

**Single domain antibody and derivative proteins thereof against
programmed death ligand (PDL1)**

Technical field

5 The present invention relates to the field of medical biology, and discloses
a single domain antibody and derivative proteins thereof against programmed
death ligand (PDL1). In particular, the present invention discloses a
programmed death ligand 1 (PDL1) binding molecule and the use thereof,
especialy the use for treating and/or preventing or diagnosing PDL1 relating
10 diseases such as tumor.

Background

Programmed death 1 (PD-1) is a member of the CD28 family of receptors,
which includes CD28, CTLA-4, ICOS, PD-1, and BTLA. The initial members
15 of the family, CD28 and ICOS, were discovered by functional effect on
augmenting T cell proliferation following the addition of monoclonal antibodies
(Hutloff et al. (1999) Nature 397:263- 266; Hansen et al. (1980) Immunogenics
10:247-260). Two cell surface glycoprotein ligands for PD-1 have been
identified, PDL1 and PD-L2, and have been shown to downregulate T cell
20 activation and cytokine secretion upon binding to PD-1 (Freeman et al (2000) J
Exp Med 192:1027-34; Latchman et al (2001) Nat Immunol 2:261-8; Carter et
al. (2002) Eur J Immunol 32:634-43; Ohigashi et al. (2005) Clin Cancer Res
11:2947-53). Both PDL1 (B7-H1) and PDL2 (B7-DC) are B7 homologs that
bind to PD-1 but do not bind to other CD28 family members (Blank et al.

(2004). Expression of PDL1 on the cell surface has also been shown to be upregulated through IFN- γ stimulation.

PDL1 expression has been found in several murine and human cancers, including human lung, ovarian and colon carcinoma and various myelomas (Iwai et al (2002) PNAS 99:12293-7; Ohigashi et al. (2005), Clin Cancer Res 11:2947-53). Currently available results reveal that PDL1 overexpressed in tumor cells play a key role in tumor immunity escape by increasing apoptosis of T-cells. Researchers found that P815 tumor cell line transfected with PDL1 gene can be resistant to lysis specific by CTL, and has increased oncogenicity and invasive activity. These biological activities can be reversed by blocking PDL1. Tumor cells transplanted into mice with PDL1 knocked out to block PDL1/PD-1 interaction, cannot form tumors (Dong et al. (2002) Nat Med 8:793-800). It has also been suggested that PD- L1 might be involved in intestinal mucosal inflammation and inhibition of PDL1 suppresses wasting disease associated with colitis (Kanai et al.(2003) J Immunol 171:4156-63).

There is still a need in the art for anti-PDL1 antibody which can bind to PDL1 with high affinity and be capable of blocking the binding of PDL1 to PD-1 and, especially a heavy chain single domain antibody against PDL1.

Brief description of the invention

The present inventors have obtained anti-PDL1 heavy chain single domain antibody (VHH) with high specificity, high affinity and high stability by screening with phage display technology.

In a first aspect, the invention provides a PDL1-binding molecule

comprising immunoglobulin single variable domain consisting of an amino acid sequence selected from SEQ ID No:1-6 and a human immunoglobulin Fc region.

In another aspect, the present invention relates to a nucleic acid molecule
5 encoding the PDL1-binding molecule, and an expression vector and host cell containing said nucleic acid molecule.

The present invention further relates to an pharmaceutical composition comprising the PDL1-binding molecule of the invention.

The present invention further relates to a method for producing the
10 PDL1-binding molecule of the invention.

The present invention further relates to use of the PDL1-binding molecule, and pharmaceutical composition of the invention, especially the use and method for preventing and/or treating PDL1 relating diseases.

15 **Description of drawings**

Figure 1. shows the blocking effect of PDL1 heavy chain single domain antibodies to PD1/PDL1 interaction.

Figure 2. shows the binding curves of PDL1 heavy chain single domain antibodies to PDL1 antigen protein.

20 Figure 3. shows the blocking curves of PDL1 heavy chain single domain antibodies to PD1/PDL1 interaction.

Figure 4. shows the sequence alignment of five humanized variants of antibody No.5.

Figure 5. shows the binding curves of PDL1 single domain antibody-Fc

fusion proteins to PDL1(by ELISA).

Figure 6. shows the blocking curves of PDL1 single domain antibody-Fc fusion proteins to to PD1/PDL1 interaction (by competitive ELISA).

Figure 7. shows the blocking curves of PDL1 single domain antibody-Fc fusion proteins to to CD80/PDL1 interaction (by competitive ELISA).

Figure 8. shows the blocking curves of PDL1 single domain antibody-Fc fusion proteins to to PD1/293-PDL1 interaction (by FACS).

Figure 9. shows the blocking curves of PDL1 single domain antibody-Fc fusion proteins to to Jurket-PD1/PDL1 interaction (by FACS).

Figure 10. shows the binding specificity of PDL1 single domain antibody-Fc fusion proteins ot PDL1 protein detected by flow cytometry.

Figure 11. shows the binding of PDL1 single domain antibody-Fc fusion proteins to monkey PDL1 protein detected by flow cytometry.

Figure 12. shows that PDL1 single domain antibody-Fc fusion proteins identify PDL1 positive cell population on the tissue sections from patients.

Figure 13. shows the activation of PBMC by PDL1 single domain antibody-Fc fusion proteins.

Figure 14. shows the activation of CD4+T cells by PDL1 single domain antibody-Fc fusion proteins.

Figure 15. shows that PDL1 single domain antibody-Fc fusion proteins promote the secretion of IL-2.

Figure 16. shows the CDC and ADCC activities of the PDL1 single domain antibody-Fc fusion proteins carrying mutated Fc.

Figure 17. shows the tumor growth curves after treatment with PDL1 single

domain antibody-Fc fusion proteins.

Figure 18. shows the inhibition of tumor growth by administering PDL1 single domain antibody-Fc fusion proteins for various times.

Figure 19. shows the comparison between the tumor growth inhibitory activities of hu56V2-Fc and 2.41. A, A375:PBMC=5:1; B, A375:PBMC=1:1.

Figure 20. shows the influence of alkali and oxidation treatments to the activity of PDL1 single domain antibody-Fc fusion proteins.

Detailed description of the invention

Definitions

Unless indicated or defined otherwise, all terms used have their usual meaning in the art, which will be clear to the skilled person. Reference is for example made to the standard handbooks, such as Sambrook et al, "Molecular Cloning: A Laboratory Manual" (2nd Ed.), Vols. 1-3, Cold Spring Harbor Laboratory Press (1989); Lewin, "Genes IV", Oxford University Press, New York, (1990), and Roitt et al., "Immunology" (2nd Ed.), Gower Medical Publishing, London, New York (1989), as well as to the general background art cited herein. Furthermore, unless indicated otherwise, all methods, steps, techniques and manipulations that are not specifically described in detail can be performed and have been performed in a manner known perse, as will be clear to the skilled person. Reference is for example again made to the standard handbooks, to the general background art referred to above and to the further references cited therein.

Unless indicated otherwise, the exchangeable terms "antibody" and

"immunoglobulin" - whether used herein to refer to a heavy chain antibody or to a conventional 4-chain antibody - are used as general terms to include both the full-size antibody, the individual chains thereof, as well as all parts, domains or fragments thereof (including but not limited to antigen-binding domains or fragments such as VHH domains or VH/VL domains, respectively). In addition, the term "sequence" as used herein (for example in terms like "immunoglobulin sequence", "antibody sequence", "(single) variable domain sequence", "VHH sequence" or "protein sequence"), should generally be understood to include both the relevant amino acid sequence as well as nucleic acid sequences or nucleotide sequences encoding the same, unless the context requires a more limited interpretation.

The term "domain" (of a polypeptide or protein) as used herein refers to a folded protein structure which has the ability to retain its tertiary structure independently of the rest of the protein. Generally, domains are responsible for discrete functional properties of proteins, and in many cases may be added, removed or transferred to other proteins without loss of function of the remainder of the protein and/or of the domain.

The term "immunoglobulin domain" as used herein refers to a globular region of an antibody chain (such as e.g. a chain of a conventional 4-chain antibody or of a heavy chain antibody), or to a polypeptide that essentially consists of such a globular region. Immunoglobulin domains are characterized in that they retain the immunoglobulin fold characteristic of antibody molecules, which consists of a 2-layer sandwich of about 7 antiparallel beta-strands arranged in two beta-sheets, optionally stabilized by a conserved disulphide

bond.

The term "immunoglobulin variable domain" as used herein means an immunoglobulin domain essentially consisting of four "framework regions" which are referred to in the art and hereinbelow as "framework region 1 " or "FR1 "; as "framework region 2" or "FR2"; as "framework region 3" or "FR3";
5 and as "framework region 4" or "FR4", respectively; which framework regions are interrupted by three "complementarity determining regions" or "CDRs", which are referred to in the art and hereinbelow as "complementarity determining region or "CDR1 "; as "complementarity determining region 2" or "CDR2"; and as "complementarity determining region 3" or "CDR3",
10 respectively. Thus, the general structure or sequence of an immunoglobulin variable domain can be indicated as follows: FR1 - CDR1 - FR2 - CDR2 - FR3 - CDR3 - FR4. It is the immunoglobulin variable domain(s) that confer specificity to an antibody for the antigen by carrying the antigen-binding site.

15 The term "immunoglobulin single variable domain" as used herein means an immunoglobulin variable domain which is capable of specifically binding to an epitope of the antigen without pairing with an additional variable immunoglobulin domain. One example of immunoglobulin single variable domains in the meaning of the present invention is "domain antibody", such as
20 the immunoglobulin single variable domains VH and VL (VH domains and VL domains). Another example of immunoglobulin single variable domains is "VHH domain" (or simply "VHH") from camelids, as defined hereinafter.

"VHH domains", also known as heavy chain single domain antibodies, VHHs, V_HH domains, VHH antibody fragments, and VHH antibodies, are the

antigen binding immunoglobulin variable domain of "heavy chain antibodies" (i.e., "antibodies devoid of light chains")(Hamers-Casterman C, Atarhouch T, Muyldermans S, Robinson G, Hamers C, Songa EB, Bendahman N, Hamers R.: "Naturally occurring antibodies devoid of light chains"; Nature 363, 446-448
5 (1993)). The term "VHH domain" has been chosen in order to distinguish these variable domains from the heavy chain variable domains that are present in conventional 4-chain antibodies (which are referred to herein as "VH domains") and from the light chain variable domains that are present in conventional 4-chain antibodies (which are referred to herein as "VL domains"). VHH
10 domains can specifically bind to an epitope without an additional antigen binding domain (as opposed to VH or VL domains in a conventional 4-chain antibody, in which case the epitope is recognized by a VL domain together with a VH domain). VHH domains are small, robust and efficient antigen recognition units formed by a single immunoglobulin domain.

15 In the context of the present invention, the terms heavy chain single domain antibody, VHH domain, VHH, V_HH domain, VHH antibody fragment, VHH antibody, as well as "Nanobody®" and "Nanobody® domain" ("Nanobody" being a trademark of the company Ablynx N.V.; Ghent; Belgium) are used interchangeably.

20 The amino acid residues of VHH domains from Camelids are numbered according to the general numbering for VH domains given by Kabat et al. ("Sequence of proteins of immunological interest", US Public Health Services, NIH Bethesda, MD, Publication No. 91), as shown e.g. in Figure 2 of Riechmann and Muyldermans, J. Immunol. Methods 231, 25-38 (1999).

According to this numbering,

- FR1 comprises the amino acid residues at positions 1-30,
- CDR1 comprises the amino acid residues at positions 31-35,
- FR2 comprises the amino acids at positions 36-49,
- 5 - CDR2 comprises the amino acid residues at positions 50-65,
- FR3 comprises the amino acid residues at positions 66-94,
- CDR3 comprises the amino acid residues at positions 95-102, and
- FR4 comprises the amino acid residues at positions 103-113.

However, it should be noted that - as is well known in the art for VH
10 domains and for VHH domains - the total number of amino acid residues in each
of the CDRs may vary and may not correspond to the total number of amino
acid residues indicated by the Kabat numbering (that is, one or more positions
according to the Kabat numbering may not be occupied in the actual sequence,
or the actual sequence may contain more amino acid residues than the number
15 allowed for by the Kabat numbering). This means that, generally, the numbering
according to Kabat may or may not correspond to the actual numbering of the
amino acid residues in the actual sequence.

Alternative methods for numbering the amino acid residues of VH
domains, which methods can also be applied in an analogous manner to VHH
20 domains, are known in the art. However, in the present description, claims and
figures, the numbering according to Kabat and applied to VHH domains as
described above will be followed, unless indicated otherwise.

The total number of amino acid residues in a VHH domain will usually be
in the range of from 110 to 120, often between 112 and 115. It should however

be noted that smaller and longer sequences may also be suitable for the purposes described herein.

Further structural characteristics and functional properties of VHH domains and polypeptides containing the same can be summarized as follows:

5 VHH domains (which have been "designed" by nature to functionally bind to an antigen without the presence of, and without any interaction with, a light chain variable domain) can function as a single, relatively small, functional antigen-binding structural unit, domain or polypeptide. This distinguishes the VHH domains from the VH and VL domains of conventional 4-chain
10 antibodies, which by themselves are generally not suitable for practical application as single antigen-binding proteins or immunoglobulin single variable domains, but need to be combined in some form or another to provide a functional antigen-binding unit (as in for example conventional antibody fragments such as Fab fragments; in scFvs, which consist of a VH domain
15 covalently linked to a VL domain).

Because of these unique properties, the use of VHH domains - either alone or as part of a larger polypeptide - offers a number of significant advantages over the use of conventional VH and VL domains, scFvs or conventional antibody fragments (such as Fab- or F(ab')₂-fragments):

20 - only a single domain is required to bind an antigen with high affinity and with high selectivity, so that there is no need to have two separate domains present, nor to assure that these two domains are present in the right spacial conformation and configuration (i.e. through the use of especially designed linkers, as with scFvs);

- VHH domains can be expressed from a single gene and require no post-translational folding or modifications;
- VHH domains can easily be engineered into multivalent and multispecific formats (formatted);
- 5 - VHH domains are highly soluble and do not have a tendency to aggregate;
- VHH domains are highly stable to heat, pH, proteases and other denaturing agents or conditions and, thus, may be prepared, stored or transported without the use of refrigeration equipments, conveying a cost, time and environmental savings;
- 10 - VHH domains are easy and relatively cheap to prepare, even on a scale required for production;
- VHH domains are relatively small (approximately 15 kDa, or 10 times smaller than a conventional IgG) compared to conventional 4-chain antibodies and antigen-binding fragments thereof, and therefore show high(er) penetration
- 15 into tissues and can be administered in higher doses than such conventional 4-chain antibodies and antigen-binding fragments thereof;
- VHH domains can show so-called cavity-binding properties (especially due to their extended CDR3 loop, compared to conventional VH domains) and can therefore also access targets and epitopes not accessible to conventional 4-chain
- 20 antibodies and antigen-binding fragments thereof.

Methods of obtaining VHH domains binding to a specific antigen or epitope have been described earlier, e.g. in WO2006/040153 and WO2006/122786; R. van der Linden et al., Journal of Immunological Methods, 240 (2000) 185-195; Li et al., J Biol Chem., 287 (2012) 13713-13721; Deffar et

al., African Journal of Biotechnology Vol. 8 (12), pp. 2645-2652, 17 June, 2009 and WO94/04678.

VHH domains derived from camelids can be "humanized" by replacing one or more amino acid residues in the amino acid sequence of the original VHH sequence by one or more of the amino acid residues that occur at the corresponding position(s) in a VH domain from a conventional 4-chain antibody from a human being. A humanized VHH domain can contain one or more fully human framework region sequences, and in a specific embodiment, containing IGHV3 human framework region sequence.

Generally, the term "specificity" refers to the number of different types of antigens or epitopes to which a particular antigen-binding molecule or antigen-binding protein (such as an immunoglobulin single variable domain of the invention) molecule can bind. The specificity of an antigen-binding molecule can be determined based on its affinity and/or avidity. The affinity, represented by the equilibrium constant for the dissociation of an antigen with an antigen-binding protein (KD), is a measure for the binding strength between an epitope and an antigen-binding site on the antigen-binding protein: the lesser the value of the KD, the stronger the binding strength between an epitope and the antigen-binding molecule (alternatively, the affinity can also be expressed as the affinity constant (KA), which is 1/KD). As will be clear to the skilled person, affinity can be determined in a manner known per se, depending on the specific antigen of interest. Avidity is the measure of the strength of binding between an antigen-binding molecule (such as an immunoglobulin, an antibody, an immunoglobulin single variable domain or a polypeptides containing it) and the

pertinent antigen. Avidity is related to both the affinity between an epitope and its antigen binding site on the antigen-binding molecule and the number of pertinent binding sites present on the antigen-binding molecule.

Typically, specific binding molecules will bind to PDL1 with a
5 dissociation constant (KD) of 10^{-7} to 10^{-11} moles/liter (M), and preferably
 10^{-8} to 10^{-11} moles/liter, more preferably 10^{-9} to 10^{-11} moles/liter, and even
more preferably 10^{-10} to 10^{-11} moles/liter or less (as measured in a Biacore or
in a KinExA assay), and/or with an association constant (KA) of at least 10^7
 M^{-1} , preferably at least $10^8 M^{-1}$, more preferably at least $10^9 M^{-1}$, more
10 preferably at least $10^{10} M^{-1}$, such as at least $10^{10} M^{-1}$. Any KD value greater
than $10^{-4} M$ is generally considered to indicate non-specific binding.
Specific binding of an antigen-binding protein to an antigen or epitope can
be determined in any suitable manner known per se, including, for example,
the assays described herein, Scatchard analysis and/or competitive binding
15 assays, such as radioimmunoassays (RIA), enzyme immunoassays (EIA)
and sandwich competition assays.

Amino acid residues will be indicated according to the standard
three-letter or one-letter amino acid code, as generally known and agreed
upon in the art. When comparing two amino acid sequences, the term
20 "amino acid difference" refers to insertions, deletions or substitutions of the
indicated number of amino acid residues at a position of the reference
sequence, compared to a second sequence. In case of substitution(s), such
substitution(s) will preferably be conservative amino acid substitution(s),
which means that an amino acid residue is replaced with another amino acid

residue of similar chemical structure and which has little or essentially no influence on the function, activity or other biological properties of the polypeptide. Such conservative amino acid substitutions are well known in the art, wherein conservative amino acid substitutions preferably are substitutions in which one amino acid within the following groups (i) - (v) is substituted by another amino acid residue within the same group: (i) small aliphatic, nonpolar or slightly polar residues: Ala, Ser, Thr, Pro and Gly; (ii) polar, negatively charged residues and their (uncharged) amides: Asp, Asn, Glu and Gln; (iii) polar, positively charged residues: His, Arg and Lys; (iv) large aliphatic, nonpolar residues: Met, Leu, Ile, Val and Cys; and (v) aromatic residues: Phe, Tyr and Trp. Particularly preferred conservative amino acid substitutions are as follows: Ala into Gly or into Ser; Arg into Lys; Asn into Gln or into His; Asp into Glu; Cys into Ser; Gln into Asn; Glu into Asp; Gly into Ala or into Pro; His into Asn or into Gln; Ile into Leu or into Val; Leu into Ile or into Val; Lys into Arg, into Gln or into Glu; Met into Leu, into Tyr or into Ile; Phe into Met, into Leu or into Tyr; Ser into Thr; Thr into Ser; Trp into Tyr; Tyr into Trp or into Phe; Val into Ile or into Leu.

A polypeptide or nucleic acid molecule is considered to be "essentially isolated" - for example, when compared to its native biological source and/or the reaction medium or cultivation medium from which it has been obtained - when it has been separated from at least one other component with which it is usually associated in said source or medium, such as another protein/polypeptide, another nucleic acid, another biological

component or macromolecule or at least one contaminant, impurity or minor component. In particular, a polypeptide or nucleic acid molecule is considered "essentially isolated" when it has been purified at least 2-fold, in particular at least 10- fold, more in particular at least 100-fold, and up to 5 1000-fold or more. A polypeptide or nucleic acid molecule that is "in essentially isolated form" is preferably essentially homogeneous, as determined using a suitable technique, such as a suitable chromatographical technique, such as polyacrylamide gel electrophoresis.

10 As used herein, the term "subject" refers to mammalian, especially primate, in particular human.

PDL1 binding molecule of the invention

In a first aspect, the invention provides an programmed death ligand 15 1(PDL1)-binding molecule, which can specifically bind to PDL1 and consists of an amino acid sequence of A-L-B, wherein A represents an immunoglobulin single variable domain, L is absent or represents an amino acid linker, and B represents an human immunoglobulin Fc region,

wherein the immunoglobulin single variable domain consisting of an amino 20 acid sequence selected from SEQ ID NO:1-6,

said PDL1-binding molecule is capable of forming homodimers via said human immunoglobulin Fc region.

As used herein, "human immunoglobulin Fc region" refers to an Fc region from constant region of human IgG1, IgG2, IgG3 or IgG4 (amino acid

sequences of the constant regions refer to Items P01857, P01859, P01860, P01861 in www.uniprot.org protein database), which comprises a Hinge region or part of the hinge region, CH2 region, and CH3 region of immunoglobulin constant region. In the present invention, ADCC or CDC activity may be increased or removed, or the affinity of FcRn may be increased or decreased, by
5 mutating 1-5 amino acids in CH2 region of the amino acid sequence of the “human immunoglobulin Fc region”; or protein stability can be increased by mutating 1-4 amino acids in the hinge region. However, in the present invention, “human immunoglobulin Fc region” does not include any mutation that
10 promotes or prevents the formation of Fc heterodimers, nor any modification of adding other functional protein sequence to N-terminal or C-terminal to the Fc fragment.

In a preferred embodiment, said immunoglobulin Fc region is mutated to remove ADCC and CDC activities. In a specific embodiment, the sequence of
15 said immunoglobulin Fc region is selected from SEQ ID NOs:7-9.

A person skilled in the art will understand that PDL1-binding molecule of the present invention will generally present in the form of homodimers due to the human immunoglobulin Fc region.

As used herein, the term “linker” means a non-functional amino acid
20 sequence of 1-20 amino acid residues in length, without secondary or higher structures. For example, said linker is a flexible linker, such as GGGS, GS, GAP and the like.

In some embodiments, the PDL1-binding molecule of the invention consists of an amino acid sequence selected from SEQ ID NOs:10-27.

The PDL1-binding molecule of the invention has at least one of the following features:

- (a) binding to human PDL1 with a KD of less than 1×10^{-7} M;
- (b) blocking the interaction between PDL1 and PD-1;
- 5 (c) enhancing activation of PBMC and/or T cells;
- (d) inhibiting tumor growth.

The PDL1-binding molecule of the invention may bind to PDL1 with a KD of less than 1×10^{-7} M, preferably less than 1×10^{-8} M, more preferably less than 1×10^{-9} M, more preferably less than 1×10^{-10} M, and even more preferably less
10 than 1×10^{-11} M.

In some embodiments, the PDL1-binding molecule of the invention can specifically bind to human PDL1 and block the interaction between PDL1 and PD-1. In some embodiments, the PDL1-binding molecule of the invention can specifically bind to human PDL1 and block the interaction between PDL1 and
15 CD80.

The PDL1-binding molecule of the invention can inhibit tumor growth by at least about 10%, preferably at least about 20%, more preferably at least about 30%, more preferably at least about 40%, more preferably at least about 50%, more preferably at least about 60%, more preferably at least about 70%, and
20 more preferably at least about 80%.

Furthermore, the PDL1-binding molecule of the invention is resistant to alkali treatment and oxidation treatment. For example, the PDL1-binding molecule of the invention maintains its activity after treatment with strong base (such as 500mM ammonium bicarbonate) for about 8 hours, preferably about 16

hours, more preferably about 24 hours or more preferably about 32 hours. Alternatively, the PDL1-binding molecule of the invention maintains its activity after treatment with oxidant (1% hydrogen peroxide) for about 2 hours, preferably about 4 hours, or more preferably about 8 hours.

5 In addition, the PDL1-binding molecule of the invention is stable at high concentration. For example, the PDL1-binding molecule of the invention keeps stable at a concentration of about 100mg/ml, more preferably about 150mg/ml, more preferably about 200mg/ml or more preferably about 250mg/ml without forming aggregates.

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Nucleic acid, vector and host cell

In another aspect, the invention relates to nucleic acid molecule that encodes the PDL1-binding molecules of the invention. A nucleic acid of the invention may be RNA, DNA or cDNA. According to one embodiment of
15 the invention, the nucleic acid of the invention is in essentially isolated form.

The nucleic acid of the invention may also be in the form of, may be present in and/or may be part of a vector, such as for example a plasmid, cosmid or YAC. The vector may especially be an expression vector, i.e. a
20 vector that can provide for expression of the PDL1-binding molecule in vitro and/or in vivo (i.e. in a suitable host cell, host organism and/or expression system). Such expression vector generally comprises at least one nucleic acid of the invention that is operably linked to one or more suitable regulatory elements, such as promoter(s), enhancer(s), terminator(s), and

the like. Such elements and their selection in view of expression of a specific sequence in a specific host are common knowledge of the skilled person. Specific examples of regulatory elements and other elements useful or necessary for expressing PDL1-binding molecules of the invention
5 include such as promoters, enhancers, terminators, integration factors, selection markers, leader sequences, reporter genes, and the like.

The nucleic acids of the invention may be prepared or obtained in a manner known per se (e.g. by automated DNA synthesis and/or recombinant DNA technology), based on the information on the amino acid sequences
10 for the polypeptides of the invention given herein, and/or can be isolated from a suitable natural source.

In another aspect, the invention relates to host cells that express or that are capable of expressing one or more PDL1-binding molecule of the invention; and/or that contain a nucleic acid of the invention. According to
15 a particularly preferred embodiment, said host cells are bacterial cells; other useful cells are yeast cells, fungal cells or mammalian cells.

Suitable bacterial cells include cells from gram-negative bacterial strains such as strains of *Escherichia coli*, *Proteus*, and *Pseudomonas*, and gram-positive bacterial strains such as strains of *Bacillus*, *Streptomyces*,
20 *Staphylococcus*, and *Lactococcus*. Suitable fungal cell include cells from species of *Trichoderma*, *Neurospora*, and *Aspergillus*.

Suitable fungal cell include cells from species of *Trichoderma*, *Neurospora*, and *Aspergillus*. Suitable yeast cells include cells from species of *Saccharomyces* (for example, *Saccharomyces cerevisiae*),

Schizosaccharomyces (for example, Schizosaccharomyces pombe), Pichia (for example, Pichia pastoris and Pichia methanolica), and Hansenula.

Suitable mammalian cells include for example HEK293 cells, CHO cells, BHK cells, HeLa cells, COS cells, and the like.

5 However, amphibian cells, insect cells, plant cells, and any other cells used in the art for the expression of heterologous proteins can be used as well.

The invention further provides methods of manufacturing a PDL1-binding molecule of the invention, such methods generally comprise
10 the steps of:

- culturing host cells of the invention under conditions that allow expression of the PDL1-binding molecule of the invention; and
- recovering the PDL1-binding molecule expressed by the host cells from the culture; and
- 15 - optionally further purifying and/or modifying the PDL1-binding molecule of the invention.

In a preferred embodiment, the PDL1-binding molecule of the invention is produced by using mammalian cells. The PDL1-binding molecule of the invention can achieve high expression in mammalian cells.
20 For example, the expression level can be up to about 5 g/L, preferably about 6 g/L, preferably about 7 g/L, preferably about 8 g/L, preferably about 9 g/L, preferably about 10 g/L or higher.

PDL1-binding molecules of the invention may be produced in a cell as set out above either intracellularly (e.g. in the cytosol, in the periplasma or

in inclusion bodies) and then isolated from the host cells and optionally further purified; or they can be produced extracellularly (e.g. in the medium in which the host cells are cultured) and then isolated from the culture medium and optionally further purified.

5 Methods and reagents used for the recombinant production of polypeptides, such as specific suitable expression vectors, transformation or transfection methods, selection markers, methods of induction of protein expression, culture conditions, and the like, are known in the art. Similarly, protein isolation and purification techniques useful in a method of
10 manufacture of a PDL1-binding molecule of the invention are well known to the skilled person.

However, the PDL1-binding molecules of the invention can also be obtained by other methods for production of proteins known in the art, such as, chemical synthesis, including solid phase or liquid phase synthesis.

15

Pharmaceutical Compositions

In another aspect, the present invention provides a composition, e.g., a pharmaceutical composition, containing one or a combination of
20 PDL1-binding molecule of the present invention, formulated together with a pharmaceutically acceptable carrier. Such compositions may include one or a combination of (e.g., two or more different) PDL1-binding molecules of the invention. A person skilled in the art will understand that PDL1-binding molecule of the present invention will generally present in the form of

homodimer due to the human immunoglobulin Fc region.

Pharmaceutical compositions of the invention also can be administered in combination therapy, i.e., combined with other agents. For example, the combination therapy can include a PDL1-binding molecule of the present invention combined with at least one other anti-tumor agent. For example, PDL1-binding molecule of the invention may be administered in combination with antibodies targeting other tumor-specific antigens. Said antibodies targeting other tumor-specific antigens include, but are not limited to anti-EGFR antibody, anti-EGFR variant antibody, anti-VEGFA antibody, anti-HER2 antibody, or anti-CMET antibody. Preferably, said antibodies are monoclonal.

As used herein, "pharmaceutically acceptable carrier" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like that are physiologically compatible. Preferably, the carrier is suitable for intravenous, intramuscular, subcutaneous, parenteral, spinal or epidermal administration (e.g., by injection or infusion). Depending on the route of administration, the active compound, i.e., antibody, or immunoconjugate, may be coated in a material to protect the compound from the action of acids and other natural conditions that may inactivate the compound.

The pharmaceutical compounds of the invention may include one or more pharmaceutically acceptable salts. A "pharmaceutically acceptable salt" refers to a salt that retains the desired biological activity of the parent compound and does not impart any undesired toxicological effects (see e.g.,

Berge, S.M., et al. (1977) J. Pharm. Sci. 66:1-19). Examples of such salts include acid addition salts and base addition salts. Acid addition salts include those derived from nontoxic inorganic acids, such as hydrochloric, nitric, phosphoric, sulfuric, hydrobromic, hydroiodic, phosphorous and the like, as well as from nontoxic organic acids such as aliphatic mono- and dicarboxylic acids, phenyl-substituted alkanolic acids, hydroxy alkanolic acids, aromatic acids, aliphatic and aromatic sulfonic acids and the like. Base addition salts include those derived from alkaline earth metals, such as sodium, potassium, magnesium, calcium and the like, as well as from nontoxic organic amines, such as N,N'-dibenzylethylenediamine, N-methylglucamine, chlorprocaine, choline, diethanolamine, ethylenediamine, procaine and the like.

A pharmaceutical composition of the invention also may include a pharmaceutically acceptable anti-oxidant. Examples of pharmaceutically acceptable antioxidants include: (1) water soluble antioxidants, such as ascorbic acid, cysteine hydrochloride, sodium bisulfate, sodium metabisulfite, sodium sulfite and the like; (2) oil- soluble antioxidants, such as ascorbyl palmitate, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), lecithin, propyl gallate, alpha-tocopherol, and the like; and (3) metal chelating agents, such as citric acid, ethylenediamine tetraacetic acid (EDTA), sorbitol, tartaric acid, phosphoric acid, and the like.

These compositions may also contain adjuvants such as preservatives, wetting agents, emulsifying agents and dispersing agents.

Prevention of presence of microorganisms may be ensured both by sterilization procedures, supra, and by the inclusion of various antibacterial and antifungal agents, for example, paraben, chlorobutanol, phenol sorbic acid, and the like. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like into the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption such as aluminum monostearate and gelatin.

Pharmaceutically acceptable carriers include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion. The use of such media and agents for pharmaceutically active substances is known in the art. Except insofar as any conventional media or agent is incompatible with the active compound, use thereof in the pharmaceutical compositions of the invention is contemplated. Supplementary active compounds can also be incorporated into the compositions.

Therapeutic compositions typically must be sterile and stable under the conditions of manufacture and storage. The composition can be formulated as a solution, microemulsion, liposome, or other ordered structure suitable to high drug concentration. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol, and liquid polyethylene glycol, and the like), and suitable mixtures thereof. The proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the

required particle size in the case of dispersion and by the use of surfactants.

Sterile injectable solutions can be prepared by incorporating the active compound in the required amount in an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by
5 sterilization microfiltration. Generally, dispersions are prepared by incorporating the active compound into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum
10 drying and freeze-drying (lyophilization) that yield a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will vary depending upon the
15 subject being treated, and the particular mode of administration. The amount of active ingredient which can be combined with a carrier material to produce a single dosage form will generally be that amount of the composition which produces a therapeutic effect. Generally, out of one hundred percent, this amount will range from about 0.01 percent to about
20 ninety-nine percent of active ingredient, preferably from about 0.1 per cent to about 70 per cent, most preferably from about 1 percent to about 30 percent of active ingredient in combination with a pharmaceutically acceptable carrier.

Dosage regimens are adjusted to provide the optimum desired response

(e.g., a therapeutic response). For example, a single bolus may be administered, several divided doses may be administered over time or the dose may be proportionally reduced or increased as indicated by the exigencies of the therapeutic situation. It is especially advantageous to
5 formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the subjects to be treated; each unit contains a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association
10 with the required pharmaceutical carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on (a) the unique characteristics of the active compound and the particular therapeutic effect to be achieved, and (b) the limitations inherent in the art of compounding such an active compound for the treatment of sensitivity in
15 individuals.

For administration of the antibody molecule, the dosage ranges from about 0.0001 to 100 mg/kg, and more usually 0.01 to 5 mg/kg, of the subject body weight. For example dosages can be 0.3 mg/kg body weight, 1 mg/kg body weight, 3 mg/kg body weight, 5 mg/kg body weight, 10 mg/kg
20 body weight or 20 mg/kg body weight or within the range of 1-20 mg/kg. An exemplary treatment regime entails administration once per week, once every two weeks, once every three weeks, once every four weeks, once a month, once every 3 months or once every three to 6 months, or with a short administration interval at the beginning (such as once per week to once

every three weeks), and then an extended interval later (such as once a month to once every three to 6 months).

Alternatively, antibody can be administered as a sustained release formulation, in which case less frequent administration is required. Dosage and frequency vary depending on the half-life of the antibody in the patient. In general, human antibodies show the longest half life, followed by humanized antibodies, chimeric antibodies, and nonhuman antibodies. The dosage and frequency of administration can vary depending on whether the treatment is prophylactic or therapeutic. In prophylactic applications, a relatively low dosage is administered at relatively infrequent intervals over a long period of time. Some patients continue to receive treatment for the rest of their lives. In therapeutic applications, a relatively high dosage at relatively short intervals is sometimes required until progression of the disease is reduced or terminated, and preferably until the patient shows partial or complete amelioration of symptoms of disease. Thereafter, the patient can be administered a prophylactic regime.

Actual dosage levels of the active ingredients in the pharmaceutical compositions of the present invention may be varied so as to obtain an amount of the active ingredient which is effective to achieve the desired therapeutic response for a particular patient, composition, and mode of administration, without being toxic to the patient. The selected dosage level will depend upon a variety of pharmacokinetic factors including the activity of the particular compositions of the present invention employed, or the ester, salt or amide thereof, the route of administration, the time of

administration, the rate of excretion of the particular compound being employed, the duration of the treatment, other drugs, compounds and/or materials used in combination with the particular compositions employed, the age, sex, weight, condition, general health and prior medical history of the patient being treated, and like factors well known in the medical arts.

A "therapeutically effective amount" of a PDL1-binding molecule of the invention preferably results in a decrease in severity of disease symptoms, an increase in frequency and duration of disease symptom-free periods, or a prevention of impairment or disability due to the disease affliction. For example, for the treatment of PDL1 relating tumors, a "therapeutically effective amount " preferably inhibits cell growth or tumor growth by at least about 10%, at least about 20%, more preferably by at least about 40%, even more preferably by at least about 60%, and still more preferably by at least about 80% relative to untreated subjects. The ability to inhibit tumor growth can be evaluated in an animal model system predictive of efficacy in human tumors. Alternatively, this property of a composition can be evaluated by examining the ability of the compound to inhibit cell growth; such inhibition can be determined in vitro by assays known to the skilled practitioner. A therapeutically effective amount of a therapeutic compound can decrease tumor size, or otherwise ameliorate symptoms in a subject. One of ordinary skill in the art would be able to determine such amounts based on such factors as the subject's size, the severity of the subject's symptoms, and the particular composition or route of administration selected.

A composition of the present invention can be administered via one or more routes of administration using one or more of a variety of methods known in the art. As will be appreciated by the skilled artisan, the route and/or mode of administration will vary depending upon the desired results.

5 Preferred routes of administration for PDL1-binding molecules of the invention include intravenous, intramuscular, intradermal, intraperitoneal, subcutaneous, spinal or other parenteral routes of administration, for example by injection or infusion. The phrase "parenteral administration" as used herein means modes of administration other than enteral and topical
10 administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion.

15 Alternatively, a PDL1-binding molecule of the invention can be administered via a non-parenteral route, such as a topical, epidermal or mucosal route of administration, for example, intranasally, orally, vaginally, rectally, sublingually or topically.

The active compounds can be prepared with carriers that will protect
20 the compound against rapid release, such as a controlled release formulation, including implants, transdermal patches, and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Many

methods for the preparation of such formulations are patented or generally known to those skilled in the art. See, e.g., Sustained and Controlled Release Drug Delivery Systems, J.R. Robinson, ed., Marcel Dekker, Inc., New York, 1978.

5 Therapeutic compositions can be administered with medical devices known in the art. For example, in a preferred embodiment, a therapeutic composition of the invention can be administered with a needleless hypodermic injection device, such as the devices disclosed in U.S. Patent Nos. 5,399,163; 5,383,851; 5,312,335; 5,064,413; 4,941,880; 4,790,824; or
10 4,596,556. Examples of well-known implants and modules useful in the present invention include: U.S. Patent No. 4,487,603, which discloses an implantable micro-infusion pump for dispensing medication at a controlled rate; U.S. Patent No. 4,486, 194, which discloses a therapeutic device for administering medicants through the skin; U.S. Patent No. 4,447,233, which
15 discloses a medication infusion pump for delivering medication at a precise infusion rate; U.S. Patent No. 4,447,224, which discloses a variable flow implantable infusion apparatus for continuous drug delivery; U.S. Patent No. 4,439,196, which discloses an osmotic drug delivery system having multi-chamber compartments; and U.S. Patent No. 4,475,196, which
20 discloses an osmotic drug delivery system. These patents are incorporated herein by reference. Many other such implants, delivery systems, and modules are known to those skilled in the art.

In certain embodiments, the PDL1-binding molecules of the invention can be formulated to ensure proper distribution in vivo. For example, the

blood-brain barrier (BBB) excludes many highly hydrophilic compounds. To ensure that the therapeutic compounds of the invention cross the BBB (if desired), they can be formulated, for example, in liposomes. For methods of manufacturing liposomes, see, e.g., U.S. Patents 4,522,811; 5,374,548; and 5,399,331. The liposomes may comprise one or more moieties which are selectively transported into specific cells or organs, thus enhance targeted drug delivery (see, e.g., V. V. Ranade (1989) J. Clin. Pharmacol. 29:685). Exemplary targeting moieties include folate or biotin (see, e.g., U.S. Patent 5,416,016 to Low et al); mannosides (Umezawa et al., (1988) Biochem. Biophys. Res. Commun. 153:1038); antibodies (P.G. Bloeman et al. (1995) FEBS Lett. 357:140; M. Owais et al. (1995) Antimicrob. Agents Chemother. 39:180); surfactant protein A receptor (Briscoe et al. (1995) Am. J. Physiol. 1233: 134); p120 (Schreier et al. (1994) J Biol. Chem. 269:9090); see also K. Keinanen; M.L. Laukkanen (1994) FEBS Lett. 346:123; Jj. Killion; LJ. Fidler (1994) Immunomethods 4:273.

Preventing and treating of diseases

In another aspect, the present invention provides the use of the PDL1 binding molecule, nucleic acid, host cell, and pharmaceutical composition of the invention for preventing and/or treating PDL1 relating diseases, as well as the corresponding methods. PDL1 relating diseases that can be prevented and/or treated with the PDL1 binding molecule of the invention are described in detailed as follows.

Cancer

Blocking PDL1 by PDL1-binding molecule of the invention can enhance the immune response to cancerous cells in the patient. PDL1 is not expressed in normal human cells, but is abundant in a variety of human
5 cancers (Dong et al. (2002) Nat Med 8:787-9). The interaction between PD-1 and PDL1 results in a decrease in tumor infiltrating lymphocytes, a decrease in T-cell receptor mediated proliferation, and immune evasion by the cancerous cells (Dong et al. (2003) JMoI Med 81:281-7; Blank et al. (2004) Cancer Immunol. Immunother. [epub]; Konishi et al. (2004) Clin.
10 Cancer Res.10:5094-100). Immune suppression can be reversed by inhibiting the local interaction of PDL1 to PD-1 and the effect is additive when the interaction of PD-L2 to PD-1 is blocked as well (Iwai et al. (2002) PNAS 99:12293-7; Brown et al. (2003) J. Immunol. JTO: 1257-66). A PDL1-binding molecule of the invention may be used alone to inhibit the
15 growth of cancerous tumors. Alternatively, a PDL1-binding molecule of the invention may be used in conjunction with other immunogenic agents, standard cancer treatments, or other antibodies, as described below.

Accordingly, in one embodiment, the invention provides a method of preventing or treating cancer in a subject, comprising administering to the
20 subject a therapeutically effective amount of PDL1-binding molecule of the invention so as to inhibit growth of tumor cells in the subject.

Preferred cancers whose growth may be inhibited using the antibodies of the invention include cancers typically responsive to immunotherapy. Non-limiting examples of preferred cancers for treatment include lung

cancer, ovarian cancer, colon cancer, rectal cancer, melanoma(e.g., metastatic malignant melanoma), renal cancer, bladder cancer, breast cancer, liver cancer, lymphoma, hematological malignancy, head and neck cancer, glioma, gastric cancer, nasopharyngeal cancer, laryngeal cancer, cervical cancer, corpus carcinoma, osteosarcoma. Examples of other cancers that may be treated using the methods of the invention include bone cancer, pancreatic cancer, prostatic cancer, skin cancer, cancer of the head or neck, cutaneous or intraocular malignant melanoma, uterine cancer, cancer of the anal region, testicular cancer, carcinoma of the fallopian tubes, carcinoma of the endometrium, carcinoma of the cervix, carcinoma of the vagina, carcinoma of the vulva, Hodgkin's Disease, non-Hodgkin's lymphoma, cancer of the esophagus, cancer of the small intestine, cancer of the endocrine system, cancer of the thyroid gland, cancer of the parathyroid gland, cancer of the adrenal gland, sarcoma of soft tissue, cancer of the urethra, cancer of the penis, chronic or acute leukemias including acute myeloid leukemia, chronic myeloid leukemia, acute lymphoblastic leukemia, chronic lymphocytic leukemia, solid tumors of childhood, lymphocytic lymphoma, cancer of the bladder, cancer of the kidney or ureter, carcinoma of the renal pelvis, neoplasm of the central nervous system (CNS), primary CNS lymphoma, tumor angiogenesis, spinal axis tumor, brain stem glioma, pituitary adenoma, Kaposi's sarcoma, epidermoid cancer, squamous cell cancer, T-cell lymphoma, environmentally induced cancers including those induced by asbestos, and combinations of said cancers. The present invention is also useful for treatment of metastatic

cancers, especially metastatic cancers that express PDL1 (Iwai et al. (2005) Int. Immunol.17:133-144).

Optionally, PDL1-binding molecule of the invention can be combined with an immunogenic agent, such as cancerous cells, purified tumor antigens (including recombinant proteins, peptides, and carbohydrate molecules), cells, and cells transfected with genes encoding immune stimulating cytokines (He et al (2004) J. Immunol.173:4919-28). Non-limiting examples of tumor vaccines that can be used include peptides of melanoma antigens, such as peptides of gp100, MAGE antigens, Trp-2, MART1 and/or tyrosinase, or tumor cells transfected to express the cytokine GM-CSF.

In humans, some tumors have been shown to be immunogenic such as melanomas. It is anticipated that by raising the threshold of T cell activation by PDL1 blockade with PDL1-binding molecule of the invention, it is possible to activate tumor responses in the host. PDL1 blockade (such as PDL1 antibody, e.g., the PDL1-binding molecule of the invention) is likely to be most effective when combined with a vaccination protocol. Many experimental strategies for vaccination against tumors have been devised (see Rosenberg, S., 2000, Development of Cancer Vaccines, ASCO Educational Book Spring: 60-62; Logothetis, C, 2000, ASCO Educational Book Spring: 300-302; Khayat, D. 2000, ASCO Educational Book Spring: 414-428; Foon, K. 2000, ASCO Educational Book Spring: 730-738; see also Restifo, N. and Sznol, M., Cancer Vaccines, Ch. 61, pp. 3023-3043 in DeVita, V. et al. (eds.), 1997, Cancer: Principles and Practice of Oncology.

Fifth Edition). In one of these strategies, a vaccine is prepared using autologous or allogeneic tumor cells. These cellular vaccines have been shown to be most effective when the tumor cells are transduced to express GM-CSF. GM-CSF has been shown to be a potent activator of antigen presentation for tumor vaccination (Dranoff et al. (1993) Proc. Natl. Acad. Sd U.S.A. 90: 3539-43).

The study of gene expression and large scale gene expression patterns in various tumors has led to the definition of so-called tumor specific antigens (Rosenberg, SA (1999) Immunity 10: 281-7). In many cases, these tumor specific antigens are differentiation antigens expressed in the tumors and in the cell from which the tumor arose, for example melanocyte antigens gp100, MAGE antigens, and Trp-2. More importantly, many of these antigens can be shown to be the targets of tumor specific T cells found in the host. PDL1-binding molecule of the invention may be used in conjunction with a collection of recombinant proteins and/or peptides expressed in a tumor in order to generate an immune response to these proteins. These proteins are normally viewed by the immune system as self antigens and are therefore tolerant to them. The tumor antigen may also include the protein telomerase, which is required for the synthesis of telomeres of chromosomes and which is expressed in more than 85% of human cancers and in only a limited number of somatic tissues (Kim, N et al. (1994) Science 266: 2011-2013). Tumor antigen may also be "neo-antigens" expressed in cancer cells because of somatic mutations that alter protein sequence or create fusion proteins between two unrelated

sequences (i.e. bcr-abl in the Philadelphia chromosome).

Other tumor vaccines may include the proteins from viruses implicated in human cancers such as Human Papilloma Viruses (HPV), Hepatitis Viruses (HBV and HCV) and Kaposi's Herpes Sarcoma Virus (KHSV).

5 Another form of tumor specific antigen which may be used in conjunction with PDL1 blockade (such as PDL1 antibody, e.g., PDL1-binding molecule of the invention) is purified heat shock proteins (HSP) isolated from the tumor tissue itself. These heat shock proteins contain fragments of proteins from the tumor cells and these HSPs are highly efficient at delivery to
10 antigen presenting cells for eliciting tumor immunity (Suot, R & Srivastava, P (1995) Science 269:1585-1588; Tamura, Y. et al. (1997) Science 278:117-120).

Dendritic cells (DC) are potent antigen presenting cells that can be used to prime antigen-specific responses. DCs can be produced ex vivo and
15 loaded with various protein and peptide antigens as well as tumor cell extracts (Nestle, F. et al. (1998) Nature Medicine 4: 328-332). DCs may also be transduced by genetic means to express these tumor antigens as well. DCs have also been fused directly to tumor cells for the purposes of immunization (Kugler, A. et al. (2000) Nature Medicine 6:332-336). As a
20 method of vaccination, DC immunization may be effectively combined with PDL1 blockade (such as PDL1 antibody, e.g., PDL1-binding molecule of the invention) to activate more potent anti-tumor responses.

CAR-T (Chimeric Antigen Receptor T-Cell Immunotherapy) is another cell therapy for treating tumors. Chimeric Antigen Receptor T-Cell (CAR-T

cells) are T cells from a patient that have been genetically infected with a chimeric protein of an antigen-binding moiety of an antibody against certain tumor antigen coupled with CD3- ζ chain or intracellular portion of Fc ϵ RI γ for expressing a chimeric antigen receptor (CAR). Also, co-stimulate
5 signaling sequence may be introduced for increasing cytotoxic activity, proliferation and survival of T cells, and promoting the release of cytokines. After reprogramming, T cells from the patient expanded in vitro to produce a large number tumor-specific CAR-T cells which are then transfused back into the patient for treating tumor. PDL1 blocking agents (such as PDL1
10 antibodies, e.g., the PDL1 binding molecule of the invention) may be used in combination with CAR-T cell therapy for activate stronger anti-tumor response.

PDL1-binding molecule of the invention may also be combined with standard cancer treatments. PDL1-binding molecule of the invention may be
15 effectively combined with chemotherapeutic regimes. In these instances, it may be possible to reduce the dose of chemotherapeutic reagent administered (Mokyr, M. et al. (1998) Cancer Research 58: 5301-5304). An example of such a combination is an anti-PDL1 antibody in combination with decarbazine for the treatment of melanoma. Another example of such a
20 combination is an anti-PDL1 antibody in combination with interleukin-2 (IL-2) for the treatment of melanoma. The scientific rationale behind the combined use of PDL1-binding molecule of the invention and chemotherapy is that cell death, that is a consequence of the cytotoxic action of most chemotherapeutic compounds, should result in increased

levels of tumor antigen in the antigen presentation pathway. Other combination therapies that may result in synergy with PDL1 blockade through cell death are radiation, surgery, and hormone deprivation. Each of these protocols creates a source of tumor antigen in the host. Angiogenesis inhibitors may also be combined with PDL1-binding molecule of the invention. Inhibition of angiogenesis leads to tumor cell death which may feed tumor antigen into host antigen presentation pathways.

The PDL1 binding molecule of the invention can also be used in combination with antibody against other tumor-specific antigen. Said antibody against other tumor-specific antigen includes but not limited to anti-EGFR antibody, anti-EGFR variant antibody, anti-VEGFa antibody, anti-HER2 antibody, or anti-CMET antibody. Preferably, said antibody is an monoclonal antibody.

PDL1-binding molecule of the invention can also be used in combination with bispecific antibodies that target Fc alpha or Fc gamma receptor-expressing effectors cells to tumor cells (see, e.g., U.S. Pat. Nos. 5,922,845 and 5,837,243). Bispecific antibodies can be used to target two separate antigens. For example anti-Fc receptor/anti tumor antigen (e.g., Her-2/neu) bispecific antibodies have been used to target macrophages to sites of tumor. This targeting may more effectively activate tumor specific responses. The T cell arm of these responses would be augmented by the use of PDL1 blockade. Alternatively, antigen may be delivered directly to DCs by the use of bispecific antibodies which bind to tumor antigen and a dendritic cell specific cell surface marker.

Tumors evade host immune surveillance by a large variety of mechanisms. Many of these mechanisms may be overcome by the inactivation of proteins which are expressed by the tumors and which are immunosuppressive. These include among others TGF-beta (Kehrl, J. et al. (1986) J. Exp. Med. 163: 1037-1050), IL-10 (Howard, M. & O'Garra, A. (1992) Immunology Today 13: 198-200), and Fas ligand (Hahne, M. et al. (1996) Science 274: 1363-1365). Antibodies to each of these entities may be used in combination with PDL1-binding molecule of the invention to counteract the effects of the immunosuppressive agent and favor tumor immune responses by the host.

Other antibodies which may be used to activate host immune responsiveness can be used in combination with anti-PDL1. These include molecules on the surface of dendritic cells which activate DC function and antigen presentation. Anti-CD40 antibodies are able to substitute effectively for T cell helper activity (Ridge, J. et al (1998) Nature 393: 474-478) and can be used in conjunction with PDL1-binding molecule of the invention (Ito, N. et al (2000) Immunobiology 201 (5) 527-40). Activating antibodies to T cell costimulatory molecules such as OX-40 (Weinberg, A. et al. (2000) Immunol J34: 2160- 2169), 4-1BB (Melero, I. et al. (1997) Nature Medicine 3: 682-685 (1997), and ICOS (Hutloff, A. et al (1999) Nature 397: 262-266) as well as antibodies which block the activity of negative costimulatory molecules such as CTLA-4 (e.g., US Patent No. 5,811,097) or BTLA (Watanabe, N. et al. (2003) Nat Immunol 4:670-9), B7-H4 (Sica, GL et al (2003) Immunity 18:849-61) may also provide for increased levels of T

cell activation.

Bone marrow transplantation is currently being used to treat a variety of tumors of hematopoietic origin. While graft versus host disease is a consequence of this treatment, therapeutic benefit may be obtained from graft vs. tumor responses. PDL1 blockade can be used to increase the effectiveness of the donor engrafted tumor specific T cells. There are also several experimental treatment protocols that involve ex vivo activation and expansion of antigen specific T cells and adoptive transfer of these cells into recipients in order to antigen-specific T cells against tumor (Greenberg, R. & Riddell, S. (1999) Science 285: 546-51). These methods may also be used to activate T cell responses to infectious agents such as CMV. Ex vivo activation in the presence of PDL1-binding molecule of the invention may be expected to increase the frequency and activity of the adoptively transferred T cells.

15 Infectious Diseases

Other methods of the invention are used to treat patients that have been exposed to particular toxins or pathogens. Accordingly, another aspect of the invention provides a method of preventing or treating an infectious disease in a subject comprising administering to the subject a PDL1-binding molecule of the invention, such that the subject is treated for the infectious disease.

Similar to its application to tumors as discussed above, PDL1 blockade can be used alone, or as an adjuvant, in combination with vaccines, to stimulate the immune response to pathogens, toxins, and self-antigens.

Examples of pathogens for which this therapeutic approach may be particularly useful, include pathogens for which there is currently no effective vaccine, or pathogens for which conventional vaccines are less than completely effective. These include, but are not limited to HTV, Hepatitis (A, B, & C), Influenza, Herpes, Giardia, Malaria, Leishmania, Staphylococcus aureus, Pseudomonas Aeruginosa. PDL1 blockade is particularly useful against established infections by agents such as HIV that present altered antigens over the course of the infections. These novel epitopes are recognized as foreign at the time of anti-human PD- L1 administration, thus provoking a strong T cell response that is not dampened by negative signals through PDL1.

Some examples of pathogenic viruses causing infections treatable by methods of the invention include HIV, hepatitis (A, B, or C), herpes virus (e.g., VZV, HSV-1, HAV-6, HSV-II, and CMV, Epstein Barr virus), adenovirus, influenza virus, flaviviruses, echovirus, rhinovirus, coxsackie virus, cornovirus, respiratory syncytial virus, mumps virus, rotavirus, measles virus, rubella virus, parvovirus, vaccinia virus, HTLV virus, dengue virus, papillomavirus, molluscum virus, poliovirus, rabies virus, JC virus and arboviral encephalitis virus.

Some examples of pathogenic bacteria causing infections treatable by methods of the invention include chlamydia, rickettsial bacteria, mycobacteria, staphylococci, streptococci, pneumonococci, meningococci and conococci, klebsiella, proteus, serratia, pseudomonas, legionella, diphtheria, salmonella, bacilli, cholera, tetanus, botulism, anthrax, plague,

leptospirosis, and Lyme's disease bacteria.

Some examples of pathogenic fungi causing infections treatable by methods of the invention include *Candida* (*albicans*, *krusei*, *glabrata*, *tropicalis*, etc.), *Cryptococcus neoformans*, *Aspergillus* (*fumigatus*, *niger*, etc.), Genus *Mucorales* (*mucor*, *absidia*, *rhizopus*), *Sporothrix schenckii*,
5 *Blastomyces dermatitidis*, *Paracoccidioides brasiliensis*, *Coccidioides immitis* and *Histoplasma capsulatum*.

Some examples of pathogenic parasites causing infections treatable by methods of the invention include *Entamoeba histolytica*, *Balantidium coli*,
10 *Naegleria fowleri*, *Acanthamoeba* sp., *Giardia lamblia*, *Cryptosporidium* sp., *Pneumocystis carinii*, *Plasmodium vivax*, *Babesia microti*, *Trypanosoma brucei*, *Trypanosoma cruzi*, *Leishmania donovani*, *Toxoplasma gondii*, *Nippostrongylus brasiliensis*.

In all of the above methods, PDL1 blockade can be combined with
15 other forms of immunotherapy such as cytokine treatment (e.g., interferons, GM-CSF, G-CSF, IL-2), or bispecific antibody therapy, which provides for enhanced presentation of tumor antigens (see, e.g., Holliger (1993) Proc. Natl. Acad. Sci. USA 90:6444-6448; Poljak (1994) Structure 2:1121-1123).

20 Autoimmune reactions

Anti-PDL1 antibodies may provoke and amplify autoimmune responses. Therefore, it is possible to consider using anti-PDL1 blockade in conjunction with various self proteins in order to devise vaccination protocols to efficiently generate immune responses against these self

proteins for disease treatment.

For example, Alzheimer's disease involves inappropriate accumulation of A β peptide in amyloid deposits in the brain; antibody responses against amyloid are able to clear these amyloid deposits (Schenk et al, (1999)

5 Nature 400: 173-177). Other self proteins may also be used as targets such as IgE for the treatment of allergy and asthma, and TNF α for rheumatoid arthritis. Finally, antibody responses to various hormones may be induced by the use of anti-PDL1 antibody. Neutralizing antibody responses to reproductive hormones may be used for contraception. Neutralizing
10 antibody response to hormones and other soluble factors that are required for the growth of particular tumors may also be considered as possible vaccination targets.

Analogous methods as described above for the use of anti-PDL1 antibody can be used for induction of therapeutic autoimmune responses to
15 treat patients having an inappropriate accumulation of other self-antigens, such as amyloid deposits, including A β in Alzheimer's disease, cytokines such as TNF α , and IgE.

Chronic inflammatory diseases

20 Anti-PDL1 antibodies may also be used to treat diseases such as chronic inflammatory diseases, such as lichen planus, a T-cell mediated chronic inflammatory mucocutaneous disease (Youngnak-Piboonratanakit et al. (2004) Immunol Letters 94:215-22). Accordingly, in another aspect the invention provides a method of abrogating chronic inflammatory disease

by T cells, comprising administering to the subject a PDL1-binding molecule of the invention.

Vaccine adjuvant

5 In one aspect, the invention provides use of PDL1-binding molecule of the invention as vaccine adjuvant. Anti-PDL1 antibodies may be used to stimulate antigen-specific immune responses by coadministration of an anti-PDL1 antibody with an antigen of interest (e.g., a vaccine).

 Accordingly, in another aspect the invention provides a method of
10 enhancing an immune response to an antigen in a subject, comprising administering to the subject: (i) the antigen; and (ii) a PDL1-binding molecule of the invention, such that an immune response to the antigen in the subject is enhanced. The antigen can be, for example, a tumor antigen, a viral antigen, a bacterial antigen or an antigen from a pathogen.
15 Non-limiting examples of such antigens include those discussed in the sections above, such as the tumor antigens (or tumor vaccines) discussed above, or antigens from the viruses, bacteria or other pathogens described above.

20

Kit

 Also within the scope of the present invention are kits comprising the PDL1-binding molecule, immunoconjugate or pharmaceutical composition of the invention and instructions for use. The kit can further contain a least

one additional reagent, or one or more additional PDL1-binding molecules of the invention (e.g., binding molecules which bind to different epitopes in PDL1). Kits typically include a label indicating the intended use of the contents of the kit. The term label includes any writing, or recorded material
5 supplied on or with the kit, or which otherwise accompanies the kit.

Examples

The present invention is further illustrated by the following examples, but the scope of the invention should not be limited to the specific examples
10 in any way.

Example 1: Screen of heavy chain single domain antibody against PDL1

1.1 Library construction

PDL1-Fc fusion protein (SEQ ID NO:28) for immunization was
15 expressed by CHO cells (pCDNA4, Invitrogen, Cat V86220), purified by Protein A affinity chromatography. One Camelus bactrianus was chosen for immunization. After 4 immunizations, lymphocytes were isolated from 100ml camel peripheral blood, and total RNA was extracted by RNA Extraction kit (QIAGEN). Extracted RNA was reverse transcribed into
20 cDNA using Super-Script III FIRST STRANDSUPERMIX kit according to instructions.

Nucleic acid fragments encoding heavy chain antibodies were amplified by nested PCR:

First round PCR:

Upstream primer : GTCCTGGCTGCTCTTCTACAAGGC (SEQ ID NO:29);

Downstream primer : GGTACGTGCTGTTGAACTGTTCC (SEQ ID NO:30).

Second round PCR:

PCR products from first round PCR as template,

Upstream primer: GATGTGCAGCTGCAGGAGTCTGGRGGAGG (SEQ ID NO:31);

Downstream primer: GGACTAGTGCGCCGCTGGAGACGGTGACCTGGGT (SEQ ID NO:32).

Target heavy chain single domain antibody nucleic fragments were recovered and cloned into phage display vector pCDisplay-3 (Creative Biolabs , Cat: VPT4023) using endonuclease PstI and NotI (from NEB). The products were then electroporated into E.coli competent cell TG1, and phage display library for heavy chain single domain antibodies against PDL1 was constructed and verified. By plating serial dilutions, library capacity was determined as 1.33×10^8 . To determine the insertion ratio of the library, 24 clones were randomly selected for colony PCR. The results revealed an insertion ratio of 100%.

1.2 Panning for heavy chain single domain antibody against PDL1

Multi-well plates were coated with PDL1-Fc fusion protein at 10µg/well, 4°C overnight. On next day, after blocking with 1% skim milk at room

temperature for 2 hours, 100 μ l phages (8×10^{11} tfu, from the phage display library for camel heavy chain single domain antibodies constructed in 1.1) were added, room temperature for 1 hour. Then unbound phages were removed by washing with PBST (0.05% tween 20 in PBS) for 5 times. Phages that specifically bind
5 to PDL1 were dissociated with triethylammonium (100mM), and used to infect E.coli TG1 of log phase, producing phages which were then purified for next round screen. The same screen was repeated for 3-4 rounds. Thereby, positive clones were enriched, achieving the purpose of selecting PDL1 specific antibodies from the antibody library by phage display technology.

10

1.3 Specific selection of individual positive clones by phage enzyme-linked immunoassay (ELISA)

PDL1 binding positive phages obtained after 3-4 rounds of panning were used to infect blank E.coli and plated. 96 single colonies were randomly selected
15 for culturing, and phages were produced and purified respectively. Plates were coated with PDL1-Fc fusion protein at 4°C overnight; sample phages as obtained were added (blank phages as control) and incubated at room temperature for 1 hour. Primary antibody, mouse anti-HA tag antibody (Beijing Kangwei Shiji Biotech. Ltd.) , was added after washes and incubated at room temperature, 1
20 hour for reaction. Secondary antibody, goat anti-mouse alkaline phosphatase labeled antibody (Amyject Scientific Ltd.) was added after washes and incubated at room temperature, 1 hour for reaction. Alkaline phosphatase chromogenic solution was added after washes, and absorption value was read at 405 nm wave length. When the OD of the sample well is 3 times higher than the

OD of control well, the sample is determined as positive. Bacteria in the positive wells were transferred to and cultured in LB liquid medium supplemented with 100 ug/ml Ampicillin for plasmid extraction and subsequent sequencing.

The protein sequences of each clone were analyzed according to the sequence alignment software Vector NTI. Clones with the same CDR1, CDR2, and CDR3 sequences are considered as the same antibody, while clones with different CDR sequences are considered as different antibody.

Example 2 Preliminary evaluation of heavy chain single domain antibodies against PDL1

2.1 Expression of heavy chain single domain antibodies in E.coli and purification thereof

The coding sequence of the heavy chain single domain antibody obtained by sequencing analysis was subcloned into the expression vector PET32b (Novagen, product number: 69016-3) and the correct recombinant plasmid was transformed into expression host strain BL1 (DE3) (Tiangen Biotech, CB105-02), plated on LB solid medium containing 100 micrograms per milliliter ampicillin overnight at 37°C. Single colonies were inoculated and cultured overnight, transferred in the next day for expansion at 37°C by shaking. When the culture reached OD value of 0.6-1, 0.5mM IPTG was added for induction, 28°C overnight with shaking. The next day, the bacteria were harvested by centrifugation, and lysed to obtain antibody crude extracts. Nickel ion affinity chromatography was then used to purify the antibody proteins, resulting in antibody proteins of more than 90% purity.

2.2 Specific binding of the candidate PDL1 heavy chain single domain antibody to human PDL1 protein

Plastes were coated with PDL1-Fc fusion protein overnight at 4°C and
5 100ng of the heavy chain single-domain antibody obtained in Example 2.1 (the control was a single domain antibody not binding to the PDL1-Fc protein) was added to each well and allowed to react for 1 hour at room temperature. After washing, primary antibody anti-His tag antibody (purchased from Beijing Kangwei Century Biotechnology Co., Ltd.) was added and reacted for 1 hour at
10 room temperature. After washing, a secondary goat anti-mouse horseradish peroxidase-labeled antibody (Yiqiao Shenzhou, Cat: SSA007200) was added and reacted for 1 hour at room temperature. After washing, chromogenic agent was added and the absorbance was read at 405nm.

The plates were coated with Fc protein overnight at 4°C and 100 ng of the
15 heavy chain single domain antibody obtained in Example 2.1 was added to each well (control was a single domain antibody against other unrelated targets) and allowed to react for 1 hour at room temperature. After washing, an anti-rabbit anti-human Fc antibody (purchased from Shanghai Pu Xin Biotechnology Co., Ltd.) was added and reacted for 1 hour at room temperature. After washing, goat
20 anti-rabbit anti-rabbit horseradish peroxidase labeled antibody (purchased from Shanghai Pu Xin Biotechnology Co., Ltd.) was added and reacted at room temperature for 1 hour. After washing, chromogenic agent was added and the absorbance was read at 405nm.

The candidate antibody is considered as binding to the PDL1-Fc protein

when the ratio of the OD value for the PDL1-Fc protein divided by the OD value for the blank control is greater than or equal to 4; and simultaneously, the above antibody capable of binding to PDL1-Fc antigen protein, when the ratio of the OD value for binding to PDL1-Fc divided by the OD value for binding Fc protein is ≥ 5 , is considered as specifically binding to the PDL1 moiety rather than the Fc moiety.

The results showed that antibody No. 56 could specifically bind to PDL1 without binding to Fc. The specific results are shown in the following Table 1:

Table 1

	OD (against PDL1)	OD (against Fc)	OD (PDL1/Fc)	OD (PDL1/blank)	SEQ ID NO
<i>PDL1-56 dAb</i>	<i>2.931</i>	<i>0.068</i>	<i>43.10294118</i>	<i>54.27777778</i>	<i>28</i>
blank	0.054	0.072	0.75	1	

2.3 Binding of PDL1 heavy chain single domain antibody to mouse PDL1 protein

Mouse PDL1-Fc protein (SEQ ID NO: 33) was obtained by expression in HEK293 cells (pCDNA4, Invitrogen, Cat V86220).

The plates were coated overnight at 4°C with mouse PDL1-Fc fusion protein at 0.5 ug/well and 100 ng of the heavy chain single domain antibody obtained in Example 2.1 (control group is a single domain antibody against other unrelated target) was added and allowed to react under room temperature

for 1 hour. After washing, primary antibody anti-His tag antibody was added and reacted at room temperature for 1 hour. After washing, goat anti-mouse horseradish peroxidase labeled antibody was added and reacted for 1 hour at room temperature. After washing, chromogenic agent was added and the absorbance was read at 405nm. The results are shown in Table 2.

Table 2

	OD (against mouse PDL1)
PDL1-56 dAb	0.075
blank	0.096

It can be seen that the heavy chain single domain antibody of human PDL1 of the present invention does not bind to the mouse PDL1-Fc protein.

2.4 Examination of the blocking effect of PDL1 heavy chain single-domain antibody to the interaction of PD-1 and PDL1 by competitive ELISA

PDL1-Fc protein and PD1-Fc protein (SEQ ID NO: 34) were obtained by expression in HEK293 cells (pCDNA4, Invitrogen, Cat V86220). Biotinylated protein PD1-Fc-Biotin was obtained using the Thermo Biotinlytion kit.

The plates were coated overnight at 4°C with PDL1-Fc fusion protein at 0.5 ug/well followed by addition of 100 ng of the heavy chain single domain antibody obtained in Example 2.1 (controls are single domain antibodies against other unrelated targets or simply buffer) and 10 µg of PD1-Fc-Biotin (no antibody or protein was added to the blank group, only an equal volume of buffer was added), and allowed to react for 1 hour at room temperature. SA-HRP (purchased from Sigma) was added and allowed to react for 1 hour at

room temperature. After adding chromogenic solution, absorbance was read at 405nm wavelength. When the sample OD value relative to the control OD value is <0.8 , the antibody is considered as possessing blocking effect.

As shown in Table 3, the antibody No. 56 showed a blocking effect on the
5 PD-1/PDL1 interaction.

Table 3

	OD
Control 1	2.335
Control 2	2.413
blank	0.079
PDL1-56	0.129

2.5 The blocking effect of PDL1 heavy chain single-domain antibody on PDL1 and PD-1 interaction on cell surface was investigated by FACS

10 HEK293 cells transiently expressing human PDL1 protein on the membrane (293-PDL1 cells) were obtained by transient transfection of a plasmid carrying human PDL1 full length gene (pCDNA4, Invitrogen, Cat V86220) into human HEK293 cells.

293-PDL1 cells were harvested, resuspended in 0.5% PBS-BSA buffer in a
15 96-well plate, and the above-mentioned antibodies to be detected were added. Negative controls were also set at the same time, and negative controls were 2 μ g of a single domain antibody against other target. 0.3 μ g hPD-1-Fc-biotin and eBioscience SA-PE were added to all the samples, and the flow cytometry was performed after staining. The antibody is considered to block the cell-surface

interaction of PDL1 and PD-1 if the fluorescence value is shifted to the blank direction as compared to the antibody-free group. In this way, antibodies that block the binding of PDL1 antigen to PD-1 on the cell surface were identified.

The results are shown in Figure 1, antibody No. 56 exhibits a blocking
5 effect on the PD-1/PDL1 interaction.

2.6 Binding curves of PDL1 heavy chain single domain antibodies to PDL1 antigen protein

The plates were coated with the obtained PDL1 heavy chain single-domain
10 antibody at 0.5 µg/well overnight at 4°C followed by addition of a gradient dilution series of PDL1-Fc fusion protein and allowed to react for 1 hour at room temperature. After washing, goat anti-human IgG-Fc horseradish peroxidase labeled antibody was added and allowed to react for 1 hour at room temperature. After washing, horseradish peroxidase color developing solution
15 was added and the absorbance was read at a wavelength of 405 nm. SoftMax Pro v5.4 was used for data processing and mapping analysis to get binding curve of the antibody to PDL1 and EC50 value (about 5 ng/ml) through four-parameter fitting. The results are shown in Figure 2.

20 2.7 Blocking curves of PDL1 heavy chain single-domain antibodies on the interaction of PD-1 and PDL1

Plates were coated with PDL1-Fc fusion protein 0.5 ug / well overnight at 4°C followed by the addition of 100uL of a gradient dilution series (containing 100 ug/mL PD1-Fc- Biotin) of 100uL PDL1 blocking single domain antibody Fc

fusion protein per well, allowed to react for 1 hour at room temperature. SA-HRP (purchased from Sigma) was added and allowed to react for 1 hour at room temperature. After adding chromogenic solution, absorbance was read at 405nm wavelength.

5 SotfMax Pro v5.4 was used for data processing and mapping analysis to obtain blocking curve and IC50 value of antibody No. 56 to PDL1/PD-1 through four-parameter fitting (IC50 for antibody No.56 is 143ng/mL). The results are shown in Figure 3.

10 Example 3 Humanization of PDL1 single domain antibodies

The humanization is performed by the method of protein surface amino acid humanization (resurfacing) and universal framework grafting method for VHH humanization (CDR grafting to a universal framework).

The steps of humanization are as follows: The homologous modeling of
15 antibody No. 56 was performed with the modeling software Modeller9. The reference homologous sequence is NbBcII10 antibody (PDB code: 3DWT), and the relative solvent accessibility of the amino acids is calculated according to the three-dimensional structure of the protein. If one of the amino acids of antibody No. 56 is exposed to a solvent, it was replaced with the amino acid at the same
20 position of the reference human antibody DP-47 sequence, until all substitutions were completed.

Specific steps of universal framework grafting method for VHH humanization are as follows: First, universal humanized VHH framework h-NbBcII10FGLA (PDB code: 3EAK) designed by Cécile Vincke et al. based on

sequence homology, the framework was designed based on Nanobody NbBcII10 (PDB code: 3DWT); protein surface amino acid humanization was performed with reference to the human antibody DP-47, and partial amino acids FGLA of VHH sequence framework 2 were modified. We directly used h-NbBcII10FGLA as a framework and replaced the CDRs with the CDR regions of antibody No. 56 to achieve humanization of the antibody.

The antibody No. 56 was humanized, and five humanized variants of the antibody No. 56 were obtained. Table 4 lists the SEQ ID No of these humanized variants as well as the amino acid changes therein, with amino acid residue numbers following Kabat numbering. Figure 4 shows the alignment of humanized sequences.

Table 4

		K27 F	M2 8T	S29 F	E44 G	R45 L	Q71 R	N72 D	A74 S	S76 N	K83 R	P84 A	M8 9V
Hu56V1 (SEQ ID NO:2)	√						√	√	√	√	√	√	√
Hu56V2 (SEQ ID NO:3)	√	√	√	√			√	√	√	√	√	√	√
Hu56V3 (SEQ ID NO:4)	√				√	√	√	√	√	√	√	√	√
Hu56V4	√	√	√	√	√	√	√	√	√	√	√	√	√

(SEQ ID NO:5)													
Hu56V5 (SEQ ID NO:6)	√						√	√	√	√		√	√

Example 4 Preparation of PDL1 blocking antibody protein using mammalian cells

4.1 Preparation of Fc fusion protein of PDL1 single domain antibody

5 The amino acid sequence of human IgG1-Fc region (SEQ ID NO: 7) was obtained based on the constant region amino acid sequence of human immunoglobulin gamma1 (IgG1) from the protein database Uniprot (P01857). The nucleic acid fragment encoding human IgG1-Fc was obtained from human PBMC total RNA by reverse transcription PCR, and the nucleic acid fragment

10 encoding the fusion protein of PDL1 single domain antibody obtained in the above Example and Fc was obtained by overlapping PCR, then subcloned into vector pCDNA4 (Invitrogen, Cat V86220). Fc region sequences, such as SEQ ID NO: 8 or 9, in which ADCC activity or CDC activity was removed by Site-directed mutagenesis, may also be used .

15 Recombinant single domain antibody-Fc fusion protein plasmid was transfected into HEK293 cells for antibody expression. The recombinant expression plasmids were diluted with Freestyle 293 medium and added into PEI (polyethylenimine) solution for transformation. Each plasmid / PEI mixture was added to HEK293 cell suspension and incubated at 37°C and 10% CO₂ at

90 rpm. At the same time, 50 µg/L IGF-1 was added. Four hours later EX293 medium, 2mM glutamine and 50µg/L IGF-1 were supplemented, cultured at 135rpm. After 24 hours, 3.8 mM VPA was added . After cultured for 5 to 6 days, the transient expression supernatant was collected and purified by Protein A
5 affinity chromatography to obtain the target PDL1 single domain antibody-Fc fusion protein.

The sequences of the PDL1 single domain antibody-Fc fusion proteins as obtained are shown in SEQ ID NO: 10-27.

10 4.2 Preparation of PDL1 antibodies from MedImmune LLC and Roche

The gene of anti-PDL1 antibody from MedImmune LLC, Inc. was cloned by the method of 2.14H9 in US20130034559 and cloned into the vector pCDNA4. TM004 is Roche's anti-PDL1 antibody. The antibody gene was cloned according to YW243.55.S70.hIgG in US20130045201 A1, and cloned
15 into vector pCDNA4.

The recombinant plasmid was transiently transfected into HEK293 cells by the same method as in Example 4.1, and the resulting anti-PDL1 antibody of MedImmune LLC was renamed as 2.41H90P; Roche's anti-PDL1 antibody was renamed as 243.55.

20

4.3 Comparison of the expression of PDL1 single-domain antibody Fc fusion protein and the two known PDL1 antibodies

Using the same expression system and transient transfection conditions, the expression level of the Fc fusion protein of the PDL1 single domain antibody of

the present invention was higher than 200 mg/L, while the expression level of the antibody 2.41H90P was about 80 mg/L and the expression level of the antibody 243.55 was about 40mg/L. This result indicates that the PDL1 single-domain antibody Fc fusion protein of the present invention is more stable
5 in structure and can result in higher expression level than the other two known PDL1 antibodies.

Example 5 Characterization of PDL1 single domain antibody Fc fusion protein

5.1 binding ability of PDL1 single domain antibody Fc fusion protein to PDL1 10 (by ELISA)

The PDL1-Chis protein (SEQ ID NO: 35) was obtained by transient expression in HEK293 and purification with nickel column affinity chromatography. Plates were coated with the resulting PDL1-Chis protein at 0.5 µg/well overnight at 4°C. Then gradient dilution series of PDL1 single-domain
15 antibody Fc fusion proteins obtained in the above Example were added and allowed to react for 1 hour at room temperature. After washing, goat anti-human IgG-Fc horseradish peroxidase labeled antibody was added and allowed to react for 1 hour at room temperature. After washing, chromogenic agent was added and the absorbance was read at 405nm. SoftMax Pro v5.4 was used for data
20 processing and mapping analysis, through the four-parameter fitting, to obtain binding curve and EC50 value of the antibody to PDL1 (all test antibody EC50 value of about 150ng / mL) to reflect the affinity to PDL1.

The results are shown in Figure 5, where the longitudinal coordinate is OD405 and the horizontal ordinate is the concentration of PDL1 single domain

antibody Fc-fusion protein (in ng/mL); inverted triangles, triangles, and squares represent the three different humanized forms of Fc fusion proteins: hu56v1-Fc, hu56v2-Fc, hu56v5-Fc. The three proteins have comparable affinity for PDL1.

5.2 Identification of the binding ability of PDL1 single-domain antibody Fc fusion protein to PDL1 (SPR method) and compared with known antibodies

The binding kinetics of the PDL1 single domain antibody Fc fusion protein to recombinant human PDL1 obtained in the above examples was measured by the surface plasmon resonance (SRP) method using a BIAcore X100 instrument.

Recombinant human PDL1-Fc was coated directly onto a CM5 biosensor chip to obtain approximately 1000 response units (RU). For kinetic measurements, the antibodies were serially diluted (1.37 to 1000 nm) in HBS-EP + 1x buffer (GE, cat # BR-1006-69) and injected for 120s at 25°C with a dissociation time of 30 min, regenerated with 10 mM Glycine-HCl (pH 2.0) for 120s. Binding rates (kon) and dissociation rates (koff) were calculated using a simple one-to-one Langmuir binding model (BIAcore Evaluation Software version 3.2). The equilibrium dissociation constant (Kd) is calculated as the ratio koff / kon.

The measured binding affinities of anti-PDL1 antibodies are shown in Table 5. The results show that the affinity of PDL1-56-Fc protein to the PDL1 target protein is significantly higher than that of two PDL1 antibodies known in the art, and its higher Ka and lower Kd values indicate that the antibody fusion protein can bind PDL1 antigen more rapidly and thus is difficult to dissociate, which further shows that PDL1-56-Fc as a blocking antibody, with properties better than the two known PDL1 antibody.

Table 5

	Ka	Kd	KD
PDL1-56-Fc	1.796E+6	1.432E-5	7.975E-12
PDL1-hu56V2-Fc	2.123E+6	1.820E-5	8.573E-12
PDL1-56	3.323E+6	8.213E-4	2.472E-10
2.41H90P	7.949E+5	6.160E-5	7.750E-11
243.55	4.481E+5	6.055E-5	1.351E-10

5.3 Blocking effect of PDL1 Single Domain Fc Fusion Protein on PDL1-PD1 Interaction (by Competitive ELISA)

Plates were coated with PDL1-Fc fusion protein 0.5 µg/well overnight at 4°C, followed by addition of gradient dilution series (containing 100 ug/mL PD1-Fc-Biotin) of the PDL1 single-domain antibody Fc fusion protein obtained in the above Example at 100 uL per well, allowed to react for 1 hour at room temperature. After washing, SA-HRP (purchased from Sigma) was added and allowed to react at room temperature for 1 hour. After washing, chromogenic agent was added and the absorbance was read at 405nm.

SotfMax Pro v5.4 was used for data processing and mapping analysis, through the four-parameter fitting, to obtain blocking curve and IC50 value of the antibody to PDL1-PD1. The results are shown in Fig. 6, where longitudinal coordinate is OD405 and the abscissa is the concentration of the PDL1 single domain antibody Fc fusion protein (in ng/mL); the inverted triangle, the trigonometric triangle and the square represent the three different humanized forms of Fc fusion proteins: hu56v1-Fc, hu56v2-Fc, hu56v5-Fc. The three

proteins have similar ability to block the PDL1-PD1 interaction.

5.4 Blocking effect of PDL1 Single Domain Fc Fusion Protein on PDL1-CD80 Interaction (by Competitive ELISA)

5 The CD80-Fc protein (SEQ ID NO: 36) was obtained from HEK293 cells. Biotinylated protein CD80-Fc-Biotin was obtained using the Thermo Biotinylation kit.

Plates were coated with PDL1-Fc fusion protein 0.5 µg/well overnight at 4°C, followed by addition of gradient dilution series (containing 300 ug/mL
10 CD80- Fc-Biotin) of the PDL1 single-domain antibody Fc fusion protein obtained in the above Example at 100 uL per well, allowed to react for 1 hour at room temperature. After washing, SA-HRP (purchased from Sigma) was added and allowed to react at room temperature for 1 hour. After washing, chromogenic agent was added and the absorbance was read at 405nm.

15 SoftMax Pro v5.4 was used for data processing and mapping analysis, through the four-parameter fitting, to obtain blocking curve and IC50 value of the antibody to PDL1-CD80. The results are shown in Fig. 7, where the longitudinal coordinate is OD405 and the abscissa is the concentration (in ng/mL) of PDL1 single domain antibody Fc fusion protein hu56V2-Fc. The
20 results show that PDL1 blocking single-domain antibody Fc fusion protein hu56V2-Fc can effectively block the interaction between PDL1 and CD80.

5.5 Blocking effect of PDL1 Single Domain Fc Fusion Protein on PDL1-PD1 Interaction (by FACS)

Human HEK293 cells transiently express monkey PDL1 protein on membranes by transient transfection of plasmids containing the full length human PDL1 gene.

PDI-muFc (SEQ ID NO: 39) at a working concentration of 2ug/ml was added to each group according to a 5×10^5 cells/tube grouping, and then different concentrations of KN035 were added to each group. After incubating on ice for 30min and washing for three times, PE-labeled goat-anti-mouse secondary antibody was added as the detection antibody, and the fluorescence intensity was detected by flow cytometry after incubation on ice for 30 minutes.

GraphPad Prism software was used for data processing and mapping analysis. By four-parameter fitting, the blocking curve and IC50 value of the antibody on the direct interaction between PDL1 expressed on 293 cell membrane and soluble PD1 were obtained. The results are shown in FIG. 8, wherein the longitudinal ordinate is MFI and the abscissa is the concentration (in $\mu\text{g/mL}$) of the PDL1 single domain antibody fusion protein hu56V1-Fcm1. The results show that PDL1 single-domain antibody Fc fusion protein could effectively block the interaction between PDL1 expressed on 293 cell membrane and PD1.

Plasmid containing human PD1 full-length gene was transformed and integrated into Jurket cell line to obtain Jurket cell line stably expressing human PD1 protein which was named Jurket-PD1.

After incubation of Jurkat-PD1 cells with biotinylated PDL1-muFc (SEQ ID NO: 38) protein (30 ug/ml) for 30 min on ice, a gradient dilution of PDL1 single domain antibody Fc fusion protein hu56V1-Fcm1 were added, incubated

for 1h on ice, washed for three times with PBS, and then 1: 250 diluted Streptavidin PE was added, incubated on ice for 30 min and washed three times with PBS. Fluorescence intensity was detected by flow cytometry.

Data processing and mapping analysis were performed using GraphPad
5 Prism software. The blocking curves and IC₅₀ values of the antibodies on the direct interaction between Jurkat-PD1 and soluble PDL1-muFc protein were obtained by four-parameter fitting. The results are shown in Figure 9, where the longitudinal ordinate is MFI and the abscissa is the concentration (in ug/mL) of the PDL1 single domain antibody fusion protein hu56V1-Fcm1. The results
10 show that PDL1 blocking single-domain antibody Fc fusion protein could effectively block the interaction between Jurkat-PD1 and PDL1.

5.6 binding specificity of the PDL1 single domain antibody Fc fusion protein for PDL1 protein

15 Human HEK293 cells transiently express human PDL1 protein on membranes by transient transfection of a plasmid carrying the full-length human B7 family protein genes (pCDNA4, Invitrogen, Cat V86220). The plasmid also allows the C-terminus of the target protein to be fused to the EGFP protein so that the level of B7 family protein expressed on the membrane can be examined
20 by green fluorescence intensity. The constructed transient transfected cell lines include 293-PDL1-EGFP, 293-PDL2-EGFP, 293-B7H3-EGFP and 293-B7H3-EGFP.

The constructed cells were resuspended in 0.5% PBS-BSA buffer and hu56V2-Fc antibody was added. At the same time, a negative control of 2 µg of

a single domain antibody against other unrelated target was set up and incubated on ice for 20 minutes. After washing, eBioscience secondary antibody anti-hIg-PE was added, on ice for 20 min. After washing, the cells were resuspended in 500 µl of 0.5% PBS-BSA buffer and detected by flow cytometry.

5 The results are shown in Figure 10. The upper row shows the control group, the lower row shows the sample groups. It is clear that hu56V2-Fc antibody specifically binds to human PDL1 protein only, not to other B7 family proteins.

5.7 Binding of PDL1 Single Domain Antibody Fc Fusion Protein to Monkey

10 PDL1 Protein

Human HEK293 cells transiently express monkey PDL1 protein (SEQ ID NO: 57) by transient transfection of plasmids containing the full length of the monkey PDL1 gene. The plasmid also allows the target protein C-terminal fused to EGFP protein, which allows monkey PDL1 protein membrane expression
15 levels can be investigated by green fluorescence intensity.

The constructed cells were resuspended in 0.5% PBS-BSA buffer, hu56V2-Fc antibody was added and incubated on ice for 20 min. After washing, eBioscience secondary antibody anti-hIg-PE was added, on ice for 20 min. After washing, the cells were resuspended in 500 µl of 0.5% PBS-BSA buffer and
20 detected by flow cytometry.

The results are shown in Figure 11. It is clear that the hu56V2-Fc antibody binds effectively to the monkey PDL1 protein.

5.8 PDL1 single-domain antibody Fc fusion protein can effectively identify

PDL1 positive cell population on the patient's tissue sections

Tumor tissue sections of PDL1-positive lung cancer patients were stained with 5 µg/mL hu56V2-Fc antibody as primary antibody overnight and incubated with goat-anti-human HRP-labeled antibody (Perkin-Elmer, Cat: NEF802001EA), then visualized.

The results are shown in Figure 12. hu56V2-Fc antibody can effectively identify PDL1-positive cell population on lung cancer patient's tissue sections, and can simultaneously identify PDL1-positive tumor cells and PDL1-positive immune cells.

5.9 Activation of PBMC by PDL1 single domain antibody Fc fusion protein

Peripheral blood mononuclear cells (PBMCs) were isolated from peripheral blood of healthy donors by density gradient centrifugation using isolation solution for human lymphocytes (Tianjin Hao Yang).

2.5 µg/mL anti-CD3 antibody and gradient dilution series of PDL1 single domain antibody Fc fusion protein hu56V2-Fc (also designated as KN035 in experiment) were coated on cell culture plates overnight at 4°C. The next day, 1×10^5 PBMCs were added to each well. After cultured for 5 days, the supernatant was taken and the level of IFN- γ in the supernatant was detected by IFN- γ ELISA kit (ebioscience).

The results are shown in Figure 13. It can be seen that the PDL1 single-domain antibody Fc fusion protein combined with anti-CD3 antibody can enhance the secretion of γ -interferon from PBMC cells, ie, PDL1 single domain Fc fusion protein enhances the activation of PBMC cells. At the same

time, the activation effect is concentration-dependent.

5.10 Activation of CD4⁺ T cells by PDL1 single-domain antibody Fc fusion protein in dendritic cell-T cell mixed lymphoid reaction and comparison with MedImmune LLC anti-PDL1 antibody

Peripheral blood mononuclear cells (PBMCs) were isolated from white blood cells of peripheral blood from healthy donors by density gradient centrifugation using isolation solution for human lymphocytes (Tianjin Hao Yang). They were then incubated with serum-free RPMI 1640 medium for 1-2 hours to remove non-adherent cells and cells were cultured in RPMI containing 10% FBS, 10 ng/ml GM-CSF and 20ng/mL IL-4. After culturing for 5-6 days, 10ng/ml of TNF- α was added and incubated for 24 hours to obtain mature dendritic cells.

Dendritic cells obtained by this method were resuspended in RPMI complete medium, 2×10^5 /ml. Then 50 μ l per well was added to a 96-well U-bottom plate (Costar: 3799) and cultured in an incubator.

CD4⁺ T cells were isolated from PBMC of another donor using a magnetic bead isolation kit (Miltenyi Biotec: 130-096-533) following the instructions of the manufacturer.

1×10^4 dendritic cells and 1×10^5 CD4⁺ T cells obtained by the above methods were mixed, resuspended in RPMI complete medium and added to a 96-well culture plate, and 50 μ l of the cell mixture was added to each well. 100 μ l per well of hu56V2-Fc diluted in RPMI complete medium was added to a final antibody concentration of 0.1 μ g/ml or 0 μ g/ml. Supernatants were

collected 5-7 days after culture, and IFN- γ level in the supernatant was detected by IFN- γ ELISA kit (ebioscience).

The results are shown in Figure 14A. It can be seen that PDL1 single-domain antibody Fc fusion protein can enhance the IFN- γ secretion of CD4⁺ T cells in mixed lymphocyte reaction. That is, the PDL1 blocking single-domain antibody Fc fusion protein enhances T cell activation.

PBMCs from Subjects 1 were cultured with 50 ng/ml GM-CSF + 25 ng/ml IL-4, and DCs were harvested 6 days after maturation with TNF- α (50 ng/ml); CD4⁺ T cells were sorted by magnetic bead isolation kit (Miltenyi Biotec: 130-096-533); DC cells were added to 96-well U-bottom plates at 10^4 /well and 10^5 /well of CD4⁺ T cells were added after 2-4 h; different concentrations of PDL1 single domain antibody Fc fusion protein hu56V1-Fcm1 or MedImmune LLC anti-PDL1 antibody 2.41H90P were added to respective wells; after culturing for 5 days, IFN- γ level in the supernatant was detected by IFN- γ ELISA detection kit (ebioscience).

The results are shown in Figure 14B, in which the gray histogram indicates that the stimulation of IFN- γ secretion by PDL1 single domain antibody Fc fusion protein and the black bar indicates MedImmune LLC anti-PDL1 antibody 2.41H90P. PDL1 single-domain antibody Fc fusion protein with increasing concentrations can enhance the ability of CD4⁺ T cells to secrete IFN- γ in mixed lymphocyte reaction, and the ability of PDL1 single domain antibody Fc fusion protein to activate T cells is slightly stronger than MedImmune LLC anti-PDL1 antibody 2.41H90P under the same concentration.

5.11 Stimulattion of IL-2 secretion of T cells in Jurkat / Raji-PDL1 mixed culture system by PDL1 single-domain antibody Fc fusion protein and comparison with MedImmune LLC anti-PDL1 antibody

We constructed a T cell activation system, the Jurkat/Raji-PDL1 co-culture system, to test the effect of PDL1 single domain antibody Fc fusion protein on T cell activation, which was compared with MedImmune LLC anti-PDL1 antibody.

The system uses Jurkat cells (T cells) as effector cells and anti-human CD3 antibody as the first signal for activation of Jurkat cells. B7 family CD80 on the surface of Raji-PDL1 cells which are genetically engineered and stably expressing human PDL1, provides a second co-stimulatory signal to activate Jurket cells, while PDL1 highly expressed on the same cell surface, acts as a negative regulator by binding PD1 to inhibit Jurket cell activation.

Gradient dilutions of hu56V1-Fcm1 and 2.41H90P antibody proteins were prepared using 10% FBS+1640+150ng/ml anti-CD3; Jurkat and Raji-PDL1 cells were adjusted to 3×10^6 cells/ml and 1.5×10^6 cells/ml, 50ul was added to each well, stored at 37°C for 24 hours. 100ul of culture supernatant was removed and measured for the expression of IL-2 with kit.

Figure 15 shows the case where the black histogram indicates stimulation of IL-2 secretion by PDL1 single domain antibody Fc fusion protein and the gray histogram indicates MedImmune LLC anti-PDL1 antibody 2.41H90P. PDL1 single-domain antibody Fc fusion protein can enhance the ability of Jurkat cells to secrete IL-2 with increasing concentration, and its ability to activate Jurkat cells is slightly stronger than that of MedImmune LLC PDL1

antibody 2.41H90P at the same concentration.

5.12 Affinity of PDL1 single-domain antibody Fc fusion protein to FcRn

Biotinylated PDL1 single domain antibody Fc fusion proteins hu56V1-Fc, hu56V2-Fc, hu56V1-Fcm1 and hu56V2-Fcm1 were diluted to 10 ug/ml and immobilized onto SA biosensors. Human FcRn protein (RnD Systems Cat. No. 8639-FC) was diluted 200nM, 100nM, 50nM, 25nM, 12.5nM. Interaction was detected using Octet K2 from Fortebio Corporation, with solidifying for 100s curing binding for 60s, dissociation for 30s.

Table 6 shows that the average KD of PDL1 single-domain antibody Fc fusion proteins to FcRn is about 5.1E-07M. There was no significant difference in affinity between mutant Fc (Fcm1) and wild-type Fc.

Table 6

	KD (M)	kon(1/Ms)	kdis(1/s)
hu56V1-Fc	5.13E-07	1.95E+05	1.00E-01
hu56V2-Fc	5.05E-07	2.10E+05	1.06E-01
hu56V1-Fcm1	5.10E-07	1.89E+05	9.63E-02
hu56V2-Fcm1	5.10E-07	2.34E+05	1.19E-01

5.13 CDC and ADCC Activity of PDL1 Single Domain Antibody Fc Fusion Protein with Mutant Fc

PBMCs were activated with 300IU/ml IL-2 for 24 hours as effector cells, with cell number of 8×10^5 cells/well; Raji-PDL1 stably expressing human PDL1

protein was used as target cells with a cell number of 2×10^5 cells/well; various concentration of hu56V1-Fcm1 or Rituxan protein as positive control were added, and ADCC activity (%) under each concentration was measured using a CytoTox 96® non-radioactive cytotoxicity detection kit after incubation at 37°C for 6 hours.

Figure 16A shows that hu56V1-Fcm1 showed no significant ADCC activity as compared to the positive control Rituxan.

Raji-PDL1 cells are used as target cells with a cell number of 2×10^4 cells/well and 5% of cynomolgus serum for providing complements, different concentrations of hu56V1-Fcm1 and positive control Rituxan were added, cultured at 37°C for 2h. CDC activity of the sample was detected using CCK-8.

Figure 16B shows that hu56V1-Fcm1 has no CDC activity at concentrations ranging from 0.02 ug/ml to 20 ug/ml compared to the positive control.

5.14 Inhibitory activity of PDL1 single domain antibody Fc fusion protein on tumor growth

Immunodeficient NOD/SCID (non-obese diabetic/severe combined immunodeficiency) mice were used for studying in vivo activity of the PDL1 single domain antibody Fc fusion protein, hu56V2-Fc that can not recognize mouse PDL1. The purpose of this study was achieved by experiments in which NOD/SCID mice were subcutaneously transplanted with human PDL1-expressing melanoma cell line A375 (ATCC, CRL-1619™) and human

peripheral blood mononuclear cells (PBMCs). A375 and PBMC were mixed in a 5:1 ratio prior to injection and subcutaneously injected in a total volume of 100 μ l (containing 5 million A375 and 1 million PBMCs). Antibodies were administered intraperitoneally 24 hours after tumor inoculation and then once a week at a dose of 0.3 mg/kg; PBS served as a negative control. 4-6 mice per experimental group. Tumor formation was observed twice weekly and the long and short diameters of the tumors were measured with a vernier caliper. The tumor volume was calculated and the tumor growth curve was plotted (see Figure 17A). It can be seen that antibody hu56V2-Fc at 0.3 mg/kg dose significantly inhibited tumor growth.

The same in vivo model was used to examine the PDL1 single domain antibody Fc fusion protein, hu56V1-Fcm1, that did not recognize mouse PDL1 either. A375 and human PBMCs were inoculated into NOD-SCID mice subcutaneously at a ratio of 4:1. Four hours later, different doses of hu56V1-Fcm1 (0.1, 0.3, 1, 3 and 10 mg/kg) were administered intraperitoneally. Anti-tumor effect to A375/human PBMCs xenografts in NOD-SCID mice was studied after weekly administration for 4 weeks. PBS was used as a negative control. 4-6 mice per experimental group. Tumor formation was observed twice weekly and the major and minor diameters of the tumors were measured using a vernier caliper. The tumor volume was calculated and the tumor growth curve was plotted (see Figure 17B). The results show that all doses of hu56V1-Fcm1 (0.1-10mg/kg) had significant anti-tumor effect on A375/human PBMCs allogeneic xenografts of NOD-SCID mice, but without significant dose-relevance. Antibody hu56V1-Fcm1 significantly inhibited tumor growth

even at a dose of 0.1 mg/kg.

5.15 Inhibitory activity on tumor growth of PDL1 single-domain antibody Fc fusion protein administered for different times

5 NOD-SCID mouse A375 / human PBMCs xenograft tumor model was used. A375 with human PBMCs at a ratio of 4: 1 was subcutaneously inoculated to NOD-SCID mice and hu56V1-Fcm1 (0.3 mg/kg) was injected intraperitoneally 4 hours later followed by intraperitoneal administration once every three days. The final numbers of administration were 1, 2, 3, 4 times.

10 Tumor formation was observed every three days and the major and minor diameters of the tumors were measured with a vernier caliper to calculate the tumor volume until the 33rd day from the first administration. The tumor growth curve was plotted (Fig. 18). The results showed that different number of administration in the study period all had significant antitumor effects on

15 A375/human PBMCs allogeneic xenografts of NOD-SCID mice.

5.16 Inhibition of Tumor Growth by PDL1 Single Domain Antibody Fc Fusion Protein and Comparison with MedImmune LLC Anti-PDL1 Antibody

 The purpose of this study was achieved by experiments in which

20 NOD/SCID mice were subcutaneously transplanted with human PDL1-expressing melanoma cell line A375 (ATCC, CRL-1619 TM) and human peripheral blood mononuclear cells (PBMCs). A375 and PBMC were mixed in a 5:1 ratio prior to injection in a total volume of 100 µl (containing 5 million A375 and 1 million PBMCs). The antibodies were administered intraperitoneally for

24 hours after tumor inoculation and then weekly once, at a dose of 1 mg/kg. The treatment group included hu56V2-Fc (denoted hu56) and MedImmune LLC's anti-PDL1 antibody group (indicated as 2.41) with PBS as a negative control. 4-6 mice per experimental group. Tumor formation was observed twice a week, and the major and minor diameters of the tumors were measured with a vernier caliper. The tumor volume was calculated and the tumor growth curve was plotted (see Figure 19 A). MedImmune LLC's anti-PDL1 antibody was essentially ineffective in this model and the tumor volume exceeded the negative control group on day 35, thus the administration and tumor volume measurement were stopped. It can be seen that the effect of hu56V2-Fc in inhibiting A375 tumor growth at 1 mg/kg dose is significantly superior to MedImmune LLC's anti-PDL1 antibody 2.41H90P under this model.

Since anti-PDL1 antibodies from MedImmune LLC did not show tumor suppression under the above system, it is possible that the activation of PBMC in the system is insufficient to inhibit tumor cell growth. Thus the content of PBMC in mixed cells was increased for examining again the anti-tumor effect of MedImmune LLC anti-PDL1 antibody.

The A375 and PBMC were mixed 1: 1 prior to injection in a total volume of 100 μ l (containing 5 million A375 and 5 million PBMCs) subcutaneously and MedImmune LLC anti-PD -L1 antibody (2.41H90P) was administered intraperitoneally followed by weekly administration at a dose of 1 mg/kg; PBS was used as a negative control. 4-6 mice per experimental group. Tumor formation was observed twice weekly and the major and minor diameters of the tumors were measured using a vernier caliper. The tumor volume was calculated

and the tumor growth curve was plotted (see Figure 19B). It can be seen that anti-PDL1 antibody from MedImmune LLC shows anti-tumor effect in in vivo model after increasing the proportion of PMBC.

The mean tumor inhibition (TGI = (1- tumor volume of treatment group/
5 tumor volume of control group) x 100%) on day 42 of the antibody is calculated and presented in Table 7 below:

Table 7

	TGI	
	hu56V2-Fc	2.41H90P
5:1	65.7%	N.A.
5:5	——	41.7%

The above in vivo antitumor experiment results show that the PDL1 blocking single-domain antibody Fc fusion proteins of the present invention
10 have significantly superiority to the known PDL1 blocking antibodies(Anti-PDL1 antibody from MedImmune LLC) in an in vivo melanoma A375 nude mouse model.

Example 6 Stability of PDL1 Single Domain Antibody Fc Fusion Protein

15 6.1 Resistance of PDL1 single domain antibody Fc fusion protein to alkali and oxidative stress

500 mM ammonium bicarbonate was used as alkali disrupting agent and fusion proteins were treated at 37°C for 38 hours. 1% hydrogen peroxide was used as the oxidant, 8 hours treatment at room temperature

20 The changes in the biological activity of the PDL1 single-domain antibody

Fc fusion protein obtained by the above Examples before and after treatment were measured using competitive ELISA. As can be seen in Figure 20, alkali and oxidative treatments did not affect the activity of the candidate PDL1 single domain antibody Fc fusion protein, and the competitive ELISA activity after 38
5 hours of alkali treatment was 103% relative to 0 hour. The competitive ELISA activity at 8 hours of oxidation treatment was 106% relative to 0 hour.

6.2 Stability of PDL1 Single Domain Antibody Fc Fusion Protein at High Concentration

10 The PDL1 single domain antibody Fc fusion protein was concentrated by UF/DF and exchanged into PBS buffer. And the aggregate formation tendency thereof was examined by SE-HPLC.

When concentrated to 200 mg/mL, the purity of the PDL1 single domain Fc fusion protein was 96.8% by SE-HPLC detection. Aggregates was increased
15 by about 2.4% over that at low concentrations (-2 mg/mL). Throughout the concentration process, no turbid phenomenon or aggregation occurred in the protein solution.

Sequence listing

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5 AKLLTSGSTYLADSVKGRFTISQNNAKSTVYLMNSLKPEDTAMYYC
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5

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5 KLLTTSGSTYLADSVKGRFTISRDN SKNTVY LQMNSLRAEDTAVYYCAA
DSFEDPTCTLVTSSGAFQYWGGQGLVTVSSEPKSSDKTHTCPPCPAPELL
GGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEV
HNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPI
EKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWE
10 SNGQPENNYKTTTPVLDS DGSFFLYSKLTVDKSRWQQGNVFSCSVMHE
ALHNHYTQKSLSLSPGK

> SEQ ID NO:25 Hu56V3-Fc-m2

QVQLVESGGGLVQPGGSLRLSCAASGKMSSRRCMAWFRQAPGKGLERV
15 AKLLTTSGSTYLADSVKGRFTISRDN SKNTVY LQMNSLRAEDTAVYYCA
ADSFEDPTCTLVTSSGAFQYWGGQGLVTVSSEPKSSDKTHTCPPCPAPEL
LGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVE
VHNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAP
IEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWE
20 SNGQPENNYKTTTPVLDS DGSFFLYSKLTVDKSRWQQGNVFSCSVMHE
ALHNHYTQKSLSLSPGK

> SEQ ID NO:26 Hu56V4-Fc-m2

QVQLVESGGGLVQPGGSLRLSCAASGFTFSRRCMAWFRQAPGKGLERV

AKLLTSGSTYLADSVKGRFTISRDN SKNTVYLQMNSLRAEDTAVYYCA
 ADSFEDPTCTLVTSSGAFQYWGGTLTVSSEPKSSDKTHTCPPCPAPEL
 LGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVE
 VHNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAP
 5 IEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWE
 SNGQPENNYKTTTPVLDSGSSFLYSKLTVDKSRWQQGNV FSCSVMHE
 ALHNHYTQKSLSLSPGK

> SEQ ID NO:27 Hu56V5-Fc-m2

10 QVQLVESGGGLVQPGGSLRLSCAASGKMSSRRCMAWFRQAPGKERERV
 AKLLTSGSTYLADSVKGRFTISRDN SKNTVYLQMNSLKAEDTAVYYCA
 ADSFEDPTCTLVTSSGAFQYWGGTLTVSSEPKSSDKTHTCPPCPAPEL
 LGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVE
 VHNAKTKPREEQYASTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAP
 15 IEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWE
 SNGQPENNYKTTTPVLDSGSSFLYSKLTVDKSRWQQGNV FSCSVMHE
 ALHNHYTQKSLSLSPGK

>SEQ ID NO:28 Human PDL1-Fc

20 TVTVPKDLYVVEYGSNM TIECKFPVEKQLDLAALIVYWEMEDKNIIQFV
 HGEEDLKVQHSSYRQRARLLKDQLSLGNAALQITDVKLQDAGVYRCMI
 SYGGADYKRITVKVNAPYNKINQRILVDPVTSEHELTCQAEGYPKAEV
 IWTSSDHQVLSGKTTTTNSKREENLFNVTSTLRINTTTNEIFYCTFRRLDP
 EENHTAELVIPELPLAHPNERTDDKTHTCPPCPAPELLGGPSVFLFPPKP

KDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQ
YNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPR
EPQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTT
PPVLDSDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSL
5 SPGK

>SEQ ID NO:29

GTCTTGCTGCTCTTCTACAAGGC

10 >SEQ ID NO:30

GGTACGTGCTGTTGAACTGTTCC

>SEQ ID NO:31

GATGTGCAGCTGCAGGAGTCTGGRGGAGG

15

>SEQ ID NO:32

GGACTAGTGCGCCGCTGGAGACGGTGACCTGGGT

>SEQ ID NO:33 mice PDL1-Fc

20 FTITAPKDLYVVEYGSNVTMECRFPVERELDLLALVVYWEKEDEQVIQF
VAGEEDLKPQHSNFRGRASLPKDQLLKGNAALQITDVKLQDAGVYCCII
SYGGADYKRITLKVNPYRKINQRISVDPATSEHELICQAEGYPEAEVIW
TNSDHQPVSGKRSVTTSRTEGMLLNVTSSLRVNATANDVFYCTFWRSQP
GQNHTAELIPELPPQNRTHDKTHTCPPCPAPPELLGGPSVFLFPPKPK

DTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQY
NSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPRE
PQVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTP
PVLDSGDGSFFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLS
5 PGK

>SEQ ID NO:34 Human PD1-Fc

PGWFLDSPDRPWNPPTFSPALLVVTEDGNATFTCSFSNTSESFVLNWYR
MSPSNQTDKLAAPEDRSQPGQDCRFRVTQLPNGRDFHMSVVRARRND
10 SGTYLCAISLAPKAQIKESLRAELRVTERRAEVPTAHPSPSPRPAGQFQD
KTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPE
VKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVLHQDWLNGKEY
KCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDELTKNQVSLTCLV
KGFYPSDIAVEWESNGQPENNYKTPPVLDSGDGSFFLYSKLTVDKSRWQ
15 QGNVFSCSVMHEALHNHYTQKSLSLSPGK

>SEQ ID NO:35 PDL1-Chis

TVTVPKDLYVVEYGSNMTIECKFPVEKQLDLAALIVYWEMEDKNIIQFV
HGEEDLKVQHSSYRQRARLLKDQLSLGNAALQITDVKLQDAGVYRCMI
20 SYGGADYKRITVKVNAPYNKINQRILVDPVTSEHELTCQAEGYPKAEV
IWTSSDHQVLSGKTTTTNSKREENLFNVTSTLRINTTTNEIFYCTFRRLDP
EENHTAELVIPELPLAHPPNERTDGSHHHHHHHH

>SEQ ID NO:36 CD80-Fc

VIHVTKEVKEVATLSCGHNVSVVEELAQTRIYWQKEKKMVLTMMSGDM
NIWPEYKNRTIFDITNNLSIVILALRPSDEGTYECVVLKYEKDAFKREHL
AEVTL SVKADFPTPSISDFEIPTSNIRRIICSTSGGFPEPHLSWLENGEELNA
INTTVSQDPETELYAVSSKLDFNMTTNHSFMCLIKYGH LRVNQTFNWNT
5 TKQEHFPDNDKTHTCPPCPAPELLGGPSVFLFPPKPKDTLMISRTPEVTCV
VVDVSHEDPEVKFNWYVDGVEVHNAKTKPREEQYNSTYRVVSVLTVL
HQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREPQVYTLPPSRDEL
TKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYS
KLTVDKSRWQQGNV FSCSV MHEALHNHYTQKSLSLSPGK

10

>SEQ ID NO:37 monkey PDL1

FTVTVPKDLYVVEYGSNM TIECKFPVEKQLDLTSLIVYWEMEDKNIIQFV
HGEEDLKVQHSNYRQRAQL LKDQLSLGNAALRITDVKLQDAGVYRCMI
SYGGADYKRITVKVNAPYNKINQRILVDPVTSEHELTCAEGYPKAEV
15 IWTSSDHQVLSGKTTTTNSKREEKLLNVTSTLRINTTANEIFYCIFRRLDP
EENHTAELVIP ELPLALPPNER THLVILGAIFLLLGVALTFIFYLRKGRMMD
MKKSGIRVTNSKKQRDTQLEET

>SEQ ID NO:38 human PDL1-muFc

20 FTVTVPKDLYVVEYGSNM TIECKFPVEKQLDLAALIVYWEMEDKNIIQF
VHGEEDLKVQHSSYRQRARLLKDQLSLGNAALQITDVKLQDAGVYRC
MISYGGADYKRITVKVNAPYNKINQRILVDPVTSEHELTCAEGYPKA
EVIWTSSDHQVLSGKTTTTNSKREEKLFNVTSTLRINTTTNEIFYCTFRRL
DPEENHTAELVIP ELPLAHPPNERTDIEGRMDPKSSDKTHTCPPCPAPEVS

SVFIFPPKPKDVLTTITLTPKVTCVVVDISKDDPEVQFSWFVDDVEVHTAQ
 TQPREEQFNSTFRSVSELPIMHQDWLNGKEFKCRVNSAAFPAPIEKTISK
 KGRPKAPQVYTIPPPKEQMAKDKVSLTCMITDFFPEDITVEWQWNGQPA
 ENYKNTQPIMNTNGSYFVYSKLVQKSNWEAGNTFTCSVLHEGLNHH
 5 TEKSLSHSPGK

>SEQ ID NO:39 Human PD1-muFc

PGWFLDSPDRPWNPTTFSPALLVTEGDNATFTCSFSNTSESFVLNWYR
 MSPSNQTDKLAAPEDRSQPGQDCRFRVTQLPNGRDFHMSVVRARRND
 10 SGTYLCAISLAPKAQIKESLRAELRVTERRAEVPTAHPSPSPRPAGQFQI
 EGRMDPKSSDKTHTCPPCAPEVSSVFIFPPKPKDVLTTITLTPKVTCVVVD
 ISKDDPEVQFSWFVDDVEVHTAQ TQPREEQFNSTFRSVSELPIMHQDWL
 NGKEFKCRVNSAAFPAPIEKTISKTKGRPKAPQVYTIPPPKEQMAKDKVS
 LTCMITDFFPEDITVEWQWNGQPAENYKNTQPIMNTNGSYFVYSKLVQ
 15 KSNWEAGNTFTCSVLHEGLNHHTEKSLSHSPGK

Claims:

1. An programmed death ligand 1(PDL1)-binding molecule, which can specifically bind to PDL1 and consists of an amino acid sequence of A-L-B, wherein A represents an immunoglobulin single variable domain, L is absent or represents an amino acid linker, and B represents an human immunoglobulin Fc region;

wherein said immunoglobulin single variable domain consists of an amino acid sequence selected from SEQ ID NOs:1-6;

said PDL1- binding molecule is capable of forming homodimers via said human immunoglobulin Fc region.

2. The PDL1-binding molecule of claim 1, wherein said immunoglobulin Fc region is a Fc region of human IgG1, IgG2, IgG3 or IgG4.

3. The PDL1-binding molecule of claim 1, wherein said immunoglobulin Fc region is mutated to remove ADCC and CDC activities.

4. The PDL1-binding molecule of claim 1, wherein the sequence of said immunoglobulin Fc region is selected from SEQ ID NOs:7-9.

5. The PDL1-binding molecule of any one of claims 1-4, wherein the linker is 1-20 amino acids in length.

6. The PDL1-binding molecule of any one of claims 1-5, which consists of an amino acid sequence selected from SEQ ID NOs:10-27.

7. The PDL1-binding molecule of any one of claims 1-6, which has at least one of the following features:

(a) binding to human PD-PDL1 with a KD of less than 1×10^{-7} M;;

(b) blocking the interaction between PDL1 and PD-1;

(c) enhancing activation of PBMC and/or T cells;

(d) inhibiting tumor growth.

8. The PDL1-binding molecule of any one of claims 1-7, which binds to PDL1 with a KD of less than 1×10^{-7} M, preferably less than 1×10^{-8} M, more

preferably less than 1×10^{-9} M, more preferably less than 1×10^{-10} M, and even more preferably less than 1×10^{-11} M.

9. A nucleic acid molecule encoding for the PDL1-binding molecule of any one of claims 1-8.

5 10. An expression vector, which comprises the nucleic acid molecule of claim 9 operably linked to an expression regulation element.

11. A host cell, which comprises the nucleic acid molecule of claim 9 or is transformed with the expression vector of claim 10, and is capable of expressing said PDL1-binding molecule.

10 12. A method for producing the PDL1-binding molecule of any one of claims 1-8, which comprises:

a) culturing the host cell of claim 11 under conditions that allow expression of the PDL1-binding molecule;

b) recovering the PDL1-binding molecule expressed by the host cell from
15 the culture of step a); and

c) optionally further purifying and/or modifying the PDL1-binding molecule obtained from step b).

13. A pharmaceutical composition comprising the PDL1-binding molecule of any one of claims 1-8, and a pharmaceutically acceptable carrier.

20 14. Use of the PDL1-binding molecule of any one of claims 1-8 or the pharmaceutical composition of claim 13 for the manufacture and/or preparation of a medicament or composition for treating cancer in a subject.

15. The use of claim 14, wherein said medicament or composition is to be administered in combination with additional anti-tumor therapeutic means.

16. The use of claim 15, wherein said additional anti-tumor therapeutic means comprises chemotherapy, radiotherapy or antibody against other tumor-specific antigen.

17. The use of claim 16, wherein said antibody against other tumor-specific antigen comprises anti-EGFR antibody, anti-EGFR variant antibody, anti-VEGFA antibody, anti-HER2 antibody, or anti-CMET antibody.

18. The use of claim 17, wherein said antibody against other tumor-specific antigen is a monoclonal antibody.

19. The use of any one of claims 14-18, wherein said cancer is selected from the group consisting of lung cancer, ovarian cancer, colon cancer, rectal cancer, melanoma, renal cancer, bladder cancer, breast cancer, liver cancer, lymphoma, hematological malignancy, head and neck cancer, glioma, gastric cancer, nasopharyngeal cancer, laryngeal cancer, cervical cancer, corpus carcinoma, osteosarcoma.

20. Use of the PDL1-binding molecule of any one of claims 1-8 or the pharmaceutical composition of claim 13 for the manufacture and/or preparation of a medicament or composition for treating infectious disease in a subject.

21. The use of claim 20, wherein said infectious disease is caused by a pathogen selected from the group consisting of HIV, hepatitis virus, influenza virus, herpes virus, Giardia, plasmodium, Leishmania, Staphylococcus aureus, Pseudomonas aeruginosa.