

## DESCRIPTION

## IMMUNOACTIVATING ANTIGEN-BINDING MOLECULE

5 Technical Field

The present invention relates to a novel cancer treatment method that uses a bispecific antibody.

Background Art

10 Cancer is one of the major causes of death in the world. With the exception of certain carcinomas, a cancer is often inoperable at the time it is found, and the outcome of treatment using chemotherapeutic agents, which is the main therapeutic method, is not necessarily good. Heterogeneity of cancer cells per se is not the only factor that makes cancer treatment difficult, and the tumor microenvironment has been suggested to play a major role (Non-patent Document 1). Recently, a possibility of curing unresectable malignant melanoma and such with an anti-CTLA-4 antibody which attenuates suppressor T cells has been suggested (Non-patent Document 2). This suggests that tumor immunostimulation may form the basis for designing new cancer treatment strategies.

It is understood that T cells which have important roles in tumor immunity become  
20 activated by two signals: 1) binding of a T cell receptor (TCR) to an antigenic peptide presented by major histocompatibility complex (MHC) class I molecules and activation of TCR; and 2) binding of a costimulator on the surface of T cells to the ligands on antigen-presenting cells and activation of the costimulator. Furthermore, activation of molecules belonging to the tumor necrosis factor (TNF) superfamily and the TNF receptor superfamily, such as CD137(4-1BB) on  
25 the surface of T cells, has been described to be important for T cell activation (Non-patent Document 3).

Molecules such as CD137, CD137L, CD40, CD40L, OX40, OX40L, CD27, CD70, HVEM, LIGHT, RANK, RANKL, CD30, CD153, GITR, and GITRL are included in the TNF superfamily and the TNF receptor superfamily. CD137 has been reported to be expressed not  
30 only on the surface of T cells, but also on the surface of other immune cells such as dendritic cells (DC), B cells, NK cells, and neutrophils (Non-patent Document 4).

CD137 agonist antibodies have already been demonstrated to show anti-tumor effects, and this has been shown experimentally to be mainly due to activation of CD8-positive T cells and NK cells (Non-patent Document 5). However, side effects due to non-specific  
35 hepatotoxicity of CD137 agonist antibodies have been a problem clinically and non-clinically, and development of pharmaceutical agents has not advanced (Non-patent Documents 6 and 7).

The main cause of the side effects has been suggested to involve binding to the Fcγ receptor *via* the antibody constant region (Non-patent Document 8). Furthermore, it has been reported that for agonist antibodies targeting receptors that belong to the TNF receptor superfamily to exert an agonist activity *in vivo*, antibody crosslinking by Fcγ receptor-expressing cells

(FcγRII-expressing cells) is necessary (Non-patent Document 9). More specifically, medicinal effects of CD137 agonist antibodies, which are anti-tumor effects, and side effects including hepatotoxicity both involve binding of the antibodies to Fcγ receptors. Therefore, if binding of the antibodies to Fcγ receptors is enhanced, medicinal effects are expected to improve but hepatotoxic side effects will also increase, and if binding of the antibodies to Fcγ receptors is reduced, side effects will be reduced but medicinal effects may become reduced as well, and CD137 agonist antibodies whose medicinal effects are separated from side effects have not been reported so far. Furthermore, the antitumor effects of CD137 agonist antibodies per se are not strong at all, and it is desirable to avoid toxicity and at the same time increase medicinal effects further.

Bispecific antibodies are characterized in that they have at least two binding domains, and their molecular morphology is already well known to those skilled in the art. Among them, molecules in which one of the two binding domains binds specifically to a cancer surface antigen and the second binding domain binds to a T cell surface antigen CD3 have also been constructed (Non-patent Document 10). Such bispecific single-chain antibodies have been shown to exert an antitumor effect by activating T cells in a cancer antigen-dependent manner.

Glypican 3 (GPC3) is a protein that belongs to the glypican family, i.e., a group of heparan sulfate proteoglycans bound to cell surface *via* glycosylphosphatidylinositol (Non-patent Document 11). Glypicans play an important role in cell proliferation, differentiation, and migration. GPC3 is expressed in 70% or more of hepatoma tissues obtained by surgical excision or biopsy, and is hardly or not at all expressed in neighboring nonneoplastic hepatic lesions and most adult tissues (Non-patent Documents 12 and 13). Furthermore, patients with high expression of hepatoma tissue GPC3 have been reported to have a poor prognosis (Non-patent Document 14), and GPC3 is considered to be a promising target molecule for hepatoma.

### Prior Art Documents

[Non-patent Documents]

[Non-patent Document 1] Hanahan, Cell, 2011, 144, 646-74

[Non-patent Document 2] Prieto, Clin Cancer Res. 2012, 18, 2039-47

[Non-patent Document 3] Summers, Nat. Rev. Immunol., 2012, 12, 339-51

[Non-patent Document 4] Vinay, Cell Biol Int., 2009, 33, 453-65

[Non-patent Document 5] Houot, Blood, 2009, 114, 3431-8

[Non-patent Document 6] Ascierto, Semin Oncol., 2010, 37, 508-16

[Non-patent Document 7] Dubrot, Cancer Immunol. Immunother., 2010, 59, 1223-33

[Non-patent Document 8] Schabowsky, Vaccine, 2009, 28, 512-22

5 [Non-patent Document 9] Li, Proc Natl Acad Sci U S A. 2013, 110(48), 19501-6

[Non-patent Document 10] Brandl, Cancer Immunol. Immunother., 2007, 56, 1551-63

[Non-patent Document 11] Filmus, J. Clin. Invest., 2001, 108, 497-501

[Non-patent Document 12] Zhu-Zu-W, Gut, 2001, 48, 558-564

[Non-patent Document 13] Yamauchi, Mod. Pathol., 2005, 18, 1591-1598

10 [Non-patent Document 14] Yorita, Liver Int., 2010, 1, 120-131

### Summary of the Invention

#### [Problems to be Solved by the Invention]

15 The present invention was achieved in view of the above circumstances. An objective of the present invention is to provide antigen-binding molecules that have an agonist activity against the TNF superfamily or the TNF receptor superfamily, which avoid toxicity while activating immune cells and exhibiting an excellent anti-tumor effect. Another objective of the present invention is to provide pharmaceutical compositions comprising the antigen-binding molecule as an active ingredient or methods for treating cancer using the pharmaceutical  
20 composition.

#### [Means for Solving the Problems]

The present inventors discovered that even though antigen-binding molecules having only the TNF superfamily-binding domain or only the TNF receptor superfamily-binding domain  
25 do not have an immune cell-activating effect, antigen-binding molecules having a cancer-specific antigen-binding domain and a TNF superfamily-binding domain or a cancer-specific antigen-binding domain and a TNF receptor superfamily-binding domain activate immune cells by exerting an agonist activity against factors belonging to the TNF superfamily or the TNF receptor superfamily only in the presence of cancer-specific antigen-expressing cells, and avoid  
30 side effects such as hepatotoxicity while maintaining an anti-tumor activity. Furthermore, the present inventors discovered that by using the antigen-binding molecules in combination with antigen-binding molecules having a cancer-specific antigen-binding domain and a T cell receptor complex-binding domain, side effects can be avoided and antitumor activity can be increased, and thereby completed the present invention.

35 More specifically, the present invention provides the following:

[1] an antigen-binding molecule comprising:

- (1) a cancer-specific antigen-binding domain; and
- (2) a tumor necrosis factor (TNF) superfamily-binding domain or a tumor necrosis factor (TNF) receptor superfamily-binding domain;
- [2] the antigen-binding molecule of [1], further comprising an FcRn-binding domain;
- 5 [3] the antigen-binding molecule of [2], wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity;
- [4] the antigen-binding molecule of any one of [1] to [3], wherein the TNF superfamily-binding domain or the TNF receptor superfamily-binding domain is a CD137-binding domain;
- [5] the antigen-binding molecule of any one of [1] to [4], which is a bispecific antibody;
- 10 [6] a pharmaceutical composition comprising as an active ingredient the antigen-binding molecule of any one of [1] to [5];
- [7] the pharmaceutical composition of [6], which is a cytotoxicity-inducing composition;
- [8] the pharmaceutical composition of [6], which is a composition for use in the treatment of cancer;
- 15 [9] a pharmaceutical composition comprising a combination of a first antigen-binding molecule of any one of [1] to [5], and a second antigen-binding molecule that comprises:
  - (1) a cancer-specific antigen-binding domain; and
  - (2) a T cell receptor complex-binding domain;
- [10] the pharmaceutical composition of [9], wherein the second antigen-binding molecule is an
- 20 antigen-binding molecule that further comprises an FcRn-binding domain;
- [11] the pharmaceutical composition of [10], wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity;
- [12] the pharmaceutical composition of any one of [9] to [11], wherein the T cell receptor complex-binding domain is a T cell receptor-binding domain;
- 25 [13] the pharmaceutical composition of any one of [9] to [11], wherein the T cell receptor complex-binding domain is a CD3-binding domain;
- [14] the pharmaceutical composition of any one of [9] to [13], wherein the second antigen-binding molecule is a bispecific antibody;
- [15] the pharmaceutical composition of any one of [9] to [14], wherein the first antigen-binding
- 30 molecule and the second antigen-binding molecule are mixed;
- [16] the pharmaceutical composition of any one of [9] to [14], wherein the first antigen-binding molecule and the second antigen-binding molecule are used concomitantly;
- [17] the pharmaceutical composition of any one of [9] to [14], wherein the first antigen-binding molecule and the second antigen-binding molecule are administered simultaneously;
- 35 [18] the pharmaceutical composition of any one of [9] to [14], wherein the first antigen-binding molecule and the second antigen-binding molecule are administered separately;

[19] the pharmaceutical composition of any one of [9] to [18], which is a cytotoxicity-inducing composition;

[20] the pharmaceutical composition of any one of [9] to [18], which is a composition for use in the treatment of cancer;

5 [21] a pharmaceutical composition comprising as an active ingredient a first antigen-binding molecule that comprises:

(1) a cancer-specific antigen-binding domain; and

(2) a tumor necrosis factor (TNF) superfamily-binding domain or a tumor necrosis factor (TNF) receptor superfamily-binding domain,

10 for concomitant use with a second antigen-binding molecule that comprises:

(1) a cancer-specific antigen-binding domain; and

(2) a T cell receptor complex-binding domain;

[22] the pharmaceutical composition of [21], which is a cytotoxicity-inducing composition;

15 [23] the pharmaceutical composition of [21], which is a composition for use in the treatment of cancer;

[24] the pharmaceutical composition of any one of [21] to [23], wherein the first antigen-binding molecule and/or the second antigen-binding molecule is an antigen-binding molecule that further comprises an FcRn-binding domain;

20 [25] the pharmaceutical composition of [24], wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity;

[26] the pharmaceutical composition of any one of [21] to [25], wherein the TNF superfamily-binding domain or the TNF receptor superfamily-binding domain is a CD137-binding domain or a CD40-binding domain;

25 [27] the pharmaceutical composition of any one of [21] to [26], wherein the T cell receptor complex-binding domain is a T cell receptor-binding domain;

[28] the pharmaceutical composition of any one of [21] to [26], wherein the T cell receptor complex-binding domain is a CD3-binding domain;

[29] the pharmaceutical composition of any one of [21] to [28], wherein the first antigen-binding molecule and/or the second antigen-binding molecule is a bispecific antibody;

30 [30] the pharmaceutical composition of any one of [21] to [29], which is administered simultaneously with the second antigen-binding molecule;

[31] the pharmaceutical composition of any one of [21] to [29], which is administered separately from the second antigen-binding molecule;

35 [32] a pharmaceutical composition comprising as an active ingredient a second antigen-binding molecule that comprises:

(1) a cancer-specific antigen-binding domain; and

(2) a T cell receptor complex-binding domain,

for concomitant use with a first antigen-binding molecule that comprises:

(1) a cancer-specific antigen-binding domain; and

(2) a tumor necrosis factor (TNF) superfamily-binding domain or a tumor necrosis factor (TNF)

5 receptor superfamily-binding domain;

[33] the pharmaceutical composition of [32], which is a cytotoxicity-inducing composition;

[34] the pharmaceutical composition of [32], which is a composition for use in the treatment of cancer;

[35] the pharmaceutical composition of any one of [32] to [34], wherein the first antigen-binding molecule and/or the second antigen-binding molecule is an antigen-binding molecule that further comprises an FcRn-binding domain;

[36] the pharmaceutical composition of [35], wherein the FcRn-binding domain is an antibody Fc region having decreased Fcγ receptor-binding activity;

[37] the pharmaceutical composition of any one of [32] to [36], wherein the T cell receptor complex-binding domain is a T cell receptor-binding domain;

[38] the pharmaceutical composition of any one of [32] to [36], wherein the T cell receptor complex-binding domain is a CD3-binding domain;

[39] the pharmaceutical composition of any one of [32] to [38], wherein the TNF superfamily-binding domain or the TNF receptor superfamily-binding domain is a CD137-binding domain or a CD40-binding domain;

[40] the pharmaceutical composition of any one of [32] to [39], wherein the first antigen-binding molecule and/or the second antigen-binding molecule is a bispecific antibody;

[41] the pharmaceutical composition of any one of [32] to [40], which is administered simultaneously with the first antigen-binding molecule;

[42] the pharmaceutical composition of any one of [32] to [40], which is administered separately from the first antigen-binding molecule;

[43] a method for inducing cytotoxicity, suppressing cell proliferation, activating immunity against a cancer cell or a cancer cell-comprising tumor tissue, or treating or preventing cancer, which comprises the step of administering the antigen-binding molecule of any one of [1] to [5]

30 or the pharmaceutical composition of any one of [6] to [42];

[44] the antigen-binding molecule of any one of [1] to [5] or the pharmaceutical composition of any one of [6] to [42], for use in inducing cytotoxicity, suppressing cell proliferation, activating immunity against a cancer cell or a cancer cell-comprising tumor tissue, or treating or preventing cancer;

35 [45] use of the antigen-binding molecule of any one of [1] to [5] in production of the pharmaceutical composition of any one of [6] to [42]; and

[46] a method for producing the pharmaceutical composition of any one of [6] to [42], which comprises the step of using the antigen-binding molecule of any one of [1] to [5].

Furthermore, the present invention relates to methods for treating or preventing cancer, which comprises administering an antigen-binding molecule of the present invention or a pharmaceutical composition of the present invention to a patient in need of treatment. The present invention also relates to a kit for use in the method of the present invention, which comprises an antigen-binding molecule of the present invention. The present invention also relates to the use of an antigen-binding molecule of the present invention in producing a pharmaceutical composition for inducing cytotoxicity (for example, a pharmaceutical composition for treating or preventing cancer). Furthermore, the present invention relates to antigen-binding molecules of the present invention or pharmaceutical compositions of the present invention for use in methods of the present invention.

#### Brief Description of the Drawings

Fig. 1 presents a graph showing results of assessing the effect of anti-mouse CD137 antibodies on T cell activation by IFN- $\gamma$  ELISA. Ctrl mIgG1 indicates the negative control mouse IgG1 antibody.

Fig. 2 presents a diagram that conceptually demonstrates the T cell activation effect of an anti-mouse CD137 antibody in various molecular forms.

Fig. 3 presents a diagram that conceptually demonstrates the GPC3 antigen-dependent T cell activation effect of an anti-human GPC3/anti-mouse CD137 bispecific antibody.

Fig. 4 presents a graph showing the result of assessing the GPC3 antigen-dependent T cell activation effect of an anti-human GPC3/anti-mouse CD137 bispecific antibody using IFN- $\gamma$  ELISA.

Fig. 5 presents a graph showing the result of assessing the influence of changes in the antibody constant regions of an anti-human GPC3/anti-mouse CD137 bispecific antibody on the GPC3 antigen-dependent T cell activation effect using IFN- $\gamma$  ELISA.

Fig. 6 presents a graph showing the result of assessing the effect of enhancing T cell activation produced by a mixture of an anti-human GPC3/anti-mouse CD137 bispecific antibody and an anti-human GPC3/anti-mouse CD3 bispecific antibody using IFN- $\gamma$  ELISA. Ctrl hIgG1 indicates the negative control human IgG1 antibody (Alexis Corporation).

Fig. 7 presents a graph showing the antitumor effect of an anti-human GPC3/mouse CD137 bispecific antibody and an anti-mouse CD137 antibody on a syngeneic CT26 tumor mouse model. The arrows indicate the time when the antibodies were administered.

Fig. 8 presents a graph showing the influence of an anti-human GPC3/mouse CD137 bispecific antibody and an anti-mouse CD137 antibody on aspartate aminotransferase (AST) in

the blood of a syngeneic CT26 tumor mouse model.

Fig. 9 presents a graph showing the influence of an anti-human GPC3/mouse CD137 bispecific antibody and an anti-mouse CD137 antibody on alanine aminotransferase (ALT) in the blood of a syngeneic CT26 tumor mouse model.

5 Fig. 10 presents a graph showing the influence of an anti-human GPC3/mouse CD137 bispecific antibody and an anti-mouse CD137 antibody on total bilirubin in the blood of a syngeneic CT26 tumor mouse model.

Fig. 11 shows photographs of hepatic histopathological findings in a syngeneic CT26 tumor mouse model by an anti-human GPC3/mouse CD137 bispecific antibody and an  
10 anti-mouse CD137 antibody. The photographs are hematoxylin-eosin stained histopathological images of liver sections from a representative mouse, where a and d show the results of administering the solvent, b and e show the results of administering 1D8-MB492, and c and f show the results of administering GPC3 ERY22-3-1D8. The arrow heads indicate the degenerated or necrotic liver cells, and \* indicates finding of inflammation.

15 Fig. 12 presents a graph demonstrating the antitumor effect of concomitant use of an anti-human GPC3/mouse CD137 bispecific antibody and an anti-human GPC3/mouse CD3 bispecific antibody on a syngeneic LLC tumor mouse model. The arrows show the time when the antibodies were administered.

Fig. 13 shows the relationship between the amino acid residues constituting the Fc regions of IgG1, IgG2, IgG3, and IgG4, and Kabat's EU numbering (herein, it is also called the  
20 EU INDEX).

Fig. 14-1 shows the results of ELISA for assessing the binding of anti-human CD137 antibodies to fragmented human CD137-Fc fusion proteins. In the figure, "Non" indicates the level of ELISA color development in wells that have not been immobilized with the antigen  
25 (Non-Coating).

Fig. 14-2 shows the values (ratios relative to the level in Non-Coating) obtained by dividing the levels of ELISA color development of each sample shown in Fig. 14-1 by the level of ELISA color development in Non-Coating (Non) wells (binding to wells that have not been immobilized with the antigen).

30 Fig. 15 presents a graph showing the IFN $\gamma$ -inducing activity of anti-human CD137 antibodies.

Fig. 16 shows the T cell activation effect and binding profile of anti-human CD137 antibodies.

Fig. 17 presents a graph showing the results of assessing the effect of enhancing T cell  
35 activation produced by a mixture of an anti-human GPC3/anti-mouse CD40 bispecific antibody and an anti-human GPC3/anti-mouse CD3 bispecific antibody using IFN- $\gamma$  ELISA. Ctrl hIgG1

indicates the negative control human IgG1 antibody.

Fig. 18 presents a graph showing the results of assessing the T cell activation effect of the anti-human GPC3/anti-human CD137 bispecific antibody GPC3 FAE-BMS using IFN- $\gamma$  ELISA. Ctrl hIgG1 indicates the negative control human IgG1 antibody.

Fig. 19 presents a graph showing the results of assessing the CD137-mediated agonist activity of various anti-human GPC3/anti-human CD137 bispecific antibodies by the level of production of IL-6 which activates B cells. Ctrl hIgG1 indicates the negative control human IgG1 antibody.

## Mode for Carrying Out the Invention

The following definitions are provided in order to facilitate understanding of the invention described herein.

### Antigen-binding molecules

In the present invention, “antigen-binding molecules” are not particularly limited as long as they are molecules that comprise a “binding domain” of the present invention, and they may further comprise a peptide or protein having a length of about five amino acids or more. The peptide and protein are not limited to those derived from a living organism, and for example, they may be a polypeptide produced from an artificially designed sequence. They may also be any of a naturally-occurring polypeptide, synthetic polypeptide, recombinant polypeptide, and such.

A favorable example of an antigen-binding molecule of the present invention is an antigen-binding molecule that comprises an FcRn-binding domain contained in an antibody Fc region. As a method for extending the blood half-life of a protein administered to a living body, the method of adding an FcRn-binding domain of an antibody to the protein of interest and utilizing the function of FcRn-mediated recycling is well known.

In the present invention, the “FcRn-binding domain” is not particularly limited as long as it has binding activity to FcRn, and examples include antibody variable regions, Fab and antibody Fc regions whose antigens are FcRn, and fragments thereof. A preferred embodiment of the present invention includes antibody Fc regions or fragments containing an FcRn-binding region of an Fc region. Herein, for example, an Fc region derived from a naturally-occurring IgG may be used as the “Fc region”. A naturally-occurring IgG means a polypeptide that comprises the same amino acid sequence as an IgG found in nature, and belongs to a class of antibodies substantially encoded by immunoglobulin gamma genes. A naturally-occurring human IgG means, for example, a naturally-occurring human IgG1, a naturally-occurring human IgG2, a naturally-occurring human IgG3, or a naturally-occurring human IgG4.

Naturally-occurring IgGs also include mutants and such that naturally generate therefrom. A plurality of allotype sequences that result from genetic polymorphism have been described in Sequences of Proteins of Immunological Interest, NIH Publication No. 91-3242 for the human IgG1, human IgG2, human IgG3, and human IgG4 antibody constant region, and any of the sequences may be used in the present invention. In particular, the amino acid sequence of positions 356 to 358 according to EU numbering may be DEL or EEM for the human IgG1 sequence.

Existing antibody Fc regions are, for example, IgA1, IgA2, IgD, IgE, IgG1, IgG2, IgG3, IgG4, and IgM-type Fc regions. For example, an Fc region derived from a naturally-occurring human IgG antibody can be used as the antibody Fc region of the present invention. Fc regions derived from a constant region of a naturally-occurring IgG, or more specifically, a constant region derived from a naturally-occurring human IgG1 (SEQ ID NO: 1), a constant region derived from a naturally-occurring human IgG2 (SEQ ID NO: 2), a constant region derived from a naturally-occurring human IgG3 (SEQ ID NO: 3), and a constant region derived from a naturally-occurring human IgG4 (SEQ ID NO: 4), can be used as an Fc region of the present invention. Mutants and such that naturally generate therefrom are also included in the naturally-occurring IgG constant regions.

Such antibody Fc regions can be suitably obtained, for example, by partial digestion of antibodies such as monoclonal antibodies using a protease such as pepsin, then adsorption of the resulting fragments onto a protein A column or a protein G column, and subsequent elution using an appropriate elution buffer and such. The protease is not particularly limited as long as it can digest an antibody such as a monoclonal antibody by appropriately establishing the enzyme reaction conditions such as pH, and examples include pepsin and ficin.

The isotype of an antibody is determined by the structure of the constant region. The constant region of isotypes IgG1, IgG2, IgG3, and IgG4 is called C $\gamma$ 1, C $\gamma$ 2, C $\gamma$ 3, and C $\gamma$ 4, respectively. The amino acid sequences of polypeptides constituting the Fc regions of human C $\gamma$ 1, C $\gamma$ 2, C $\gamma$ 3, and C $\gamma$ 4 are exemplified in SEQ ID NOs: 5, 6, 7, and 8. The relationship between amino acid residues constituting each of these amino acid sequences and Kabat's EU numbering (herein, also referred to as EU INDEX) is shown in Fig. 13.

An Fc region refers to a region that excludes F(ab')<sub>2</sub> which contains two light chains and two heavy chains containing part of the constant region between the CH1 domain and the CH2 domain such that the disulfide bonds between the chains are formed between the two heavy chains. Fc regions forming the antigen-binding molecules disclosed herein can be obtained suitably by partially digesting the IgG1, IgG2, IgG3, or IgG4 monoclonal antibodies or the like using a protease such as pepsin, and then re-eluting fractions adsorbed to the protein A column. The protease is not particularly limited as long as it can digest a full-length antibody in a

restrictive manner to produce F(ab')<sub>2</sub> by appropriately establishing the enzyme reaction conditions such as pH. Such proteases include, for example, pepsin and ficin.

A domain with decreased Fcγ receptor-binding activity is particularly preferred as the FcRn-binding domain of the present invention. Here, an Fcγ receptor (herein, also denoted as Fcγ receptor, FcγR, or FcγR) refers to a receptor that can bind to the Fc region of IgG1, IgG2, IgG3, or IgG4, and includes all members belonging to the family of proteins substantially encoded by Fcγ receptor genes. In humans, this family includes, but is not limited to, FcγRI (CD64) including isoforms FcγRIa, FcγRIb, and FcγRIc; FcγRII (CD32) including isoforms FcγRIIa (including allotypes H131 (type H) and R131 (type R), FcγRIIb (including FcγRIIb-1 and FcγRIIb-2), and FcγRIIc; and FcγRIII (CD16) including isoforms FcγRIIIa (including allotypes V158 and F158) and FcγRIIIb (including allotypes FcγRIIIb-NA1 and FcγRIIIb-NA2); as well as any undiscovered human FcγRs, and FcγR isoforms or allotypes. FcγRs include, but are not limited to, those derived from humans, mice, rats, rabbits, and monkeys, and may be derived from any organism. Mouse FcγRs include, but are not limited to, FcγRI (CD64), FcγRII (CD32), FcγRIII (CD16), and FcγRIII-2 (CD16-2), as well as any undiscovered mouse FcγRs, and FcγR isoforms or allotypes. Suitable examples of such Fcγ receptors include human FcγRI (CD64), FcγRIIa (CD32), FcγRIIb (CD32), FcγRIIIa (CD16) and/or FcγRIIIb (CD16).

Activating receptors which carry an immunoreceptor tyrosine-based activation motif (ITAM) and inhibitory receptors which carry an immunoreceptor tyrosine-based inhibitory motif (ITIM) are present among FcγRs. FcγRs are categorized into activating FcγRs: FcγRI, FcγRIIa, FcγRIIb, and FcγRIIIa, and inhibitory FcγR: FcγRIIb.

The polynucleotide sequence and amino acid sequence of FcγRI are shown in NM\_000566.3 and NP\_000557.1, respectively; the polynucleotide sequence and amino acid sequence of FcγRIIa are shown in BC020823.1 and AAH20823.1, respectively; the polynucleotide sequence and amino acid sequence of FcγRIIb are shown in BC146678.1 and AAI46679.1, respectively; the polynucleotide sequence and amino acid sequence of FcγRIIIa are shown in BC033678.1 and AAH33678.1, respectively; and the polynucleotide sequence and amino acid sequence of FcγRIIIb are shown in BC128562.1 and AAI28563.1, respectively (RefSeq accession number). There are two types of gene polymorphisms for FcγRIIa, where the amino acid at position 131 of FcγRIIa is substituted into histidine (type H) or arginine (type R) (J. Exp. Med, 172, 19-25, 1990). Furthermore, there are two types of gene polymorphisms for FcγRIIb, where the amino acid at position 232 of FcγRIIb is substituted with isoleucine (type I) or threonine (type T) (Arthritis. Rheum. 46: 1242-1254 (2002)). In addition, there are two types of gene polymorphisms for FcγRIIIa, where the amino acid at position 158 of FcγRIIIa is substituted with valine (type V) or phenylalanine (type F) (J. Clin. Invest. 100(5): 1059-1070 (1997)). There are also two types of gene polymorphisms for FcγRIIIb, which are type NA1

and type NA2 (J. Clin. Invest. 85: 1287-1295 (1990)).

Whether the binding activity to an Fc $\gamma$  receptor is decreased can be confirmed by well-known methods such as FACS, ELISA format, screening by Amplified Luminescent Proximity Homogeneous Assay (ALPHA), surface plasmon resonance (SPR)-based BIACORE method, and others (Proc. Natl. Acad. Sci. USA (2006) 103(11), 4005-4010).

ALPHA screening is performed with ALPHA technology which uses two beads, a donor and an acceptor bead, based on the following principle. Luminescent signals are detected only when molecules bound to donor beads interact biologically with molecules bound to the acceptor beads, and the two beads are in close proximity to each other. The laser-excited photosensitizer within the donor beads converts ambient oxygen to excited-state singlet oxygen. Singlet oxygen is dispersed around the donor beads; and when it reaches the adjacent acceptor beads, a chemiluminescent reaction is induced within the beads, and light is ultimately emitted. When molecules bound to the donor beads do not interact with molecules bound to the acceptor beads, the chemiluminescent reaction does not take place because singlet oxygen produced by the donor beads does not reach the acceptor beads.

For example, when an antigen-binding molecule contains an antibody Fc region as the FcRn-binding domain, an antigen-binding molecule having a wild-type Fc region and an antigen-binding molecule having a mutant Fc region produced by adding amino acid mutations to change the binding to an Fc $\gamma$  receptor are prepared, a biotinylated antigen-binding molecule is bound to the donor beads, and an Fc $\gamma$  receptor tagged with glutathione S transferase (GST) is bound to the acceptor beads. In the presence of an antigen-binding molecule having a mutant Fc region, the antigen-binding molecule having a wild-type Fc region interacts with the Fc $\gamma$  receptor and produces 520-620 nm signals. When the antigen-binding molecule having a mutant Fc region is untagged, it competes with the antigen-binding molecule having a wild-type Fc region for interaction with the Fc $\gamma$  receptor. The relative binding affinity can be determined by quantifying the decrease in fluorescence observed as a result of the competition. Biotinylation of antigen-binding molecules using Sulfo-NHS-biotin and such is well known. As a method for tagging an Fc $\gamma$  receptor with GST, the method of expressing the Fc $\gamma$  receptor and GST in a cell carrying a vector that can express a fusion gene produced by fusing a polynucleotide encoding the Fc $\gamma$  receptor in frame with a GST-encoding polynucleotide, and purifying it using a glutathione column can be appropriately adopted. The obtained signals are suitably analyzed, for example, by fitting them into a one-site competition model that utilizes a non-linear regression analysis with software such as GRAPHPAD PRISM (GraphPad, San Diego).

One of the substances (ligand) observed for interaction is immobilized onto a gold thin film on a sensor chip, and by shining light from the reverse side of the sensor chip so that total reflection takes place at the interface between the gold thin film and glass, a portion with reduced

reflection intensity is formed in part of the reflected light (SPR signal). The other substance (analyte) observed for interaction is made to flow over the sensor chip surface; and when the ligand binds to the analyte, the mass of the immobilized ligand molecule increases and the refractive index of the solvent on the sensor chip surface changes. The position of the SPR signal shifts as a result of this change in the refractive index (reversely, the signal position returns if this binding dissociates). The Biacore system shows the amount of shift mentioned above, or more specifically the time variable of mass, by plotting the change in mass on the sensor chip surface on the vertical axis as the measurement data (sensorgram). Kinetic parameters such as association rate constant ( $k_a$ ) and dissociation rate constant ( $k_d$ ) are determined from the curve in the sensorgram, and the affinity ( $K_D$ ) is determined from the ratio of these constants. In the BIACORE method, a method for measuring inhibition is also suitably used. An example of the method for measuring inhibition is described in Proc. Natl. Acad. Sci USA (2006) 103 (11): 4005-4010.

Herein, “decreased  $Fc\gamma$  receptor-binding activity” means that, for example, based on the above-described analytical method, the binding activity of the test antigen-binding molecule is 50% or less, preferably 45% or less, 40% or less, 35% or less, 30% or less, 20% or less, 15% or less, or particularly preferably 10% or less, 9% or less, 8% or less, 7% or less, 6% or less, 5% or less, 4% or less, 3% or less, 2% or less, or 1% or less as compared to the binding activity of the control antigen-binding molecule containing an Fc region.

For the control antigen-binding molecule, antigen-binding molecules having, for example, a domain comprising an Fc region of a monoclonal IgG1, IgG2, IgG3, or IgG4 antibody may be suitably used. The structures of the Fc regions are shown in SEQ ID NO: 1 (A is added to the N terminus of RefSeq Accession No. AAC82527.1), SEQ ID NO: 2 (A is added to the N terminus of RefSeq Accession No. AAB59393.1), SEQ ID NO: 3 (A is added to the N terminus of RefSeq Accession No. CAA27268.1), and SEQ ID NO: 4 (A is added to the N terminus of RefSeq Accession No. AAB59394.1). Further, when an antigen-binding molecule containing a mutant of an Fc region of a particular antibody isotype is used as the test substance, the effect of a mutation possessed by the mutant on the  $Fc\gamma$  receptor-binding activity is tested by using as a control an antigen-binding molecule having an Fc region of an antibody of that particular isotype. In this way, antigen-binding molecules containing an Fc region mutant whose binding activity toward the  $Fc\gamma$  receptor verified to be decreased are suitably produced.

Examples of such mutants include mutants with a 231A-238S deletion (WO 2009/011941), or C226S, C229S, P238S, (C220S) (J. Rheumatol (2007) 34, 11), C226S, C229S (Hum. Antibod. Hybridomas (1990) 1(1), 47-54), C226S, C229S, E233P, L234V, or L235A (Blood (2007) 109, 1185-1192) mutants, where the amino acids are specified by EU numbering.

That is, suitable examples include antigen-binding molecules having an Fc region in

which any of the amino acids at positions 220, 226, 229, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 264, 265, 266, 267, 269, 270, 295, 296, 297, 298, 299, 300, 325, 327, 328, 329, 330, 331, and 332 specified according to EU numbering has been substituted in the amino acids constituting the Fc region of an antibody of a specific isotype. The isotype of the antibody from which the Fc region originates is not particularly limited, and the Fc region derived from an IgG1, IgG2, IgG3, or IgG4 monoclonal antibody can be used appropriately, and the Fc region derived from a naturally-occurring human IgG1 antibody is suitably used.

For example, an antigen-binding molecule having an Fc region that comprises any substitution specified below based on EU numbering from among amino acids constituting the IgG1 antibody Fc region (wherein the number indicates the position of the amino acid residue specified according to EU numbering, the one-letter amino acid code positioned before the number indicates the amino acid residue before the substitution, and the one-letter amino acid code positioned after the number indicates the amino acid residue before the substitution):

(a) L234F, L235E, P331S

(b) C226S, C229S, P238S

(c) C226S, C229S

(d) C226S, C229S, E233P, L234V, L235A;

or an Fc region lacking the amino acid sequence of positions 231 to 238 from among amino acids constituting the IgG1 antibody Fc region may be appropriately used.

Furthermore, antigen-binding molecules having an Fc region that comprises any substitution specified below based on EU numbering from among amino acids constituting the IgG2 antibody Fc region (wherein the number indicates the position of the amino acid residue specified according to EU numbering, the one-letter amino acid code positioned before the number indicates the amino acid residue before the substitution, and the one-letter amino acid code positioned after the number indicates the amino acid residue before the substitution):

(e) H268Q, V309L, A330S, P331S

(f) V234A

(g) G237A

(h) V234A, G237A

(i) A235E, G237A

(j) V234A, A235E, G237A

may be appropriately used.

Furthermore, antigen-binding molecules having an Fc region that comprises any substitution specified below based on EU numbering from among amino acids constituting the IgG3 antibody Fc region (wherein the number indicates the position of the amino acid residue specified according to EU numbering, the one-letter amino acid code positioned before the

number indicates the amino acid residue before the substitution, and the one-letter amino acid code positioned after the number indicates the amino acid residue before the substitution):

(k) F241A

(l) D265A

5 (m) V264A

may be appropriately used.

Furthermore, antigen-binding molecules having an Fc region that comprises any substitution specified below based on EU numbering from among amino acids constituting the IgG4 antibody Fc region (wherein the number indicates the position of the amino acid residue specified according to EU numbering, the one-letter amino acid code positioned before the number indicates the amino acid residue before the substitution, and the one-letter amino acid code positioned after the number indicates the amino acid residue before the substitution):

10 (n) L235A, G237A, E318A

(o) L235E

15 (p) F234A, L235A

may be appropriately used.

Other preferred examples include antigen-binding molecules having an Fc region in which any of the amino acids at positions 233, 234, 235, 236, 237, 327, 330, and 331 specified according to EU numbering in the amino acids constituting the Fc region of a naturally-occurring human IgG1 antibody is substituted with amino acids of corresponding EU numbering in the corresponding IgG2 or IgG4.

Other preferred examples suitably include antigen-binding molecules having an Fc region in which any one or more of the amino acids at positions 234, 235, and 297 specified according to EU numbering in the amino acids constituting the Fc region of a naturally-occurring human IgG1 antibody are substituted by other amino acids. The type of amino acid present after substitution is not particularly limited, and an antigen-binding molecule having an Fc region in which any one or more of the amino acids at positions 234, 235, and 297 are substituted with alanine is particularly preferred.

Other preferred examples suitably include antigen-binding molecules having an Fc region in which the amino acid at position 265 specified according to EU numbering in the amino acids constituting an IgG1 antibody Fc region is substituted by another amino acid. The type of amino acid present after substitution is not particularly limited, and an antigen-binding molecule having an Fc region in which the amino acid at position 265 is substituted with alanine is particularly preferred.

35 The “cancer-specific antigen-binding domain”, “tumor necrosis factor (TNF) superfamily-binding domain”, “tumor necrosis factor (TNF) receptor superfamily-binding

domain”, and “T cell receptor complex-binding domain” (hereinafter, the four binding domains are collectively referred to as antigen-binding domains) included in the antigen-binding molecules of the present invention refer to regions that bind specifically to the whole or a portion of their respective antigens which are cancer-specific antigens, factors belonging to the TNF superfamily, factors belonging to the TNF receptor superfamily, or T cell receptor complex; and an example of the binding domain is a region that comprises the antigen-binding region of an antibody. When the molecular weight of the antigen is large, the antigen-binding region of the antibody can bind only to a specific portion of the antigen. This specific portion is called an epitope. The antigen-binding domain is provided by one or more variable domains of an antibody. Preferably, an antigen-binding domain comprises an antibody light chain variable region (VL) and an antibody heavy chain variable region (VH). Suitable examples of such antigen-binding domains include “single chain Fv (scFv)”, “single chain antibody”, “Fv”, “single chain Fv 2 (scFv2)”, “Fab”, “F(ab')<sub>2</sub>”, and such.

Herein, a “cancer-specific antigen” refers to an antigen expressed by cancer cells, which enables one to distinguish between cancer cells and healthy cells; and for example, it includes antigens that are expressed as cells become malignant, or abnormal sugar chains that appear on protein molecules or cell surface when cells become cancerous. Specific examples include ALK receptor (pleiotrophin receptor); pleiotrophin; KS 1/4 pancreas carcinoma antigen; ovarian carcinoma antigen (CA125); prostatic acid phosphate; prostate-specific antigen (PSA); melanoma-associated antigen p97; melanoma antigen gp75; high molecular weight melanoma antigen (HMW-MAA); prostate-specific membrane antigen; carcinoembryonic antigen (CEA); polymorphic epithelial mucin antigen; human milk fat globule antigen; colorectal tumor-associated antigens such as CEA, TAG-72, CO17-1A, GICA 19-9, CTA-1, and LEA; Burkitt's lymphoma antigen-38.13; CD19; human B-lymphoma antigen-CD20; CD33; melanoma-specific antigens such as ganglioside GD2, ganglioside GD3, ganglioside GM2, and ganglioside GM3; tumor-specific transplantation type cell-surface antigen (TSTA); virus-induced tumor antigens including T antigen and envelope antigens of DNA tumor viruses and RNA tumor viruses; CEA of colon; oncofetal antigens such as 5T4 oncofetal trophoblast glycoprotein and bladder tumor oncofetal antigen;  $\alpha$ -fetoprotein; differentiation antigens such as human lung carcinoma antigens L6 and L20; antigens of fibrosarcoma; human leukemia T cell antigen-Gp37; neoglycoprotein; sphingolipids; breast cancer antigens such as EGFR (epidermal growth factor receptor); NY-BR-16; NY-BR-16 and HER2 antigen (p185HER2); polymorphic epithelial mucin (PEM); malignant human lymphocyte antigen-APO-1; differentiation antigens such as I antigen found in fetal erythrocytes; primary endoderm I antigen found in adult erythrocytes; preimplantation embryos; I(Ma) found in gastric cancer; M18 and M39 found in mammary epithelium; SSEA-1, VEP8, VEP9, Myl, and VIM-D5 found in myeloid cells; D156-22 found in

colorectal cancer; TRA-1-85 (blood group H); SCP-1 found in testis and ovarian cancer; C14 found in colon cancer; F3 found in lung cancer; AH6 found in gastric cancer; Y hapten; Ley found in embryonal carcinoma cells; TL5 (blood group A); EGF receptor found in A431 cells; E1 series (blood group B) found in pancreatic cancer; FC10.2 found in embryonal carcinoma cells; gastric cancer antigen; CO-514 (blood group Lea) found in adenocarcinomas; NS-10 found in adenocarcinomas; CO-43 (blood group Leb); G49 found in EGF receptor of A431 cells; MH2 (blood group ALeb/Ley) found in colon cancer; 19.9 found in colon cancer; gastric cancer mucins; T5A7 found in myeloid cells; R24 found in melanoma; 4.2, GD3, D1.1, OFA-1, GM2, OFA-2, GD2, and M1:22:25:8 found in embryonal carcinoma cells as well as SSEA-3 and SSEA-4 found in 4 to 8-cell stage embryos; subcutaneous T cell lymphoma antigen; MART-1 antigen; sialyl Tn (STn) antigen; colon cancer antigen NY-CO-45; lung cancer antigen NY-LU-12 variant A; adenocarcinoma antigen ART1; paraneoplastic associated brain-testis-cancer antigen (onconeural antigen MA2; paraneoplastic neuronal antigen); Neuro-oncological ventral antigen 2 (NOVA2); hemocyte carcinoma antigen gene 520; tumor-associated antigen CO-029; tumor-associated antigens MAGE-C1 (cancer/testis antigen CT7), MAGE-B1 (MAGE-XP antigen), MAGE-B2 (DAM6), MAGE-2, MAGE-4a, MAGE-4b and MAGE-X2; Cancer-Testis Antigen (NY-EOS-1); YKL-40, fragments of any of the aforementioned polypeptides, or structures produced by modification thereof (for example, the above-mentioned modified phosphate group or sugar chain); EpCAM; EREG; CA19-9; CA15-3; sialyl SSEA-1(SLX); HER2; PSMA; CEA; and CLEC12A. Cancer-specific antigens which become targets of the cancer-specific antigen-binding domains of the present invention are, in particular, preferably those expressed on cell surface, and examples of such cancer-specific antigens include CD19, CD20, EGFR, HER2, EpCAM, and EREG.

Furthermore, as factors belonging to the “TNF superfamily” or the “TNF receptor superfamily”, ligands having a trimeric structure and receptors with a trimeric structure to which the ligands bind, which contribute to activation of various immune cells are known (Nat. Rev. Immunol., 2012, 12, 339-51). Examples of factors belonging to the TNF superfamily or the TNF receptor superfamily include CD137, CD137L, CD40, CD40L, OX40, OX40L, CD27, CD70, HVEM, LIGHT, RANK, RANKL, CD30, CD153, GITR, and GITRL. Preferred factors include, for example, CD137 and CD40. A more preferred factor is, for example, CD137.

Furthermore, the “T cell-receptor complex” may be a T cell receptor itself, or an adaptor molecule constituting a T cell-receptor complex together with a T cell receptor. CD3 is suitable as an adaptor molecule.

For the T cell receptor, an epitope to which the T cell receptor binding domain binds may be a variable region or a constant region, but an epitope present in the constant region is preferred. Examples of the constant region sequence include the T cell receptor  $\alpha$  chain of

RefSeq Accession No. CAA26636.1 (SEQ ID NO: 9), the T cell receptor  $\beta$  chain of RefSeq Accession No. C25777 (SEQ ID NO: 10), the T cell receptor  $\gamma$ 1 chain of RefSeq Accession No. A26659 (SEQ ID NO: 11), the T cell receptor  $\gamma$ 2 chain of RefSeq Accession No. AAB63312.1 (SEQ ID NO: 12), and the T cell receptor  $\delta$  chain of RefSeq Accession No. AAA61033.1 (SEQ ID NO: 13).

In the present invention, when the “CD3-binding domain” is used as the T cell receptor complex-binding domain, the CD3-binding domain may be provided by one or more antibody variable domains. Preferably, the CD3-binding domain includes a light chain variable region (VL) and a heavy chain variable region (VH) of the CD3 antibody. Suitable examples of such CD3-binding domains include “single chain Fv (scFv)”, “single chain antibody”, “Fv”, “single chain Fv 2 (scFv2)”, “Fab”, “F(ab')<sub>2</sub>”, and such.

The CD3-binding domain of the present invention may be those that bind to any epitope as long as the epitope exists in the  $\gamma$ -chain,  $\delta$ -chain, or  $\epsilon$ -chain sequence constituting human CD3. In the present invention, preferably, a CD3-binding domain that comprises a light chain variable region (VL) of a CD3 antibody and a heavy chain variable region (VH) of a CD3 antibody, and which binds to an epitope present in the extracellular region of the  $\epsilon$  chain of the human CD3 complex, is suitably used. For such CD3-binding domain, a CD3-binding domain comprising the light chain variable region (VL) and heavy chain variable region (VH) of the OKT3 antibody (Proc. Natl. Acad. Sci. USA (1980) 77, 4914-4917) or various known CD3 antibodies is suitably used. A CD3-binding domain derived from a CD3 antibody that has the desired properties and is obtained by immunizing a desired animal with the  $\gamma$ -chain,  $\delta$ -chain, or  $\epsilon$ -chain constituting the human CD3 by the above-mentioned method may be appropriately used. Human antibodies and appropriately humanized antibodies as described below may be suitably used as the CD3 antibody that serves as the origin for the CD3-binding domain. For the structure of the CD3-constituting  $\gamma$ -chain,  $\delta$ -chain, or  $\epsilon$ -chain, their polynucleotide sequences are shown in SEQ ID NOs: 14 (NM\_000073.2), 16 (NM\_000732.4), and 18 (NM\_000733.3), and their polypeptide sequences are shown in SEQ ID NOs: 15 (NP\_000064.1), 17 (NP\_000723.1), and 19 (NP\_000724.1) (the RefSeq accession number is shown in parentheses).

A preferred embodiment of the “antigen-binding molecule” of the present invention includes an antibody comprising an antibody variable region of the present invention.

Examples of the antibodies provided by the present invention include the following antibodies:

[1] an antibody comprising the amino acid sequence of SEQ ID NO: 66 as the heavy-chain variable region and the amino acid sequence of SEQ ID NO: 85 as the light-chain variable region;

[2] an antibody comprising the amino acid sequence of SEQ ID NO: 67 as the heavy-chain

variable region and the amino acid sequence of SEQ ID NO: 86 as the light-chain variable region;

[3] an antibody comprising the amino acid sequence of SEQ ID NO: 70 as the heavy-chain variable region and the amino acid sequence of SEQ ID NO: 89 as the light-chain variable

5 region;

[4] an antibody comprising the amino acid sequence of SEQ ID NO: 76 as the heavy-chain variable region and the amino acid sequence of SEQ ID NO: 95 as the light-chain variable region;

[5] an antibody comprising the amino acid sequence of SEQ ID NO: 77 as the heavy-chain  
10 variable region and the amino acid sequence of SEQ ID NO: 96 as the light-chain variable region;

[6] an antibody comprising the amino acid sequence of SEQ ID NO: 78 as the heavy-chain variable region and the amino acid sequence of SEQ ID NO: 97 as the light-chain variable region;

[7] the antibody of any one of [1] to [6], which comprises the amino acid sequence of SEQ ID  
15 NO: 99 as the heavy-chain constant region and the amino acid sequence of SEQ ID NO: 59 or the amino acid sequence of SEQ ID NO: 60 as the light-chain constant region;

[8] an antibody that has an activity equivalent to that of the antibody of any one of [1] to [7]; and

[9] an antibody that binds to the same epitope as the epitope bound by the antibody of any one of  
20 [1] to [7].

In the antibody of [8], an “equivalent activity” refers to a CD137 agonist activity that is 70% or more, preferably 80% or more, and more preferably 90% or more of the binding activity of the antibody of any one of [1] to [7].

The present invention also provides the antibody of [9] which binds to the same epitope  
25 as the epitope bound by the anti-CD137 antibody disclosed in this invention. Such an antibody can be obtained, for example, by the method below.

Whether a test antibody shares a common epitope with a certain antibody can be assessed based on competition between the two antibodies for the same epitope. The competition between antibodies can be detected by a cross-blocking assay or the like. For  
30 example, the competitive ELISA assay is a preferred cross-blocking assay. Specifically, in a cross-blocking assay, the CD137 protein used to coat the wells of a microtiter plate is pre-incubated in the presence or absence of a candidate competitor antibody, and then an anti-CD137 antibody of the present invention is added thereto. The quantity of the anti-CD137 antibody of the present invention bound to the CD137 protein in the wells is indirectly correlated  
35 with the binding ability of a candidate competitor antibody (test antibody) that competes for the binding to the same epitope. That is, the greater the affinity of the test antibody for the same

epitope, the lower the amount of the anti-CD137 antibody of the present invention bound to the CD137 protein-coated wells, and the higher the amount of the test antibody bound to the CD137 protein-coated wells.

The quantity of the antibody bound to the wells can be readily determined by labeling the antibody in advance. For example, a biotin-labeled antibody can be measured using an avidin/peroxidase conjugate and an appropriate substrate. In particular, a cross-blocking assay that uses an enzyme label such as peroxidase is called a “competitive ELISA assay”. The antibody can be labeled with other labeling substances that enable detection or measurement. Specifically, radiolabels, fluorescent labels, and such are known.

Furthermore, when the test antibody has a constant region derived from a species different from that of the anti-CD137 antibody of the present invention, the amount of antibody bound to the wells can be measured by using a labeled antibody that recognizes the constant region of that antibody. Alternatively, if the antibodies are derived from the same species but belong to different classes, the amount of the antibodies bound to the wells can be measured using antibodies that distinguish individual classes.

If a candidate antibody can block binding of an anti-CD137 antibody by at least 20%, preferably by at least 20% to 50%, and even more preferably, by at least 50%, as compared to the binding activity obtained in a control experiment performed in the absence of the candidate competing antibody, the candidate competing antibody is either an antibody that binds substantially to the same epitope or an antibody that competes for binding to the same epitope as that by an anti-CD137 antibody of the present invention.

A preferred example of an antibody that binds to the same epitope as the epitope bound by the antibody of any one of [1] to [7] includes, for example, an antibody that recognizes a region comprising the

SPCPPNSFSSAGGQRTCDICRQCKGVFRTRKECSSTSNAECDCTPGFHCLGAGCSMCEQDCKQGQELTKKGC sequence (SEQ ID NO: 113) in the CD137 protein. A further example includes an antibody that recognizes a region comprising the DCTPGFHCLGAGCSMCEQDCKQGQELTKKGC sequence (SEQ ID NO: 108) in the CD137 protein.

An anticancer antigen/anti-human CD137 bispecific antibody that exhibits the desired antitumor effects can be provided by modifying the above-mentioned anti-human CD137 antibody into a bispecific antibody with a cancer-specific antigen antibody (for example, an anti-human GPC3 antibody), and evaluating its cancer-specific antigen-dependent CD137 agonist ability.

As a non-limiting embodiment of the present invention, a bispecific antibody comprising a cancer-specific antigen-binding domain and a human CD137-binding domain is

provided.

Examples of a bispecific antibody provided by the present invention include the following antibodies:

[i] a bispecific antibody comprising the amino acid sequence of SEQ ID NO: 122 (heavy chain variable region) and the amino acid sequence of SEQ ID NO: 123 (light chain variable region) as the human CD137-binding domain;

[ii] a bispecific antibody comprising the amino acid sequence of SEQ ID NO: 124 (heavy chain variable region) and the amino acid sequence of SEQ ID NO: 82 (light chain variable region) as the human CD137-binding domain;

[iii] a bispecific antibody comprising the amino acid sequence of SEQ ID NO: 125 (heavy chain variable region) and the amino acid sequence of SEQ ID NO: 84 (light chain variable region) as the human CD137-binding domain; and

[iv] an antibody that binds to the same epitope as the epitope bound by the bispecific antibody of any one of [i] to [iii].

Depending on the target cancer antigen, those skilled in the art can appropriately select a heavy chain variable region sequence and a light chain variable region sequence that bind to the cancer antigen as the heavy chain variable region and the light chain variable region to be included in the cancer-specific antigen-binding domain.

The present invention also provides the bispecific antibody of [iv] which binds to the same epitope as the epitope bound by the anti-cancer-specific antigen/anti-human CD137 bispecific antibody disclosed in this invention. Such an antibody can be obtained, for example, by the method below.

Whether a test antibody shares a common epitope with a certain antibody can be assessed based on competition between the two antibodies for the same epitope. The competition between antibodies can be detected by a cross-blocking assay or the like. For example, the competitive ELISA assay is a preferred cross-blocking assay. Specifically, in a cross-blocking assay, the CD137 protein used to coat the wells of a microtiter plate is pre-incubated in the presence or absence of a candidate competitor antibody, and then an anti-CD137 antibody of the present invention is added thereto. The amount of the anti-CD137 antibody of the present invention bound to the CD137 protein in the wells is indirectly correlated with the binding ability of a candidate competitor antibody (test antibody) that competes for the binding to the same epitope. That is, the greater the affinity of the test antibody for the same epitope, the lower the amount of the anti-CD137 antibody of the present invention bound to the CD137 protein-coated wells, and the higher the amount of the test antibody bound to the CD137 protein-coated wells.

The amount of the antibody bound to the wells can be readily determined by labeling

the antibody in advance. For example, a biotin-labeled antibody can be measured using an avidin/peroxidase conjugate and an appropriate substrate. In particular, a cross-blocking assay that uses enzyme labels such as peroxidase is called a “competitive ELISA assay”. The antibody can be labeled with other labeling substances that enable detection or measurement.

5 Specifically, radiolabels, fluorescent labels, and such are known.

Furthermore, when the test antibody has a constant region derived from a species different from that of the anti-CD137 antibody of the present invention, the amount of antibody bound to the wells can be measured by using a labeled antibody that recognizes the constant region of that antibody. Alternatively, if the antibodies are derived from the same species but  
10 belong to different classes, the amount of the antibodies bound to the wells can be measured using antibodies that distinguish individual classes.

If a candidate antibody can block binding of an anti-CD137 antibody by at least 20%, preferably by at least 20% to 50%, and even more preferably, by at least 50%, as compared to the binding activity obtained in a control experiment performed in the absence of the candidate  
15 competing antibody, the candidate competing antibody is either an antibody that binds substantially to the same epitope or an antibody that competes for binding to the same epitope as an anti-CD137 antibody of the present invention.

In another embodiment, the ability of a test antibody to competitively or cross competitively bind with another antibody can be appropriately determined by those skilled in the  
20 art using a standard binding assay such as BIAcore analysis or flow cytometry known in the art.

Methods for determining the spatial conformation of an epitope include, for example, X ray crystallography and two-dimensional nuclear magnetic resonance (see, Epitope Mapping Protocols in Methods in Molecular Biology, G. E. Morris (ed.), Vol. 66 (1996)).

Favorable examples of a bispecific antibody that binds to the same epitope as the human  
25 CD137 epitope bound by the bispecific antibody of any one of [i] to [iii] include bispecific antibodies that recognize a region comprising the

SPCPPNSFSSAGGQRTCDICRQCKGVFRTRKECSSTSNAECDCTPGFHCLGAGCSMCEQD  
CKQGQELTKKGC sequence (SEQ ID NO: 113), a region comprising the

DCTPGFHCLGAGCSMCEQDCKQGQELTKKGC sequence (SEQ ID NO: 108), a region

30 comprising the

LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTCDICRQCKGVFRTRKECSSTSNA  
EC sequence (SEQ ID NO: 111), or a region comprising the

LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTC sequence (SEQ ID NO: 106) in

the human CD137 protein. More preferable examples include bispecific antibodies that

35 recognize a region comprising the

LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTCDICRQCKGVFRTRKECSSTSNA

EC sequence (SEQ ID NO: 111) or a region comprising the LQDPCSNCPAGTFCDNRRNQICSPCPPNSFSSAGGQRTC sequence (SEQ ID NO: 106) in the human CD137 protein.

A bispecific antibody comprising a cancer-specific antigen-binding domain and a human CD40-binding domain is provided as a non-limiting embodiment of the present invention.

Depending on the targeted cancer antigen, those skilled in the art can appropriately select a heavy chain variable region sequence and a light chain variable region sequence that bind to the cancer antigen for the heavy chain variable region and the light chain variable region to be included in the cancer-specific antigen-binding domain.

#### Binding activity of antibodies

The antigen-binding activity of an antibody can be measured using known means (Antibodies A Laboratory Manual. Ed Harlow, David Lane, Cold Spring Harbor Laboratory, 1988). For example, an enzyme linked immunosorbent assay (ELISA), an enzyme immunoassay (EIA), a radioimmunoassay (RIA), FACS, ALPHA screen (Amplified Luminescent Proximity Homogeneous Assay), surface plasmon resonance (SPR)-based BIACORE method, or a fluoroimmunoassay can be used. Methods for assaying the binding activity of an antibody towards an antigen expressed by a cell include, for example, the methods described on pages 359 to 420 in “Antibodies: A Laboratory Manual”.

In particular, methods that use a flow cytometer can be suitably used as a method for measuring the binding between an antigen expressed on the surface of cells suspended in buffer or the like and an antibody against the antigen. Flow cytometers that are used include, for example, FACSCanto™ II, FACS Aria™, FACSArray™, FACSVantage™ SE, and FACSCalibur™ (the above are from BD Biosciences); and EPICS ALTRA HyPerSort Cytomics FC 500, EPICS XL-MCL ADC EPICS XL ADC, and Cell Lab Quanta/Cell Lab Quanta SC (the above are all from Beckman Coulter).

An example of a suitable method for measuring the binding activity of a test CD137 antibody toward an antigen includes the method of reacting CD137-expressing cells with a test antibody, and then staining this with an FITC-labeled secondary antibody that recognizes the test antibody, and subsequently taking measurements using FACSCalibur (BD), and analyzing the obtained fluorescence intensity using the CELL QUEST Software (BD).

#### Antibody

Herein, an “antibody” refers to a naturally occurring immunoglobulin or an immunoglobulin produced by partial or complete synthesis. Antibodies can be isolated from natural sources such as naturally-occurring plasma and serum, or culture supernatants of

antibody-producing hybridoma cells. Alternatively, antibodies can be partially or completely synthesized using techniques such as genetic recombination. Suitable examples of the antibodies include antibodies of an immunoglobulin isotype or subclass of such isotype. Known human immunoglobulins include those of the following nine classes (isotypes): IgG1, IgG2, IgG3, IgG4, IgA1, IgA2, IgD, IgE, and IgM. Of these isotypes, antibodies of the present invention include IgG1, IgG2, IgG3, and IgG4.

Methods for producing antibodies having the desired binding activity are known to those skilled in the art, and the antibodies may be obtained as polyclonal or monoclonal antibodies. Monoclonal antibodies derived from mammals may be suitably produced as the antibodies of the present invention. Such mammalian-derived monoclonal antibodies include antibodies produced by hybridomas and antibodies produced by host cells transformed with an expression vector carrying an antibody gene by genetic engineering techniques.

There is no particular limitation on the mammal to be immunized for obtaining antibodies. It is preferable to select the mammal by considering its compatibility with the parent cells to be used in cell fusion for hybridoma production. In general, rabbits, monkeys, and rodents such as mice, rats, and hamsters are suitably used.

The above animals are immunized with a sensitizing antigen by known methods. Generally performed immunization methods include, for example, intraperitoneal or subcutaneous injection of a sensitizing antigen into mammals. Specifically, a sensitizing antigen is appropriately diluted with Phosphate-Buffered Saline (PBS), physiological saline, or the like. If desired, a conventional adjuvant such as Freund's complete adjuvant is mixed with the antigen, and the mixture is emulsified. Then, the sensitizing antigen is administered to a mammal several times at 4- to 21-day intervals. Appropriate carriers may be used in immunization with the sensitizing antigen. In particular, when a low-molecular-weight partial peptide is used as the sensitizing antigen, it is sometimes desirable to couple the sensitizing antigen peptide to a carrier protein such as albumin or keyhole limpet hemocyanin for immunization.

Alternatively, hybridomas producing a desired antibody can be prepared using DNA immunization as mentioned below. DNA immunization is an immunization method that confers immunostimulation by expressing a sensitizing antigen in an animal immunized as a result of administering a vector DNA constructed to allow expression of an antigen protein-encoding gene in the animal. As compared to conventional immunization methods in which a protein antigen is administered to animals to be immunized, DNA immunization is expected to be superior in that:

- immunostimulation can be provided while retaining the structure of a membrane protein; and
- there is no need to purify the antigen for immunization.

In order to prepare a monoclonal antibody of the present invention using DNA immunization, first, a DNA expressing an antigen protein is administered to an animal to be immunized. The antigen protein-encoding DNA can be synthesized by known methods such as PCR. The obtained DNA is inserted into an appropriate expression vector, and then this is administered to an animal to be immunized. Preferably used expression vectors include, for example, commercially-available expression vectors such as pcDNA3.1. Vectors can be administered to an organism using conventional methods. For example, DNA immunization is performed by using a gene gun to introduce expression vector-coated gold particles into cells in the body of an animal to be immunized.

After immunizing a mammal as described above, an increase in the titer of an antigen-binding antibody is confirmed in the serum. Then, immune cells are collected from the mammal, and then subjected to cell fusion. In particular, splenocytes are preferably used as immune cells.

A mammalian myeloma cell is used as a cell to be fused with the above-mentioned immune cells. The myeloma cells preferably comprise a suitable selection marker for screening. A selection marker confers characteristics to cells for their survival (or death) under a specific culture condition. Hypoxanthine-guanine phosphoribosyltransferase deficiency (hereinafter abbreviated as HGPRT deficiency) and thymidine kinase deficiency (hereinafter abbreviated as TK deficiency) are known as selection markers. Cells with HGPRT or TK deficiency have hypoxanthine-aminopterin-thymidine sensitivity (hereinafter abbreviated as HAT sensitivity). HAT-sensitive cells cannot synthesize DNA in a HAT selection medium, and are thus killed. However, when the cells are fused with normal cells, they can continue DNA synthesis using the salvage pathway of the normal cells, and therefore they can grow even in the HAT selection medium.

HGPRT-deficient and TK-deficient cells can be selected in a medium containing 6-thioguanine, 8-azaguanine (hereinafter abbreviated as 8AG), or 5'-bromodeoxyuridine. Normal cells are killed because they incorporate these pyrimidine analogs into their DNA. Meanwhile, cells that are deficient in these enzymes can survive in the selection medium, since they cannot incorporate these pyrimidine analogs. In addition, a selection marker referred to as G418 resistance provided by the neomycin-resistant gene confers resistance to 2-deoxystreptamine antibiotics (gentamycin analogs). Various types of myeloma cells that are suitable for cell fusion are known.

For example, myeloma cells including the following cells can be preferably used:  
 P3(P3x63Ag8.653) (J. Immunol. (1979) 123 (4), 1548-1550);  
 P3x63Ag8U.1 (Current Topics in Microbiology and Immunology (1978)81, 1-7);  
 NS-1 (C. Eur. J. Immunol. (1976)6 (7), 511-519);

MPC-11 (Cell (1976) 8 (3), 405-415);  
 SP2/0 (Nature (1978) 276 (5685), 269-270);  
 FO (J. Immunol. Methods (1980) 35 (1-2), 1-21);  
 S194/5.XX0.BU.1 (J. Exp. Med. (1978) 148 (1), 313-323);  
 5 R210 (Nature (1979) 277 (5692), 131-133), etc.

Cell fusions between the immunocytes and myeloma cells are essentially carried out using known methods, for example, a method by Kohler and Milstein *et al.* (Methods Enzymol. (1981) 73: 3-46).

10 More specifically, cell fusion can be carried out, for example, in a conventional culture medium in the presence of a cell fusion-promoting agent. The fusion-promoting agents include, for example, polyethylene glycol (PEG) and Sendai virus (HVJ). If required, an auxiliary substance such as dimethyl sulfoxide is also added to improve fusion efficiency.

15 The ratio of immunocytes to myeloma cells may be arbitrarily set, preferably, for example, one myeloma cell for every one to ten immunocytes. Culture media to be used for cell fusions include, for example, media that are suitable for the growth of myeloma cell lines, such as RPMI1640 medium and MEM medium, and other conventional culture medium used for this type of cell culture. In addition, serum supplements such as fetal calf serum (FCS) may be preferably added to the culture medium.

20 For cell fusion, predetermined amounts of the above immune cells and myeloma cells are mixed well in the above culture medium. Then, a PEG solution (for example, the average molecular weight is about 1,000 to 6,000) prewarmed to about 37°C is added thereto at a concentration of generally 30% to 60% (w/v). The mixed solution is gently mixed to produce desired fusion cells (hybridomas). Then, an appropriate culture medium mentioned above is gradually added to the cells, and this is repeatedly centrifuged to remove the supernatant. Thus,  
 25 cell fusion agents and such which are unfavorable to hybridoma growth can be removed.

The hybridomas thus obtained can be selected by culture using a conventional selective medium, for example, HAT medium (a culture medium containing hypoxanthine, aminopterin, and thymidine). Culture is continued in the above medium using the HAT medium for a period of time sufficient to kill cells other than the desired hybridomas (non-fused cells). Typically,  
 30 the period is several days to several weeks. Then, hybridomas producing the desired antibody are screened and singly cloned by conventional limiting dilution methods.

The hybridomas thus obtained can be selected using a selection medium based on the selection marker possessed by the myeloma used for cell fusion. For example, HGPRT- or TK-deficient cells can be selected by culture using the HAT medium (a culture medium  
 35 containing hypoxanthine, aminopterin, and thymidine). Specifically, when HAT-sensitive myeloma cells are used for cell fusion, cells successfully fused with normal cells can selectively

proliferate in the HAT medium. Culture is continued in the above medium using the HAT medium for a period of time sufficient to kill cells other than the desired hybridomas (non-fused cells). Specifically, desired hybridomas can be selected by culture for generally several days to several weeks. Then, hybridomas producing the desired antibody are screened and singly  
5 cloned by conventional limiting dilution methods.

Screening and single cloning of desired antibodies can be suitably performed by screening methods based on known antigen-antibody reaction. For example, a desired antibody can be selected by screening using fluorescence activated cell sorting (FACS). FACS is a system that enables measurement of the binding of an antibody to cell surface by analyzing cells  
10 contacted with a fluorescent antibody using laser beam, and measuring the fluorescence emitted from individual cells.

To screen for hybridomas that produce a monoclonal antibody of the present invention by FACS, cells that express the antigen bound by the produced antibody are first prepared. Preferred cells used for screening are mammalian cells that are forced to express the antigen.  
15 By using mammalian cells that are used as the host cell but have not been transformed as a control, the activity of an antibody to bind to the cell-surface antigen can be selectively detected. Specifically, hybridomas producing a desired monoclonal antibody can be obtained by selecting hybridomas that produce an antibody which binds to cells forced to express the antigen but not to the host cell.

Alternatively, cells expressing the antigen of interest are immobilized and the activity of an antibody to bind to the antigen-expressing cells can be assessed based on the principle of ELISA. For example, antigen-expressing cells are immobilized to the wells of an ELISA plate. Culture supernatants of hybridomas are contacted with the immobilized cells in the wells, and antibodies that bind to the immobilized cells are detected. When the monoclonal antibodies are  
20 derived from mouse, antibodies bound to the cells can be detected using an anti-mouse immunoglobulin antibody. Hybridomas producing a desired antibody having the antigen-binding ability are selected by the above screening, and they can be cloned by a limiting dilution method or the like.

Monoclonal antibody-producing hybridomas thus prepared can be passaged in a  
30 conventional culture medium. The hybridomas can be stored in liquid nitrogen for a long period.

The above hybridomas are cultured by a conventional method, and desired monoclonal antibodies can be obtained from the culture supernatants. Alternatively, the hybridomas are administered to and grown in compatible mammals, and monoclonal antibodies can be obtained  
35 from the ascites. The former method is suitable for obtaining antibodies with high purity.

Antibodies that are encoded by antibody genes cloned from antibody-producing cells

such as the above hybridomas can also be preferably used. A cloned antibody gene is inserted into an appropriate vector, and this is introduced into a host to express the antibody encoded by the gene. Methods for isolating antibody genes, inserting the genes into vectors, and transforming host cells have already been established, for example, by Vandamme *et al.* (Eur. J. Biochem. (1990) 192(3), 767-775). Methods for producing recombinant antibodies are also known as described below.

Generally, to obtain a cDNA encoding the antibody variable region (V region), total RNA is first extracted from hybridomas. For example, the following methods can be used as methods for extracting mRNAs from cells:

- the guanidine ultracentrifugation method (Biochemistry (1979) 18(24), 5294-5299), and
- the AGPC method (Anal. Biochem. (1987) 162(1), 156-159).

Extracted mRNAs can be purified using the mRNA Purification Kit (GE Healthcare Bioscience) or such. Alternatively, kits for extracting total mRNA directly from cells, such as the QuickPrep mRNA Purification Kit (GE Healthcare Bioscience), are also commercially available. mRNAs can be prepared from hybridomas using such kits. cDNAs encoding the antibody V region can be synthesized from the prepared mRNAs using a reverse transcriptase. cDNAs can be synthesized using the AMV Reverse Transcriptase First-strand cDNA Synthesis Kit (Seikagaku Corporation) or such. Furthermore, the SMART RACE cDNA amplification kit (Clontech) and the PCR-based 5'-RACE method (Proc. Natl. Acad. Sci. USA (1988) 85(23), 8998-9002; Nucleic Acids Res. (1989) 17(8), 2919-2932) can be appropriately used to synthesize and amplify cDNAs. In such a cDNA synthesis process, appropriate restriction enzyme sites described below may be introduced into both ends of a cDNA.

The cDNA fragment of interest is purified from the resulting PCR product, and then this is ligated to a vector DNA. A recombinant vector is thus constructed, and introduced into *E. coli* or such. After colony selection, the desired recombinant vector can be prepared from the colony-forming *E. coli*. Then, whether the recombinant vector has the cDNA nucleotide sequence of interest is tested by a known method such as the dideoxy nucleotide chain termination method.

The 5'-RACE method which uses primers to amplify the variable region gene is conveniently used for isolating the gene encoding the variable region. First, a 5'-RACE cDNA library is constructed by cDNA synthesis using RNAs extracted from hybridoma cells as a template. A commercially available kit such as the SMART RACE cDNA amplification kit is appropriately used to synthesize the 5'-RACE cDNA library.

The antibody gene is amplified by PCR using the prepared 5'-RACE cDNA library as a template. Primers for amplifying the mouse antibody gene can be designed based on known antibody gene sequences. The nucleotide sequences of the primers vary depending on the

immunoglobulin subclass. Therefore, it is preferable that the subclass is determined in advance using a commercially available kit such as the Iso Strip mouse monoclonal antibody isotyping kit (Roche Diagnostics).

Specifically, for example, primers that allow amplification of genes encoding  $\gamma 1$ ,  $\gamma 2a$ ,  $\gamma 2b$ , and  $\gamma 3$  heavy chains and  $\kappa$  and  $\lambda$  light chains are used to isolate mouse IgG-encoding genes. In general, a primer that anneals to a constant region site close to the variable region is used as a 3'-side primer to amplify an IgG variable region gene. Meanwhile, a primer attached to a 5' RACE cDNA library construction kit is used as a 5'-side primer.

Immunoglobulins composed of a combination of heavy and light chains may be reshaped using the thus amplified PCR products. A desired antibody can be selected by screening using the antigen-binding activity of a reshaped immunoglobulin as an indicator. The screening can be carried out, for example, by the following steps:

(1) contacting a desired antigen-expressing cell with an antibody comprising the V region encoded by a cDNA obtained from a hybridoma;

(2) detecting the binding of the antibody to the antigen-expressing cell; and

(3) selecting an antibody that binds to the antigen-expressing cell.

Methods for detecting the binding of an antibody to the antigen-expressing cells are known. Specifically, the binding of an antibody to the antigen-expressing cells can be detected by the above-described techniques such as FACS. Fixed samples of the antigen-expressing cells may be appropriately used to assess the binding activity of an antibody.

For antibody screening methods that use the binding activity as an indicator, panning methods that use phage vectors can also be used suitably. Screening methods using phage vectors are advantageous when the antibody genes are obtained from a polyclonal antibody-expressing cell population as heavy-chain and light-chain subclass libraries. Genes encoding the heavy-chain and light-chain variable regions can be linked by an appropriate linker sequence to form a single-chain Fv (scFv). Phages expressing scFv on their surface can be produced by inserting an scFv-encoding gene into a phage vector. The phages are contacted with an antigen of interest. Then, a DNA encoding scFv having the binding activity of interest can be isolated by collecting phages bound to the antigen. This process can be repeated as necessary to enrich scFv having the binding activity of interest.

After isolation of the cDNA encoding the V region of the antibody of interest, the cDNA is digested with restriction enzymes that recognize the restriction sites introduced into both ends of the cDNA. Preferred restriction enzymes recognize and cleave a nucleotide sequence that occurs in the nucleotide sequence of the antibody gene at a low frequency. Furthermore, a restriction site for an enzyme that produces a sticky end is preferably introduced into a vector to insert a single-copy digested fragment in the correct orientation. The cDNA encoding the V

region of the antibody is digested as described above, and this is inserted into an appropriate expression vector to construct an antibody expression vector. In this case, if a gene encoding the antibody constant region (C region) and a gene encoding the above V region are fused in-frame, a chimeric antibody is obtained. Herein, a “chimeric antibody” means that the origin of the constant region is different from that of the variable region. Thus, in addition to mouse/human heterochimeric antibodies, human/human allochimeric antibodies are included in the chimeric antibodies of the present invention. A chimeric antibody expression vector can be constructed by inserting the above V region gene into an expression vector that already has the constant region. Specifically, for example, a recognition sequence for a restriction enzyme that excises the above V region gene can be appropriately placed on the 5' side of an expression vector carrying a DNA that encodes a desired antibody constant region (C region). A chimeric antibody expression vector is constructed by fusing in-frame two genes digested with the same combination of restriction enzymes.

To produce a monoclonal antibody, antibody genes are inserted into an expression vector so that the genes are expressed under the control of an expression regulatory region. The expression regulatory region for antibody expression includes, for example, enhancers and promoters. Furthermore, an appropriate signal sequence may be attached to the amino terminus so that the expressed antibody is secreted to the outside of cells. The signal sequence is cleaved from the carboxyl terminus of the expressed polypeptide, and the resulting antibody can be secreted to the outside of cells. Then, appropriate host cells are transformed with the expression vector, and recombinant cells expressing the antibody-encoding DNA can be obtained.

DNAs encoding the antibody heavy chain (H chain) and light chain (L chain) are separately inserted into different expression vectors to express the antibody gene. An antibody molecule having the H and L chains can be expressed by co-transfecting the same host cell with vectors inserted with the H chain and L chain. Alternatively, host cells can be transformed with a single expression vector into which DNAs encoding the H and L chains are inserted (see WO 94/11523).

There are many known combinations of host cells and expression vectors for antibody preparation by introducing isolated antibody genes into appropriate hosts. All these expression systems are applicable to isolation of the cancer-specific antigen-binding domains of the present invention, tumor necrosis factor receptor superfamily (TNFRSF) and T cell receptor complex-binding domain.

Appropriate eukaryotic cells used as host cells include animal cells, plant cells, and fungal cells. Specifically, the animal cells include, for example, the following cells.

(1) mammalian cells: CHO, COS, myeloma, baby hamster kidney (BHK), HeLa, Vero, or such;

(2) amphibian cells: *Xenopus* oocytes, or such; and

(3) insect cells: sf9, sf21, Tn5, or such.

In addition, as a plant cell, an antibody gene expression system using cells derived from the *Nicotiana* genus such as *Nicotiana tabacum* is known. Callus cultured cells can be appropriately used to transform plant cells.

Furthermore, the following cells can be used as fungal cells:  
 yeasts: the *Saccharomyces* genus such as *Saccharomyces cerevisiae*, and the *Pichia* genus such as *Pichia pastoris*; and  
 filamentous fungi: the *Aspergillus* genus such as *Aspergillus niger*.

Furthermore, antibody gene expression systems that utilize prokaryotic cells are also known. For example, when using bacterial cells, *E. coli* cells, *Bacillus subtilis* cells, and such can suitably be utilized in the present invention. Expression vectors carrying the antibody genes of interest are introduced into these cells by transfection. The transfected cells are cultured *in vitro*, and the desired antibody can be prepared from the culture of transformed cells.

In addition to the above-described host cells, transgenic animals can also be used to produce a recombinant antibody. That is, the antibody can be obtained from an animal into which the gene encoding the antibody of interest is introduced. For example, the antibody gene can be constructed as a fusion gene by inserting in frame into a gene that encodes a protein produced specifically in milk. Goat  $\beta$ -casein or such can be used, for example, as the protein secreted in milk. DNA fragments containing the fused gene inserted with the antibody gene is injected into a goat embryo, and then this embryo is introduced into a female goat. Desired antibodies can be obtained as a protein fused with the milk protein from milk produced by the transgenic goat born from the embryo-recipient goat (or progeny thereof). In addition, to increase the volume of milk containing the desired antibody produced by the transgenic goat, hormones can be administered to the transgenic goat as necessary (Bio/Technology (1994) 12 (7), 699-702).

When an antigen-binding molecule described herein is administered to human, an antigen-binding domain derived from a genetically recombinant antibody that has been artificially modified to reduce the heterologous antigenicity against human and such, can be appropriately used as the various binding domains in the molecule when domains comprising an antibody variable region are used. Such genetically recombinant antibodies include, for example, humanized antibodies. These modified antibodies are appropriately produced by known methods.

An antibody variable region used to produce the various binding domains of antigen-binding molecules described herein is generally formed by three

complementarity-determining regions (CDRs) that are separated by four framework regions (FRs). CDR is a region that substantially determines the binding specificity of an antibody. The amino acid sequences of CDRs are highly diverse. On the other hand, the FR-forming amino acid sequences often have high identity even among antibodies with different binding specificities. Therefore, generally, the binding specificity of a certain antibody can be introduced into another antibody by CDR grafting.

A humanized antibody is also called a reshaped human antibody. Specifically, humanized antibodies prepared by grafting the CDR of a non-human animal antibody such as a mouse antibody to a human antibody and such are known. Common genetic engineering techniques for obtaining humanized antibodies are also known. Specifically, for example, overlap extension PCR is known as a method for grafting a mouse antibody CDR to a human FR. In overlap extension PCR, a nucleotide sequence encoding a mouse antibody CDR to be grafted is added to primers for synthesizing a human antibody FR. Primers are prepared for each of the four FRs. It is generally considered that when grafting a mouse CDR to a human FR, selecting a human FR that has high identity to a mouse FR is advantageous for maintaining the CDR function. That is, it is generally preferable to use a human FR comprising an amino acid sequence which has high identity to the amino acid sequence of the FR adjacent to the mouse CDR to be grafted.

Nucleotide sequences to be ligated are designed so that they will be connected to each other in frame. Human FRs are individually synthesized using the respective primers. As a result, products in which the mouse CDR-encoding DNA is attached to the individual FR-encoding DNAs are obtained. Nucleotide sequences encoding the mouse CDR of each product are designed so that they overlap with each other. Then, complementary strand synthesis reaction is conducted to anneal the overlapping CDR regions of the products synthesized using a human antibody gene as template. Human FRs are ligated *via* the mouse CDR sequences by this reaction.

The full length V region gene, in which three CDRs and four FRs are ultimately ligated, is amplified using primers that anneal to its 5'- or 3'-end, which are added with suitable restriction enzyme recognition sequences. An expression vector for humanized antibody can be produced by inserting the DNA obtained as described above and a DNA that encodes a human antibody C region into an expression vector so that they will ligate in frame. After the recombinant vector is transfected into a host to establish recombinant cells, the recombinant cells are cultured, and the DNA encoding the humanized antibody is expressed to produce the humanized antibody in the cell culture (see, European Patent Publication No. EP 239400 and International Patent Publication No. WO 1996/002576).

By qualitatively or quantitatively measuring and evaluating the antigen-binding activity

of the humanized antibody produced as described above, one can suitably select human antibody FRs that allow CDRs to form a favorable antigen-binding site when ligated through the CDRs. Amino acid residues in FRs may be substituted as necessary, so that the CDRs of a reshaped human antibody form an appropriate antigen-binding site. For example, amino acid sequence mutations can be introduced into FRs by applying the PCR method used for grafting a mouse CDR into a human FR. More specifically, partial nucleotide sequence mutations can be introduced into primers that anneal to the FR. Nucleotide sequence mutations are introduced into the FRs synthesized by using such primers. Mutant FR sequences having the desired characteristics can be selected by measuring and evaluating the activity of the amino acid-substituted mutant antibody to bind to the antigen by the above-mentioned method (Sato, K. *et al.*, Cancer Res. (1993) 53: 851-856).

Alternatively, desired human antibodies can be obtained by immunizing transgenic animals having the entire repertoire of human antibody genes (see WO 1993/012227; WO 1992/003918; WO 1994/002602; WO 1994/025585; WO 1996/034096; WO 1996/033735) by DNA immunization.

Furthermore, techniques for preparing human antibodies by panning using human antibody libraries are also known. For example, the V region of a human antibody is expressed as a single-chain antibody (scFv) on phage surface by the phage display method. Phages expressing an scFv that binds to the antigen can be selected. The DNA sequence encoding the human antibody V region that binds to the antigen can be determined by analyzing the genes of selected phages. The DNA sequence of the scFv that binds to the antigen is determined. An expression vector is prepared by fusing the V region sequence in frame with the C region sequence of a desired human antibody, and inserting this into an appropriate expression vector. The expression vector is introduced into cells appropriate for expression such as those described above. The human antibody can be produced by expressing the human antibody-encoding gene in the cells. These methods are already known (see WO 1992/001047; WO 1992/020791; WO 1993/006213; WO 1993/011236; WO 1993/019172; WO 1995/001438; WO 1995/015388).

In addition to the phage display method, techniques that use a cell-free translation system, techniques for displaying antigen-binding molecules on the surface of viruses or cells, and techniques that use emulsions are also known as techniques for obtaining human antibodies by panning using human antibody libraries. For example, the ribosome display method where a complex is formed between the translated protein and mRNA *via* the ribosome by removing the stop codon and such, the cDNA display method or the mRNA display method where a genetic sequence and the translated protein are covalently linked using a compound such as puromycin, the CIS display method where a complex is formed between the gene and the translated protein using a nucleic acid-binding protein, or such may be used as techniques of using a cell-free

translation system. For the technique of presenting antigen-binding molecules on the surface of cells or viruses, besides the phage display method, the *E. coli* display method, Gram-positive bacteria display method, yeast display method, mammalian cell display method, virus display method, and such may be used. As a technique that uses emulsions, the *in vitro* virus display method which involves incorporating genes and translation-related molecules into an emulsion, and such may be used. These methods are already publicly known (Nat Biotechnol. 2000 Dec;18(12):1287-92; Nucleic Acids Res. 2006;34(19): e127; Proc Natl Acad Sci U S A. 2004 Mar 2;101(9):2806-10; Proc Natl Acad Sci U S A. 2004 Jun 22;101(25):9193-8; Protein Eng Des Sel. 2008 Apr;21(4):247-55; Proc Natl Acad Sci U S A. 2000 Sep 26;97(20):10701-5; MAbs. 2010 Sep-Oct;2(5):508-18; and Methods Mol Biol. 2012, 911:183-98).

In the present invention, “specific” means a condition where one of the molecules involved in specific binding does not show any significant binding to molecules other than a single or a number of binding partner molecules. Furthermore, “specific” is also used when an antigen-binding domain is specific to a particular epitope among multiple epitopes contained in an antigen. When an epitope bound by an antigen-binding domain is contained in multiple different antigens, antigen-binding molecules containing the antigen-binding domain can bind to various antigens that have the epitope.

“Epitope” means an antigenic determinant in an antigen, and refers to an antigen site to which various binding domains in antigen-binding molecules disclosed herein bind. Thus, for example, an epitope can be defined according to its structure. Alternatively, the epitope may be defined according to the antigen-binding activity of an antigen-binding molecule that recognizes the epitope. When the antigen is a peptide or polypeptide, the epitope can be specified by the amino acid residues that form the epitope. Alternatively, when the epitope is a sugar chain, the epitope can be specified by its specific sugar chain structure.

A linear epitope is an epitope that contains an epitope whose primary amino acid sequence is recognized. Such a linear epitope typically contains at least three and most commonly at least five, for example, about 8 to 10 or 6 to 20 amino acids in its specific sequence.

In contrast to the linear epitope, “conformational epitope” is an epitope in which the primary amino acid sequence containing the epitope is not the only determinant of the recognized epitope (for example, the primary amino acid sequence of a conformational epitope is not necessarily recognized by an epitope-defining antibody). Conformational epitopes may contain a greater number of amino acids compared to linear epitopes. A conformational epitope-recognizing antibody recognizes the three-dimensional structure of a peptide or protein. For example, when a protein molecule folds and forms a three-dimensional structure, amino acids and/or polypeptide main chains that form a conformational epitope become aligned, and

the epitope is made recognizable by the antibody. Methods for determining epitope conformations include, for example, X ray crystallography, two-dimensional nuclear magnetic resonance spectroscopy, site-specific spin labeling, and electron paramagnetic resonance spectroscopy, but are not limited thereto. See, for example, Epitope Mapping Protocols in  
5 Methods in Molecular Biology (1996), Vol. 66, Morris (ed.).

Examples of a method for assessing the binding of an epitope in a cancer-specific antigen by a test antigen-binding molecule are shown below. According to the examples below, methods for assessing the binding of an epitope in a target antigen by another binding domain can also be appropriately conducted.

10 For example, whether a test antigen-binding molecule that comprises an antigen-binding domain for a cancer-specific antigen recognizes a linear epitope in the antigen molecule can be confirmed for example as mentioned below. For example, a linear peptide comprising an amino acid sequence forming the extracellular domain of a cancer-specific antigen is synthesized for the above purpose. The peptide can be synthesized chemically, or obtained by genetic  
15 engineering techniques using a region in a cDNA of a cancer-specific antigen encoding the amino acid sequence that corresponds to the extracellular domain. Then, a test antigen-binding molecule containing an antigen-binding domain for a cancer-specific antigen is assessed for its binding activity towards a linear peptide comprising the extracellular domain-constituting amino acid sequence. For example, an immobilized linear peptide can be used as an antigen to  
20 evaluate the binding activity of the antigen-binding molecule towards the peptide by ELISA. Alternatively, the binding activity towards a linear peptide can be assessed based on the level at which the linear peptide inhibits binding of the antigen-binding molecule to cancer-specific antigen-expressing cells. The binding activity of the antigen-binding molecule towards the linear peptide can be demonstrated by these tests.

25 Whether the above-mentioned test antigen-binding molecule containing an antigen-binding domain towards an antigen recognizes a conformational epitope can be confirmed as below. For example, an antigen-binding molecule that comprises an antigen-binding domain for a cancer-specific antigen strongly binds to cancer-specific antigen-expressing cells upon contact, but does not substantially bind to an immobilized linear  
30 peptide comprising an amino acid sequence forming the extracellular domain of the cancer-specific antigen. Herein, “does not substantially bind” means that the binding activity is 80% or less, generally 50% or less, preferably 30% or less, and particularly preferably 15% or less compared to the binding activity to antigen-expressing cells.

35 Methods for assaying the binding activity of a test antigen-binding molecule comprising an antigen-binding domain to antigen-expressing cells include, for example, the methods described in Antibodies A Laboratory Manual (Ed Harlow, David Lane, Cold Spring Harbor

Laboratory (1988) 359-420). Specifically, the assessment can be performed based on the principle of ELISA or fluorescence activated cell sorting (FACS) using antigen-expressing cells as antigen.

In the ELISA format, the binding activity of a test antigen-binding molecule comprising an antigen-binding domain towards antigen-expressing cells can be assessed quantitatively by comparing the levels of signals generated by enzymatic reaction. Specifically, a test antigen-binding molecule is added to an ELISA plate onto which antigen-expressing cells are immobilized. Then, the test antigen-binding molecule bound to the cells is detected using an enzyme-labeled antibody that recognizes the test antigen-binding molecule. Alternatively, when FACS is used, a dilution series of a test antigen-binding molecule is prepared, and the antibody-binding titer for antigen-expressing cells can be determined to compare the binding activity of the test antigen-binding molecule towards antigen-expressing cells.

The binding of a test antigen-binding molecule to an antigen expressed on the surface of cells suspended in buffer or the like can be detected using a flow cytometer. Known flow cytometers include, for example, the following devices:

FACSCanto™ II

FACSAria™

FACSArray™

FACSVantage™ SE

FACSCalibur™ (all are trade names of BD Biosciences)

EPICS ALTRA HyPerSort

Cytomics FC 500

EPICS XL-MCL ADC EPICS XL ADC

Cell Lab Quanta/Cell Lab Quanta SC (all are trade names of Beckman Coulter).

Suitable methods for assaying the binding activity of the above-mentioned test antigen-binding molecule comprising an antigen-binding domain towards an antigen include, for example, the method below. First, antigen-expressing cells are reacted with a test antigen-binding molecule, and then this is stained with an FITC-labeled secondary antibody that recognizes the antigen-binding molecule. The test antigen-binding molecule is appropriately diluted with a suitable buffer to prepare the antigen-binding molecule at a desired concentration. For example, the molecule can be used at a concentration within the range of 10 µg/ml to 10 ng/ml. Then, the fluorescence intensity and cell count are determined using FACSCalibur (BD). The fluorescence intensity obtained by analysis using the CELL QUEST Software (BD), i.e., the Geometric Mean value, reflects the quantity of antibody bound to the cells. That is, the binding activity of a test antigen-binding molecule, which is represented by the quantity of the test antigen-binding molecule bound, can be measured by determining the Geometric Mean value.

Whether a test antigen-binding molecule comprising an antigen-binding domain of the present invention shares a common epitope with another antigen-binding molecule can be assessed based on competition between the two molecules for the same epitope. The competition between antigen-binding molecules can be detected by a cross-blocking assay or the like. For example, the competitive ELISA assay is a preferred cross-blocking assay.

Specifically, in a cross-blocking assay, the antigen coating the wells of a microtiter plate is pre-incubated in the presence or absence of a candidate competitor antigen-binding molecule, and then a test antigen-binding molecule is added thereto. The quantity of test antigen-binding molecule bound to the antigen in the wells indirectly correlates with the binding ability of a candidate competitor antigen-binding molecule that competes for the binding to the same epitope. That is, the greater the affinity of the competitor antigen-binding molecule for the same epitope, the lower the binding activity of the test antigen-binding molecule towards the antigen-coated wells.

The quantity of the test antigen-binding molecule bound to the wells *via* the antigen can be readily determined by labeling the antigen-binding molecule in advance. For example, a biotin-labeled antigen-binding molecule can be measured using an avidin/peroxidase conjugate and appropriate substrate. In particular, a cross-blocking assay that uses enzyme labels such as peroxidase is called “competitive ELISA assay”. The antigen-binding molecule can also be labeled with other labeling substances that enable detection or measurement. Specifically, radiolabels, fluorescent labels, and such are known.

When the candidate competitor antigen-binding molecule can block the binding of a test antigen-binding molecule comprising an antigen-binding domain by at least 20%, preferably at least 20 to 50%, and more preferably at least 50% compared to the binding activity in a control experiment conducted in the absence of the competitor antigen-binding molecule, the test antigen-binding molecule is determined to substantially bind to the same epitope bound by the competitor antigen-binding molecule, or to compete for binding to the same epitope.

When the structure of an epitope bound by a test antigen-binding molecule comprising an antigen-binding domain of the present invention is already identified, whether the test and control antigen-binding molecules share a common epitope can be assessed by comparing the binding activities of the two antigen-binding molecules towards a peptide prepared by introducing amino acid mutations into the peptide forming the epitope.

As a method for measuring such binding activities, for example, the binding activities of test and control antigen-binding molecules towards a linear peptide into which a mutation is introduced are measured by comparison in the above ELISA format. Besides the ELISA methods, the binding activity towards the mutant peptide bound to a column can be determined by passing the test and control antigen-binding molecules through the column, and then

quantifying the antigen-binding molecule eluted in the eluate. Methods for adsorbing a mutant peptide to a column, for example, in the form of a GST fusion peptide, are known.

Alternatively, when the identified epitope is a conformational epitope, whether test and control antigen-binding molecules share a common epitope can be assessed by the following method. First, cells expressing an antigen targeted by an antigen-binding domain and cells expressing an antigen having an epitope introduced with a mutation are prepared. The test and control antigen-binding molecules are added to a cell suspension prepared by suspending these cells in an appropriate buffer such as PBS. Then, the cell suspension is appropriately washed with a buffer, and an FITC-labeled antibody that can recognize the test and control antigen-binding molecules is added thereto. The fluorescence intensity and number of cells stained with the labeled antibody are determined using FACSCalibur (BD). The test and control antigen-binding molecules are appropriately diluted using a suitable buffer, and used at desired concentrations. For example, they may be used at a concentration within the range of 10 µg/ml to 10 ng/ml. The fluorescence intensity determined by analysis using the CELL QUEST Software (BD), i.e., the Geometric Mean value, reflects the quantity of the labeled antibody bound to the cells. That is, the binding activities of the test and control antigen-binding molecules, which are represented by the quantity of the labeled antibody bound, can be measured by determining the Geometric Mean value.

An “antigen-binding molecule” of the present invention comprises both heavy and light chains which form an “antibody variable region” of this invention within a single polypeptide chain; however, it may be an antibody fragment lacking a constant region. Examples of such antibody fragments include a diabody (Db), an scFv, a single-chain antibody, an sc(Fv)<sub>2</sub>, and an sc(Fab')<sub>2</sub>.

Db is a dimer composed of two polypeptide chains (Holliger P *et al.*, Proc. Natl. Acad. Sci. USA 90: 6444-6448 (1993); EP404,097; W093/11161). In each polypeptide chain, an L-chain variable region (VL) and an H-chain variable region (VH) are linked by a linker short enough so that these two regions on the same chain cannot associate with each other, for example, a linker of about five residues.

Because the linker between VL and VH is too short for formation of a single chain variable region fragment, VL and VH encoded on the same polypeptide chain dimerize to form two antigen-binding sites.

Furthermore, herein, the terms “scFv”, “single-chain antibody”, and “sc(Fv)<sub>2</sub>” all refer to an antibody fragment of a single polypeptide chain that contains variable regions derived from the heavy and light chains, but not the constant region. In general, a single-chain antibody also contains a polypeptide linker between the VH and VL domains, which enables formation of a desired structure that is thought to allow antigen binding. The single-chain antibody is

discussed in detail by Pluckthun in “The Pharmacology of Monoclonal Antibodies, Vol. 113, Rosenberg and Moore, eds., Springer-Verlag, New York, 269-315 (1994)”. See also International Patent Publication WO 1988/001649; US Patent Nos. 4,946,778 and 5,260,203. In a particular embodiment, the single-chain antibody can be bispecific and/or humanized.

5 scFv is an antigen-binding domain in which VH and VL forming Fv are linked together by a peptide linker (Proc. Natl. Acad. Sci. U.S.A. (1988) 85(16), 5879-5883). VH and VL can be retained in close proximity by the peptide linker.

sc(Fv)<sub>2</sub> is a single-chain antibody in which four variable regions of two VL and two VH are linked by linkers such as peptide linkers to form a single chain (J Immunol. Methods (1999) 10 231(1-2), 177-189). The two VH and two VL may be derived from different monoclonal antibodies. Such sc(Fv)<sub>2</sub> preferably includes, for example, a bispecific sc(Fv)<sub>2</sub> that recognizes two types of epitopes present in a single antigen as disclosed in the Journal of Immunology (1994) 152(11), 5368-5374. sc(Fv)<sub>2</sub> can be produced by methods known to those skilled in the art. For example, sc(Fv)<sub>2</sub> can be produced by linking scFv by a linker such as a peptide linker.

15 Herein, the form of an antigen-binding domain forming an sc(Fv)<sub>2</sub> include an antibody in which the two VH units and two VL units are arranged in the order of VH, VL, VH, and VL ([VH]-linker-[VL]-linker-[VH]-linker-[VL]) beginning from the N terminus of a single-chain polypeptide. The order of the two VH units and two VL units is not limited to the above form, and they may be arranged in any order. Example order of the form is listed below.

20 [VL]-linker-[VH]-linker-[VH]-linker-[VL]  
[VH]-linker-[VL]-linker-[VL]-linker-[VH]  
[VH]-linker-[VH]-linker-[VL]-linker-[VL]  
[VL]-linker-[VL]-linker-[VH]-linker-[VH]  
[VL]-linker-[VH]-linker-[VL]-linker-[VH]

25 The molecular form of sc(Fv)<sub>2</sub> is also described in detail in WO2006/132352. According to these descriptions, those skilled in the art can appropriately prepare desired sc(Fv)<sub>2</sub> to produce the antigen-binding molecules disclosed herein.

Herein, the term “variable fragment (Fv)” refers to the minimum unit of an antibody-derived antigen-binding domain composed of a pair of the antibody light chain variable 30 region (VL) and antibody heavy chain variable region (VH). In 1988, Skerra and Pluckthun found that homogeneous and active antibodies can be prepared from the *E. coli* periplasm fraction by inserting an antibody gene downstream of a bacterial signal sequence and inducing expression of the gene in *E. coli* (Science (1988) 240(4855), 1038-1041). In the Fv prepared from the periplasm fraction, VH associates with VL in a manner so as to bind to an antigen.

35 Furthermore, the antigen-binding molecule of the present invention may be conjugated with a carrier polymer such as PEG or an organic compound such as an anticancer agent.

Alternatively, a glycosylation sequence can be inserted to suitably add a sugar chain for the purpose of producing a desired effect.

The linkers to be used for linking the variable regions of an antibody comprise arbitrary peptide linkers that can be introduced by genetic engineering, synthetic linkers, and linkers disclosed in, for example, Protein Engineering, 9(3), 299-305, 1996. However, peptide linkers are preferred in the present invention. The length of the peptide linkers is not particularly limited, and can be suitably selected by those skilled in the art according to the purpose. The length is preferably five amino acids or more (without particular limitation, the upper limit is generally 30 amino acids or less, preferably 20 amino acids or less), and particularly preferably 15 amino acids. When  $sc(Fv)_2$  contains three peptide linkers, their length may be all the same or different.

For example, such peptide linkers include:

Ser  
Gly·Ser  
15 Gly·Gly·Ser  
Ser·Gly·Gly  
Gly·Gly·Gly·Ser (SEQ ID NO: 20)  
Ser·Gly·Gly·Gly (SEQ ID NO: 21)  
Gly·Gly·Gly·Gly·Ser (SEQ ID NO: 22)  
20 Ser·Gly·Gly·Gly·Gly (SEQ ID NO: 23)  
Gly·Gly·Gly·Gly·Gly·Ser (SEQ ID NO: 24)  
Ser·Gly·Gly·Gly·Gly·Gly (SEQ ID NO: 25)  
Gly·Gly·Gly·Gly·Gly·Gly·Ser (SEQ ID NO: 26)  
Ser·Gly·Gly·Gly·Gly·Gly·Gly (SEQ ID NO: 27)  
25 (Gly·Gly·Gly·Gly·Ser (SEQ ID NO: 22))<sub>n</sub>  
(Ser·Gly·Gly·Gly·Gly (SEQ ID NO: 23))<sub>n</sub>

where  $n$  is an integer of 1 or larger. The length or sequences of peptide linkers can be selected accordingly by those skilled in the art depending on the purpose.

Synthetic linkers (chemical crosslinking agents) is routinely used to crosslink peptides, and for example:  
30 N-hydroxy succinimide (NHS),  
disuccinimidyl suberate (DSS),  
bis(sulfosuccinimidyl) suberate (BS3),  
dithiobis(succinimidyl propionate) (DSP),  
35 dithiobis(sulfosuccinimidyl propionate) (DTSP),  
ethylene glycol bis(succinimidyl succinate) (EGS),

ethylene glycol bis(sulfosuccinimidyl succinate) (sulfo-EGS),  
 disuccinimidyl tartrate (DST), disulfosuccinimidyl tartrate (sulfo-DST),  
 bis[2-(succinimidoxycarbonyloxy)ethyl] sulfone (BSOCOES),  
 and bis[2-(sulfosuccinimidoxycarbonyloxy)ethyl] sulfone (sulfo-BSOCOES). These  
 5 crosslinking agents are commercially available.

In general, three linkers are required to link four antibody variable regions together.  
 The linkers to be used may be of the same type or different types.

Furthermore, “Fab” is composed of a single light chain, and a CH1 domain and variable  
 region from a single heavy chain. The heavy chain of Fab molecule cannot form disulfide  
 10 bonds with another heavy chain molecule.

“F(ab')<sub>2</sub>” or “Fab” is produced by treating an immunoglobulin (monoclonal antibody)  
 with a protease such as pepsin and papain, and refers to an antibody fragment generated by  
 digesting an immunoglobulin (monoclonal antibody) at near the disulfide bonds present between  
 the hinge regions in each of the two H chains. For example, papain cleaves IgG upstream of  
 15 the disulfide bonds present between the hinge regions in each of the two H chains to generate  
 two homologous antibody fragments, in which an L chain comprising VL (L-chain variable  
 region) and CL (L-chain constant region) is linked to an H-chain fragment comprising VH  
 (H-chain variable region) and CH<sub>γ</sub>1 (γ1 region in an H-chain constant region) *via* a disulfide  
 bond at their C-terminal regions. Each of these two homologous antibody fragments is called  
 20 Fab'.

“F(ab')<sub>2</sub>” contains two light chains and two heavy chains comprising the constant region  
 of a CH1 domain and a portion of a CH2 domain so that disulfide bonds are formed between the  
 two heavy chains. The F(ab')<sub>2</sub> constituting an antigen-binding molecule disclosed herein can  
 be preferably obtained as below. A full-length monoclonal antibody or such comprising a  
 25 desired antigen-binding domain is partially digested with a protease such as pepsin, and then Fc  
 fragments are removed by adsorption onto a Protein A column. The protease is not particularly  
 limited, as long as it can digest the full-length antibody in a restrictive manner to produce F(ab')<sub>2</sub>  
 under an appropriately established enzyme reaction condition such as pH. Such proteases  
 include, for example, pepsin and ficin.

A preferred embodiment of the “antigen-binding molecule” of the present invention  
 includes a multispecific antibody. When using an Fc region with decreased Fc<sub>γ</sub>  
 receptor-binding activity as the Fc region of a multispecific antibody, an Fc region derived from  
 a multispecific antibody may also be used appropriately. For the multispecific antibodies of the  
 present invention, in particular, bispecific antibodies are preferred.

35 For association of multispecific antibodies, one can apply the technique of introducing  
 charge repulsion at the interface of the second constant region of the antibody H chain (CH2) or

the third constant region of the H chain (CH3) to suppress undesired associations between H chains (WO2006/106905).

In the technique of suppressing unintended association between H chains by introducing charge repulsion at the interface of CH2 or CH3, examples of the amino acid residues that are contacted at the interface of other constant regions of the H chain include the region facing the residue at position 356 (EU numbering), the residue at position 439 (EU numbering), the residue at position 357 (EU numbering), the residue at position 370 (EU numbering), the residue at position 399 (EU numbering), and the residue at position 409 (EU numbering) in the CH3 region.

More specifically, for example, for an antibody comprising two types of H chain CH3 regions, the antibody can be made so that one to three pairs of amino acid residues selected from the amino acid residue pairs shown below in (1) to (3) in the first H chain CH3 region have the same charge: (1) amino acid residues at positions 356 and 439 (EU numbering) which are amino acid residues contained in the H chain CH3 region; (2) amino acid residues at positions 357 and 370 (EU numbering) which are amino acid residues contained in the H chain CH3 region; and (3) amino acid residues at positions 399 and 409 (EU numbering) which are amino acid residues contained in the H chain CH3 region.

Furthermore, the antibody can be made so that one to three pairs of amino acid residues corresponding to the amino acid residue pairs shown above in (1) to (3) having the same type of charge in the first H chain CH3 region, which are amino acid residue pairs selected from the amino acid residue pairs shown above in (1) to (3) in the second H chain CH3 region which differs from the first H chain CH3 region, have a charge opposite to the corresponding amino acid residues in the aforementioned first H chain CH3 region.

The respective amino acid residues of (1) to (3) mentioned above are positioned close to each other when associated. For the desired H chain CH3 region or H chain constant region, those skilled in the art can find sites corresponding to the above-mentioned amino acid residues of (1) to (3) by homology modeling and such using commercially available software, and amino acid residues of these sites can be subjected to modifications as appropriate.

In the above-mentioned antibodies, “amino acid residues having a charge” are preferably selected, for example, from amino acid residues contained in either one of groups (a) and (b) below:

- (a) glutamic acid (E) and aspartic acid (D); and
- (b) lysine (K), arginine (R), and histidine (H).

Regarding the above-mentioned antibodies, “having the same type of charge” means, for example, that two or more amino acid residues all have amino acid residues included in either one of the above-mentioned groups (a) and (b). The phrase “having the opposite charge” means

that, for example, when at least one of the two or more amino acid residues has an amino acid residue included in either one of the above-mentioned groups (a) and (b), the remaining amino acid residue(s) will have an amino acid residue included in the other group.

In a preferred embodiment of the above-mentioned antibody, the first H chain CH3 region and the second H chain CH3 region may be cross-linked by a disulfide bond.

In the present invention, the amino acid residue to be subjected to alteration is not limited to an amino acid residue of the constant region or variable region of the antibody described above. With regard to polypeptide mutants or heteromultimers, those skilled in the art can find amino acid residues that form the interface through homology modeling and such using commercially available software, and can subject the amino acid residues at those sites to alterations so that association is regulated.

Other known techniques can also be used for the association of multispecific antibodies of the present invention. Polypeptides with different amino acids having an Fc region can be efficiently associated with each other by substituting an amino acid side chain present in one of the H chain variable regions of the antibody with a larger side chain (knob), and substituting an amino acid side chain present in the corresponding variable region of the other H chain with a smaller side chain (hole), to allow placement of the knob within the hole (WO1996/027011; Ridgway JB *et al.*, Protein Engineering (1996) 9, 617-621; Merchant AM *et al.* Nature Biotechnology (1998) 16, 677-681; and US20130336973).

In addition, other known techniques can also be used to form multispecific antibodies of the present invention. Association of polypeptides having different sequences can be induced efficiently by complementary association of CH3s, using a strand-exchange engineered CH3 domain produced by changing part of CH3 in one of the H chains of an antibody into its corresponding IgA-derived sequence, and introducing into the complementary portion of the CH3 in the other H chain its corresponding IgA-derived sequence (Protein Engineering Design & Selection, 23; 195-202, 2010). This known technique can also be used to efficiently form multispecific antibodies of interest.

In addition, the following techniques and such may be used for the formation of multispecific antibodies: techniques for antibody production using association of antibody CH1 and CL, and association of VH and VL as described in WO 2011/028952, WO2014/018572, and Nat Biotechnol. 2014 Feb;32(2):191-8; techniques for producing bispecific antibodies using separately prepared monoclonal antibodies in combination (Fab Arm Exchange) as described in WO2008/119353 and WO2011/131746; techniques for regulating association between antibody heavy chain CH3s as described in WO2012/058768 and WO2013/063702; techniques for producing bispecific antibodies composed of two types of light chains and one type of heavy chain as described in WO2012/023053; techniques for producing bispecific antibodies using two

bacterial cell strains that individually express one of the chains of an antibody comprising a single H chain and a single L chain as described by Christoph *et al.* (Nature Biotechnology Vol. 31, p 753-758 (2013)).

An embodiment of multispecific antibody formation includes methods for obtaining bispecific antibodies by mixing two types of monoclonal antibodies in the presence of a reducing agent to cleave the disulfide bonds in the core hinge region, followed by re-association for heterodimerization (FAE) as described above. Meanwhile, introduction of electrostatic interactions at the interacting interface of the CH3 region (WO2006/106905) can induce even more efficient heterodimerization during the re-association (WO2015/046467). In FAE using naturally-occurring IgG, re-association takes place randomly; and thus theoretically, bispecific antibodies can only be obtained at 50% efficiency; however, in this method, bispecific antibodies can be produced in high yield.

Alternatively, even when a multispecific antibody of interest cannot be formed efficiently, a multispecific antibody of the present invention can be obtained by separating and purifying the multispecific antibody of interest from the produced antibodies. For example, a method has been reported that enables purification of two types of homologous forms and the heterologous antibody of interest by ion exchange chromatography, by conferring a difference in the isoelectric points by introducing amino acid substitutions into the variable regions of the two types of H chains (WO2007114325). To date, as a method for purifying heterologous forms, a method using Protein A to purify a heterodimerized antibody comprising a mouse IgG2a H chain that binds to Protein A and a rat IgG2b H chain that does not bind to Protein A has been reported (WO98050431 and WO95033844). Furthermore, the heterodimerized antibody per se can be purified efficiently using a Protein A column by changing the interaction between each of the H chains and Protein A, by using H chains in which amino acid residues at the IgG-Protein A binding site, positions 435 and 436 (EU numbering), are substituted with amino acids that yield a different binding strength to Protein A such as Tyr, His, or such.

Alternatively, a common L chain that can confer binding ability to a plurality of different H chains can be obtained and used as the common L chain of a multispecific antibody. Efficient expression of a multispecific IgG can be achieved by introducing the genes of such a common L chain and a plurality of different H chains into cells and expressing the IgG (Nature Biotechnology (1998) 16, 677-681). A method for selecting a common L chain that shows strong binding ability to any different H chains can also be used when selecting a common H chain (WO 2004/065611).

Furthermore, an Fc region whose C-terminal heterogeneity has been improved can be appropriately used as an Fc region of the present invention. More specifically, Fc regions lacking glycine at position 446 and lysine at position 447, as specified by EU numbering, in the

amino acid sequences of two polypeptides constituting an Fc region derived from IgG1, IgG2, IgG3, or IgG4, are provided.

A plurality, such as two or more, of these techniques can be used in combination.

Furthermore, these techniques can be appropriately and separately applied to the two H chains to

5 be associated. Furthermore, these techniques can be used in combination with the above-mentioned Fc region of which Fc $\gamma$  receptor-binding activity has been decreased.

Furthermore, an antigen-binding molecule of the present invention may be a molecule produced separately based on an antigen-binding molecule subjected to the above-described modifications so as to have the same amino acid sequence.

10 An antigen-binding molecule (first antigen-binding molecule) of the present invention may comprise (1) the cancer-specific antigen-binding domain mentioned above and (2) a tumor necrosis factor (TNF) superfamily-binding domain or a tumor necrosis factor (TNF) receptor superfamily-binding domain, and its structure is not limited. By comprising these two binding domains, the first antigen-binding molecule specifically activates cells that express a molecule  
15 belonging to the TNF superfamily or the TNF receptor superfamily, and which express a cancer-specific antigen or are cells contained in tumor tissues comprising these cells, and induces excellent (specific) cytotoxic effects against these cancer-specific antigen-expressing cells or tumor tissues containing these cells. A cancer-specific antigen-binding domain, TNF superfamily-binding domain, and TNF receptor superfamily-binding domain of the present  
20 invention can be appropriately selected using a cancer-specific antigen or an antigen belonging to the TNF superfamily or the TNF receptor superfamily described above, respectively. These binding domains can be linked directly by peptide bonds or bound *via* linkers.

Antigen-binding molecules of the present invention may further comprise an FcRn-binding domain. When using an antibody Fc region described above as the FcRn-binding  
25 domain, it is preferably an Fc region with decreased Fc $\gamma$  receptor-binding activity. Reducing the activity to bind to an Fc $\gamma$  receptor enables suppression of side effects produced by immunostimulation such as cytokine release caused by the crosslinking between Fc $\gamma$  receptor-expressing cells and cells that express factors belonging to the TNF receptor superfamily.

30 Antigen-binding molecules of the present invention can be produced using known methods described above. For example, when (1) F(ab')<sub>2</sub> as a cancer-specific antigen-binding domain, (2) F(ab')<sub>2</sub> as a TNF superfamily-binding domain or a TNF receptor superfamily-binding domain, and (3) a domain comprising an Fc region with decreased Fc $\gamma$  receptor-binding activity as the FcRn-binding domain are used, and when the antigen-binding  
35 domains described in (1) and (2) and the Fc region-containing domain described in (3) are directly linked by peptide bonds, the linked polypeptides will form an antibody structure. Such

antibodies can be produced by purification from the afore-mentioned hybridoma culture medium, and also by purifying antibodies from the culture medium of desired host cells that stably carry polynucleotides encoding polypeptides constituting the antibody.

In addition to the linkers exemplified above, linkers with peptide tags such as His tag, HA tag, myc tag, and FLAG tag may also be suitably used as the linkers to be employed when connecting each of the domains *via* linkers. Furthermore, hydrogen bonding, disulfide bonding, covalent bonding, ionic interaction, or the property of mutual binding as a result of combination thereof may be suitably used. For example, the affinity between antibody CH1 and CL may be used, and Fc regions derived from the above-described multispecific antibodies may also be used for heterologous Fc region association.

In the present invention, a first antigen-binding molecule can be used in combination with a second antigen-binding molecule.

As in the case with the first antigen-binding molecule, the structure of a second antigen-binding molecule is not limited and it may comprise:

(1) a cancer-specific antigen-binding domain, and

(2) a T cell receptor complex-binding domain;

and it can be obtained by methods similar to those for the first antigen-binding molecule.

Furthermore, as long as the second antigen-binding molecule contains a cancer-specific antigen-binding domain and a T cell receptor complex-binding domain, its structure does not have to be the same as that of the first antigen-binding molecule. The cancer-specific antigen bound by the cancer-specific antigen-binding domain of the first antigen-binding molecule and the cancer-specific antigen bound by the cancer-specific antigen-binding domain of the second antigen-binding molecule may be the same or different, but they are preferably the same cancer-specific antigen. When the cancer-specific antigens are the same, the epitopes to which the first and second antigen-binding molecules bind may be the same or different. Use of these first and second antigen-binding molecules in combination yields an excellent cytotoxic activity. The cancer-specific antigen-binding domain and T cell receptor complex-binding domain in the second antigen-binding domain can be appropriately selected, respectively, from the above-mentioned cancer-specific antigens or antigens belonging to T cell receptor complexes.

Similarly to the first antigen-binding molecule, the second antigen-binding molecule of the present invention may further comprise an FcRn-binding domain. When an antibody Fc region described above is used as the FcRn-binding domain, an Fc region with decreased Fc $\gamma$  receptor-binding activity is preferred, as in the case of the first antigen-binding molecule.

Reducing the activity to bind to an Fc $\gamma$  receptor enables suppression of side effects produced by immunostimulation such as cytokine release caused by the crosslinking between Fc $\gamma$  receptor-expressing cells and T cell receptor complex-expressing cells and/or cells that express

factors belonging to the TNF receptor superfamily.

The present invention also relates to polynucleotides encoding the antigen-binding molecules of the present invention, and they can be incorporated into arbitrary expression vectors. Suitable hosts can be transformed with the expression vectors to produce cells that  
 5 express the antigen-binding molecules. Antigen-binding molecules encoded by the polynucleotides can be obtained by culturing cells that express the antigen-binding molecules, and collecting expression products from the culture supernatant. That is, the present invention relates to vectors comprising a polynucleotide that encodes an antigen-binding molecule of the  
 10 present invention, cells carrying such a vector, and methods for producing antigen-binding molecules, which comprise culturing the cells and collecting antigen-binding molecules from the culture supernatant. These can be obtained by techniques similar to those for recombinant antibodies mentioned above.

#### Pharmaceutical compositions

From another viewpoint, the present invention provides pharmaceutical compositions comprising the above-described first antigen-binding molecule as the active ingredient. Furthermore, the present invention relates to pharmaceutical compositions that induce cytotoxicity (cytotoxicity-inducing therapeutic agents), cell proliferation inhibitors, and anticancer agents, which comprise the antigen-binding molecule as an active ingredient.  
 20 Pharmaceutical compositions of the present invention can be used as agents for treating cancer or agents for preventing cancer. The cytotoxicity-inducing therapeutic agents, cell proliferation inhibitors, and anticancer agents of the present invention are preferably administered to subjects suffering from cancer, or subjects who may undergo relapse.

Furthermore, in the present invention, cytotoxicity-inducing therapeutic agents, cell  
 25 proliferation inhibitors and anticancer agents that comprise the first antigen-binding molecule as an active ingredient described above can be presented as methods for inducing cytotoxicity, methods for suppressing cell proliferation, methods for activating immunity against cancer cells or tumor tissues containing cancer cells, or methods for preventing or treating cancer, which comprise the step of administering the antigen-binding molecule to a subject; or they can be  
 30 presented as use of the antigen-binding molecules in producing pharmaceutical compositions for inducing cytotoxicity, cell proliferation inhibitors, and anticancer agents. Alternatively, they can be presented as antigen-binding molecules for use in inducing cytotoxicity, suppressing cell proliferation, activating immunity against cancer cells or tumor tissues containing cancer cells, or treating or preventing cancer.

35 In the present invention, “comprising the antigen-binding molecule as an active ingredient” means containing the antigen-binding molecule as a major active component, and

does not limit the content of the antigen-binding molecule.

Furthermore, pharmaceutical compositions, or pharmaceutical compositions for inducing cytotoxicity, cell proliferation inhibitors, and anticancer agents of the present invention (hereinafter, referred to as pharmaceutical compositions or such) can be used in combination with the above-described second antigen-binding molecules. Use of a second antigen-binding molecule in combination with a pharmaceutical composition or such containing a first antigen-binding molecule can strengthen the cytotoxic actions against the antigen-expressing cells. Here, “use of a second antigen-binding molecule in combination” may refer to the case of mixing a second antigen-binding molecule into a pharmaceutical composition or such containing a first antigen-binding molecule, or the case where a second antigen-binding molecule is included in a pharmaceutical composition or such that is different from the pharmaceutical composition or such containing a first antigen-binding molecule. Their dosage forms may be the same or different. Furthermore, when the first antigen-binding molecule and the second antigen-binding molecule are included in different pharmaceutical compositions or such, these pharmaceutical compositions or such may be administered simultaneously or separately to the subject. In addition, these pharmaceutical compositions or such may be provided as a kit.

In the present invention, a first antigen-binding molecule or a pharmaceutical composition comprising a first antigen-binding molecule as an active ingredient can be used as a pharmaceutical composition for strengthening the cytotoxic activity or enhancing the induction of cytotoxic activity by concomitantly using it with a second antigen-binding molecule or a pharmaceutical composition or such comprising a second antigen-binding molecule as an active ingredient. Furthermore, a second antigen-binding molecule or a pharmaceutical composition comprising a second antigen-binding molecule as an active ingredient can be used as a pharmaceutical composition for strengthening the cytotoxic activity or enhancing the induction of cytotoxic activity by concomitantly using it with a first antigen-binding molecule or a pharmaceutical composition or such comprising a first antigen-binding molecule as an active ingredient.

Herein, “concomitant use” includes the case where a pharmaceutical composition or such comprising a first antigen-binding molecule as an active ingredient and a pharmaceutical composition or such comprising a second antigen-binding molecule as an active ingredient are simultaneously administered to a subject, and the case where they are separately administered to a subject. Their dosage forms may be the same or different. Furthermore, these pharmaceutical compositions or such may be provided as a kit.

Furthermore, the present invention provides a method that utilizes the effects produced by concomitant use of a first antigen-binding molecule described above or a pharmaceutical composition or such comprising this antigen-binding molecule as an active ingredient and a

second antigen-binding molecule or a pharmaceutical composition or such comprising the second antigen-binding molecule as an active ingredient to enhance the cytotoxic activity or antitumor effect of the second antigen-binding molecule or a pharmaceutical composition or such comprising the second antigen-binding molecule as an active ingredient by the first  
 5 antigen-binding molecule or a pharmaceutical composition or such comprising the first antigen-binding molecule as an active ingredient. Furthermore, the present invention provides a method for strengthening the cytotoxic activity or antitumor effect of a first antigen-binding molecule or a pharmaceutical composition or such comprising a first antigen-binding molecule as an active ingredient with a second antigen-binding molecule or a pharmaceutical composition  
 10 or such comprising a second antigen-binding molecule as an active ingredient.

Furthermore, pharmaceutical compositions or such of the present invention can be used by combining multiple types of a first antigen-binding molecule and/or a second antigen-binding molecule as necessary. For example, by using a cocktail of a plurality of antigen-binding  
 15 molecules of the present invention that bind to the same antigen, one can enhance the cytotoxic action against cells expressing the antigen.

If necessary, the antigen-binding molecules of the present invention may be encapsulated in microcapsules (microcapsules made from hydroxymethylcellulose, gelatin, poly[methylmethacrylate], and the like), and made into components of colloidal drug delivery systems (liposomes, albumin microspheres, microemulsions, nano-particles, and nano-capsules)  
 20 (for example, see "Remington's Pharmaceutical Science 16th edition", Oslo Ed. (1980)). Moreover, methods for preparing agents as sustained-release agents are known, and these can be applied to the antigen-binding molecules of the present invention (J. Biomed. Mater. Res. (1981) 15, 267-277; Chemtech. (1982) 12, 98-105; US Patent No. 3773719; European Patent Application (EP) Nos. EP58481 and EP133988; Biopolymers (1983) 22, 547-556).

The pharmaceutical compositions, cell proliferation-suppressing agents, or anticancer agents of the present invention may be administered either orally or parenterally to patients. Parental administration is preferred. Specifically, such administration methods include injection, nasal administration, transpulmonary administration, and percutaneous administration. Injections include, for example, intravenous injections, intramuscular injections, intraperitoneal  
 30 injections, and subcutaneous injections. For example, pharmaceutical compositions, therapeutic agents for inducing cellular cytotoxicity, cell proliferation-suppressing agents, or anticancer agents of the present invention can be administered locally or systemically by injection. Furthermore, appropriate administration methods can be selected according to the patient's age and symptoms. The administered dose can be selected, for example, from the  
 35 range of 0.0001 mg to 1,000 mg per kg of body weight for each administration. Alternatively, the dose can be selected, for example, from the range of 0.001 mg/body to 100,000 mg/body per

patient. However, the dose of a pharmaceutical composition of the present invention is not limited to these doses.

The pharmaceutical compositions of the present invention can be formulated according to conventional methods (for example, Remington's Pharmaceutical Science, latest edition, Mark Publishing Company, Easton, U.S.A.), and may also contain pharmaceutically acceptable carriers and additives. Examples include, but are not limited to, surfactants, excipients, coloring agents, flavoring agents, preservatives, stabilizers, buffers, suspension agents, isotonic agents, binders, disintegrants, lubricants, fluidity promoting agents, and corrigents, and other commonly used carriers can be suitably used. Specific examples of the carriers include light anhydrous silicic acid, lactose, crystalline cellulose, mannitol, starch, carmellose calcium, carmellose sodium, hydroxypropyl cellulose, hydroxypropyl methylcellulose, polyvinylacetal diethylaminoacetate, polyvinylpyrrolidone, gelatin, medium-chain triglyceride, polyoxyethylene hardened castor oil 60, saccharose, carboxymethyl cellulose, corn starch, inorganic salt, and such.

Furthermore, the present invention provides methods of inducing damage to cells expressing a cancer-specific antigen or to tumor tissues containing cells expressing a cancer-specific antigen and methods for suppressing proliferation of these cells or these tumor tissues, by contacting cells that express the certain cancer-specific antigen to a first antigen-binding molecule or to a first antigen-binding molecule as well as a second antigen-binding molecule of the present invention which binds to the cancer specific antigen. The cells bound by an antigen-binding molecule of the present invention that binds to the cancer-specific antigen are not particularly limited as long as they are cells that express the cancer-specific antigens. Suitable examples of the preferred cancer antigen-expressing cells of the present invention are specifically, cells of ovarian cancer, prostate cancer, breast cancer, uterine cancer, hepatic cancer, lung cancer, pancreatic cancer, gastric cancer, bladder cancer, and colorectal cancer.

In the present invention, "contact" is carried out, for example, by adding an antigen-binding molecule of the present invention that binds to the cancer antigen to a solution of cancer antigen-expressing cells cultured *in vitro*. In this case, a form suitable for use of the added antigen-binding molecule may be a solution, or a solid or such obtained by freeze-drying, and the like. When added as an aqueous solution, an aqueous solution containing purely the antigen-binding molecule of the present invention alone may be used, or a solution containing surfactants, excipients, coloring agents, perfumes, preservatives, stabilizers, buffers, suspending agents, isotonization agents, binders, disintegrants, lubricants, fluidity promoting agents, flavoring agents, and such described above may be used. The concentration used for the addition is not particularly limited, but a suitable final concentration in the culture solution is

preferably in the range of 1 pg/ml to 1 g/ml, more preferably 1 ng/ml to 1 mg/ml, and even more preferably 1 µg/ml to 1 mg/ml.

Furthermore, in another embodiment, “contact” of the present invention is carried out by administering an antigen-binding molecule of the present invention that binds to a cancer antigen to a non-human animal with cells expressing the cancer-specific antigen transplanted into their bodies, and to an animal having cancer cells that intrinsically express the cancer-specific antigens. The method of administration may be oral or parenteral, and parenteral administration is particularly preferred. Specific examples of the administration method include administration by injection, transnasal administration, transpulmonary administration, and transdermal administration. Examples of administration by injection include intravenous injection, intramuscular injection, intraperitoneal injection, and subcutaneous injection. A pharmaceutical composition of the present invention or a pharmaceutical composition for inducing cytotoxicity, a cell proliferation inhibitor, and an anticancer agent can be administered systemically or locally, for example, through administration by injection. The method of administration can be selected appropriately according to the age and symptoms of the test animal. When administered as an aqueous solution, an aqueous solution containing purely the antigen-binding molecule of the present invention alone may be used, or a solution containing surfactants, excipients, coloring agents, perfumes, preservatives, stabilizers, buffers, suspending agents, isotonation agents, binders, disintegrants, lubricants, fluidity promoting agents, flavoring agents, and such described above may be used. The dose can be selected, for example, from the range of 0.0001 mg to 1000 mg per kilogram body weight for a single administration. Alternatively, for example, the dose may be selected from the range of 0.001 mg/body to 100000 mg/body per patient. However, the dose of the antigen-binding molecule of the present invention is not limited to these doses.

The following method is suitably used as a method for evaluating or measuring cytotoxicity induced in cells expressing a cancer-specific antigen bound by the cancer specific antigen-binding domain constituting an antigen-binding molecule of the present invention, as a result of contacting the antigen-binding molecule with the cells. Examples of a method for evaluating or measuring the cytotoxic activity *in vitro* include methods for measuring cytotoxic T cell activity, and such. Whether an antigen-binding molecule of the present invention has T cell cytotoxicity can be measured by known methods (for example, Current protocols in Immunology, Chapter 7. Immunologic studies in humans, Editor, John E. Coligan *et al.*, John Wiley & Sons, Inc., (1993) and the like). For activity measurements, an antigen-binding molecule with an antigen-binding domain that binds to an antigen which differs from the antigen bound in the present invention and is an antigen not expressed in the cells used for the examination can be used as a control and in the same manner as the antigen-binding molecule of the present

invention, and the activity can be determined to be present when the antigen-binding molecule of the present invention shows a stronger cytotoxic activity than that of the antigen-binding molecule used as a control.

To evaluate or measure cytotoxic activity *in vivo*, for example, cells expressing an antigen bound by a cancer-specific antigen-binding domain that constitutes an antigen-binding molecule of the present invention are intradermally or subcutaneously transplanted into a non-human test animal, and then a test antigen-binding molecule is intravenously or intraperitoneally administered daily or with an interval of few days, starting from the day of transplantation or the following day. Tumor size is measured daily and the difference in the change of tumor size can be defined as the cytotoxic activity. In a similar manner to the *in vitro* evaluation, a control antigen-binding molecule is administered, and an antigen-binding molecule of the present invention can be determined as exhibiting cytotoxic activity based on the finding that the tumor size in the group subjected to administration of an antigen-binding molecule of the present invention is significantly smaller than the tumor size in the group subjected to administration of the control antigen-binding molecule.

As a method for evaluating or measuring the suppressive effect on proliferation of cells expressing an antigen bound by a cancer-specific antigen-binding domain that constitutes an antigen-binding molecule of the present invention by contact with the antigen-binding molecule, a method of measuring the uptake of isotope-labeled thymidine into cells, or the MTT method may be suitably used. As a method for evaluating or measuring the cell proliferation-suppressing activity *in vivo*, the same method as that described above for evaluating or measuring cytotoxic activity *in vivo* may be suitably used.

The present invention also provides kits for use in the methods of the present invention, which comprise an antigen-binding molecule of the present invention or an antigen-binding molecule produced by a production method of the present invention. Additionally, the kit may include in its package, a pharmaceutically acceptable carrier, solvent, and instructions describing the method of use.

The present invention also relates to an antigen-binding molecule of the present invention or an antigen-binding molecule produced by a production method of the present invention for use in a method of the present invention.

Those skilled in the art will naturally understand that optional combinations of one or more of the embodiments described herein are included in the present invention, as long as they are not technically inconsistent based on common technical knowledge of those skilled in the art.

All prior art references cited herein are incorporated by reference into this description.

### Examples

Herein below, the present invention will be specifically described with reference to the Examples, but the scope of the present invention is not to be construed as being limited thereto.

[Reference Example 1] Construction of antibody expression vectors, and expression and  
5 purification of antibodies

Synthesis of full-length genes encoding the nucleotide sequences of the H chain and L chain of the antibody variable regions was carried out by production methods known to those skilled in the art using Assemble PCR and such. Introduction of amino acid substitutions was carried out by methods known to those skilled in the art using PCR or such. The obtained  
10 plasmid fragment was inserted into an animal cell expression vector, and the H-chain expression vector and L-chain expression vector were produced. The nucleotide sequence of the obtained expression vectors was determined by methods known to those skilled in the art. The produced plasmids were transiently introduced into the HEK293H cell line derived from human embryonic kidney cancer cells (Invitrogen) or into FreeStyle293 cells (Invitrogen) for antibody expression.  
15 The obtained culture supernatant was collected, and then passed through a 0.22  $\mu$ m MILLEX(R)-GV filter (Millipore), or through a 0.45  $\mu$ m MILLEX(R)-GV filter (Millipore) to obtain the culture supernatant. The antibodies were purified from the obtained culture supernatant by methods known to those skilled in the art using rProtein A Sepharose Fast Flow (GE Healthcare) or Protein G Sepharose 4 Fast Flow (GE Healthcare). For the concentration of  
20 the purified antibodies, their absorbance at 280 nm was measured using a spectrophotometer. From the obtained value, the antibody concentration was calculated using the extinction coefficient determined by methods such as PACE (Protein Science 1995; 4: 2411-2423).

[Reference Example 2] Method for preparing mouse Fc $\gamma$  receptor (mFc $\gamma$ R) and method for  
25 analyzing the interaction between a modified antibody and mFc $\gamma$ R

Extracellular domains of mouse Fc $\gamma$ Rs were prepared by the following method. First, genes of Fc $\gamma$ R extracellular domains were synthesized by a method well known to those skilled in the art. In so doing, the sequence of each Fc $\gamma$ R was produced based on the information registered at NCBI. Specifically, mFc $\gamma$ RI was produced based on the sequence of NCBI  
30 Reference Sequence: NP\_034316.1; mFc $\gamma$ RII was produced based on the sequence of NCBI Reference Sequence: NP\_034317.1; mFc $\gamma$ RIII was produced based on the sequence of NCBI Reference Sequence: NP\_034318.2; and mFc $\gamma$ RIV was produced based on the sequence of NCBI Reference Sequence: NP\_653142.2. A His tag was attached to the C terminus of these sequences. Each of the obtained gene fragments was inserted into an animal cell expression  
35 vector to construct expression vectors. The constructed expression vector was transiently introduced into human embryonic kidney cancer cell-derived FreeStyle293 cells (Invitrogen) to

express the proteins of interest. The obtained culture supernatant was collected, and then passed through a 0.22  $\mu$ m filter to obtain the culture supernatant. The obtained culture supernatants were purified in principle by the following four steps: step 1 - ion exchange column chromatography, step 2 - affinity column chromatography for His tag (HisTrap HP), step 3 - gel filtration column chromatography (Superdex200), and step 4 - aseptic filtration. The ion exchange column chromatography of step 1 was carried out using Q Sepharose HP for mFc $\gamma$ RI, using SP Sepharose FF for mFc $\gamma$ RII and mFc $\gamma$ RIV, and using SP Sepharose HP for mFc $\gamma$ RIII. While the solvent used in step 3 and the subsequent step was D-PBS(-), D-PBS(-) containing 0.1 M Arginine was used for mFc $\gamma$ RIII. The absorbance at 280 nm was measured for the purified proteins using a spectrophotometer. From the obtained values, the concentrations of the purified proteins were calculated using the extinction coefficients determined using methods such as PACE (Protein Science 1995; 4: 2411-2423). The interaction between each modified antibody and the Fc $\gamma$  receptor prepared as mentioned above was analyzed using Biacore T100 (GE Healthcare), Biacore T200 (GE Healthcare), Biacore A100, and Biacore 4000. The running buffer used was HBS-EP+ (GE Healthcare) and the measurement temperature was set to 25°C. The chip used was: a Series S Sensor Chip CM5 (GE Healthcare) or Series S Sensor Chip CM4 (GE Healthcare) to which Protein L (ACTIGEN or BioVision) was immobilized by the amine coupling method. Antibodies of interest were captured onto these sensor chips, and mFc $\gamma$ R diluted with the running buffer was allowed to interact with them. The amount bound by the antibodies was measured and compared between the antibodies. However, since the amount of mFc $\gamma$ R bound depends on the amount of the captured antibody, the comparison was carried out on corrected values obtained by dividing the amount of bound mFc $\gamma$ R by the amount of each antibody captured. Furthermore, 10 mM glycine-HCl, pH 1.5 was reacted to wash out the captured antibody from the sensor chips, and the sensor chip was regenerated and used repeatedly. Kinetic analyses for calculating the KD values of each altered antibody to Fc $\gamma$ R were performed according to the method below. First, antibodies of interest were captured onto the above-mentioned sensor chips, and mFc $\gamma$ R diluted with the running buffer was allowed to interact with them. As for the obtained sensorgrams, the measurement results were processed by global fitting according to a 1:1 Langmuir binding model using Biacore Evaluation Software to calculate the association rate constant  $k_a$  (L/mol/s) and the dissociation rate constant  $k_d$  (1/s). From those values, the dissociation constant KD (mol/L) was determined.

#### [Reference Example 3] Experimental animals and cell lines

The experimental animals used were female C57BL/6 mice (Charles River Laboratories Japan, Inc.) or female Balb/c mice (Charles River Laboratories Japan, Inc.). They were bred in a breeding room under constant conditions (temperature: 20°C to 26°C; lighting: 12-hour

light-dark cycle) with ad libitum access to feed and water. The human GPC3 gene was integrated into the chromosome of the mouse lung cancer cell line LLC (ATCC No. CRL-1642) by a method well known to those skilled in the art to obtain an LLC-GPC3 cell line that expresses human GPC3 in high levels. The expression level of human GPC3 ( $2.3 \times 10^5$ /cell) was determined using the QIFI kit (Dako) by the manufacturer's recommended method. Similarly, the human GPC3 gene was integrated into the mouse colorectal cancer cell line CT-26 (ATCC No. CRL-2638) to obtain the high expression CT26-GPC3 cell line (expression level:  $3.1 \times 10^5$ /cell). To maintain the human GPC3 gene, these recombinant cell lines were cultured in ATCC-recommended media by adding Geneticin (GIBCO) at 400  $\mu$ g/ml for LLC-GPC3 and 200  $\mu$ g/ml for CT26-GPC3. After culturing, these cells were detached using 2.5 g/L trypsin–1 mM EDTA (nacalai tesque), and then used for each of the experiments.

[Example 1] Preparation of anti-CD137 mouse antibodies and assessment of agonist activity

1-1. Preparation of anti-mouse CD137 mouse antibody and assessment of mFc $\gamma$ R binding

1D8VH (SEQ ID NO: 28), a variable region against mouse CD137 disclosed in WO2005/017148, which was used as the antibody H-chain variable region, and 1D8VH-mIgG1 (SEQ ID NO: 29) having the H-chain constant region of a naturally-occurring mouse IgG1, which was used as the antibody H-chain constant region, were prepared according to the method of Reference Example 1. 1D8VH-mF18 (SEQ ID NO: 30) was produced by introducing into 1D8VH-mIgG1 a modification of substituting Lys for Pro at position 235 (EU numbering) and a modification of substituting Lys for Ser at position 239 (EU numbering), which are modifications that eliminate Fc $\gamma$ R binding as described in WO2012/133782. Furthermore, 1D8VH-MB492 (SEQ ID NO: 31) was produced by introducing into 1D8VH-mIgG1 modifications (T230E, V231P, P232N, S238E, S239D, N324D) that enhance mFc $\gamma$ RII binding. 1D8VL disclosed in WO2005/017148 was used as the antibody L-chain variable region, and 1D8VL-mk0 (SEQ ID NO: 32) which has the constant region of the mouse  $\kappa$  chain was used as the L-chain constant region. They were expressed and purified according to the method of Reference Example 1 to obtain 1D8VH-mIgG1/1D8VL-mk0, 1D8VH-mF18/1D8VL-mk0, and 1D8VH-MB492/1D8VL-mk0. Herein below, these antibodies will be denoted as 1D8-mIgG1, 1D8-mF18, and 1D8-MB492 for simplicity.

Furthermore, to measure mFc $\gamma$ R binding of each constant region, H237-mIgG1 (SEQ ID NO: 34) and H237-MB492 (SEQ ID NO: 35) which have the variable region H237 of the anti-human interleukin 6 receptor antibody (SEQ ID NO: 33) described in WO2009/125825 were prepared as the H-chain variable region. MRAL-k0 (SEQ ID NO: 36) which is the L chain of tocilizumab was used as the antibody L chain. Expression and purification were performed according to the method of Reference Example 1 to obtain H237-mIgG1/MRAL-k0 and

H237-MB492/MRAL-k0. Similarly, mPM1H-mIgG1 (SEQ ID NO: 37) and mPM1H-mF18 (SEQ ID NO: 38) were produced, which have the variable region (mPM1H) of mouse PM-1, a mouse antibody that binds to human IL6R (Sato, Cancer Res., 1993, 53, 851-856), as the antibody H chain variable region. MRAL-k0 was used as the antibody L chain. Expression and purification were carried out according to the method of Reference Example 1 to obtain mPM1H-mIgG1/MRAL-k0 and mPM1H-mF18/MRAL-k0.

The ability of mPM1H-mIgG1/MRAL-k0 and mPM1H-mF18/MRAL-k0 to bind mFcγRII and mFcγRIII was assessed according to the method of Reference Example 2. Naturally-occurring mouse IgG1 (mIgG1) does not bind to mFcγRI or mFcγRIV, and binds only to mFcγRII and mFcγRIII among the four types of mouse FcγR (Nimmerjahn, 2005, Science, 310, 1510-1512). Therefore, introduction of modifications that decrease mFcγR binding into naturally-occurring mIgG1 was expected to provide variants having decreased binding to mFcγRII and mFcγRIII, and thus reduced binding to all mFcγRs. The results are shown in Table 1.

Table 1.

| Name of the constant region | Amount of binding (RU) |          |
|-----------------------------|------------------------|----------|
|                             | mFcγRII                | mFcγRIII |
| mIgG1                       | 202.1                  | 450      |
| mF18                        | 1.01                   | 2.75     |

The above-mentioned results demonstrated that the constant region mF18 is a variant having remarkably reduced mFcγR binding.

Similarly, Table 2 shows the results of assessing H237-mIgG1/MRAL-k0 and H237-MB492/MRAL-k0 for the binding towards mFcγRII and mFcγRIII.

Table 2

| Name of the constant region | KD (M)    |            | Relative binding activity |            |
|-----------------------------|-----------|------------|---------------------------|------------|
|                             | mFc γ RII | mFc γ RIII | mFc γ RII                 | mFc γ RIII |
| mIgG1                       | 2.10E-07  | 2.82E-07   | 1.0                       | 1.0        |
| MB492                       | 3.38E-10  | 2.58E-08   | 621.5                     | 10.9       |

“Relative binding activity” in the table indicates the binding activity of MB492 when the binding activity of the naturally-occurring mIgG1 towards each mFcγR is defined as 1. The above-mentioned results showed that MB492 is a variant with 621.5-fold increase in mFcγRII

binding and 10.9-fold increase in mFcγRIII binding in comparison to mIgG1.

## 1-2. Assessment of the *in vitro* CD137 agonist effect of anti-mouse CD137 antibodies.

Spleen was collected from naive female C57BL/6 mice. Cells were suspended in 10% FBS-containing RPMI1640 medium supplemented with 0.5 µg/ml ionomycin and 10 ng/ml PHORBOL 12-MYRISTATE 13-ACETATE (PMA), and they were seeded into a 96-well plate at a density of  $2 \times 10^5$  cells/100 µl/well. Anti-mouse CD137 antibodies were added to these wells at 3 µg/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for 3 days. The culture supernatant was collected, and the concentration of mouse IFN-γ contained in the supernatant was determined by ELISA to assess the activation of spleen-derived T cells. ELISA was performed by following the instructions provided by the kit manufacturer (PeproTech).

As a result (Fig. 1), among the prepared anti-mouse CD137 mouse IgG1 antibodies, the antibody (1D8-mF18) having extremely decreased FcγR binding did not show the activity, and the antibody (1D8-mIgG1) having a wild-type Fc showed T cell activation. Furthermore, the specific activity of the antibody (1D8-MB492) having an enhanced binding ability towards FcγRIIB was increased by approximately eight-fold compared to that of the wild-type Fc antibody.

This revealed that, in a similar manner to agonist antibodies against other TNFRSF as described in Proc Natl Acad Sci U S A. 2013, 110(48), 19501-6, in order for anti-CD137 antibodies to exert an agonist activity, the antibodies must bind to FcγRII, and the anti-CD137 antibodies bound to CD137-expressing T cells must crosslink with FcγRII-expressing cells (Fig. 2). FcγRII is expressed in many immune cells and phagocytes such as B cells. Therefore, the agonist activity by anti-CD137 antibodies may take place systemically, and thereby causes side effects.

[Example 2] Preparation of anti-human GPC3/anti-mouse CD137 bispecific antibodies and assessment of their agonist activities

## 2-1. Concept of a cancer antigen-dependent agonist antibody based on cancer antigen- and CD137-bispecific antibodies

According to the examination in Example 1, since agonist activity by common anti-CD137 antibodies takes place systemically, antitumor effects and side effects in normal tissues (such as T cell activation) have been considered to be inseparable. Therefore, the present inventors conceived that use of bispecific antibodies against a cancer antigen and CD137 may enable exhibition of the agonist activity by an anti-CD137 antibody only in cancer tissues where the cancer antigen is present by crosslinking CD137-expressing T cells and cancer

antigen-expressing cells (such as cancer cells) *via* the bispecific antibodies (Fig. 3).

## 2-1. Preparation of anti-human GPC3/anti-mouse CD137 bispecific antibodies (GPC3 ERY22-1D8, GPC3 ERY22-G2-1D8, and GPC3 ERY22-G4-1D8)

Three types of anti-human GPC3/anti-mouse CD137 bispecific antibodies having the constant region of human IgG1, IgG2, or IgG4, were prepared respectively. For these molecules, the CrossMab technique reported by Schaefer *et al.* (Schaefer, Proc. Natl. Acad. Sci., 2011, 108, 11187-11192) was used to regulate the association between the H and L chains and efficiently obtain the bispecific antibodies. More specifically, these molecules were produced by exchanging the VH and VL domains of Fab against human GPC3 described in WO2012/073985. For promotion of heterologous association, the Knobs-into-Holes technology was used for the constant region of the antibody H chain. The Knobs-into-Holes technology is a technique that enables preparation of heterodimerized antibodies of interest through promotion of the heterodimerization of H chains by substituting an amino acid side chain present in the CH3 region of one of the H chains with a larger side chain (Knob) and substituting an amino acid side chain in the CH3 region of the other H chain with a smaller side chains (Hole) so that the knob will be placed into the hole (Burmeister, Nature, 1994, 372, 379-383). Hereinafter, the constant region into which the Knob modification has been introduced will be indicated as Kn, and the constant region into which the Hole modification has been introduced will be indicated as Hl. Furthermore, the modifications described in WO2011/108714 were used to reduce the Fcγ binding. Specifically, the IgG1 type and the IgG4 type were introduced with modifications of substituting Ala for the amino acids at positions 234, 235, and 297 (EU numbering). The IgG2 type was introduced with modifications of substituting Ala for the amino acids at positions 234, 237, and 297. Gly at position 446 and Lys at position 447 (EU numbering) were removed from the C termini of the antibody H chains. In order to further facilitate purification after antibody expression, a histidine tag was added to the C terminus of the anti-human GPC3 H chain, and a FLAG tag was added to the C terminus of the anti-mouse CD137 H chain. The anti-human GPC3 H chains prepared by introducing the above-mentioned modifications were GC33(2)H-G1dKnHS (SEQ ID NO: 39), GC33(2)H-G2dmKnHS (SEQ ID NO: 40), and GC33(2)H-G4dKnHS (SEQ ID NO: 41). The anti-mouse CD137 H chains prepared were 1D8VH-G1dHlFS (SEQ ID NO: 42), 1D8VH-G2dmHlFS (SEQ ID NO: 43), and 1D8VH-G4dHlFS (SEQ ID NO: 44). In GC33(2)H-G2dmKnHS and 1D8VH-G2dmHlFS having the IgG2-type constant region, only the CH1 domain and the first half of the hinge region are of the IgG1 type. Specifically, they contain, compared to the CH1 sequence of naturally-occurring human IgG2, Ser at position 131, Lys at position 133, and Gly at positions 137 and 138; and the hinge region contains Ser at

position 219 (EU numbering). The antibody L chains GC33(2)L-k0 (SEQ ID NO: 45) and 1D8VL-k0 (SEQ ID NO: 46) were commonly used on the anti-human GPC3 side and the anti-mouse CD137 side, respectively. The antibodies having the combinations shown in Table 3 were expressed to obtain the bispecific antibodies of interest. These antibodies were expressed by transient expression in FreeStyle293 cells (Invitrogen) according to “1-1”. The obtained culture supernatant was added to an Anti-FLAG M2 column (Sigma), and the column was washed, followed by elution with 0.1 mg/mL FLAG peptide (Sigma). The antibody-containing fraction was added to a HisTrap HP column (GE Healthcare), and the column was washed, followed by elution using an imidazole concentration gradient. The antibody-containing fraction was concentrated using an ultrafiltration membrane, and then the concentrated solution was added to Superdex 200 column (GE Healthcare). Only the monomeric antibodies in the eluate were collected to obtain the purified antibodies.

Table 3

| Antibody name     | H-chain gene 1    | L-chain gene 1 | H-chain gene 2 | L-chain gene 2 |
|-------------------|-------------------|----------------|----------------|----------------|
| GPC3 ERY22-1D8    | GC33(2)H-G1dKnHS  | GC33(2)L-k0    | 1D8VH-G1dHIFS  | 1D8VL-k0       |
| GPC3 ERY22-G2-1D8 | GC33(2)H-G2dmKnHS | GC33(2)L-k0    | 1D8VH-G2dmHIFS | 1D8VL-k0       |
| GPC3 ERY22-G4-1D8 | GC33(2)H-G4dKnHS  | GC33(2)L-k0    | 1D8VH-G4dHIFS  | 1D8VL-k0       |

## 2-2. Assessment of the *in vitro* GPC3-dependent CD137 agonistic effect of anti-human GPC3/anti-mouse CD137 bispecific antibodies

The mouse T cell line CTLL-2 (ATCC Cat. No. TIB-214) was suspended in 10% FBS-containing RPMI1640 medium supplemented with 0.5 µg/ml ionomycin and 10 ng/ml PMA, and the cells were seeded into a 96-well plate at a density of  $2 \times 10^4$  cells/100 µl/well. The human GPC3-expressing mouse lung cancer cell line LLC-GPC3 (Reference Example 3) was suspended in the same medium, and this was seeded into the same 96-well plate at a density of  $2 \times 10^4$  cells/100 µl/well. Furthermore, suspensions each containing the same number of CTLL-2 or LLC-GPC3 cells were prepared, and then the cells were seeded into a 96-well plate at a density of  $4 \times 10^4$  cells/100 µl/well. To the wells, an anti-human GPC3/anti-mouse CD137 bispecific human IgG1 type antibody having extremely reduced FcγR binding (GPC3 ERY22-1D8), or an anti-human GPC3 monospecific human IgG-type antibody (GC33(2)-hG1S comprising GC33(2)H2-G1dS and GC33(2)L2-k0) was added at a concentration of 5 µg/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for 24 hours. The culture supernatant was collected, and the mouse IFN-γ concentration in the supernatant was measured by ELISA to assess the CTLL-2 activation. ELISA was performed by following the instructions provided by the kit manufacturer (PeproTech).

As a result, mouse IFN-γ was found to highly accumulate only under conditions where

both LLC-GPC3 and CTLL-2 cells were present (Fig. 4). Based on this result, it was thought that T cell activation occurred in accordance with the association of CD137 on T cells mediated by a plurality of the bispecific antibodies bound to GPC3-expressing cells (Fig. 3).

Furthermore, Fig. 5 shows the activity of bispecific antibodies whose Fc portion has been changed to that of the human IgG2 type (GPC3 ERY22-G2-1D8) or human IgG4 type (GPC3 ERY22-G4-1D8) which has extremely decreased Fc $\gamma$ R binding. Changing the antibody subclass did not result in any significant changes in the CD137 agonist activity.

From these results, it was confirmed that bispecific antibodies with reduced Fc $\gamma$ R binding against a cancer antigen (GPC3 in the present Examples) and CD137 are able to exhibit an agonist activity upon association of CD137 on T cells only when cancer antigen-expressing cells (cancer cells and such) are present. More specifically, T cells are not activated in normal tissues where the cancer antigen is absent, and thus, side effects may be reduced or avoided.

[Example 3] The T cell activation-enhancing effect by a mixture of an anti-human GPC3/anti-mouse CD137 bispecific antibody and an anti-human GPC3/anti-mouse CD3 bispecific antibody

### 3-1. Concept

While anti-CD137 agonist antibodies are known to exert an anti-tumor effect by activating T cells, this effect is known to be low when the anti-CD137 agonist antibodies are used as a single agent. Therefore, to enhance the ability of anti-cancer antigen/anti-CD137 bispecific antibodies to activate T cells, and thereby exert a stronger antitumor effect, concomitant use with an agent that similarly activates T cells was examined. Anti-cancer antigen/anti-CD3 bispecific antibodies can redirect T cells to the cancer antigen, and exert a T cell-mediated cytotoxic activity against cancer cells. However, the antitumor effect of the anti-cancer antigen/anti-CD3 bispecific antibodies is also not necessarily high when they are used as single agents. Therefore, concomitant use of an anti-cancer antigen/anti-CD137 bispecific antibody and an anti-cancer antigen/anti-CD3 bispecific antibody was examined to see whether synergistic T cell-activating ability and antitumor effect can be demonstrated.

### 3-2. Preparation of GPC3 ERY22-3-1D8 and GPC3 ERY22-3-2C11

An anti-human GPC3/anti-mouse CD137 bispecific antibody, GPC3 ERY22-3-1D8, and an anti-human GPC3/anti-mouse CD3 bispecific antibody, GPC3 ERY22-3-2C11, were prepared. GPC3 ERY22-3-1D8 was produced by adding modifications that are known to those skilled in the art to further simplify purification to the constant region of the GPC3 ERY22-1D8 bispecific antibody prepared in Example 2-1. Specifically, GC33(2)H-G1dKnHSG3 (SEQ ID NO: 48) was prepared by adding the H435R modification for simplifying purification, which is known to

those skilled in the art, to the anti-human GPC3 H-chain constant region gene GC33(2)H-G1dKnHS. Along with this, 1D8VH-G1dHIS (SEQ ID NO: 47) was prepared by removing the FLAG tag from the anti-mouse CD137 H-chain constant region gene 1D8VH-G1dHIFS. Furthermore, 2C11VH-G1dHIS (SEQ ID NO: 50) was prepared by using the sequence of 2C11VH (SEQ ID NO: 49) as the H-chain variable region of the anti-mouse CD3 antibody. Antibody L chains GC33(2)L-k0, 1D8VL-k0, and 2C11VL-k0 (SEQ ID NO: 51) were used for the anti-humanGPC3 side, the anti-mouse CD137 side, and the anti-mouse CD3 side, respectively. The antibodies having the combinations shown in Table 4 were expressed to obtain the bispecific antibodies of interest. These antibodies were expressed by transient expression in FreeStyle293 cells according to Reference Example 1. The obtained culture supernatant was added to a MabSelect SuRe column (GE Healthcare), and the column was washed, followed by elution with 50 mM acetic acid. The antibody-containing fraction was added to a HisTrap HP column (GE Healthcare) or a Ni Sepharose FF column (GE Healthcare), and the column was washed, followed by elution with imidazole. The antibody-containing fraction was concentrated using an ultrafiltration membrane. Then, the concentrated solution was added to a Superdex 200 column (GE Healthcare). Only the monomeric antibodies in the eluate were collected to obtain the purified antibodies.

Table 4

| Antibody name     | H-chain gene 1     | L-chain gene 1 | H-chain gene 2 | L-chain gene 2 |
|-------------------|--------------------|----------------|----------------|----------------|
| GPC3 ERY22-3-1D8  | GC33(2)H-G1dKnHSG3 | GC33(2)L-k0    | 1D8VH-G1dHIS   | 1D8VL-k0       |
| GPC3 ERY22-3-2C11 | GC33(2)H-G1dKnHSG3 | GC33(2)L-k0    | 2C11VH-G1dHIS  | 2C11VL-k0      |

Furthermore, GC33(2)-G1dS, which has decreased FcγR binding and is also an anti-human GPC3 antibody, was prepared as a comparative control. GC33(2)-G1dS is a naturally-occurring anti-human GPC 3 antibody prepared without using the CrossMab technique, and has a constant region with decreased FcγR binding. Specifically, GC33(2)H2-G1dS (SEQ ID NO: 53), which has GC33(2)H2 (SEQ ID NO: 52) as the antibody H-chain variable region and has G1d introduced with L234A, L235A, and N297A as the antibody H-chain constant region, was prepared. GC33(2)L2-k0 (SEQ ID NO: 54) was used as the antibody L chain. Expression and purification were performed according to the method of Reference Example 1 to obtain GC33(2)H2-G1dS/GC33(2)L2-k0. Hereinafter, for simplicity, the antibody will be denoted as GC33(2)-G1dS.

### 3-3. Assessment of the *in vitro* T cell activation-enhancing effect by a mixture of an anti-human GPC3/anti-mouse CD137 bispecific antibody and an anti-human GPC3/anti-mouse CD3

### bispecific antibody

Spleen was collected from naive female C57BL/6 mice. Cells were suspended in 10% FBS-containing RPMI1640 medium supplemented with 10 ng/ml mouse IL2 at a density of  $4 \times 10^6$  cells/ml. Furthermore, the human GPC3-expressing mouse colorectal cancer cell line CT26-GPC3 (Reference Example 3) was suspended in the same medium at a density of  $4 \times 10^5$  cells/ml. Equal amounts of each cell suspension were mixed, and the mixture was seeded into a 96-well plate at 100  $\mu$ l/well. Some of the wells were further added with 0.5  $\mu$ g/ml ionomycin and 10 ng/ml PMA. To this, an anti-human GPC3/anti-mouse CD137 bispecific antibody with extremely reduced Fc $\gamma$ R binding (GPC3 ERY22-1D8) and an anti-human GPC3/anti-mouse CD3 bispecific antibody with extremely reduced Fc $\gamma$ R binding (GPC3 ERY22-2C11:GPC3 ERY22-3-2C11 in which the H435R modification has been restored to its original state) were added at a concentration of 3  $\mu$ g/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for 24 hours. The culture supernatant was collected, and the concentration of mouse IFN- $\gamma$  contained in the supernatant was measured by ELISA to assess the activation of T cells contained in the spleen cells. ELISA was performed by following the instructions provided by the kit manufacturer (PeproTech).

As a result (Fig. 6), 1D8-MB492 and GPC3 ERY22-1D8 showed an IFN- $\gamma$ -inducing activity when added with ionomycin and PMA. This was assumed to be a result of CD137 induction in spleen T cells due to stimulation by mitogen and such. Furthermore, IFN- $\gamma$  was found to highly accumulate in the mixture containing GPC3 ERY22-1D8 and GPC3 ERY22-2C11. This suggests that simultaneous stimulation of CD3 and CD137 strongly elicits T cell activation.

[Example 4] Antitumor effect of anti-human GPC3/anti-mouse CD137 bispecific antibodies and their effect in reducing liver toxicity

#### 4-1. Comparison of the drug efficacy of anti-human GPC3/anti-mouse CD137 bispecific antibodies and anti-mouse CD137 antibodies

The recombinant mouse colorectal cancer cell line CT26-GPC3 which expresses human GPC3 (Reference Example 3) was placed into Hanks' Balanced Salt Solution (HBSS) at  $5 \times 10^6$  cells/mL, and 200  $\mu$ L of this ( $1 \times 10^6$  cells) was transplanted subcutaneously into the abdomen of BALB/c mice (female, 7-weeks old, Charles River Laboratories Japan Inc.). The animals were randomly divided into five groups of five individuals each, and then the antibodies were administered by intravenous injection through the tail vein three days, seven days, ten days, and 17 days after transplantation. The anti-human GPC3/mouse CD137 bispecific antibody (GPC3 ERY22-3-1D8) was made into 0.75 mg/mL and 0.15 mg/mL preparations using a solvent (an aqueous solution containing 150 mM NaCl and 20 mM His-HCl (pH 6.0) that has been passed

through a 0.22 µm filter), and this was administered at 10 mL/kg (7.5 mg/kg and 1.5 mg/kg, respectively). The anti-mouse CD137 antibody (1D8-MB492) was made into 1.5 mg/mL and 0.3 mg/mL preparations using a solvent, and this was administered at 10 mL/kg (15 mg/kg and 3 mg/kg, respectively). Percentage of tumor growth-inhibition (%) was assessed from the tumor volume calculated using the equation below.

$$\text{Tumor volume (mm}^3\text{)} = \text{major axis (mm)} \times \text{minor axis (mm)} \times \text{minor axis (mm)} / 2$$

$$\text{Percentage of tumor growth inhibition (\%)} = [1 - (T - T_0)/(C - C_0)] \times 100$$

T: Average tumor volume of each group on each assay date

T<sub>0</sub>: Average tumor volume of each group on the first day of administration

C: Average tumor volume of the control group on each assay date

C<sub>0</sub>: Average tumor volume of the control group on the first day of administration

As shown in Fig. 7, all groups subjected to antibody administration showed strong antitumor effects with 95% or higher tumor growth inhibition. More specifically, the anti-human GPC3/mouse CD137 bispecific antibodies were shown to have strong antitumor effects similar to those of the anti-mouse CD137 antibodies, and also exhibit strong antitumor effects when CD137 is activated in a cancer antigen-dependent manner.

#### 4-2. Attenuation of liver damage by anti-human GPC3/mouse CD137 bispecific antibodies in the CT26-GPC3 subcutaneous transplant model

At the end of the drug efficacy tests for antibody administration, the animals were euthanized by exsanguination under anesthesia, and plasma was isolated. The plasma was used to measure aspartate amino transferase (AST; JSCC Transferable method), alanine amino transferase (ALT; JSCC Transferable method), and total bilirubin (TBIL; enzyme method) on an automatic analyzer TBA-120FR (Toshiba Medical Systems Corporation). The liver was collected during autopsy, fixed in a 10% neutrally-buffered formalin solution to prepare a tissue preparation of paraffin-embedded thin-tissue sections (hematoxylin-eosin (HE)) by following general methods, and histopathologically observed under a light microscope. Statistical analysis was carried out by performing a non-parametric Dunnett's multiple comparison test with the control group.

As a result, as shown in Figs. 8 to 11, in the anti-mouse CD137 antibody (1D8-MB492)-administered group, AST, ALT, and TBIL in blood was found to increase or show an increasing trend at all doses; and histopathologically, slight to mild liver damage such as degeneration/necrosis and inflammation of liver cells was found in all examples. On the other

hand, in the anti-human GPC3/mouse CD137 bispecific antibody (GPC3 ERY22-3-1D8)-administered group, changes that are thought to be caused by liver damage could not be found with regard to AST, ALT, and TBIL in blood. Histopathologically, slight degeneration/necrosis or inflammation of liver cells was found in two to three cases out of five in each dosage group, and hepatic disorder was decreased. In one case in the group subjected to administration of the same antibody at 3 mg/kg, remarkable increases of AST and ALT in blood were observed while there was no change in blood TBIL. Since findings suggestive of liver damage were not found from histopathological observation of the liver, the source of the enzymes was judged not to attribute to liver damage.

From the above-mentioned results, the anti-human GPC3/anti-mouse CD137 bispecific antibody GPC3 ERY22-3-1D8 was shown to have a strong antitumor effect without inducing severe liver damage such as those reported so far with general anti-CD137 agonist antibodies. More specifically, bispecific antibodies with reduced Fc $\gamma$ R binding against a cancer antigen and CD137 were believed to exert a cancer antigen-dependent CD137 agonist activity, and by activating T cells only in tumors without activation of T cells in normal tissues, exert a cytotoxic activity selectively against cancer cells while avoiding side effects such as cytotoxicity and cytokine release.

[Example 5] Antitumor effect by concomitant use of an anti-human GPC3/anti-mouse CD137 bispecific antibody and an anti-human GPC3/anti-mouse CD3 bispecific antibody

The mouse lung cancer cell line LLC-GPC3 which expresses human GPC3 (Reference Example 3) was suspended in HBSS at  $5 \times 10^6$  cells/mL, and 200  $\mu$ L of this ( $1 \times 10^6$  cells) was transplanted subcutaneously to the abdomen of C57BL/6N mice (female, 6-weeks old, Charles River Laboratories Japan Inc.). Ten days after transplantation, based on the data on tumor volume and body weight, the animals were divided into five groups of five individuals each unbiased, and then the antibodies were administered by intravenous injection through the tail vein ten days, 14 days, and 17 days after transplantation. An anti-human GPC3/mouse CD137 bispecific antibody (GPC3 ERY22-3-1D8) was made into a 0.5 mg/mL preparation using a solvent (an aqueous solution containing 150 mM NaCl and 20 mM His-HCl (pH 6.0) that has been passed through a 0.22  $\mu$ m filter), and this was administered at 10 mL/kg (5 mg/kg). An anti-human GPC3/mouse CD3 bispecific antibody (GPC3 ERY22-3-2C11) was made into a 0.45 mg/mL preparation using the solvent, and this was administered at 10 mL/kg (4.5 mg/kg). Furthermore, a group administered with two types of antibodies concomitantly was prepared. Percentage of tumor growth-inhibition (%) was assessed from the tumor volume calculated using the equation below.

Tumor volume (mm<sup>3</sup>) = major axis (mm) x minor axis (mm) x minor axis (mm) / 2

Percentage of tumor growth inhibition (%) = [1 - (T - T<sub>0</sub>)/(C - C<sub>0</sub>)] x 100

T: Average tumor volume of each group on each assay date

T<sub>0</sub>: Average tumor volume of each group on the first day of administration

5 C: Average tumor volume of the control group on each assay date

C<sub>0</sub>: Average tumor volume of the control group on the first day of administration

As shown in Fig. 12, the percentage of tumor growth inhibition 23 days after tumor transplantation was 36% for the group administered with an anti-human GPC3/mouse CD137 bispecific antibody alone, and 29% for the group administered with an anti-human GPC3/mouse CD3 bispecific antibody alone, but the group administered with these two antibodies concomitantly showed 100% inhibition, and a synergistic effect of the concomitant use was clearly observed.

At the end of the drug efficacy tests, analysis of the liver function parameters (AST, ALT, and TBIL) in plasma and histopathological analysis of liver tissue sections by HE staining were carried out by methods similar to those of “4-2”. Changes suggesting liver damage were not observed in any of the administration groups.

Accordingly, it was shown that concomitant use of a bispecific antibody against a cancer antigen and CD137 and a bispecific antibody against a cancer antigen and CD3 results in simultaneous association of CD137 and CD3 specifically and locally at the tumor and exerts a strong T cell-activating ability, which could not be achieved by singular stimulation of each of the antibodies as observed in the *in vitro* experiments, and thereby achieves a strong antitumor effect that also could not be exerted by their single agents *in vivo*.

25 [Example 6] Acquisition of human CD137-binding antibodies from a human antibody library using a phage display technique

#### 6-1. Preparation of a naive human antibody phage display library

According to methods known to those skilled in the art, poly A RNA prepared from human PBMC and commercially available human poly A RNA and such were used as a template to construct a human antibody phage display library comprising a plurality of phages displaying the Fab domains of human antibody sequences that are different from each other.

#### 6-2. Acquisition of human CD137-binding antibodies from a naive human antibody library by bead panning

35 Antibodies that show antigen-binding activities were selected by screening from the naive human antibody phage display library constructed in Example 6-1. More specifically,

phages presenting antibodies that show a binding activity towards antigens captured by the beads were collected. Biotinylated human CD137 was used as the antigen. Specifically, panning was performed using the antigen fixed onto magnetic beads. NeutrAvidin-coated beads (Sera-Mag SpeedBeads NeutrAvidin-coated) or Streptavidin-coated beads (Dynabeads M-280 Streptavidin) were used as the magnetic beads.

First, phages produced from *Escherichia coli* carrying the constructed phagemids for phage display were purified by a common method. Then, a phage library suspension that has been dialyzed against TBS was obtained. Next, BSA was added to the phage library suspension to make a final concentration of 4%.

Then, 250 pmol of biotinylated human CD137 was added to the prepared phage library suspension to contact the phage library suspension with human CD137 at room temperature for 60 minutes. Next, BSA-blocked magnetic beads were added to the phage library suspension, and the human CD137-phage complexes were allowed to bind to the magnetic beads at room temperature for 15 minutes. The beads were washed once with TBS. Then, 0.5 ml of 1 mg/mL trypsin solution was added to the beads, the beads were suspended at room temperature for 15 minutes, and the beads were immediately separated using a magnetic stand to collect a phage suspension. The collected phage suspension was added to 10 mL of the *E. coli* strain ER2738 in the logarithmic growth phase ( $OD_{600} = 0.4$  to  $0.7$ ). The *E. coli* was gently stirred and incubated at  $37^{\circ}\text{C}$  for one hour to allow phages to infect the *E. coli*. The infected *E. coli* was seeded on a plate (225 mm x 225 mm). Then, phages were collected from the culture medium of the seeded *E. coli* to prepare a phage library suspension.

In the second round of panning, phages capable of binding to human CD137 were enriched. 100 pmol of the biotinylated human CD137 was added to the obtained phage library suspension and the phage library suspension was contacted with human CD137 at room temperature for 60 minutes. Next, BSA-blocked magnetic beads were added to the phage library suspension, and the human CD137-phage complexes were allowed to bind the magnetic beads at room temperature for 15 minutes. The beads were washed three times with TBST (TBS containing 0.1% Tween20), and twice with TBS. Thereafter, 0.5 mL of 1 mg/mL trypsin solution was added to the beads. The beads were suspended at room temperature for 15 minutes and immediately separated using a magnetic stand to collect a phage suspension. The collected phage suspension was added to 10 mL of the *E. coli* strain ER2738 in the logarithmic growth phase ( $OD_{600} = 0.4$  to  $0.7$ ). The *E. coli* was gently stirred and incubated at  $37^{\circ}\text{C}$  for one hour to allow the phages to infect the *E. coli*. The infected *E. coli* was seeded on a plate (225 mm x 225 mm). Then, phages were collected from the culture medium of the seeded *E. coli* to prepare a phage library suspension.

Panning for obtaining antibodies capable of binding to human CD137 was repeated

three times with the same procedure. A fourth panning was performed using 40 pmol of biotinylated human CD137.

### 6-3. Construction of a synthetic human antibody phage display library

A synthetic human antibody phage display library was constructed by a method known to those skilled in the art using ten types of heavy-chain germline sequences and seven types of light chain germline sequences. The frequency of appearance in the human B cell repertoire and physicochemical properties in the variable region family were used as indicators to select VH1-2, VH1-69, VH3-23, VH3-66, VH3-72, VH4-59, VH4-61, VH4-b, VH5-51, VH6-1, V $\kappa$ 1-39, V $\kappa$ 2-28, V $\kappa$ 3-20, V $\lambda$ 1-40, V $\lambda$ 1-44, V $\lambda$ 2-14, and V $\lambda$ 3-21 for use as the germline sequences. The antigen-recognition sites of the synthetic antibody library were diversified by mimicking the human B-cell antibody repertoires.

### 6-4. Acquisition of human CD137-binding antibodies from a synthetic human antibody library by bead panning

Antibodies showing an antigen-binding activity were selected by screening from the synthetic human antibody phage display library constructed in Example 6-3. More specifically, phages presenting antibodies that show binding activity towards antigens captured by the beads were collected. Biotinylated human CD137 was used as the antigen.

Phages produced from *E. coli* carrying the constructed phagemids for phage display were purified by a common method. A phage population was precipitated from the *E. coli* culture medium used for the phage production by adding 2.5 M NaCl/10% PEG. Then, the precipitate was diluted with TBS to prepare a phage library suspension. Next, BSA was added to the phage library suspension to make a final concentration of 4%. Panning was carried out using antigen-immobilized magnetic beads. The magnetic beads used were NeutrAvidin-coated beads (Sera-Mag SpeedBeads NeutrAvidin-coated) or Streptavidin-coated beads (Dynabeads M-280 Streptavidin).

Then, 250 pmol of biotinylated human CD137 was added to the prepared phage library suspension to place the phage library suspension in contact with human CD137 at room temperature for 60 minutes. Next, BSA-blocked magnetic beads were added to the phage library suspension, and the human CD137-phage complexes were allowed to bind to the magnetic beads at room temperature for 15 minutes. The beads were washed once with TBS. Then, 0.5 mL of 1 mg/mL trypsin solution was added to the beads, and the beads were suspended at room temperature for 15 minutes and immediately separated using a magnetic stand to collect a phage suspension. The collected phage suspension was added to 10 mL of the *E. coli* strain ER2738 in the logarithmic growth phase (OD<sub>600</sub> = 0.4 to 0.7). The *E. coli* was stirred and

incubated at 37°C for one hour to allow the phages to infect the *E. coli*. The infected *E. coli* was seeded on a plate (225 mm x 225 mm). Then, phages were collected from the culture medium of the seeded *E. coli* to prepare a phage library suspension.

In the second round of panning, phages capable of binding to human CD137 were enriched. 100 pmol of biotinylated human CD137 was added to the obtained phage library suspension, and the phage library suspension was contacted with human CD137 at room temperature for 60 minutes. Next, BSA-blocked magnetic beads were added to the phage library suspension, and the human CD137–phage complexes were allowed to bind to the magnetic beads for 15 minutes at room temperature. The beads were washed three times with TBST, and twice with TBS. Then, 0.5 mL of 1 mg/mL trypsin solution was added to the beads, and the beads were suspended at room temperature for 15 minutes and immediately separated using a magnetic stand to collect a phage suspension. The collected phage suspension was added to 10 mL of the *E. coli* strain ER2738 in the logarithmic growth phase (OD600 = 0.4 to 0.7). The *E. coli* was gently stirred and incubated at 37°C for one hour to allow the phages to infect the *E. coli*. The infected *E. coli* was seeded on a plate (225 mm x 225 mm). Then, phages were collected from the culture medium of the seeded *E. coli* to prepare a phage library suspension.

Panning for obtaining antibodies capable of binding to human CD137 was repeated three times with the same procedure. A fourth panning was performed using 40 pmol of biotinylated human CD137.

#### 6-5. Assessment of the human CD137-binding property by phage ELISA

From single colonies of *E. coli* obtained by the panning method described in the Examples above, phage-containing culture supernatants were collected by following a conventional method (Methods Mol. Biol. 2002, 178: 133-145).

TBS-supplemented phages were subjected to ELISA by the procedure below. StreptaWell 96 microtiter plates (Roche) were coated using 100 µL of TBS containing the biotin-labeled antigen (biotinylated human CD137) at room temperature for one hour. After each well of the plate was washed with TBST (TBS containing 0.1% Tween20) to remove the antigen that did not bind to the plate, the wells were blocked with 250 µL of 2% SkimMilk-TBS for one hour or more. 2% SkimMilk-TBS was removed, and then the prepared phages were added to each well. The plates were allowed to stand at room temperature for one hour to achieve the binding of antibody-displaying phages to the antigen in each of the wells. After each well was washed with TBST, an HRP-conjugated anti-M13 antibody (Amersham Pharmacia Biotech) diluted with TBS was added to the wells and the plates were incubated for one hour. After TBST washes, the TMB single solution (ZYMED) was added to each well.

The chromogenic reaction in the solution of each well was stopped by adding sulfuric acid. Then, the developed color was assessed by measuring the absorbance at 450 nm.

From among the 192 clones subjected to phage ELISA, a plurality of antibodies that have human CD137-binding activity were identified. The results of phage ELISA are shown in Table 5.

Table 5

| Library                                                                                 | Naive library | Synthetic library |
|-----------------------------------------------------------------------------------------|---------------|-------------------|
| Number of panning rounds                                                                | 4             | 4                 |
| Number of clones subjected to ELISA                                                     | 96            | 96                |
| Number of positive clones (absorbance > 0.2, absorbance ratio with/without antigen > 2) | 59            | 78                |
| Number of positive clone sequences                                                      | 12            | 17                |

#### 6-6. Sequence analysis of antibodies that bind to biotinylated human CD137

From clones assessed to have a specific binding activity towards human CD137 as a result of the phage ELISA described in Example 6-5, the nucleotide sequences of genes amplified using specific primer pairs (SEQ ID NOs: 55 and 56 for the naive human antibody libraries, and SEQ ID NOs: 57 and 56 for the synthetic human antibody libraries) were analyzed. The result of the analysis confirmed the presence of multiple types of antibody sequences having human CD137-binding activity.

#### 6-7. Preparation of human CD137-binding antibodies

From the clones obtained in Example 6-6, which have been assessed to have binding activity towards biotin-labeled human CD137, the heavy-chain and light-chain variable region sequences of five clones derived from the naive human antibody library (R1 to R5) and 14 clones derived from the synthetic human antibody library (R6 to R19) were linked with the heavy-chain antibody constant region (SEQ ID NO: 58 which is a sequence produced by modifying the human IgG1 constant region), or the light chain kappa constant region sequence (SEQ ID NO: 59) or lambda constant region sequence (SEQ ID NO: 60), and then each were inserted into plasmids for animal expression. The heavy-chain and light-chain variable region sequences of each of the clones are shown in Table 6.

Table 6

| Clone name | SEQ ID NO of the heavy-chain variable region | SEQ ID NO of the light-chain variable region |
|------------|----------------------------------------------|----------------------------------------------|
| R1         | 61                                           | 80                                           |
| R2         | 62                                           | 81                                           |
| R3         | 63                                           | 82                                           |
| R4         | 64                                           | 83                                           |
| R5         | 65                                           | 84                                           |
| R6         | 66                                           | 85                                           |
| R7         | 67                                           | 86                                           |
| R8         | 68                                           | 87                                           |
| R9         | 69                                           | 88                                           |
| R10        | 70                                           | 89                                           |
| R11        | 71                                           | 90                                           |
| R12        | 72                                           | 91                                           |
| R13        | 73                                           | 92                                           |
| R14        | 74                                           | 93                                           |
| R15        | 75                                           | 94                                           |
| R16        | 76                                           | 95                                           |
| R17        | 77                                           | 96                                           |
| R18        | 78                                           | 97                                           |
| R19        | 79                                           | 98                                           |

5

Each of the antibodies was expressed and purified by the method described in Reference Example 1. Furthermore, with the objective of enhancing the *in vitro* T cell-activating effect of anti-human CD137 antibodies, genes in which a VH region shown in Table 6 is linked with the constant region (SEQ ID NO: 99) that has enhanced binding to human FcγRIIB were produced, the genes were inserted into a plasmid vector for expression in animal cells, and antibodies were expressed and purified by a similar method so as to make their combination of variable regions as the combinations shown in Table 6.

10

[Example 7] Epitope analysis of anti-human CD137 antibodies

#### 15 7-1. Preparation of fragmented human CD137-Fc fusion proteins and antibody preparation

For analyzing the epitope of the obtained anti-human CD137 antibodies, fusion proteins

comprising a fragmented human CD137 and an antibody Fc region were prepared, where the fragmented human CD137 were divided into domains based on a structure common to the TNFRSF and structures formed by Cys-Cys called CRD by referring to J Exp Med. 2014 Jun 30;211(7):1433-48 (Table 7). The fragmented human CD137-Fc fusion protein was inserted into a plasmid vector for expression in animal cells by a method known to those skilled in the art by obtaining each gene fragment by PCR from the polynucleotide encoding the full-length human CD137-Fc fusion protein (SEQ ID NO: 100) so as to contain an amino acid sequence shown in Table 7. The fragmented human CD137-Fc fusion protein was purified in the same manner as antibodies, by the method described in Reference Example 1. Furthermore, as a control for ELISA, antibodies were obtained by the method described in Reference Example 1 by incorporating into a plasmid vector for expression in animal cells, genes encoding an antibody (SEQ ID NO: 101 for the H chain, and SEQ ID NO: 102 for the L chain) produced by changing the H chain constant region of the anti-human CD137 antibody described in WO2005/035584A1 (abbreviated as B) into a constant region removed of C-terminal Gly and Lys in the human IgG1 H-chain constant region, and encoding an antibody (SEQ ID NO: 103 for the H chain, and SEQ ID NO: 104 for the L chain) produced by changing the constant region of the anti-human CD137 antibody described in WO2012/145183A3 (abbreviated as M) into a constant region with enhanced binding to human Fc $\gamma$ RIIB.

Table 7

| Name of the fragmented human CD137 | Amino acid sequence of the fragmented human CD137                                                                                                                   | Domains that are included | SEQ ID NO |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-----------|
| Full length                        | LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSST SNAECDCTPGFHCLGAGCSMCEQDCKQGQELTKKGCKDCCFGTFNDQKRGICRPWTNCSLDGKSVLVNGTKERDVVCGPSPADLSPGASSVTPPAPAREPGHSPQ | CRD1, 2, 3, 4             | 105       |
| CRD1                               | LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTC                                                                                                                             | CRD1                      | 106       |
| CRD2                               | SPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSSTSNAEC                                                                                                                            | CRD2                      | 107       |
| CRD3                               | DCTPGFHCLGAGCSMCEQDCKQGQELTKKGC                                                                                                                                     | CRD3                      | 108       |
| CRD4                               | KDCCFGTFNDQKRGICRPWTNCSLDGKSVLVNGTKERDVVCGPSPADLSPGASSVTPPAPAREPGHSPQ                                                                                               | CRD4                      | 109       |
| CRD1-3                             | LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSST SNAECDCTPGFHCLGAGCSMCEQDCKQGQELTKKGC                                                                      | CRD1, 2, 3                | 110       |
| CRD1-2                             | LQDPCSNCPAGTFCDNNRNQICSPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSST SNAEC                                                                                                     | CRD1, 2                   | 111       |
| CRD2-4                             | SPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSSTSNAECDCTPGFHCLGAGCSMCEQDCKQGQELTKKGCKDCCFGTFNDQKRGICRPWTNCSLDGKSVLVNGTKERDVVCGPSPADLSPGASSVTPPAPAREPGHSPQ                        | CRD2, 3, 4                | 112       |
| CRD2-3                             | SPCPPNSFSSAGGQRTCDICRQCKGVFTRKECSSTSNAECDCTPGFHCLGAGCSMCEQDCKQGQELTKKGC                                                                                             | CRD2, 3                   | 113       |
| CRD3-4                             | DCTPGFHCLGAGCSMCEQDCKQGQELTKKGCKDCCFGTFNDQKRGICRPWTNCSLDGKSVLVNGTKERDVVCGPSPADLSPGASSVTPPAPAREPGHSPQ                                                                | CRD3, 4                   | 114       |

#### 7-2-1. Epitope analysis using the fragmented human CD137-Fc fusion proteins

5           The fragmented human CD137-Fc fusion proteins prepared in Example 7-1 were used to evaluate binding by ELISA to determine which of the sites on human CD137 are bound by the antibodies (which use SEQ ID NO: 99 as the heavy chain constant region) obtained in Example 6 described above. For example, in the case of an antibody that binds to domain 1, such an antibody is predicted to bind to domain1-containing fragmented human CD137-Fc fusion proteins, but not to fragmented human CD137-Fc fusion proteins that do not contain domain 1.

#### 7-2-2. ELISA method

15           Fragmented human CD137-Fc fusion proteins were diluted to 2 µg/mL in an aqueous sodium carbonate solution adjusted to pH9.6. Fifty µL of a diluted fragmented human CD137-Fc fusion protein was added individually to each well of a Nunc MaxiSorp flat-bottom 96 well plate (Nunc). This was allowed to stand at 4°C overnight or longer, and then the plate

was allowed to stand at room temperature for one hour so that the plate has the same temperature as the room temperature. The solution containing the fragmented human CD137-Fc fusion protein was removed by tilting, and each well was washed three times with 300  $\mu$ L of Wash buffer (TBS containing 0.1% Tween20, TaKaRa). Next, 150  $\mu$ L of blocking buffer (TBS containing 2% BSA) was added to each well, and this was allowed to stand for one hour or more. The blocking buffer was removed by tilting, and each well was washed three times with Wash Buffer in a similar manner to an earlier step. Then, 50  $\mu$ L of an antibody solution prepared in advance by dilution with TBS to 10  $\mu$ g/mL or 5  $\mu$ g/mL was added to each well. This was subjected to a speed of 600 rpm or so for one hour at room temperature to bind the antibody to the immobilized antigen. After removing the antibody solution by tilting, each well was washed three times with Wash Buffer in a similar manner to an earlier step. 100  $\mu$ L of a secondary antibody solution produced by 1000-fold dilution with TBS containing 0.1% Tween20 was added to each well. For the secondary antibody, ANTIBODY ALKALINE PHOSPHATASE CONJUGATE HUMAN IMMUNOGLOBULIN ABSORBED Goat Anti-Human Kappa Alkaline Phosphate from BIOSOURCE was used in the case of antibodies carrying a Kappa chain, and Human Lambda Light Chain Antibody; Goat anti-Human Lambda Light Chain Antibody Alkaline Phosphatase Conjugated from BETHYL LABORATORIES INC. was used in the case of antibodies carrying a Lambda chain. After one hour of reaction by incubation at room temperature, the antibody solution was removed by tilting, and each well was washed three times with Wash Buffer in a similar manner to an earlier step. Color development was performed using the BluePhos Microwell kit from KPL. After the chromogenic reaction was stopped using the AP stop solution from KPL, the absorbance was measured at 620 nm on an absorptiometer. The results are shown in Fig. 14. As shown in Fig. 14, each antibody showed a different value of color development towards its respective fragmented human CD137-Fc fusion protein, and binds to a different portion of human CD137-Fc. Furthermore, the obtained antibodies were shown to be different from the existing antibodies B and M.

[Example 8] Assessment of anti-human CD137 antibodies for their *in vitro* T cell-activating effect

T cells were expansively cultured from commercially available PBMC (AllCells) using Dynabeads Human T-Activator CD3/CD28 (Gibco, 11132D). Human T cells were suspended at a density of  $4 \times 10^5$  cells/ml in RPMI1640 medium containing 10% FBS, 60 U/ml human IL2, 0.5  $\mu$ g/ml ionomycin, 10 ng/ml PMA, and a specific concentration of penicillin and streptomycin. Furthermore, the human B cell lymphoma cell line Raji was suspended in the same medium at a density of  $4 \times 10^5$  cells/ml. These cell suspensions were mixed in equal quantities, and they were seeded onto a 96-well plate at 100  $\mu$ l/well. The human CD137-binding antibodies

obtained in Example 6 (R1 to R19; antibodies used were the same as in ELISA described in Example 7) were added at a concentration of 5 µg/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for three days. The culture supernatant was collected, and the concentration of human IFN-γ in the supernatant was measured by ELISA to assess the activation of human T cells. ELISA was performed by following the instructions provided by the ELISA kit manufacturer (PeproTech).

As a result (Fig. 15), compared to the control human IgG (Allexis, 804-133-C100: hIgG in Fig. 15), clones other than R7 and R15 all showed an IFN-γ-inducing activity. These antibodies having an IFN-γ-inducing activity were assessed to be agonist antibodies against CD137.

The characteristics of the obtained antibodies are summarized in Fig. 16. Many antibodies that recognize epitopes different from those of the anti-human CD137 antibodies B and M shown in the above-described Examples were obtained. These anti-human CD137 antibodies were modified into bispecific antibodies with a GPC3 antibody (anti-human GPC3 antibody), and assessed for their cancer antigen (GPC3)-dependent CD137 agonist ability. This can provide anti-human GPC3/anti-human CD137 bispecific antibodies that exert the desired antitumor effects.

[Example 9] Preparation of an anti-human GPC3/anti-mouse CD40 bispecific antibody (GPC3 FAE-FGK45)

The anti-human GPC3/anti-mouse CD40 bispecific antibody GPC3 FAE-FGK45 carrying the human IgG1 constant regions was produced by the procedure below. For the anti-mouse CD40 side, FGK45VH6 (SEQ ID NO: 120) was used for the heavy-chain variable region, and FGK45VL4 (SEQ ID NO: 121) was used for the light-chain variable region. In this case, F760nG3P17 (SEQ ID NO: 119) and k0 (SEQ ID NO: 118) were used for the heavy-chain and light-chain constant regions, respectively. The anti-human GPC3 side of the antibodies shared the heavy-chain variable region H0000 (SEQ ID NO: 115) and light-chain variable region GL4 (SEQ ID NO: 116) in common. In this case, the heavy chain constant region F760nN17 (SEQ ID NO: 117) which has been modified so that there is heterologous association between the two heavy chains and Fcγ receptor-binding is reduced, and the light chain constant region k0 (SEQ ID NO: 118) were used for the constant regions. These antibodies were expressed using the following method. Cells of the human embryonic kidney cell-derived FreeStyle 293-F strain (Invitrogen) were suspended in the FreeStyle 293 Expression Medium (Invitrogen), and seeded at a cell density of  $1.33 \times 10^6$  cells/mL. The prepared plasmids were introduced into the cells by a lipofection method. The cells were cultured for four days in a CO<sub>2</sub> incubator (37°C, 8% CO<sub>2</sub>, 90 rpm) and from the culture supernatants, antibodies were purified using the rProtein

A Sepharose™ Fast Flow (Amersham Biosciences) or Protein G Sepharose 4 Fast Flow (GE HEALTHCARE) by a method known to those skilled in the art. Absorbance at 280 nm of the purified antibody solutions was measured using a spectrophotometer. Concentrations of the purified antibodies were calculated from the determined values using an extinction coefficient calculated by the PACE method (Protein Science (1995) 4: 2411-2423). Each of the purified homologous forms were mixed using the combinations shown in Table 8 to prepare the bispecific antibodies of interest using techniques known to those skilled in the art (WO2015/046467).

Table 8

| No | Clone name     | Antibody 1             | Antibody 2                       |
|----|----------------|------------------------|----------------------------------|
| 1  | GPC3 FAE-FGK45 | H0000/<br>GL4-F760nN17 | FGK45VH6/<br>FGK45VL4-F760nG3P17 |

[Example 10] Assessment of the *in vitro* splenocyte activation-enhancing effect by a mixture of an anti-human GPC3/anti-mouse CD40 bispecific antibody and an anti-human GPC3/anti-mouse CD3 bispecific antibody

Spleen was removed from naive female Balb/c mice, and its cells were suspended at a density of  $4 \times 10^6$  cells/ml in a medium prepared by adding mouse IL2 at 10 ng/ml to a RPMI1640 medium containing 10% FBS, 0.5 µg/ml ionomycin, and 10 ng/ml PMA. The mouse colorectal cancer cell line CT26-GPC3 that expresses human GPC3 (Reference Example 3) was also suspended in the same medium at a density of  $4 \times 10^5$  cells/ml. These two cell suspensions were mixed in equal quantities, and this was seeded into a 96-well plate at 100 µl/well. An anti-human GPC3/anti-mouse CD40 bispecific antibody with extremely reduced FcγR binding (GPC3 ERY22-FGK45) was added at a concentration of 3 µg/ml, and an anti-human GPC3/anti-mouse CD3 bispecific antibody with extremely reduced FcγR binding (GPC3 ERY22-2C11) was added at 1 µg/ml, and the cells were cultured under conditions of 37°C and 5% CO<sub>2</sub> for 72 hours. The culture supernatant was collected, and the mouse IFN-γ concentration in the supernatant was measured by ELISA to assess the activation of T cells contained in the splenocytes. ELISA was performed by following the instructions provided by the ELISA kit manufacturer (PeproTech).

As a result (Fig. 17), while GPC3 ERY22-2C11 shows IFN-γ-inducing activity as a single agent, GPC3 ERY22-FGK45 as a single agent hardly showed any activity. However, a mixture of GPC3 ERY22-FGK45 and GPC3 ERY22-2C11 showed high accumulation of IFN-γ. This suggests that applying CD3 stimulation and CD40 stimulation simultaneously to various immune cell mixtures results in strong activation of T cells.

[Example 11] Preparation of anti-human GPC3/anti-human CD137 bispecific antibodies and assessment of their agonist activities

#### 11-1. Preparation of anti-human GPC3/anti-human CD137 bispecific antibodies

5           The anti-human GPC3/anti-human CD137 bispecific antibodies carrying human IgG1 constant regions were produced by the following procedure. The sequences (R3 and R5) confirmed to bind to human CD137 in Example 7, were modified using primers designed to cause random changes in the amino acids of the heavy-chain CDR3. The variable region sequences are shown in Table 9. In this case, when modified from R3 and R5, a sequence  
10           produced by adding Gly-Lys (also written as “GK”) to the C terminus of the F760nG3P17 sequence constructed in Example 9 and the lambda constant region sequence (SEQ ID NO: 60) were used for the heavy-chain constant region and light-chain constant region, respectively. The anti-human GPC3 side of the antibodies shared the heavy-chain variable region H0000 (SEQ ID NO: 115) and light-chain variable region GL4 (SEQ ID NO: 116) in common. In this  
15           case, the heavy chain constant region F760nN17 (SEQ ID NO: 117) which has been modified so that there is heterologous association between the two heavy chains and which has reduced Fcγ receptor binding, and the light chain constant region k0 (SEQ ID NO: 118) were used for the constant regions. These antibodies were expressed using the method below. Cells of the human embryonic kidney cell-derived FreeStyle 293-F strain (Invitrogen) were suspended in the  
20           FreeStyle 293 Expression Medium (Invitrogen), and plated at a cell density of  $1.33 \times 10^6$  cells/mL. The prepared plasmids were introduced into the cells by a lipofection method. The cells were cultured for four days in a CO<sub>2</sub> incubator (37°C, 8% CO<sub>2</sub>, 90 rpm), and from the culture supernatants, antibodies were purified using the rProtein A Sepharose™ Fast Flow (Amersham Biosciences) or Protein G Sepharose 4 Fast Flow (GE HEALTHCARE) by a method  
25           known to those skilled in the art. Absorbance at 280 nm of the purified antibody solutions was measured using a spectrophotometer. Concentrations of the purified antibodies were calculated from the determined values using an extinction coefficient calculated by the PACE method (Protein Science (1995) 4: 2411-2423). For the anti-human CD137 antibodies (derived from R3 and R5), calculations were carried out using E1% = 14. As shown in Table 9, the  
30           anti-human GPC antibody and homologous forms of each of the human CD137 antibodies purified in the same manner as in Example 9 were mixed to prepare the bispecific antibodies of interest using techniques known to those skilled in the art (WO2015/046467).

Table 9

| Sample name  | Human CD137 antibody        |                                              |                             |                                              | Human GPC3 antibody                                  |
|--------------|-----------------------------|----------------------------------------------|-----------------------------|----------------------------------------------|------------------------------------------------------|
|              | Heavy-chain variable region | SEQ ID NO of the heavy-chain variable region | Light-chain variable region | SEQ ID NO of the light-chain variable region | Heavy chain and light chain (described in Example 9) |
| GPC3 FAE-BMS | BH                          | 1 2 2                                        | BL                          | 1 2 3                                        | H0000/<br>GL4-F760nN17                               |
| BiAb-1       | 1150313C04                  | 1 2 4                                        | BBNM003L01                  | 8 2                                          | H0000/<br>GL4-F760nN17                               |
| BiAb-2       | 2150313B04                  | 1 2 5                                        | BBNM005L01                  | 8 4                                          | H0000/<br>GL4-F760nN17                               |

### 11-2. Assessment of the *in vitro* GPC3-dependent CD137 agonist effect of an anti-human

#### 5 GPC3/anti-human CD137 bispecific antibody

T cells were expansively cultured from commercially available PBMC (AllCells) using Dynabeads Human T-Activator CD3/CD28 (Gibco, 11132D). Human T cells were suspended at a density of  $4 \times 10^5$  cells/ml in RPMI1640 medium containing 10% FBS, 60 U/ml human IL2, 0.5  $\mu$ g/ml ionomycin, 10 ng/ml PMA, and a specified concentration of penicillin-streptomycin. Furthermore, the mouse colorectal cancer cell line CT26-GPC3 which expresses human GPC3 (Reference Example 3) was suspended in the same medium at a density of  $4 \times 10^5$  cells/ml. These two cell suspensions were mixed in equal quantities, and this was seeded into a 96-well plate at 100  $\mu$ l/well. Control human IgG (Allexis, 804-133-C100: Ctrl hIgG1 in Fig. 18) or GPC3 FAE-BMS prepared in preceding Example 11-1 (anti-human GPC3/anti-human CD137 bispecific antibody with extremely reduced Fc $\gamma$ R binding) was added to this at a concentration of 10  $\mu$ g/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for three days. The culture supernatant was collected, and the human IFN- $\gamma$  concentration in the supernatant was measured by ELISA to assess the activation of T cells. ELISA was performed by following the instructions provided by the ELISA kit manufacturer (PeproTech).

As a result (Fig. 18), the anti-human GPC3/anti-human CD137 bispecific antibody showed an IFN- $\gamma$ -inducing activity. This suggests that in human T cells as well, CD137 stimulation results in strong activation of the T cells, similarly to when mouse T cells were used in Example 2.

### 25 11-3. Assessment of the *in vitro* GPC3-dependent CD137 agonist effect of an anti-human GPC3/anti-human CD137 bispecific antibody

Human CD137 is also expressed in B cell line HDML-2, and the CD137 agonist activity

can also be measured using HDML-2. Cells of the human B cell cancer cell line HDLM-2 were suspended at a density of  $8 \times 10^5$  cells/ml in RPMI1640 medium containing 20% FBS, and a specified concentration of penicillin-streptomycin. Furthermore, the mouse colorectal cancer cell line CT26-GPC3 which expresses human GPC3 (Reference Example 3) was suspended in the same medium at a density of  $4 \times 10^5$  cells/ml. These cell suspensions were mixed in equal quantities, and this was seeded into a 96-well plate at 100  $\mu$ l/well. Control human IgG (Allexis, 804-133-C100: Ctrl hIgG1 in Fig. 19) or anti-human GPC3/anti-human CD137 bispecific antibody with extremely reduced Fc $\gamma$ R binding, which was prepared in preceding Example 11-1, was added to this at a concentration of 10  $\mu$ g/ml, and the cells were cultured under the conditions of 37°C and 5% CO<sub>2</sub> for three days. The culture supernatant was collected, and the human IL-6 concentration in the supernatant was measured by ELISA to assess the activation of B cells. ELISA was performed by following the instructions provided by the ELISA kit manufacturer (PeproTech).

As a result (Fig. 19), the anti-human GPC3/anti-human CD137 bispecific antibody showed IL-6-inducing activity. This showed that with human B cell lines as well, CD137 stimulation can be assessed in a similar manner to when mouse T cells were used in Example 2 and when human T cells were used in Example 11-2.

Examples 11-2 and 11-3 showed that similar to the results shown in Examples 2 to 5 performed with mouse CD137, the bispecific antibodies have an agonist activity towards human CD137, and that human CD137 can be expected to have effects similar to those with mouse CD137.

### Industrial Applicability

The present invention provides novel antigen-binding molecules or pharmaceutical compositions that are highly safe, have excellent antitumor activity, and do not have toxicity resulting from normal tissue injury or a cytokine storm in a cancer antigen-independent manner. Pharmaceutical compositions comprising an antigen-binding molecule of the present invention as the active ingredient active immune cells in a cancer antigen-dependent manner, and bring about cytotoxic actions that target various cells including cancer cells. This enables treatment or prevention of various cancers. The present invention can provide not only highly safe treatments, but also reduced physical burden and great convenience, which are desirable for patients.

## CLAIMS

1. A bispecific antigen-binding molecule comprising:
  - (1) a cancer-specific antigen-binding Fab domain;
  - (2) CD137-binding Fab domain; and
  - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity, wherein the antigen-binding molecule has an agonistic activity against CD137.
2. The antigen-binding molecule of claim 1, which is an antibody.
3. A pharmaceutical composition comprising as an active ingredient the antigen-binding molecule of claim 1 or 2.
4. The pharmaceutical composition of claim 3, which is a cytotoxicity-inducing composition.
5. A pharmaceutical composition comprising a combination of a first antigen-binding molecule of claim 1 or 2, and a second bispecific antigen-binding molecule that comprises:
  - (1) a cancer-specific antigen-binding domain; and
  - (2) CD3-binding domain.
6. The antigen-binding molecule of claim 1 or claim 2 or the composition of any one of claims 3 to 5 for use in the treatment of cancer.
7. Use of a bispecific agonistic antigen-binding molecule comprising:
  - (1) a cancer-specific antigen-binding Fab domain;
  - (2) a CD137-binding Fab domain; and
  - (3) FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity, wherein the antigen-binding molecule has agonistic activity against CD137, in the manufacture of a medicament for the treatment of cancer.
8. Use of a composition comprising a combination of:
  - a first bispecific agonistic antigen-binding molecule comprising:
    - (1) a cancer-specific antigen-binding Fab domain;
    - (2) a CD137-binding Fab domain; and
    - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity, and
  - a second antigen-binding molecule comprising:

- (1) a cancer-specific antigen-binding domain;
  - (2) a CD3 receptor complex-binding domain and
  - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity,
 wherein the first antigen-binding molecule has agonistic activity against CD137, in the manufacture of a medicament for the treatment of cancer.
  
- 9. The composition of claim 5 or the use of claim 8, wherein the T cell receptor complex-binding domain is a CD3-binding domain.
  
- 10. The composition of claim 5 or the use of claim 8, wherein the second antigen-binding molecule is an antibody.
  
- 11. The composition of any one of claims 3 to 5 or the use of any one of claims 7 to 10, wherein the composition or medicament is cytotoxicity-inducing composition.
  
- 12. A kit comprising:
  - a) a pharmaceutical composition comprising as an active ingredient a first bispecific agonistic antigen-binding molecule that comprises:
    - (1) a cancer-specific antigen-binding Fab domain;
    - (2) a CD137-binding Fab domain; and
    - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity; and
  - b) a second bispecific antigen-binding molecule that comprises:
    - (1) a cancer-specific antigen-binding domain;
    - (2) a CD3 receptor complex-binding domain; and
    - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity;
 wherein the first antigen-binding molecule has agonistic activity against CD137, and wherein the composition is for use concomitantly with the second antigen-binding molecule in the treatment of cancer.
  
- 13. Use of a first bispecific agonistic antigen-binding molecule comprising:
  - (1) a cancer-specific antigen-binding Fab domain;
  - (2) a CD137-binding Fab domain; and
  - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity,
 wherein the first antigen-binding molecule has agonistic activity against CD137, in the manufacture of a medicament for the treatment of cancer, wherein the medicament is to be used concomitantly with a second antigen-binding molecule that comprises:
  - (1) a cancer-specific antigen-binding domain;

- (2) a CD3 receptor complex-binding domain; and
  - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity.
14. The kit of claim 12 or the use of claim 13, wherein the composition or medicament is cytotoxicity-inducing.
15. The kit of claim 12 or the use of any one of claims 13 to 14, wherein the T cell receptor complex-binding domain is a T cell receptor-binding domain.
16. The kit of claim 12 or the use of any one of claims 13 to 14, wherein the T cell receptor complex-binding domain is a CD3-binding domain.
17. The kit of claim 12 or the use of any one of claims 13 to 16, wherein the first antigen-binding molecule and/or the second antigen-binding molecule is an antibody.
18. The kit of claim 12 or the use of any one of claims 13 to 17, wherein the composition or medicament is to be administered either simultaneously with or separately from the second antigen-binding molecule.
19. Use of a second bispecific antigen-binding molecule comprising:
- (1) a cancer-specific antigen-binding domain;
  - (2) a CD3 receptor complex-binding domain; and
  - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity, in the manufacture of a medicament for the treatment of cancer, wherein the medicament is to be used concomitantly with a first agonistic antigen-binding molecule that comprises:
    - (1) a cancer-specific antigen-binding Fab domain;
    - (2) a CD137-binding Fab domain; and
    - (3) an FcRn-binding domain, wherein the FcRn-binding domain is an antibody Fc region having decreased Fc $\gamma$  receptor-binding activity
 wherein the second antigen-binding molecule has agonistic activity against CD137.
20. The use of claim 19, wherein the composition or medicament is cytotoxicity-inducing composition.
21. The use of any one of claims 19 to 21, wherein the T cell receptor complex-binding domain is a T cell receptor-binding domain.
22. The use of any one of claims 19 to 21, wherein the T cell receptor complex-binding domain is a CD3-binding domain.

23. The use of any one of claims 19 to 23, wherein the first agonistic antigen-binding molecule and/or the second antigen-binding molecule is an antibody.
24. The use of any one of claims 19 to 24, wherein the composition or medicament is to be administered either simultaneously with or separately from the first agonistic antigen-binding molecule.