**. The sample mean (SM) and standard deviation (SD  $\sigma$ ) are provided where 2 or more separate experiments were performed.

| <b>Table 18</b>             |                                            |                               |                                            |                               |
|-----------------------------|--------------------------------------------|-------------------------------|--------------------------------------------|-------------------------------|
| <b>Molecule</b>             | <b>Block shLAG-3/MHC Class II Binding</b>  |                               |                                            |                               |
|                             | <b>EC<sub>50</sub> (<math>\mu</math>M)</b> |                               | <b>EC<sub>90</sub> (<math>\mu</math>M)</b> |                               |
|                             | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> |
| DART A                      | 1.3835                                     | 1.6465                        | 8.396102                                   | 8.3962                        |
| DART B                      | 0.4081                                     | 0.1104                        | 3.0645                                     | 0.3924                        |
| DART D                      | 1.1843                                     | 1.1398                        | 8.0041                                     | 7.3317                        |
| DART E                      | 3.2706                                     | 2.9177                        | 28.9683                                    | 24.1694                       |
| DART F                      | 1.5347                                     | 1.2674                        | 10.3920                                    | 11.2555                       |
| DART G                      | 2.0618                                     | 3.3552                        | 11.4422                                    | 12.4964                       |
| DART H                      | 2.8967                                     | 4.9817                        | 17.2533                                    | 21.1420                       |
| DART I                      | 0.4864                                     | 0.1549                        | 2.339                                      | 1.1780                        |
| DART 1                      | 15.9610                                    | 14.0883                       | 87.1486                                    | 109.533                       |
| BSAB A                      | 0.7101                                     | 0.0571                        | 7.2470                                     | 1.0706                        |
| hLAG-3 mAb 1(1.4) IgG4 (P)  | 0.4815                                     | 0.2176                        | 3.4837                                     | 1.7564                        |
| LAG-3 mAb A IgG4 (P)        | 0.7011                                     | 0.1900                        | 2.4232                                     | 0.3481                        |
| hLAG-3 mAb 1(1.4) IgG1 (AA) | 0.3637                                     | 0.1409                        | 9.4422                                     | 7.9319                        |
| LAG-3 mAb A IgG1 (AA)       | 0.5923                                     | 0.3407                        | 2.1451                                     | 1.1139                        |

[00472] The ligand binding inhibition studies demonstrate that the PD-1  $\times$  LAG-3 bispecific diabody constructs retain the ability to inhibit the binding of a shLAG-3-Fc fusion protein to MHC class II on the cell surface. With the exception of DART 1 the PD-1  $\times$  LAG-3 bispecific molecules have similar inhibition profiles as the parental anti-LAG-3 antibodies.

### Example 7

#### Blockade of the PD-1/PD-L1 Checkpoint by PD-1 $\times$ LAG-3 Bispecific Molecules

[00473] The ability of the PD-1  $\times$  LAG-3 bispecific molecules: DART A, DART B, DART D, DART E, DART F, DART G, DART H, DART I, DART 1 and BSAB A; and the anti-PD-1 antibodies: hPD-1 mAb 7(1.2) IgG4 (P), hPD-1 mAb 7(1.2) IgG1 (AA), PD-1 mAb A IgG1 (AA) and PD-1 mAb A IgG4 (P), to antagonize the PD-1/PD-L1 axis (*i.e.*, block the PD-1/PD-L1 interaction and prevent down-regulation of T-cell responses) was examined in a Jurkat-luc2-NFAT/CHO-PD-L1 luciferase reporter assay (using CHO/PD-L1 cells and MNFAT-luc2/PD-1 Jurkat cells) essentially as described above. The diabodies and antibodies were utilized at 100-0.0065  $\mu$ M (four fold serial dilutions) or 100-0.0013  $\mu$ M (five fold serial dilutions).

[00474] The IC<sub>50</sub> and IC<sub>90</sub> values were determined and are presented in **Table 19**. The sample mean (SM) and standard deviation (SD  $\sigma$ ) are provided where 2 or more separate experiments were performed.

| <b>Table 19</b>           |                                            |                               |                                            |                               |
|---------------------------|--------------------------------------------|-------------------------------|--------------------------------------------|-------------------------------|
| <b>Molecule</b>           | <b>Reporter Signaling</b>                  |                               |                                            |                               |
|                           | <b>IC<sub>50</sub> (<math>\mu</math>M)</b> |                               | <b>IC<sub>90</sub> (<math>\mu</math>M)</b> |                               |
|                           | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> | <b>SM</b>                                  | <b>SD <math>\sigma</math></b> |
| DART A                    | 0.8804                                     | 0.1949                        | 7.9115                                     | 1.3232                        |
| DART B                    | 1.079                                      | 0.1535                        | 7.5413                                     | 3.1483                        |
| DART D                    | 1.4044                                     | 0.2584                        | 12.0786                                    | 3.6616                        |
| DART E                    | 1.4060                                     | 0.1222                        | 13.7867                                    | 1.4981                        |
| DART F                    | 0.3404                                     | 0.0103                        | 1.8710                                     | 0.481                         |
| DART G                    | 0.6914                                     | 0.0206                        | 4.2090                                     | 0.7331                        |
| DART H                    | 36.6167                                    | 20.8078                       | 968.300                                    | 811.8471                      |
| DART I                    | 1.3335                                     | 0.3641                        | 12.146                                     | 6.8787                        |
| DART 1                    | 11.8807                                    | 3.4905                        | 1048.2000                                  | 1508.9992                     |
| BSAB A                    | 9.7825                                     | 1.0288                        | 113.3350                                   | 22.2951                       |
| hPD-1 mAb 7(1.2) IgG4 (P) | 0.6460                                     | 0.3035                        | 6.0736                                     | 2.5513                        |
| PD-1 mAb A IgG4 (P)       | 1.328                                      | 0.7439                        | 16.5138                                    | 9.7149                        |
| hPD-1 mAb 7(1.2) IgG1(AA) | 0.5214                                     | 0.1541                        | 4.7592                                     | 2.1044                        |
| PD-1 mAb A IgG1 (AA)      | 1.4514                                     | 1.0049                        | 35.7382                                    | 40.9858                       |

[00475] The reporter signaling studies demonstrate that the majority of the PD-1  $\times$  LAG-3 bispecific diabody constructs retain the ability to inhibit the binding of sPD-L1 to PD-1 on the cell surface. The tetravalent PD-1  $\times$  LAG-3 bispecific diabody constructs, DART A, DART B, DART D, DART-E, DART F, DART G and DART I were the strongest inhibitors in this assay. Similar results were obtained for several of these bispecific constructs examined in a PD-L2 reporter assay.

#### **Example 8** **Functional Activity of PD-1 $\times$ LAG-3 Bispecific Molecules**

[00476] The ability of PD-1  $\times$  LAG-3 bispecific molecules to enhance cytokine release through checkpoint inhibition was examined in SEB-stimulated PBMCs upon restimulation essentially as described above except where noted.

[00477] In initial studies the ability of the PD-1  $\times$  LAG-3 bispecific molecules: DART A, DART D, DART E, DART F, DART G, DART H; and the anti-PD-1 and anti-LAG antibodies:

PD-1 mAb A IgG4 (P) and LAG-3 mAb A IgG4 (P), alone or in combination to enhance cytokine release through checkpoint inhibition was examined. In these assays the PD-1 x LAG-3 bispecific molecules and antibodies were used at a total concentration of 3.125, 12.5, or 50 nM, and the PBMCs were stimulated with 0.2 ng/mL of SEB (previous studies used 0.1 ng/mL). For these studies, where a combination of antibodies is used each antibody is provided at one half of the total concentration, (*i.e.*, 1.563, 6.25, or 25 nM). **Figures 16A and 16B** shows the IFN $\gamma$  secretion profiles from SEB-stimulated PBMCs from two representative responding donors, D: 35644 and D: 59697, respectively.

**[00478]** As noted, not all donors respond to SEB at 0.1 or 0.2 ng/mL. To enhance SEB stimulation of PBMCs from a wider number of donors SEB was used at a high concentration of 85 ng/mL, or a middle concentration of 0.5 ng/mL in additional studies. At these concentrations SEB stimulation is more robust across more donors, although donor to donor variability may still be seen.

**[00479]** In one such study the ability of the PD-1 x LAG-3 bispecific molecules: DART A, DART B; the anti-PD-1 antibody: hPD-1 mAb 7(1.2) IgG4(P); the anti-LAG-3 antibody: LAG-3 mAb 1(1.4) IgG4(P); and the combination of: PD-1 mAb A IgG4 (P) and LAG-3 mAb A IgG4 (P), to enhance cytokine release through checkpoint inhibition was examined. In these assays the PD-1 x LAG-3 bispecific molecules and antibodies were used at a concentration of 0.019, 0.078, 0.3125, 1.25, 5, or 20 nM and the PBMCs were stimulated with 85 ng/mL of SEB. For this assay where a combination of antibodies is used each antibody was provided at the indicated concentration and thus the total antibody concentration is twice the concentration used for each antibody (*i.e.*, 0.038, 0.156, 0.625, 2.5, 10, or 40 nM). **Figures 17A and 17B** show the IFN $\gamma$  secretion profiles from SEB-stimulated PBMCs from two representative donors, D: 55515 and D: 54024, respectively.

**[00480]** In another study the PD-1 x LAG-3 bispecific molecules: DART A, DART B, DART C; the anti-PD-1 antibody: hPD-1 mAb 7(1.2) IgG4(P); the anti-LAG-3 antibody: LAG-3 mAb 1(1.4) IgG4(P); and the combination of: PD-1 mAb A IgG4 (P) and LAG-3 mAb A IgG4 (P), to enhance cytokine release through checkpoint inhibition was examined. In these assays the PD-1 x LAG-3 bispecific molecules and antibodies were used at a total concentration of 0.048, 0.195, 0.78, 3.125, 12.5, or 50 nM and the PBMCs were stimulated with 0.5 ng/mL of SEB. For these studies, where a combination of antibodies is used each antibody is provided at one half of the total concentration (*i.e.*, 0.024, 0.098, 0.39, 1.563, 6.25, or 25 nM). **Figures 18A**

and **18B** show the IFN $\gamma$  secretion profiles from SEB-stimulated PBMCs from two representative donors, D: 20990 and D: 54947, respectively).

**[00481]** In a further study, the release of the cytokine IL-2 was examined. Specifically, the PD-1  $\times$  LAG-3 bispecific molecules: DART D, DART H; the anti-PD-1 antibodies: PD-1 mAb A IgG4 (P), hPD-1 mAb 7(1.2) IgG4(P); the anti-LAG-3 antibodies: LAG-3 mAb A IgG4 (P) and LAG-3 mAb 1(1.4) IgG4(P); and the combination of: PD-1 mAb A IgG4 (P) and LAG-3 mAb A IgG4 (P), and hPD-1 mAb 7(1.2) IgG4(P) and LAG-3 mAb 1(1.4) IgG4(P), to enhance IL-2 release through checkpoint inhibition was examined. In these assays the PD-1  $\times$  LAG-3 bispecific molecules and antibodies were used at a total concentration of 3.125, 12.5, or 50 nM and the PBMCs were stimulated with the high 85 ng/mL concentration of SEB. For these studies, where a combination of antibodies is used each antibody is provided at one half of the total concentration (*i.e.*, 1.563, 6.25, or 25 nM). **Figure 19** shows the IL-2 secretion profile from SEB-stimulated PBMCs from a representative donor (D: 54024).

**[00482]** In additional studies the PD-1  $\times$  LAG-3 bispecific molecules: DART B, and DART I; the anti-PD-1 antibodies: PD-1 mAb A IgG4 (P), and hPD-1 mAb 7(1.2) IgG4(P); the anti-LAG-3 antibodies: LAG-3 mAb A IgG4 (P), hLAG-3 mAb 1(1.4) IgG4(P), and hLAG-3 mAb 6(1.1) IgG4 (P); and the combinations of: PD-1 mAb A IgG4 (P) and LAG-3 mAb A IgG4 (P), hPD-1 mAb 7(1.2) IgG4(P) and hLAG-3 mAb 1(1.4) IgG4(P), and hPD-1 mAb 7(1.2) IgG4(P) and hLAG-3 mAb 6(1.1) IgG4 (P) to enhance cytokine release through checkpoint inhibition was examined. In these assays the PD-1  $\times$  LAG-3 bispecific molecules and antibodies were used at a concentration of 0.0061, 0.024, 0.09, 0.39, 1.56, 6.25 or 25 nM and the PBMCs were stimulated with 0.5 ng/mL of SEB. For these studies, where a combination of antibodies is used each antibody is provided at the indicated concentration and thus the total antibody concentration is twice the concentration used for each antibody (*i.e.*, 0.0122, 0.048, 0.18, 0.78, 3.12, 12.5 or 50 nM). **Figure 20** shows the IFN $\gamma$  secretion profiles from SEB-stimulated PBMCs from a representative donor D: 56041).

**[00483]** The ability of the PD-1  $\times$  LAG-3 bispecific molecule DART I; the combination of the anti-PD-1 antibody PD-1 mAb A IgG4 and the anti-LAG-3 antibody LAG-3 mAb A IgG4 (P); and a negative control antibody to enhance antigen-specific T cell responses was examined using a Tetanus-Toxoid Recall Assay. In particular, the response of antigen-specific enhanced secretion of cytokines was measured using tetanus toxoid as a recall antigen in coculture assay system. Briefly, CD4 memory T cells ( $0.5 - 1.0 \times 10^5$  cells/well) were isolated using negative

selection isolation kits (Miltenyi Biotec, San Diego, CA and Invitrogen, Carlsbad, CA) from human peripheral blood and cultured for 5-7 days with irradiated monocytes ( $0.01 - 0.05 \times 10^5$  cells/well, 3500 rads) from the same donor in the presence or absence of 5  $\mu\text{g/mL}$  the recall antigen tetanus toxoid (TTd) and dilution (starting at 25nM) of DART I, PD-1 mAb A IgG4 + LAG-3 mAb A IgG4(P), or an isotype control. In parallel plates, proliferation was measured through the incorporation of tritiated thymidine and IL-2 and IFN $\gamma$  was measured using ELISA (R&D systems, Minneapolis, MN) at days 5-7. **Figures 21A-D** show the IFN $\gamma$  (**Figure 21A, 21C**) and IL-2 (**Figure 21B, 21D**) secretion profiles at day 7, from two representative donors (D50702 and D54267).

**[00484]** The results of these studies demonstrate that the PD-1  $\times$  LAG-3 bispecific molecules dramatically enhanced IFN $\gamma$  (**Figures 16A-16B, 17A-17B, 18A-18B, 20**), and IL-2 (**Figure 19**) production from SEB-stimulated PBMCs upon restimulation. In addition, the PD-1  $\times$  LAG-3 bispecific molecules dramatically enhanced IFN $\gamma$  production (**Figures 21A and 21C**) from CD4 memory T cells stimulated with tetanus toxoid. In particular, the tetravalent PD-1  $\times$  LAG-3 bispecific molecules provided a greater enhancement than the combination of anti-PD-1 antibodies with anti-LAG-3 antibodies.

#### **Example 9**

##### **Pharmacokinetics of PD-1 $\times$ LAG-3 Bispecific Molecules**

**[00485]** The pharmacokinetics of a representative PD-1  $\times$  LAG-3 bispecific molecule, DART I and a representative anti-PD-1 antibody, PD-1 mAb A were examined in Cynomolgus monkeys. Briefly, two cynomolgus monkeys (one male and one female) were infused with a single dose of DART I (5 mg/kg) or PD-1 mAb A (10 mg/kg) and the serum concentration of the molecules was monitored over time using a sandwich ELISA assay. Briefly, maxisorb 96-well assay plates were coated with soluble human PD-1 (shPD-1), blocked with bovine serum albumin, washed and incubated with calibration standards, quality control standards and diluted serum samples. The amount of captured DART I and PD-1 mAb A was assessed by the sequential addition of a goat anti-human IgG Fc-biotin secondary and streptavidin-horseradish peroxidase (SA-HRP). HRP activity was detected using TMB substrate. All samples were analyzed a microplate reader (SpectraMax M2e, Molecular Device, Sunnyvale, CA) and the OD signals produced by the standard calibrators were used in the four-parameter logistic model using SoftMax Pro software (Version 5.4, Molecular Devices). The concentrations of PD-1 mAb A, or DART I were determined from the interpolation of the

samples' OD signal data with the equation describing the standard curve. The lower limit of quantitation (LLOQ) for this assay was estimated at 9.775 ng/mL.

**[00486]** **Figure 22** shows the serum concentration over time, the lines represents the mean of both male (filled symbols) and female (open symbols) monkeys infused with DART I (solid line, triangles) or PD-1 mAb A (dashed line, circles). These data demonstrate that the pharmacokinetics of a PD-1 x LAG-3 bispecific molecule are comparable to those of an anti-PD-1 antibody in cynomolgus monkeys.

### Example 10

#### Toxicology Study of PD-1 Antibodies and PD-1 x LAG-3 Bispecific Molecules

**[00487]** The safety profile of a representative a representative anti-PD1 antibody, hPD-1 mAb 7 (1.2) IgG4 (P), and a representative PD1 x LAG3 bispecific molecule, DART I, was assessed in a non-GLP (Good Laboratory Practice) dosing study in cynomolgus monkeys.

**[00488]** In this study the potential toxicity and toxicokinetics of the anti-PD-1 antibody (hPD-1 mAb 7 (1.2) IgG4 (P)), when administered by multiple intravenous infusions was evaluated. In addition, the potential toxicity and pharmacokinetics of the PD-1 x LAG-3 DART molecule (DART I), when administered by single intravenous infusion was also evaluated. The study design is presented in **Table 20**.

| <b>Table 20</b>                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                    |             |             |              |                |                |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------------------|-------------|-------------|--------------|----------------|----------------|
| Group No.                                                                                                                                                                                                                                                                                                                                                                                                                               | Test Material              | Dose Level (mg/kg) | Dosing Days | Dose Volume | Dose (mg/mL) | No. of Animals |                |
|                                                                                                                                                                                                                                                                                                                                                                                                                                         |                            |                    |             |             |              | Males          | Females        |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                       | Control                    | 0                  | 1, 8, 15    | 5           | 0            | 1 <sup>a</sup> | 1 <sup>a</sup> |
| 2A                                                                                                                                                                                                                                                                                                                                                                                                                                      | hPD-1 mAb 7 (1.2) IgG4 (P) | 1                  | 1, 8, 15    | 5           | 0.2          | 1 <sup>a</sup> | 1 <sup>a</sup> |
| 2B                                                                                                                                                                                                                                                                                                                                                                                                                                      | hPD-1 mAb 7 (1.2) IgG4 (P) | 1                  | 1, 8, 15    | 5           | 0.2          | 1 <sup>b</sup> | 1 <sup>b</sup> |
| 3A                                                                                                                                                                                                                                                                                                                                                                                                                                      | hPD-1 mAb 7 (1.2) IgG4 (P) | 100                | 1, 8, 15    | 5           | 20           | 1 <sup>a</sup> | 1 <sup>a</sup> |
| 3B                                                                                                                                                                                                                                                                                                                                                                                                                                      | hPD-1 mAb 7 (1.2) IgG4 (P) | 100                | 1, 8, 15    | 5           | 20           | 1 <sup>b</sup> | 1 <sup>b</sup> |
| 4                                                                                                                                                                                                                                                                                                                                                                                                                                       | DART I                     | 5                  | 1           | 5           | 1            | 1 <sup>c</sup> | 1 <sup>c</sup> |
| <sup>a</sup> Groups 1, 2A, and 3A were dosed beginning on Day 1 and necropsied 72 hours following their last (third) dose on Day 18.<br><sup>b</sup> Groups 2B and 3B were dosed beginning on Day 1 and necropsied 7 days following their last (third) dose on Day 22.<br><sup>c</sup> Group 4 was dosed beginning on Day 1 and followed for 28 days post single dose administration (to Day 29); animals were then returned to colony. |                            |                    |             |             |              |                |                |

**[00489]** The following parameters and endpoints were evaluated in this study: clinical signs, body weights, food consumption, body temperature, clinical pathology parameters (hematology, coagulation, and clinical chemistry), bioanalysis and toxicokinetic parameters, anti-drug antibody analysis, flow cytometry, cytokine, gross necropsy findings, organ weights, and histopathologic examinations.

**[00490]** All animals survived until scheduled euthanasia on Day 18 or 22 or release from study on Day 29. For hPD-1 mAb 7 (1.2) IgG4 (P) there were no test article-related changes in clinical signs, food consumption, body weights, body temperature, hematology, coagulation, or clinical chemistry parameters, or gross necropsy findings. At Days 18 and 22, increases in spleen weight and a dose-dependent mild to moderate lymphohistiocytic infiltrate of the red pulp were evident in animals receiving hPD-1 mAb 7 (1.2) IgG4 (P) at 1 or 100 mg/kg. As compared to surrounding lymphocytes, the lymphohistiocytic cells had pale cytoplasm and irregular nuclei. Rare mitotic figures were evident. The infiltrate was a microscopic correlate for the increased spleen weight.

**[00491]** The serum concentration-time profiles for animals given hPD-1 mAb 7 (1.2) IgG4 (P) show the profile expected for an antibody in this species, with a few exceptions. The slopes of the curves after the third dose dropped more sharply than after the first dose for two animals in the 1 mg/kg dose group and two animals in the 100 mg/kg dose group, indicating the possible emergence of anti-drug antibodies (ADA) at the later cycles. Analysis showed that 2/4 animals developed ADA in the 1 mg/kg group and 1/4 animals developed ADA in the 100 mg/kg group.

**[00492]** In conclusion, administration of hPD-1 mAb 7 (1.2) IgG4 (P) by intravenous infusion once weekly for 3 weeks (Days 1, 8, and 15) was well-tolerated in cynomolgus monkeys at levels of 1 and 100 mg/kg. A dose-dependent mild to moderate lymphohistiocytic cellular infiltrate of the splenic red pulp was present at 1 and 100 mg/kg hPD-1 mAb 7 (1.2) IgG4 (P).

**[00493]** For DART I, there were no test article-related changes in clinical signs, food consumption, body weights, body temperature, hematology, or coagulation parameters. DART I-related changes in clinical chemistry parameters included non-adverse, transient elevations in aspartate aminotransferase (AST) and lactate dehydrogenase (LDH) on Day 2. The average AST change was 3.2x vehicle-treated control animals and 7.8x prestudy levels, with levels above the control reference range<sup>2</sup>. The average LDH change was 2.5x vehicle-treated control

animals and 6.9x prestudy levels. Both parameters returned to near baseline levels on Day 8. In conclusion, single administration of DART-I by intravenous infusion was well tolerated in cynomolgus monkeys at a level of 5 mg/kg.

#### **Example 11**

##### **Single Dose PK Study with anti-PD-1 Antibodies**

**[00494]** A single-dose PK study with selected toxicological endpoints was conducted in cynomolgus monkeys. In this study, hPD-1 mAb 7 (1.2) IgG4 (P) was compared to two other anti-PD1 IgG4 (P),  $\kappa$  mAbs: PD-1 mAb A IgG4 (P) and PD-1 mAb B IgG4 (P). Each antibody was administered at 10 mg/kg by 1-hour intravenous infusion to 2 monkeys (1M, 1F) and animals were monitored for 65 days.

**[00495]** There were no test article-related clinical signs, changes in body weight, food consumption, cytokine, or immunophenotyping associated with administration of hPD-1 mAb 7 (1.2) IgG4 (P) or PD-1 mAb A IgG4 (P). Data were similar for PD-1 mAb B IgG4 (P) with the exception that elevations in IL-5 were observed following PD-1 mAb B IgG4 (P) administration.

**[00496]** Anti-PD-1 antibody binding to PD-1 on the surface of T cells was determined by flow cytometry using a competition method in which the mean fluorescence intensity (MFI) of fluorescently labeled hPD-1 mAb 7 (1.2) IgG4 (P) binding to T cells in the absence (PBS control) or presence of excess competitor (unlabeled hPD-1 mAb 7 (1.2) IgG4 (P)) for the full time course of blood samples collected from the cynomolgus monkeys treated with hPD-1 mAb 7 (1.2) IgG4 (P), PD-1 mAb A IgG4 (P) or PD-1 mAb B IgG4 (P). As shown in **Figures 23A-23C**, hPD-1 mAb 7 (1.2) IgG4 (P) and PD-1 mAb B IgG4 (P) demonstrated prolonged binding to PD-1 on the surface of CD4<sup>+</sup> and CD8<sup>+</sup> T cells (PD-1 binding maintained at  $\geq 80\%$  for 28 days or more) (**Figures 23A and 23C**, respectively) compared to PD-1 mAb A IgG4 (P) (PD-1 binding maintained at  $\geq 80\%$  for 21 days or less) (**Figure 23B**). For each of the anti-PD-1 antibodies, the T-cell PD-1 binding data correlated with their serum concentrations.

#### **Example 12**

##### **Repeat Dose Toxicology Studies**

**[00497]** To assess the safety, toxicokinetic, and pharmacodynamic profile of the therapeutic molecules of the present invention, an exemplary molecule (hPD-1 mAb 7 (1.2) IgG4 (P)) was administered to cynomolgus monkeys and a GLP (Good Laboratory Practice) dosing study was performed. In this study, four groups of animals (10 per group, 5 males, and 5 females) were

treated with hPD-1 mAb 7 (1.2) IgG4 (P) or a control article, once weekly by infusion at 3 dose levels. The animals were evaluated for any potential toxicity during a 4-week drug dosing period followed by monitoring during an additional 10-week drug-free period. The experimental design of this study is presented in **Table 21**. Animals were dosed once weekly via a one-hour intravenous infusion using a calibrated infusion pump on Study Days 1, 8, 15, and 22. One male and one female from each group were sacrificed on Day 25, the remaining animals were sacrificed on Study Day 95. The effects of hPD-1 mAb 7 (1.2) IgG4 (P) administration on the leukocyte subpopulations in circulation, including the occupancy of PD-1 receptors on T-lymphocytes were assessed. In addition, the anti-drug antibody (ADA) profiles were determined.

| <b>Table 21</b>  |                                  |                           |                            |                     |                                   |          |                       |          |
|------------------|----------------------------------|---------------------------|----------------------------|---------------------|-----------------------------------|----------|-----------------------|----------|
| <b>Group No.</b> | <b>Test Material<sup>a</sup></b> | <b>Dose Level (mg/kg)</b> | <b>Dose Volume (mL/kg)</b> | <b>Dose (mg/mL)</b> | <b>No. of Animals<sup>b</sup></b> |          |                       |          |
|                  |                                  |                           |                            |                     | <b>Main Study</b>                 |          | <b>Recovery Study</b> |          |
|                  |                                  |                           |                            |                     | <b>M</b>                          | <b>F</b> | <b>M</b>              | <b>F</b> |
| 1                | Control                          | 0                         | 5.88                       | 0                   | 3                                 | 3        | 2                     | 2        |
| 2                | hPD-1 mAb 7 (1.2) IgG4 (P)       | 10                        | 5.88                       | 1.7                 | 3                                 | 3        | 2                     | 2        |
| 3                | hPD-1 mAb 7 (1.2) IgG4 (P)       | 40                        | 5.88                       | 6.8                 | 3                                 | 3        | 2                     | 2        |
| 4                | hPD-1 mAb 7 (1.2) IgG4 (P)       | 150                       | 5.88                       | 25.5                | 3                                 | 3        | 2                     | 2        |

<sup>a</sup> Control and hPD-1 mAb 7 (1.2) IgG4 (P) were administered weekly via intravenous infusion

<sup>b</sup> Six monkeys (3M/3F) per group were necropsied on Day 25, while the remaining recovery group monkeys (2M/2F) were necropsied on Day 95

**[00498]** Once weekly intravenous (IV) infusions of hPD-1 mAb 7 (1.2) IgG4 (P) at 0, 10, 40, and 150 mg/kg in cynomolgus monkeys were well tolerated and all animals survived to their scheduled euthanasia on Days 25 or 95. There were no hPD-1 mAb 7 (1.2) IgG4 (P)-related changes in clinical signs, food consumption, body weights, physical, ophthalmic, and neurological examinations, electrocardiology, body temperatures, respiratory rates, blood pressure and heart rates, coagulation, clinical chemistry, and urinalysis parameters, organ weights, or gross necropsy findings.

**[00499]** hPD-1 mAb 7 (1.2) IgG4 (P)-related changes in hematology parameters included transient decreases in lymphocyte titers. Lymphocyte titers were moderately decreased compared to pre-study (Day 1 predose) on Day 2 (23 hours post infusion) in males and females at  $\geq 10$  mg/kg, statistically significant for males at 10 and 40 mg/kg and females at 40 and 150

mg/kg compared to controls. Lymphocyte titers returned to near prestudy levels on Day 8 predose but were mildly decreased for some individual males and females at all dose levels (0.47x to 0.68x prestudy) on Day 9 (23 hours post infusion). Lymphocyte titers increased prior to dosing on Days 15 and 22, but decreased for some individual males and females (0.36x to 0.54x prestudy) on Days 16 and 23 (23 hours post infusion).

**[00500]** A dose-independent, transient decline in circulating immune cell populations, including total leukocytes, T cells, B cells, and NK cells, was observed 23 hours following the end of infusion in hPD-1 mAb 7 (1.2) IgG4 (P)-treated animals compared with the control group. The largest magnitude in change was observed following the first dose administration on Day 1; smaller magnitude changes were transiently observed following subsequent doses on Days 8, 15, or 22. Immune cell populations generally recovered to at or near baseline values by 72 hours post-EOI and throughout the recovery phase. No changes in circulating monocytes were observed in hPD-1 mAb 7 (1.2) IgG4 (P)-treated animals compared with the control group.

**[00501]** Maximal hPD-1 mAb 7 (1.2) IgG4 (P) binding to PD-1+/CD4+ and PD-1+/CD8+ cells was observed during the hPD-1 mAb 7 (1.2) IgG4 (P) treatment phase of the study at all doses tested (10, 40 or 150 mg/kg). In recovery, animals that did not develop anti-drug antibody (ADA) responses, serum hPD-1 mAb 7 (1.2) IgG4 (P) concentrations remained above 29 µg/mL and maximal hPD-1 mAb 7 (1.2) IgG4 (P) binding to PD-1+/CD4+ and PD-1+/CD8+ T cells was maintained during the entire 10-week recovery period. In these animals, there was no evidence of PD-1 modulation on the T cells. In recovery animals that developed ADA responses, the frequency of MGD012-bound PD-1+ T cells declined to baseline levels. The declines from maximal hPD-1 mAb 7 (1.2) IgG4 (P) binding on PD-1+/CD4+ and PD-1+/CD8+ cells of ADA-positive animals generally occurred when the apparent serum hPD-1 mAb 7 (1.2) IgG4 (P) concentrations dropped below approximately 25 µg/mL. However, it is not known if this apparent threshold relationship applies to ADA-negative animals, since the presence of ADA in ADA-positive animals may contribute to blocking the binding of PD-1 antibodies to PD-1.

**[00502]** There were minimal sex-associated differences in the pharmacokinetic responses of hPD-1 mAb 7 (1.2) IgG4 (P), which were linear across the dose range evaluated (10 to 150 mg/kg). For hPD-1 mAb 7 (1.2) IgG4 (P) at 10, 40, and 150 mg/kg, the gender combined mean  $C_{max}$  was 240 µg/mL (0.240 mg/mL), 1078 µg/mL (1.08 mg/mL), and 3938 µg/mL

(3.94 mg/mL) and the AUC was 47310 h•µg/mL (47.3 h•mg/mL), 205723 h•µg/mL (206 h•mg/mL), and 745681 h•µg/mL (746 h•mg/mL), respectively. Mean clearance by non-compartmental analysis (NCA) of the first cycle of hPD-1 mAb 7 (1.2) IgG4 (P) before the emergence of ADA, was 0.21 mL/h/kg, substantially lower than the glomerular filtration rate of cynomolgus monkeys, as would be expected for a large molecular weight protein. Mean steady-state volume of distribution by NCA of the first cycle of hPD-1 mAb 7 (1.2) IgG4 (P) was 68 mL/kg, approximately 1.5 times the serum volume, but less than the extracellular water space. This suggests that hPD-1 mAb 7 (1.2) IgG4 (P) extravasates from the vascular compartment into the tissue extracellular space, but that not all of the extracellular space was accessible to this molecule. The average value of the mean residence time (MRT) by NCA of the first cycle of hPD-1 mAb 7 (1.2) IgG4 (P) was 335 hours or approximately 14 days. Emergence of ADA decreased the concentrations of hPD-1 mAb 7 (1.2) IgG4 (P) in Cycles 2 to 4. Evidence of decreased hPD-1 mAb 7 (1.2) IgG4 (P) serum concentrations following repeated doses of hPD-1 mAb 7 (1.2) IgG4 (P) were observed in 7/10, 4/10, and 3/10 animals in the 10, 40, and 150 mg/kg dose groups, respectively. The presence of ADA against hPD-1 mAb 7 (1.2) IgG4 (P) was confirmed in 4, 2, and 1 of these animals in the 10, 40, and 150 mg/kg dose groups, respectively; all the animals in which ADA was not confirmed were in the terminal necropsy group during which hPD-1 mAb 7 (1.2) IgG4 (P) serum concentrations likely interfered with the ability to detect ADA. Accordingly, in subsequent TK analysis, when a trough concentration was lower than the preceding trough concentration, data from this time forward were censored. From two-compartment modeling of data across all cycles for the 3 dose groups, excluding points that were affected by ADA, mean values for the primary TK parameters for a 2-compartment model were 0.22 mL/h/kg for clearance, 38.5 mL/kg for initial volume of distribution ( $V_1$ ), and 33.8 mL/kg for  $V_2$ , which yielded a mean steady-state volume of distribution ( $V_{ss}$ ) of 72.3 mL/kg, and an MRT of 329 hours. These values were consistent with parameters obtained from NCA of the first dose. In the absence of ADA, simulations predict that with weekly dosing, steady state would be achieved in cynomolgus monkeys after the 5th dose and the accumulation index would be 2.4.

**[00503]** On Day 25, hPD-1 mAb 7 (1.2) IgG4 (P)-related minimal multifocal perivascular mononuclear cell infiltrates were present in the superficial dermis of the IV injection site in males at  $\geq 40$  mg/kg and in females at  $\geq 10$  mg/kg and were an expected reaction to repeated injection of a foreign protein (monoclonal antibody). On Day 95, there were no hPD-1 mAb 7

(1.2) IgG4 (P)-related microscopic changes noted, indicating recovery of the test article-related change present on Day 25.

**[00504]** In summary, the results of this study indicate that administration of hPD-1 mAb 7 (1.2) IgG4 (P) via intravenous infusion once weekly (Days 1, 8, 15, and 22) was clinically well tolerated in cynomolgus monkeys at levels of 10, 40, or 150 mg/kg. Effects observed were limited to transient decreases in circulating lymphocytes and minimal injection-site changes related to injection of a foreign protein. Based on these results, the no-observed-adverse-effect level (NOAEL) was considered to be 150 mg/kg (gender combined mean  $C_{\max}$  of 3.94 mg/mL and AUC of 746 h•mg/mL).

**[00505]** All publications and patents mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference in its entirety. While the invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modifications and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

## What Is Claimed Is:

- Claim 1. A multispecific anti-human PD-1-binding molecule that comprises a Variable Heavy Chain Domain and a Variable Light Chain Domain, wherein:  
said Variable Heavy Chain Domain comprises the amino acid sequence of **SEQ ID NO:147**, and said Variable Light Chain Domain comprises the amino acid sequence of **SEQ ID NO:153**.
- Claim 2. The multispecific anti-human PD-1-binding molecule of claim 1, wherein said molecule is a bispecific binding molecule, capable of simultaneously binding to human PD-1 and to a second epitope.
- Claim 3. The multispecific anti-human PD-1-binding molecule of claim 2, wherein said second epitope is an epitope of a molecule involved in regulating an immune check point present on the surface of an immune cell, and wherein said second epitope is an epitope of B7-H3, B7-H4, BTLA, CD40, CD40L, CD47, CD70, CD80, CD86, CD94, CD137, CD137L, CD226, CTLA-4, Galectin-9, GITR, GITRL, HHLA2, ICOS, ICOSL, KIR, LAG-3, LIGHT, MHC class I or II, NKG2a, NKG2d, OX40, OX40L, PD1H, PD-1, PD-L1, PD-L2, PVR, SIRPa, TCR, TIGIT, TIM-3 or VISTA.
- Claim 4. The multispecific anti-human PD-1-binding molecule of claim 3, wherein said second epitope is an epitope of LAG-3.
- Claim 5. The multispecific anti-human PD-1-binding molecule of claim 4, wherein said LAG-3 epitope-binding site comprises:
- (A) (1) the CDR<sub>H1</sub> Domain, CDR<sub>H2</sub> Domain, and CDR<sub>H3</sub> Domain of the Variable Heavy Chain of LAG-3 mAb 1, and respectively comprise the amino acid sequences: **SEQ ID NO:42**, **SEQ ID NO:43**, and **SEQ ID NO:44**; and
  - (2) the CDR<sub>L1</sub> Domain, CDR<sub>L2</sub> Domain, and CDR<sub>L3</sub> Domain of the Variable Light Chain of LAG-3 mAb 1, and respectively

comprise the amino acid sequences: **SEQ ID NO:46**, **SEQ ID NO:47**, and **SEQ ID NO:48**;

or

- (B) (1) the CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain of the Variable Heavy Chain of hLAG-3 mAb 1 VH1, and respectively comprise the amino acid sequences: **SEQ ID NO:42**, **SEQ ID NO:43**, and **SEQ ID NO:44**; and
- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain of the Variable Light Chain of LAG-3 mAb 1 VL4, and respectively comprise the amino acid sequences: **SEQ ID NO:55**, **SEQ ID NO:47**, and **SEQ ID NO:48**;

or

- (C) (1) the CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain of the Variable Heavy Chain of LAG-3 mAb 6, and respectively comprise the amino acid sequences: **SEQ ID NO:57**, **SEQ ID NO:58**, and **SEQ ID NO:59**; and
- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain of the Variable Light Chain of LAG-3 mAb 6, and respectively comprise the amino acid sequences: **SEQ ID NO:61**, **SEQ ID NO:62**, and **SEQ ID NO:63**;

or

- (D) (1) the CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain of the Variable Heavy Chain of hLAG-3 mAb 6 VH1, and respectively comprise the amino acid sequences: **SEQ ID NO:57**, **SEQ ID NO:58**, and **SEQ ID NO:59**; and
- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain of the Variable Light Chain of LAG-3 mAb 6 and respectively comprise the amino acid sequences: **SEQ ID NO:298**, **SEQ ID NO:62**, and **SEQ ID NO:63**.

Claim 6. The multispecific anti-human PD-1-binding molecule of claim 5, wherein said LAG-3 epitope-binding site comprises:

- (1) the CDR<sub>H</sub>1 Domain, CDR<sub>H</sub>2 Domain, and CDR<sub>H</sub>3 Domain of the Variable Heavy Chain of hLAG-3 mAb 6 VH1, and

respectively comprise the amino acid sequences: **SEQ ID NO:57, SEQ ID NO:58, and SEQ ID NO:59**; and

- (2) the CDR<sub>L</sub>1 Domain, CDR<sub>L</sub>2 Domain, and CDR<sub>L</sub>3 Domain of the Variable Light Chain of hLAG-3 mAb 6 VL1/VL2 and respectively comprise the amino acid sequences: **SEQ ID NO:298, SEQ ID NO:62, and SEQ ID NO:63**.

Claim 7. The multispecific anti-human PD-1-binding molecule of claim 6, wherein said LAG-3 epitope-binding site comprises:

- (1) the Variable Heavy Chain of hLAG-3 mAb 6 VH1 (**SEQ ID NO:294**) and  
(2) the Variable Light Chain of hLAG-3 mAb 6 VL1 (**SEQ ID NO:296**).

Claim 8. The multispecific anti-human PD-1-binding molecule of any one of claims 1-7, wherein said molecule is:

- (A) a diabody, said diabody being a covalently bonded complex that comprises two, three, four or five polypeptide chains; or  
(B) a trivalent binding molecule, said trivalent binding molecule being a covalently bonded complex that comprises three, four or five polypeptide chains, or  
(C) a bispecific antibody.

Claim 9. The multispecific anti-human PD-1-binding molecule of claim 8, wherein said molecule is a diabody and comprises an Albumin-Binding Domain (ABD).

Claim 10. The multispecific anti-human PD-1-binding molecule of any one of claims 1-9, wherein said molecule comprises an Fc Region, and wherein:

- (a) said Fc Region, is of the IgG1, IgG2, IgG3, or IgG4 isotype;  
(b) said molecule additionally comprises a Hinge Domain;  
(c) said Fc Region is an IgG4 Fc Domain and said molecule additionally comprises an IgG4 Hinge Domain that comprises a stabilizing mutation;  
(d) said Fc region comprises one or more amino acid modifications that reduces the affinity of the variant Fc Region for an FcγR; and/or

(e) said Fc region comprises one or more amino acid modifications that enhances the serum half-life of the variant Fc Region.

Claim 11. The multispecific anti-human PD-1-binding molecule of claim 10, wherein:

(A) said one or more modifications that reduce the affinity of the variant Fc Region for an Fc $\gamma$ R, and said modifications comprise the substitution of L234A; L235A; or L234A and L235A, wherein said numbering is that of the EU index as in Kabat; and

(B) said one or more modifications that enhance the serum half-life of the variant Fc Region, and said modifications that enhance the serum half-life of the variant Fc Region comprise the substitution of M252Y; M252Y and S254T; M252Y and T256E; M252Y, S254T and T256E; or K288D and H435K, wherein said numbering is that of the EU index as in Kabat.

Claim 12. The multispecific anti-human PD-1-binding molecule of any one of claims 8, 10 or 11, wherein said molecule is a diabody comprising:

(a) **SEQ ID NO:267**, wherein X<sub>1</sub> is Ala; X<sub>2</sub> is Tyr; X<sub>3</sub> is Thr; X<sub>4</sub> is Glu, and **SEQ ID NO:268**; or

(b) **SEQ ID NO:267**, wherein X<sub>1</sub> is Gly; X<sub>2</sub> is Tyr; X<sub>3</sub> is Thr; X<sub>4</sub> is Glu, and **SEQ ID NO:268**; or

(c) **SEQ ID NO:267**, wherein X<sub>1</sub> is Gly; X<sub>2</sub> is Met; X<sub>3</sub> is Ser; X<sub>4</sub> is Thr, and **SEQ ID NO:268**; or

(d) **SEQ ID NOs:269 and 270**; or

(e) **SEQ ID NOs:271 and 272**; or

(f) **SEQ ID NOs:273, 274, 275, and 276**; or

(g) **SEQ ID NOs:277, 278, 279, and 280**; or

(h) **SEQ ID NOs:281, 282, and 283**; or

(i) **SEQ ID NOs:290 and 291**; or

(j) **SEQ ID NOs:292 and 293**.

Claim 13. The multispecific anti-human PD-1-binding molecule of claim 12, wherein said molecule is a diabody comprising **SEQ ID NOs:290 and 291**.

Claim 14. A composition comprising:

- (A) the multispecific anti-human PD-1-binding molecule of any one of claims 1-13; and
- (B) a pharmaceutically acceptable carrier.

Claim 15. The multispecific anti-human PD-1-binding molecule of any one of claims 1-13, or the composition of claim 14, for use in:

- (A) a method of stimulating a T-cell mediated immune response of a subject in need thereof; or
- (B) the treatment of a disease or condition associated with a suppressed immune system.

Claim 16. The multispecific anti-human PD-1-binding molecule or composition of claim 15, for use according to claim 15, wherein the disease or condition is cancer or an infection, optionally wherein said cancer is selected from the group consisting of: an adrenal gland tumor, an AIDS-associated cancer, an alveolar soft part sarcoma, an astrocytic tumor, bladder cancer, bone cancer, a brain and spinal cord cancer, a metastatic brain tumor, a breast cancer, a carotid body tumors, a cervical cancer, a chondrosarcoma, a chordoma, a chromophobe renal cell carcinoma, a clear cell carcinoma, a colon cancer, a colorectal cancer, a cutaneous benign fibrous histiocytoma, a desmoplastic small round cell tumor, an ependymoma, a Ewing's tumor, an extraskeletal myxoid chondrosarcoma, a fibrogenesis imperfecta ossium, a fibrous dysplasia of the bone, a gallbladder or bile duct cancer, gastric cancer, a gestational trophoblastic disease, a germ cell tumor, a head and neck cancer, hepatocellular carcinoma, an islet cell tumor, a Kaposi's Sarcoma, a kidney cancer, a leukemia, a lipoma/benign lipomatous tumor, a liposarcoma/malignant lipomatous tumor, a liver cancer, a lymphoma, a lung cancer, a medulloblastoma, a melanoma, a meningioma, a multiple endocrine neoplasia, a multiple myeloma, a myelodysplastic syndrome, a neuroblastoma, a neuroendocrine tumors, an ovarian cancer, a pancreatic cancer, a papillary thyroid carcinoma, a parathyroid tumor, a pediatric cancer, a peripheral nerve sheath tumor, a pheochromocytoma, a pituitary tumor, a prostate cancer, a posterior uveal melanoma, a rare hematologic disorder, a renal metastatic cancer, a rhabdoid tumor, a rhabdomyosarcoma, a sarcoma, a skin cancer, a soft-tissue sarcoma, a squamous

cell cancer, a stomach cancer, a synovial sarcoma, a testicular cancer, a thymic carcinoma, a thymoma, a thyroid metastatic cancer, and a uterine cancer, optionally wherein said cancer is colorectal cancer, hepatocellular carcinoma, glioma, kidney cancer, breast cancer, multiple myeloma, bladder cancer, neuroblastoma; sarcoma, non-Hodgkin's lymphoma, non-small cell lung cancer, ovarian cancer, pancreatic cancer, rectal cancer, acute myeloid leukemia (AML), chronic myelogenous leukemia (CML), acute B lymphoblastic leukemia (B-ALL), chronic lymphocytic leukemia (CLL), hairy cell leukemia (HCL), blastic plasmacytoid dendritic cell neoplasm (BPDCN), non-Hodgkin's lymphomas (NHL), including mantel cell leukemia (MCL), and small lymphocytic lymphoma (SLL), Hodgkin's lymphoma, systemic mastocytosis, or Burkitt's lymphoma.

Claim 17. The multispecific anti-human PD-1-binding molecule of any one of claims 1-13, wherein said molecule is for use in an *in vitro* method of detecting PD-1, and wherein said molecule is detectably labeled.

Claim 18. Use of the multispecific anti-human PD-1-binding molecule of any one of claims 1-13 in the *in vitro* detection of PD-1, wherein said molecule is detectably labeled.

Claim 19. Use of the multispecific anti-human PD-1-binding molecule of any one of claims 1-13, or the composition of claim 14, in the manufacture of a medicament for treatment of a cancer or an infection.

Claim 20. The use of claim 19, wherein the cancer is selected from the group consisting of an adrenal gland tumor, an AIDS-associated cancer, an alveolar soft part sarcoma, an astrocytic tumor, bladder cancer, bone cancer, a brain and spinal cord cancer, a metastatic brain tumor, a breast cancer, a carotid body tumors, a cervical cancer, a chondrosarcoma, a chordoma, a chromophobe renal cell carcinoma, a clear cell carcinoma, a colon cancer, a colorectal cancer, a cutaneous benign fibrous histiocytoma, a desmoplastic small round cell tumor, an ependymoma, a Ewing's tumor, an extraskeletal myxoid chondrosarcoma, a

fibrogenesis imperfecta ossium, a fibrous dysplasia of the bone, a gallbladder or bile duct cancer, gastric cancer, a gestational trophoblastic disease, a germ cell tumor, a head and neck cancer, hepatocellular carcinoma, an islet cell tumor, a Kaposi's Sarcoma, a kidney cancer, a leukemia, a lipoma/benign lipomatous tumor, a liposarcoma/malignant lipomatous tumor, a liver cancer, a lymphoma, a lung cancer, a medulloblastoma, a melanoma, a meningioma, a multiple endocrine neoplasia, a multiple myeloma, a myelodysplastic syndrome, a neuroblastoma, a neuroendocrine tumors, an ovarian cancer, a pancreatic cancer, a papillary thyroid carcinoma, a parathyroid tumor, a pediatric cancer, a peripheral nerve sheath tumor, a pheochromocytoma, a pituitary tumor, a prostate cancer, a posterior uveal melanoma, a rare hematologic disorder, a renal metastatic cancer, a rhabdoid tumor, a rhabdomyosarcoma, a sarcoma, a skin cancer, a soft-tissue sarcoma, a squamous cell cancer, a stomach cancer, a synovial sarcoma, a testicular cancer, a thymic carcinoma, a thymoma, a thyroid metastatic cancer, and a uterine cancer, optionally wherein said cancer is colorectal cancer, hepatocellular carcinoma, glioma, kidney cancer, breast cancer, multiple myeloma, bladder cancer, neuroblastoma; sarcoma, non-Hodgkin's lymphoma, non-small cell lung cancer, ovarian cancer, pancreatic cancer, rectal cancer, acute myeloid leukemia (AML), chronic myelogenous leukemia (CML), acute B lymphoblastic leukemia (B-ALL), chronic lymphocytic leukemia (CLL), hairy cell leukemia (HCL), blastic plasmacytoid dendritic cell neoplasm (BPDCN), non-Hodgkin's lymphomas (NHL), including mantle cell leukemia (MCL), and small lymphocytic lymphoma (SLL), Hodgkin's lymphoma, systemic mastocytosis, or Burkitt's lymphoma.