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(54) **ANTI-EPHA2 ANTIBODY AND IMMUNOLOGICAL DETECTION OF EPHA2 USING SAME**

(57) A monoclonal antibody specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 20 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 22, or a functional fragment of the monoclonal antibody specifically binding to EPHA2, and a monoclonal antibody

specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 15 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 18, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.

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Description

Technical Field

5 **[0001]** The present invention relates to a novel antibody, a functional fragment of the antibody, a modified form of the antibody, a nucleotide comprising a nucleotide sequence encoding the amino acid sequence of the antibody, a vector into which the nucleotide is inserted, a cell into which the nucleotide or the vector is introduced, a method for producing the antibody, comprising a step of culturing the cell, a pharmaceutical composition, a composition for diagnosis or examination, and the like.

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Background Art

15 **[0002]** EPHA2 is a receptor-type tyrosine kinase with a molecular weight of 130 kDa having a single-pass transmembrane structure (Non Patent Literature 1). A ligand binding domain and two fibronectin type 3 domains are present in the extracellular region on the N-terminal side of EPHA2, whereas a tyrosine kinase domain and a sterile- α -motif (SAM) domain are present in the intracellular region on the C-terminal side thereof.

20 **[0003]** As a ligand of EPHA2, Ephrin-A1 to A5 of GPI-anchored protein have been known (Non Patent Literature 2). As a result of activation of the tyrosine kinase domain of EPHA2 caused by ligand binding, tyrosine residues existing in the intracellular region of EPHA2 are auto-phosphorylated, and intracellular signal transduction is thereby induced. In addition, it has been reported that, after EPHA2 has bound to a ligand, it is incorporated into cells according to endocytosis, and is finally decomposed in the proteasome (Non Patent Literature 3).

25 **[0004]** It has been reported that EPHA2 is clinically expressed at a high level in many cancer species, and in particular, in breast cancer, esophageal cancer, prostate cancer, gastric cancer, non-small-cell lung cancer, colon cancer, and glioblastoma multiforme (Non Patent Literatures 4, 5, 6, 7, 8, 9, 10, and 11). Moreover, in esophageal cancer, a significant correlation has been observed between the expression of EPHA2, and regional lymph node metastasis, the number of lymph node metastasis and a low degree of differentiation of cancer, and it has been reported that the survival rate of EPHA2-positive patients is lower than that of EPHA2-negative patients (Non Patent Literature 5). It has been reported that, in non-small-cell lung cancer, the expression level of EPHA2 is higher in patients having a disease-free survival period of less than 5 years than in patients having a disease-free survival period of longer than 5 years, that the expression level of EPHA2 is higher in relapsed patients than in non-relapsed patients, and that the expression level of EPHA2 is higher in patients with brain metastasis than in non-relapsed patients or patients in whom metastasis is limited to the other lung (Non Patent Literature 9). It has been reported that, even in colon cancer, the expression level of EPHA2 is significantly correlated with liver metastasis, lymphatic invasion, and clinical stage (Non Patent Literature 10).

35 **[0005]** Also, it has been reported that non-cancer cells acquire cancer traits, such as anchorage independent proliferative ability, ability to form a tubular form on the extracellular matrix, and *in vivo* tumor proliferative ability, by introducing an EPHA2 gene into the cells (Non Patent Literature 4), and that the invasiveness of cancer cells into the extracellular matrix is accelerated (Non Patent Literatures 12 and 13). It has also reported that, to the contrary, if the expression of EPHA2 is suppressed by siRNA, the invasiveness of cancer cells, anchorage independent proliferation thereof, and *in vivo* tumor proliferation are suppressed (Non Patent Literatures 13 and 14), and that the invasiveness of cancer cells, anchorage independent proliferation thereof, and tubular form-forming ability thereof are suppressed by activating EPHA2 using a fusion protein of Ephrin-A1 serving as a ligand and the Fc region of human IgG, and thus inducing the decomposition of EPHA2 according to endocytosis (Non Patent Literatures 4, 11, and 12).

45 **[0006]** On the other hand, it has been reported that EPHA2 is expressed not only in cancer cells, but also in tumor or in blood vessels existing around the tumor (Non Patent Literature 15). It has been reported that, in the case of mice, EPHA2 signals are associated with angiogenesis induced by Ephrin-A1, and that EPHA2, which is particularly expressed in vascular endothelial cells, is necessary for the lumen formation of the vascular endothelial cells or the survival thereof (Non Patent Literature 16). It has been further reported that a fusion protein of the extracellular region of EPHA2 and the Fc region of human IgG suppresses angiogenesis *in vivo* and exhibits antitumor effects (Non Patent Literature 17).

50 **[0007]** Recently, it has been reported that membrane type-1 matrix metalloprotease (MT1-MMP) cleaves EPHA2 at the extracellular region, and as a result, an EPHA2 fragment remaining in the membrane promotes carcinogenic signaling (Non Patent Literatures 18 and 19).

[0008] Furthermore, it has been reported that the serum concentration of soluble EPHA2 is higher in patients with lung cancer or prostate cancer than in healthy donors (Non Patent Literatures 20 and 21).

55 **[0009]** As described above, it has been suggested that EPHA2 is likely to be an excellent therapeutic target in cancer, and as a matter of fact, several clinical tests of drugs that target EPHA2 have actually been carried out (Patent Literatures 1 to 3).

[0010] From these things, provision of a method capable of detecting the expression of EPHA2 is useful for the examination or diagnosis of diseases associated with EPHA2, such as cancer, and the expression of EPHA2. Immu-

noassays are methods for measuring EPHA2 contained in a sample derived from a subject. Among them, an ELISA (Enzyme-Linked Immuno Sorbent Assay) method has been commonly used as a simple and prompt measurement method. To date, a method of measuring EPHA2 contained in a test sample using an anti-EPHA2 antibody (ELISA method) has been reported (Patent Literatures 4 and 5 and Non Patent Literatures 20 to 27), but a method of using an anti-EPHA2 monoclonal antibody alone has not yet been established.

Citation List

Patent Literature

[0011]

- Patent Literature 1: International Publication No. WO2003/094859
- Patent Literature 2: International Publication No. WO2006/084226
- Patent Literature 3: International Publication No. WO2009/028639
- Patent Literature 4: International Publication No. WO2009/085805
- Patent Literature 5: International Publication No. WO2014/126160

Non Patent Literature

[0012]

- Non Patent Literature 1: Molecular and Cellular Biology, 1990, Vol. 10, pp. 6316-6324
- Non Patent Literature 2: Annual Review of Neuroscience, 1998, Vol. 21, pp. 309-345
- Non Patent Literature 3: Molecular Cancer Research, 2002, Vol. 1, pp. 79-87
- Non Patent Literature 4: Cancer Research, 2001, Vol. 61, pp. 2301-2306
- Non Patent Literature 5: International Journal of Cancer, 2003, Vol. 103, pp. 657-663
- Non Patent Literature 6: The Prostate, 1999, Vol. 41, pp. 275-280
- Non Patent Literature 7: American Journal of Pathology, 2003, Vol. 163, pp. 2271-2276
- Non Patent Literature 8: Cancer Science, 2005, Vol. 96, pp. 42-47
- Non Patent Literature 9: Clinical Cancer Research, 2003, Vol. 9, pp. 613-618
- Non Patent Literature 10: Oncology Reports, 2004, Vol. 11, pp. 605-611
- Non Patent Literature 11: Molecular Cancer Research, 2005, Vol. 3, pp. 541-551
- Non Patent Literature 12: Biochemical and Biophysical Research Communications, 2004, Vol. 320, pp. 1096-1102
- Non Patent Literature 13: Oncogene, 2004, Vol. 23, pp. 1448-1456
- Non Patent Literature 14: Cancer Research, 2002, Vol. 62, pp. 2840-2847
- Non Patent Literature 15: Oncogene, 2000, Vol. 19, pp. 6043-6052
- Non Patent Literature 16: Journal of Cell Science, 2004, Vol. 117, pp. 2037-2049
- Non Patent Literature 17: Oncogene, 2002, Vol. 21, pp. 7011-7026
- Non Patent Literature 18: The Journal of Cell Biology, 2013, Vol. 201, pp. 467-484
- Non Patent Literature 19: Cancer Research, 2015, Vol. 75, pp. 3327-3339
- Non Patent Literature 20: Proceedings: AACR 106th Annual Meeting 2015; April 18-22, 2015; Philadelphia, PA Cancer Research 2015; 75 (15 Suppl): Abstract nr 546.
- Non Patent Literature 21: The 74th Annual Meeting of the Japanese Cancer Association, P15-8 P-3321
- Non Patent Literature 22: RayBiotech, Human EphA2 ELISA (ELH-EPHA2-1), <URL:<http://www.raybiotech.com/epha2-elisa.html>>
- Non Patent Literature 23: CUSABIO, Human Ephrin type-A receptor 2(EPHA2) ELISA kit (CSB-EL007722HU), <<http://www.cusabio.com/ELISA-Kit/Human-Ephrin-type-A-receptor-2EPHA2-ELISA-kit-76651.html>>
- Non Patent Literature 24: LSBio, Human EPHA2 / EPH Receptor A2 ELISA Kit (Sandwich ELISA) (LS-F23977), <<https://www.lsbio.com/elisakits/human-epha2-eph-receptor-a2-elisa-kit-sandwich-elisa-ls-f23977/23977?trid=119>>
- Non Patent Literature 25: Abnova, EPHA2 (Human) Matched Antibody Pair (H00001969-AP21), <http://www.abnova.com/products/products_detail.asp?catalog_id=H00001969-AP21>
- Non Patent Literature 26: Abnova, EPHA2 (Human) Matched Antibody Pair (H00001969-AP11), <http://www.abnova.com/products/products_detail.asp?catalog_id=H00001969-AP11>
- Non Patent Literature 27: Abnova, EPHA2 (Human) Matched Antibody Pair (H00001969-AP51), <http://www.abnova.com/products/products_detail.asp?catalog_id=H00001969-AP51>

Summary of Invention

Technical Problem

- 5 **[0013]** It is one object of the present invention to provide an antibody specific to EPHA2.
[0014] It is another object of the present invention to provide a composition for immunological diagnosis, comprising an anti-EPHA2 antibody, and anti-EPHA2 antibodies used therefor or a combination thereof.
[0015] Moreover, it is a further object of the present invention to provide a method for detecting EPHA2, using anti-EPHA2 antibodies or a combination thereof, and a kit for detection or diagnosis, comprising the antibodies or a combination thereof.

Solution to Problem

- 15 **[0016]** For the purpose of simply measuring EPHA2 with high sensitivity and utilizing such a simple measurement for to improve the accuracy of cancer diagnosis, the present inventors have produced a large number of anti-EPHA2 monoclonal antibodies for the measurement of EPHA2 according to a sandwich immunoassay, have then selected monoclonal antibodies particularly suitable for the sandwich immunoassay, have then determined the amino acid sequence and the nucleotide sequence of a heavy chain variable region and a light chain variable region thereof, and have further analyzed six CDR sequences.
20 **[0017]** The present inventors have confirmed that, by using two types of antibodies developed by the present inventors, EPHA2 in a biological sample can be measured with high sensitivity and detection of cancer can also be achieved with high sensitivity and high specificity, thereby completing the present invention.
[0018] Specifically, the present invention is as follows.

- 25 [1] A monoclonal antibody specifically binding to EPHA2, comprising:
- (a) a heavy chain CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 29,
 - (b) a heavy chain CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 30,
 - (c) a heavy chain CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 31,
 - 30 (d) a light chain CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 32,
 - (e) a light chain CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 33, and
 - (f) a light chain CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 34, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
- 35 [2] A monoclonal antibody specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 20 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 22, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
- 40 [3] A monoclonal antibody specifically binding to EPHA2, comprising: a heavy chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 20, and having binding activity to human EPHA2; and a light chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 22, and having binding activity to human EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
- 45 [4] A monoclonal antibody specifically binding to EPHA2, comprising:
- (a) a heavy chain CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 23,
 - (b) a heavy chain CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 24,
 - (c) a heavy chain CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 25,
 - 50 (d) a light chain CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 26,
 - (e) a light chain CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 27, and
 - (f) a light chain CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 28, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
- 55 [5] A monoclonal antibody specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 15 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 18, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.

5 [6] A monoclonal antibody specifically binding to EPHA2, comprising: a heavy chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 15, and having binding activity to human EPHA2; and a light chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 18, and having binding activity to human EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.

10 [7] A combination of two types of monoclonal antibodies; namely, the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [3], or a functional fragment of the monoclonal antibody specifically binding to EPHA2, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [4] to [6].

[8] The combination according to the above [7], which is used in a method for detecting or measuring EPHA2 in a biological sample.

15 [9] A method for specifically detecting EPHA2 contained in a biological sample according to an immunoassay, which uses the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [6].

20 [10] A method for specifically detecting EPHA2 contained in a biological sample according to a sandwich immunoassay, which uses two types of monoclonal antibodies; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [3], and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2, according to any one of the above [4] to [6]

[11] The method according to the above [10], wherein the sandwich immunoassay is ELISA.

25 [12] A method for detecting cancer, which comprises: measuring the concentration of EPHA2 in the blood of a subject according to an immunoassay, using the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [6]; and evaluating that the subject suffers from cancer, when the concentration of EPHA2 in the blood of the subject is higher than the concentration of EPHA2 in the blood of a healthy donor.

30 [13] A method for detecting cancer, which comprises: measuring the concentration of EPHA2 in the blood of a subject according to a sandwich immunoassay, using two types of monoclonal antibodies, namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [3], and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [4] to [6]; and evaluating that the subject suffers from cancer, when the concentration of EPHA2 in the blood of the subject is higher than the concentration of EPHA2 in the blood of a healthy donor.

[14] The method according to the above [13], wherein the sandwich immunoassay is ELISA.

35 [15] The method according to any one of the above [12] to [14], wherein the cancer is selected from the group consisting of gastric cancer, ovarian cancer, breast cancer, esophageal cancer, prostate cancer, non-small-cell lung cancer, colon cancer, pancreatic cancer, liver cancer, bladder cancer, cervical cancer, uterine cancer, kidney cancer, brain tumor, malignant melanoma, and head and neck cancer.

40 [16] A kit for measuring EPHA2, comprising two types of monoclonal antibodies or functional fragments thereof; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [3], and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [4] to [6].

45 [17] A kit for detecting cancer, comprising two types of monoclonal antibodies or functional fragments thereof; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [1] to [3], and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of the above [4] to [6].

50 [18] The kit according to the above [17], wherein the cancer is selected from the group consisting of gastric cancer, ovarian cancer, breast cancer, esophageal cancer, prostate cancer, non-small-cell lung cancer, colon cancer, pancreatic cancer, liver cancer, bladder cancer, cervical cancer, uterine cancer, kidney cancer, brain tumor, malignant melanoma, and head and neck cancer.

55 **[0019]** The present description includes part or all of the contents as disclosed in Japanese Patent Application No. 2017-009349, which is a priority document of the present application.

Advantageous Effects of Invention

[0020] Among a large number of anti-EPHA2 monoclonal antibodies produced by the present inventors, when the antibody 57-1 and the antibody 230-1 are used in combination as a solid-phase antibody and a detection antibody, EPHA2 in a biological sample can be detected with higher sensitivity than in the case of using other monoclonal antibodies. Moreover, when EPHA2 is measured and cancer is detected according to a sandwich immunoassay using the above-described two types of monoclonal antibodies in combination, the cancer can be detected with high sensitivity and high specificity.

[0021] Furthermore, EPHA2 in a biological sample can be detected with higher sensitivity according to an immunoassay using the antibody 57-1 or the antibody 230-1, than in the case of using other monoclonal antibodies. Further, when EPHA2 is measured and cancer is detected according to an immunoassay using the above-described monoclonal antibodies, the cancer can be detected with high sensitivity and high specificity.

Brief Description of Drawings

[0022]

[Figure 1] Figure 1 is a view showing the reactivity of the 13 types of anti-EPHA2 monoclonal antibodies (SHM41, 57-1, 80-21, 83-21, 113-1, 119-1, 131-1, 141-21, 148-1, 151-4, 230-1, 240-4, and 245-21) according to Example 2)-1, to EPHA2.

[Figure 2] Figure 2 is a view showing reactivity in the case of using the anti-EPHA2 monoclonal antibody 230-1 as a biotin-labeled antibody according to Example 2)-2, and using 11 types of anti-EPHA2 monoclonal antibodies 57-1, 80-21, 83-21, 113-1, 119-1, 131-1, 141-21, 148-1, 151-4, 240-4, and 245-21 as capture antibodies.

[Figure 3] Figure 3 is a view showing reactivity in the case of using SHM41, 57-1 or 230-1 as a capture antibody according to Example 2)-3, and using biotin-labeled 57-1 or 230-1 as a detection antibody.

[Figure 4] Figure 4 is a view showing the reactivity of the ELISA system according to Example 2)-4 (the capture antibody 230-1, the detection antibody biotin-labeled 57-1, the capture antibody 57-1, and the detection antibody biotin-labeled 230-1) to EPHA2.

[Figure 5] Figure 5 is a view showing the calibration curve of the ELISA system according to Example 2)-5 (the capture antibody 230-1 and the detection antibody biotin-labeled 57-1).

[Figure 6] Figure 6 is a view showing the EPHA2 specificity of the ELISA system according to Example 2)-6 (the capture antibody 230-1 and the detection antibody biotin-labeled 57-1).

[Figure 7-1] Figure 7-1 is a view showing the measurement of the serum concentration of EPHA2 of healthy donors, gastric cancer patients, and ovarian cancer patients according to the ELISA system (the capture antibody 230-1 and the detection antibody biotin-labeled 57-1).

[Figure 7-2] Figure 7-2 is a view showing the measurement of the serum concentration of EPHA2 of healthy donors and non-small-cell lung cancer patients according to the ELISA system (the capture antibody 230-1 and the detection antibody biotin-labeled 57-1).

[Figure 8] Figure 8 is a view showing the nucleotide sequence (SEQ ID NO: 14) of cDNA encoding the heavy chain variable region of the mouse anti-EPHA2 monoclonal antibody 57-1.

[Figure 9] Figure 9 is a view showing the amino acid sequence (SEQ ID NO: 15) of the heavy chain variable region of the mouse anti-EPHA2 monoclonal antibody 57-1.

[Figure 10] Figure 10 is a view showing the nucleotide sequence (SEQ ID NO: 17) of cDNA encoding the light chain variable region of the mouse anti-EPHA2 monoclonal antibody 57-1.

[Figure 11] Figure 11 is a view showing the amino acid sequence (SEQ ID NO: 18) of the light chain variable region of the mouse anti-EPHA2 monoclonal antibody 57-1.

[Figure 12] Figure 12 is a view showing the nucleotide sequence (SEQ ID NO: 19) of cDNA encoding the heavy chain variable region of the mouse anti-EPHA2 monoclonal antibody 230-1.

[Figure 13] Figure 13 is a view showing the amino acid sequence (SEQ ID NO: 20) of the heavy chain variable region of the mouse anti-EPHA2 monoclonal antibody 230-1.

[Figure 14] Figure 14 is a view showing the nucleotide sequence (SEQ ID NO: 21) of cDNA encoding the light chain variable region of the mouse anti-EPHA2 monoclonal antibody 230-1.

[Figure 15] Figure 15 is a view showing the amino acid sequence (SEQ ID NO: 22) of the light chain variable region of the mouse anti-EPHA2 monoclonal antibody 230-1.

[Figure 16] Figure 16 is a view showing the amino acid sequences (SEQ ID NOS: 23 to 28) of the CDRs of the mouse anti-EPHA2 monoclonal antibody 57-1.

[Figure 17] Figure 17 is a view showing the amino acid sequences (SEQ ID NOS: 29 to 34) of the CDRs of the mouse anti-EPHA2 monoclonal antibody 230-1.

Description of Embodiments

[0023] Hereinafter, the present invention will be described in detail.

5 [0024] The present invention relates to a method for measuring EPHA2 in the biological sample of a subject according to an immunoassay of using a specific monoclonal antibody specifically binding to EPHA2, and a reagent or a kit for use in the measurement.

[0025] In addition, the present invention relates to a method for measuring EPHA2 in the biological sample of a subject according to a sandwich immunoassay of using two types of specific monoclonal antibodies specifically binding to EPHA2, and a reagent or a kit for use in the measurement.

10 [0026] Moreover, the present invention relates to anti-EPHA2 monoclonal antibodies suitable for the measurement of EPHA2 according to a sandwich immunoassay, and a combination of two types of anti-EPHA2 monoclonal antibodies.

[0027] Furthermore, the present invention relates to: a method comprising measuring EPHA2 in the biological sample of a subject (preferably, in blood) according to an immunoassay of using a specific anti-EPHA2 monoclonal antibody, and then detecting whether or not the subject suffers from cancer, using the concentration of EPHA2 in the biological sample (preferably, in the blood) as an indicator; and a reagent or a kit for detecting whether or not the subject suffers from cancer, using the concentration of EPHA2 in the biological sample (preferably, in the blood) as an indicator. The method of the present invention is also a method for obtaining auxiliary data used when EPHA2 in the biological sample of a subject (preferably, in blood) is measured according to an immunoassay of using a specific anti-EPHA2 monoclonal antibody, and then, whether or not the subject suffers from cancer is determined by using the concentration of EPHA2 in the biological sample (preferably, in the blood) as an indicator.

20 [0028] Further, the present invention relates to a method comprising measuring EPHA2 in the biological sample of a subject (preferably, in blood) according to a sandwich immunoassay of two types of specific anti-EPHA2 monoclonal antibodies, and then detecting whether or not the subject suffers from cancer, using the concentration of EPHA2 in the biological sample (preferably, in the blood) as an indicator; and a reagent or a kit for detecting whether or not the subject suffers from cancer, using the concentration of EPHA2 in the biological sample (preferably, in the blood). The method of the present invention is also a method for obtaining auxiliary data used when EPHA2 in the biological sample of a subject (preferably, in blood) is measured according to a sandwich immunoassay of using two types of specific anti-EPHA2 monoclonal antibodies, and then, whether or not the subject suffers from cancer is determined by using the concentration of EPHA2 in the biological sample (preferably, in the blood) as an indicator.

25 [0029] As a biological sample, blood (whole blood, serum, or plasma), lymph, urine, a tissue homogenate, a cell culture supernatant, or a cell lysate is used. Preferably, blood may be used, and more preferably, serum may be used.

[0030] The monoclonal antibody used in the present invention can be obtained by immunizing a mammal such as a horse, a monkey, a dog, a pig, a bovine, a goat, sheep, a rabbit, a rat, a Guinea pig, a hamster or a mouse with an immunogen that is EPHA2 or a fragment thereof, then fusing splenic cells or the like with myelomas to produce hybridomas, and then obtaining an antibody as a result of generation and secretion from the hybridomas. Hybridomas can be produced by a known method.

30 [0031] EPHA2 used as an immunogen can be chemically synthesized based on sequence information, or can also be obtained as a recombinant protein according to a known method, based on the information of the DNA sequence encoding the protein.

35 [0032] The antibody can be screened according to any given method. The antibody may be preferably screened according to Cell-ELISA using animal cells that are transfected with DNA encoding EPHA2. The nucleotide sequence of EPHA2 is as set forth in SEQ ID NO: 5, and the amino acid sequence of EPHA2 is as set forth in SEQ ID NO: 6. The specific binding ability of the selected antibody to EPHA2 can be confirmed by a flow cytometric analysis, etc.

[0033] The monoclonal antibody used in the method of the present invention is either one or both of the antibody 230-1 and the antibody 57-1. The antibody 230-1 is a monoclonal antibody having the highest reactivity with EPHA2 among the produced 13 types of monoclonal antibodies. On the other hand, the antibody 57-1 is most suitable for being combined with the antibody 230-1 for use in the measurement of EPHA2 according to a sandwich immunoassay.

45 [0034] The cDNA sequence encoding the heavy chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 14 (Figure 8), and the amino acid sequence of the heavy chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 15 (Figure 9). Moreover, the cDNA sequence encoding the light chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 17 (Figure 10), and the amino acid sequence of the light chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 18 (Figure 11).

[0035] Specifically, the anti-EPHA2 antibody of the present invention is an anti-human EPHA2 monoclonal antibody binding to human EPHA2, which comprises a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 15 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 18.

55 [0036] In addition, DNA, which consists of a nucleotide sequence having a sequence identity of at least 85% or more, preferably 90% or more, more preferably 95% or more, particularly preferably 97% or more, 98% or more, or 99% or more, to the nucleotide sequence as set forth in the above-described SEQ ID NO: 14 or 17, in which the sequence

identity is calculated using BLAST (Basic Local Alignment Search Tool at the National Center for Biological Information), etc. (for example, default, namely, initial setting parameters), and which encodes a protein having the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2, is also included in the DNA encoding the heavy chain variable region or light chain variable region of the antibody of the present invention.

[0037] Moreover, DNA, which can hybridize under stringent conditions with DNA consisting of a sequence complementary to the DNA consisting of the sequence as set forth in the above-described SEQ ID NO: 14 or 17, and which encodes a protein having the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2, is also included in the DNA encoding the heavy chain variable region or light chain variable region of the present invention.

[0038] Furthermore, the above-described heavy chain variable region or light chain variable region does not only include the heavy chain variable region or light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 15 or 18, but also includes a heavy chain variable region or a light chain variable region, which consists of an amino acid sequence comprising a deletion, substitution or addition of one or several, for example, 1 to 10, preferably 1 to 5, more preferably 1 or 2, and further preferably 1 amino acid, with respect to the amino acid sequence as set forth in SEQ ID NO: 15 or 18, and which has the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2.

[0039] An example of the amino acid sequence comprising a deletion, substitution or addition of one or several amino acids, with respect to the amino acid sequence as set forth in SEQ ID NO: 15 or 18, may be an amino acid sequence having a sequence identity of at least 85% or more, preferably 90% or more, more preferably 95% or more, particularly preferably 97% or more, 98% or more, or 99% or more, to the amino acid sequence as set forth in SEQ ID NO: 15 or 18, when the sequence identity is calculated using BLAST (Basic Local Alignment Search Tool at the National Center for Biological Information), etc. (for example, default, namely, initial setting parameters).

[0040] Such a protein having an amino acid sequence comprising a deletion, substitution or addition of one or several amino acids, with respect to the amino acid sequence as set forth in SEQ ID NO: 15 or 18, is substantially identical to the protein having the amino acid sequence as set forth in SEQ ID NO: 15 or 18.

[0041] The cDNA sequence encoding the heavy chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 19 (Figure 12), and the amino acid sequence of the heavy chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 20 (Figure 13). Moreover, the cDNA sequence encoding the light chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 21 (Figure 14), and the amino acid sequence of the light chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 22 (Figure 15).

[0042] Specifically, the anti-EPHA2 antibody of the present invention is an anti-human EPHA2 monoclonal antibody binding to human EPHA2, which comprises a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 20 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 22.

[0043] In addition, DNA, which consists of a nucleotide sequence having a sequence identity of at least 85% or more, preferably 90% or more, more preferably 95% or more, particularly preferably 97% or more, 98% or more, or 99% or more, to the nucleotide sequence as set forth in the above-described SEQ ID NO: 19 or 21, in which the sequence identity is calculated using BLAST (Basic Local Alignment Search Tool at the National Center for Biological Information), etc. (for example, default, namely, initial setting parameters), and which encodes a protein having the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2, is also included in the DNA encoding the heavy chain variable region or light chain variable region of the antibody of the present invention.

[0044] Moreover, DNA, which can hybridize under stringent conditions with DNA consisting of a sequence complementary to the DNA consisting of the sequence as set forth in the above-described SEQ ID NO: 19 or 21, and which encodes a protein having the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2, is also included in the DNA encoding the heavy chain variable region or light chain variable region of the present invention.

[0045] Furthermore, the above-described heavy chain variable region or light chain variable region does not only include the heavy chain variable region or light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 20 or 22, but also includes a heavy chain variable region or a light chain variable region, which consists of an amino acid sequence comprising a deletion, substitution or addition of one or several, for example, 1 to 10, preferably 1 to 5, more preferably 1 or 2, and further preferably 1 amino acid, with respect to the amino acid sequence as set forth in SEQ ID NO: 20 or 22, and which has the activity of the heavy chain variable region or light chain variable region of an antibody, namely, binding activity to human EPHA2.

[0046] An example of the amino acid sequence comprising a deletion, substitution or addition of one or several amino acids, with respect to the amino acid sequence as set forth in SEQ ID NO: 20 or 22, may be an amino acid sequence having a sequence identity of at least 85% or more, preferably 90% or more, more preferably 95% or more, particularly preferably 97% or more, 98% or more, or 99% or more, to the amino acid sequence as set forth in SEQ ID NO: 20 or

22, when the sequence identity is calculated using BLAST (Basic Local Alignment Search Tool at the National Center for Biological Information), etc. (for example, default, namely, initial setting parameters).

[0047] Such a protein having an amino acid sequence comprising a deletion, substitution or addition of one or several amino acids, with respect to the amino acid sequence as set forth in SEQ ID NO: 20 or 22, is substantially identical to the protein having the amino acid sequence as set forth in SEQ ID NO: 20 or 22.

[0048] Further, the antibody 57-1 comprises, as CDRs (complementarity determining regions) of the heavy chain variable region, CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 23 (NYGMN), CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 24 (WINTDTGEPFVVEEFGK), and CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 25 (SMGGFAN), and further comprises, as CDRs of the light chain variable region, CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 26 (RASQNISDYLNH), CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 27 (YASQSSIS), and CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 28 (QNGHTFPT) (Figure 16).

[0049] Specifically, the anti-EPHA2 antibody of the present invention is an antibody comprising the heavy chain variable region CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 23, the heavy chain variable region CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 24, the heavy chain variable region CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 25, the light chain variable region CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 26, the light chain variable region CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 27, and the light chain variable region CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 28.

[0050] Still further, the antibody 230-1 comprises, as CDRs (complementarity determining regions) of the heavy chain variable region, CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 29 (DYMY), CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 30 (TISDDGSFTHYLDVSKG), and CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 31 (DGYRYDRPFAY), and further comprises, as CDRs of the light chain variable region, CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 32 (KASQDVNTAVA), CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 33 (WASTRHT), and CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 34 (QQHYSTPYT) (Figure 17).

[0051] Specifically, the anti-EPHA2 antibody of the present invention is an antibody comprising the heavy chain variable region CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 29, the heavy chain variable region CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 30, the heavy chain variable region CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 31, the light chain variable region CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 32, the light chain variable region CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 33, and the light chain variable region CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 34.

[0052] The above-described each CDR includes CDR consisting of amino acid sequence comprising a deletion, substitution or addition of one or several, preferably 1 or 2, more preferably 1 amino acid, with respect to each relevant amino acid sequence.

[0053] The aforementioned anti-EPHA2 monoclonal antibody comprising the above-described heavy chain variable region and light chain variable region is composed of the above-described heavy chain variable region and a heavy chain constant region and the above-described light chain variable region and a light chain constant region. The heavy chain constant region is composed of three domains C_{H1} , C_{H2} and C_{H3} . The heavy chain constant region may be an IgG1, IgG2, IgG3, IgG4, IgA, IgE, IgM or IgD constant region. The heavy chain constant region is preferably an IgG1 or IgG2 constant region, and is most preferably an IgG1 constant region. The light chain constant region is composed of a single domain C_L . The light chain constant region is a κ or λ constant region.

[0054] The antibody of the present invention also includes a functional fragment of the antibody or a modified form thereof. For example, the functional fragment of the antibody is a fragment of the antibody that can specifically bind to an antigen. Examples of the functional fragment include Fab, Fab', F(ab')₂, disulfide-stabilized Fv (dsFv), a dimeric V region (diabody), and single chain Fv (scFv).

[0055] The antibody of the present invention can be generated using antibody-producing hybridomas. The antibody of the present invention can also be generated as a recombinant antibody from cells, by inserting DNA encoding a heavy chain variable region or DNA encoding a light chain variable region into an expression vector, then transforming host cells for use in expression with the vector, and then culturing the host cells.

[0056] The antibody of the present invention includes an antibody that binds to an epitope, to which the above-described antibody binds, and an antibody that competes against the above-described antibody regarding the binding to EPHA2.

[0057] In the present invention, the anti-human EPHA2 monoclonal antibody is used to construct an immunoassay system. Examples of the immunoassay include immunoblotting, enzyme immunoassay (EIA and ELISA), radioimmunoassay (RIA), a fluorescent antibody technique, a method utilizing an agglutination reaction, and immunochromatography.

[0058] In addition, in the present invention, the anti-human EPHA2 monoclonal antibody is used to construct a sandwich

immunoassay system, among such immunoassay systems. The sandwich immunoassay includes all sandwich immunoassay methods, such as sandwich radioimmunoassay (RIA), sandwich enzyme immunoassay (EIA), sandwich fluorescence immunoassay (FIA), sandwich chemiluminescence immunoassay (CLIA), sandwich chemiluminescent enzyme immunoassay (CLEIA), and immunochromatography based on a sandwich method. Among these methods, ELISA (Enzyme-Linked ImmunoSorbent Assay) that is one of EIA methods is preferable. Hereafter, ELISA will be described. Other sandwich immunoassay methods are the same as ELISA in that an antigen to be measured is sandwiched between two types of antibodies, and thus, a person skilled in the art could construct other sandwich immunoassay measurement systems. An unlabeled anti-human EPHA2 monoclonal antibody is immobilized as a capturing antibody (primary antibody) on a carrier such as a 96-well microtiter plate or polystyrene beads. Moreover, as a detection antibody (secondary antibody), an anti-human EPHA2 monoclonal antibody, which is labeled with an enzyme such as horse radish peroxidase (HRP) or alkaline phosphatase (ALP), a fluorescent substance such as FITC, or biotin, is used. In this case, a Fab' fragment, which is obtained by digesting an antibody molecule with pepsin, may be labeled with an enzyme or the like. Otherwise, after the anti-human EPHA2 monoclonal antibody has been reacted with an unlabeled secondary antibody, it may be then reacted with an antibody specifically binding to the secondary antibody, which is labeled with an enzyme, a fluorescent substance, etc. and is used as a third antibody for use in detection. At this time, the secondary antibody may be labeled with biotin, and the labeled avidin or streptavidin may be then bound to biotin for coloration. The antigen-antibody reaction can be carried out at a temperature of 4°C to 45°C, more preferably 20°C to 40°C, and further preferably 25°C to 38°C. The reaction time is approximately 10 minutes to 18 hours, more preferably approximately 10 minutes to 1 hour, and further preferably approximately 30 minutes to 1 hour. The concentration of EPHA2 in a sample can be calculated from a standard curve, which has previously been prepared regarding the degree of coloration, or which is simultaneously prepared upon the measurement of a sample collected from a subject. In the sandwich immunoassay, either the antibody 57-1 or the antibody 230-1 is immobilized on a carrier, such as a microtiter plate for ELISA, and is used as a solid-phase antibody, whereas the other antibody is labeled and is used as a detection antibody. The antibody 57-1 may be used as a solid-phase antibody, and the antibody 230-1 may be used as a detection antibody. Otherwise, the antibody 57-1 may be used as a detection antibody, and the antibody 230-1 may be used as a solid-phase antibody. A method, in which these monoclonal antibodies are used, has high specificity, detects only EPHA1, and does not show cross-reactivity to EPHA1, EPHA3, and EPHA4.

[0059] The present invention includes a test kit for measuring EPHA2, or a composition for use in immunological diagnosis, which comprises at least two types of antibodies, namely, the antibody 57-1 and the antibody 230-1. Either the antibody 57-1 or the antibody 230-1 may be immobilized on a microtiter plat for ELISA, and the other antibody may be labeled. The above-described test kit may include a specimen collecting tool, a specimen treating solution, and a reagent such as a chromogenic substrate, and may further include tools necessary for the test, and the like.

[0060] By measuring EPHA2 in the blood of a subject, whether or not the subject suffers from cancer can be determined. That is to say, when the concentration of EPHA2 in the blood of a subject is higher than the concentration of EPHA2 in the blood of a healthy donor, it can be determined that the subject suffers from cancer. Otherwise, the concentration of EPHA2 in the biological sample of a healthy donor has previously been measured, and based on the measured value, a cutoff value (threshold) may be set with regard to the measured value of the concentration of EPHA2. Using the cutoff value as a reference, when the measured value exceeds the cutoff value, it can be determined that the subject suffers from cancer.

[0061] The cancer is preferably gastric cancer, ovarian cancer, breast cancer, esophageal cancer, prostate cancer, non-small-cell lung cancer, colon cancer, pancreatic cancer, liver cancer, bladder cancer, cervical cancer, uterine cancer, kidney cancer, brain tumor, malignant melanoma, head and neck cancer, or the like.

[0062] The present invention includes a method for detecting cancer using the concentration of EPHA2 in blood as an indicator. This method is also a method for obtaining auxiliary data that are used to detect cancer using the concentration of EPHA2 in blood as an indicator.

[0063] The present invention includes a test kit or a composition for use in immunological diagnosis, which comprises at least the antibody 57-1 or the antibody 230-1, and is used to measure EPHA2 and detect cancer. The above-described test kit may include a specimen collecting tool, a specimen treating solution, and a reagent such as a chromogenic substrate, and may further include tools necessary for the test, and the like.

[0064] Further, the present invention includes a test kit or a composition for use in immunological diagnosis, which comprises at least two types of antibodies, namely, the antibody 57-1 and the antibody 230-1, and is used to measure EPHA2 and detect cancer. The above-described test kit may include a specimen collecting tool, a specimen treating solution, and a reagent such as a chromogenic substrate, and may further include tools necessary for the test, and the like.

Examples

[0065] Hereinafter, the present invention will be more specifically described in the following examples. However, these examples are not intended to limit the scope of the present invention. It is to be noted that, in the following examples,

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individual operations regarding genetic operations were carried out according to the methods described in "Molecular Cloning," Sambrook, J., Fritsch, E. F. and Maniatis, T., published by Cold Spring Harbor Laboratory Press in 1989, unless otherwise clearly specified. Alternatively, when commercially available reagents or kits were used, they were used in accordance with the instruction manuals included with the commercially available products.

[Example 1]

Production of anti-human EPHA2 monoclonal antibody

1)-1 Production of plasmid encoding human EPHA2

1)-1-1 Production of plasmid encoding full-length human EPHA

[0066] A PCR reaction was carried out using, as a template, cDNA synthesized from the total RNA of SK-OV-3 cells, and also using the following primer set:

Primer 1: 5'-ggggacaagttgtacaaaaagcaggcttcggggatcgaccgagagcgagaag-3' (SEQ ID NO: 1 in the sequence listing); and

Primer 2: 5'-ggggaccactttgtacaagaagctgggtcctagatggggatccccacagtgttcacctgtcctt-3' (SEQ ID NO: 2 in the sequence listing), thereby amplifying cDNA encoding human EPHA2. The PCR fragment was cloned into pDONR221 (Invitrogen, Thermo Fisher Scientific), using BP Clonase (Invitrogen, Thermo Fisher Scientific). From the cloned EPHA2 gene, a stop codon was removed using GeneTailor Site-Directed Mutagenesis System (Invitrogen, Thermo Fisher Scientific) and the following primer set:

Primer 3: 5'-ctgtggggatccccatcgaccagcttc-3' (SEQ ID NO: 3 in the sequence listing); and

Primer 4: 5'-gatggggatccccacagtgttcacctgtgc-3' (SEQ ID NO: 4 in the sequence listing).

[0067] This EPHA2 gene fragment was transferred into pcDNA-DEST40 Gateway Vector (Invitrogen, Thermo Fisher Scientific), using LR Clonase (Invitrogen, Thermo Fisher Scientific). Hereinafter, this plasmid is referred to as "pcDNA-DEST40-EPHA2" (the present plasmid has the nucleotide sequence as set forth in SEQ ID NO: 5 in the sequence listing between the attB1 and attB2 sequences). Moreover, the coding sequence of the EPHA2 gene cloned into the present plasmid is shown as nucleotide numbers 33 to 2960 of SEQ ID NO: 5 in the sequence listing. Furthermore, the amino acid sequence of EPHA2 is as set forth in SEQ ID NO: 6 in the sequence listing.

1)-1-2 Production of plasmid encoding extracellular region of EPHA2

[0068] A gene encoding the extracellular region of human EPHA2 (consisting of the amino acid sequence as shown in amino acid numbers 1 to 534 of SEQ ID NO: 6 in the sequence listing; hereinafter referred to as "EPHA2 (ECR)") was amplified by a PCR reaction using the following primer set:

Primer 5: 5'-aaaagcttatggagctccaggcagccgc-3' (SEQ ID NO: 7 in the sequence listing); and

Primer 6: 5'-aaagggccctcagttgccagatccctccgg-3' (SEQ ID NO: 8 in the sequence listing). The PCR fragment was cleaved with HindIII and Apal, and was then cloned into the HindIII/Apal site of pcDNA3.1 (hereinafter referred to as "pcDNA3.1-EPHA2 (ECR)"; and also, a recombinant protein expressed by pcDNA3.1-EPHA2 (ECR) is referred to as "EPHA2 (ECR)").

1)-2 Production of plasmid encoding human ERBB2

[0069] A PCR reaction was carried out using Human clone collection (STRATAGENE #C33830, Agilent Technologies) as a template, and also using the following primer set: Primer 7: 5'-caccatggagctggcggccttg-3' (SEQ ID NO: 9 in the sequence listing); and Primer 8: 5'-tcccactggcagctccagacc-3' (SEQ ID NO: 10 in the sequence listing). The obtained PCR fragment was cloned into pENTR/D-TOPO (Invitrogen, Thermo Fisher Scientific), using pENTR Directional TOPO Cloning kit (Invitrogen, Thermo Fisher Scientific). In order to repair a mutation involving amino acid substitution, among fragments obtained by treating this plasmid with EcoRI, a fragment comprising a sequence derived from pENTR/D-TOPO was ligated to a second largest fragment (approx. 1.6 kbp), among fragments obtained by treating Human clone collection (STRATAGENE #C14640, Agilent Technologies) with EcoRI. An ERBB2 gene fragment in this plasmid was transferred into a pcDNA-DEST40 Gateway vector, using LR Clonase. Hereinafter, this plasmid is referred to as "pcDNA-DEST40-ERBB2" (the present plasmid has the nucleotide sequence as set forth in SEQ ID NO: 11 in the sequence listing between the attB1 and attB2 sequences).

1)-3 Preparation of antigen protein

5 [0070] In order to express EPHA2 (ECR), FreeStyle 293-F cells (Invitrogen, Thermo Fisher Scientific) were transfected with pcDNA3.1-EPHA2 (ECR), using 293fectin (Invitrogen, Thermo Fisher Scientific), and the cells were then cultured at 37°C in 8% CO₂ for 5 days. The culture supernatant was recovered by centrifugation, and was then dialyzed against 20 mM Tris-HCl (pH 7.5), using a dialysis tube with a molecular weight fraction of 15000. The culture supernatant was passed through a filter (0.45 μm, PES), and was then loaded on HiPrep 16/10 Q XL (GE Healthcare) equilibrated with 20 mM Tris-HCl (pH 7.5). The binding protein was eluted with a linear concentration gradient of NaCl (20 mM Tris-HCl (pH 7.5), 0-1 M NaCl). Subsequently, a fraction comprising EPHA2 (ECR) was collected, and was then loaded on HiLoad 26/60 Superdex 200pg (GE Healthcare) equilibrated with PBS. The protein was eluted with PBS. A fraction comprising EPHA2 (ECR) was collected and was then used as an antigen for immunization. The concentration of the protein was measured using BCA Protein Assay Reagent (PIERCE, Thermo Fisher Scientific).

1)-4 Immunization

15 [0071] As initial immunization, 50 μg of EPHA2 (ECR), which had been mixed with Adjuvant Complete Freund H37 Rv (Wako Pure Chemical) or TiterMax Gold Adjuvant (SIGMA), was administered into the dorsal subcutis of BALB/cAn-NCrIcrIj mice (Charles River Laboratories Japan). As second and third immunizations, 50 μg of EPHA2 (ECR), which had been mixed with Adjuvant Incomplete Freund (Wako Pure Chemical), was administered into the dorsal subcutis of the mice. These mice were boosted with 50 μg of EPHA2 (ECR), and three days later, the spleen was collected. This spleen was used to produce hybridomas.

1)-5 Production of hybridomas

25 [0072] The splenic cells were fused with mouse myeloma P3X63Ag8U.1 cells, using PEG4000 (IBL), so as to produce hybridomas. Using a culture supernatant of the hybridomas, anti-EPHA2 antibody-producing hybridomas were screened.

1)-6 Antibody screening

30 1)-6-1 Preparation of antigen-expressing cells

35 [0073] 293T cells were seeded at a density of 5×10^4 cells/cm² on a collagen type I-coated flask (IWAKI), and were then cultured in DMEM supplemented with 10% FBS at 37°C in 5% CO₂ under a humidified atmosphere overnight. On the following day, the 293T cells were transfected with each of pcDNA-DEST40-EPHA2 and pcDNA-DEST40-ERBB2 (negative control), using Lipofectamine 2000 (Invitrogen, Thermo Fisher Scientific), and thereafter, the resulting cells were further cultured at 37°C in 5% CO₂ under a humidified atmosphere overnight. On the following day, the transfected cells were treated with trypsin, and were then washed with DMEM supplemented with 10% FBS. The resulting cells were suspended in 5% FBS-containing PBS. These cells were used in Cell-ELISA and flow cytometric analysis.

40 1)-6-2 Cell-ELISA

45 [0074] The cells prepared in the above 1)-6-1 were mixed with the culture supernatant of the hybridomas, and the thus obtained mixture was then incubated at 4°C for 1 hour. The resulting cells were washed with 5% FBS-containing PBS twice, and were then stained with Goat anti-Mouse IgG, Peroxidase Conjugated (Millipore (Chemicon) #AP181P), which had been 500-fold diluted with 5% FBS-containing PBS, at 4°C for 1 hour. Thereafter, the resulting cells were washed with 5% FBS-containing PBS twice, and an OPD coloring solution (o-phenylenediamine dihydrochloride (Wako Pure Chemical Industries, Ltd.) and H₂O₂ were added to an OPD solution (0.05 M trisodium citrate and 0.1 M disodium hydrogen phosphate 12-water (pH 4.5)) to concentrations of 0.4 mg/ml and 0.6% (v/v), respectively) was then added in an amount of 100 μl/well to the resulting cells. While stirring, a coloring reaction was carried out, and 1 M HCl was then added in an amount of 100 μl/well to the reaction mixture to terminate the coloring reaction. After centrifugation, the obtained supernatant was transferred to a novel 96-well flat bottom microplate, and the absorbance at 490 nm was then measured using a plate reader (ARVO: PerkinElmer). In order to select hybridomas generating an antibody specifically binding to EPHA2, hybridomas exhibiting higher absorbance to EPHA2-expressing 293T cells, than to ERBB2-expressing 293T cells (negative control), were selected.

55 1)-6-3 Flow cytometric analysis

[0075] In order to eliminate false-positive results in the Cell-ELISA, the specific binding ability of antibodies generated

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by the hybridomas that had been determined to be positive in the Cell-ELISA was confirmed by flow cytometry. The cells prepared in the above 1)-6-1 were mixed with a culture supernatant of the hybridomas, and the obtained mixture was then incubated at 4°C for 1 hour. The reaction mixture was washed with 5% FBS-containing PBS twice, and was then stained with Fluorescein-conjugated goat IgG fraction to mouse IgG (Whole Molecule) (ICN Pharmaceuticals #55493), which had been 1000-fold diluted with 5% FBS-containing PBS, at 4°C for 1 hour. The resultant was washed with 5% FBS-containing PBS twice, and was then re-suspended in 5% FBS-containing PBS that comprised 2 µg/ml 7-aminoactinomycin D (Invitrogen (Molecular Probes), Thermo Fisher Scientific). The re-suspension was subjected to an analysis using a flow cytometer (FC500: BeckmanCoulter). For data analysis, Flowjo (Tree Star) was used. Dead cells that were exhibited positive to 7-aminoactinomycin D were eliminated with a gate, and thereafter, a histogram of the FITC fluorescence intensity of living cells was prepared. Hybridomas, which generated antibodies exhibiting higher binding ability to EPHA2-expressing 293T cells than to ERBB2-expressing 293T cells used as controls in the histogram, were selected.

1)-7 Monocloning of hybridomas

[0076] Hybridomas generating anti-EPHA2 antibodies were cultured using ClonaCell-HY Selection Medium D (Stem-Cell Technologies #03804), and appearing colonies were then recovered, so that the monocloned cells were obtained. Using a culture supernatant of the thus monocloned cells, the binding ability of the monocloned cells to EPHA2 was confirmed by the same method as that in the above 1)-6-3. As a result, hybridomas generating the anti-EPHA2 monoclonal antibodies (57-1, 80-21, 83-21, 113-1, 119-1, 131-1, 141-21, 148-1, 151-4, 230-1, 240-4, and 245-21) were established.

1)-8 Determination of isotypes of monoclonal antibodies

[0077] The isotypes of the monoclonal antibodies were determined using Mouse monoclonal isotyping kit (Serotec). As a result, the isotypes of the monoclonal antibodies were found to be IgG1 (57-1, 113-1, 119-1, 131-1, 141-21, and 230-1), IgG2a (80-21, 83-21, 148-1, 151-4, and 240-4), and IgG2b (245-21).

[Example 2]

Development of measurement method of EPHA2

2)-1 Selection of monoclonal antibodies for use in ELISA

2)-1-1 Coating of anti-EPHA2 monoclonal antibodies

[0078] In order to select anti-EPHA2 monoclonal antibodies that can be used in sandwich ELISA for measuring EPHA2, the anti-EPHA2 monoclonal antibodies SHM41 (Toyo University, Non Patent Literatures 19 and 20), 57-1, 80-21, 83-21, 113-1, 119-1, 131-1, 141-21, 148-1, 151-4, 230-1, 240-4, and 245-21 were diluted to a concentration of 5 µg/ml with PBS, immediately before coating, and the thus obtained solutions were each added in an amount of 100 µl/well to an EIA/RIA plate high binding type flat bottom 96-well plate (Costar: No. 9018). A plate seal was attached to the plate, and the antibodies were then adsorbed on the plate at 4°C for 16 hours or more, followed by performing a blocking treatment. For blocking, an assay solution (ASSAY DILUENT: BIOLEGEND) was 5-fold diluted with deionized water and was then used, and the resultant was left at rest at 4°C overnight.

2)-1-2 Reference protein

[0079] As a human EPHA2 reference protein, human recombinant EphA2-(x6 His) purchased from R & D was used. The following five stages of dilution concentrations were set: 2000 pg/ml, 500 pg/ml, 125 pg/ml, 31.3 pg/ml, and 0 pg/ml. After the removal of the blocking solution from the plate of the above 2)-1-1, each concentration of EPHA2 reference protein solution was added in an amount of 100 µl/well to the plate, and it was then reacted at room temperature for 2 hours.

2)-1-3 Biotin-labeled detection antibody

[0080] The solution was removed from the plate of the above 2)-1-2 after completion of the reaction, and an ELISA washing solution (0.05% Tween20-containing PBS solution) was then added in an amount of 200 µl/well to the plate. After the obtained mixture had been stirred using a plate mixer (AS ONE Corp.) for 15 seconds, the washing solution was removed. This washing operation was repeated three times, and thereafter, a biotin-labeled anti-EPHA2 polyclonal antibody (R & D: BAF3035) that had been 1000-fold diluted with an assay solution was added in an amount of 100

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$\mu\text{l/well}$ to the reaction solution. The obtained mixture was reacted at room temperature for 1 hour.

2)-1-4 Avidin enzyme solution

5 **[0081]** The biotin antibody solution was removed from the plate of the above 2)-1-3 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated four times. Thereafter, Streptavidin-HRP (BD Bioscience) that had been 4000-fold diluted with an assay solution was added in an amount of 100 $\mu\text{l/well}$ to the reaction solution. The obtained mixture was reacted at room temperature for 45 minutes.

10 2)-1-5 Substrate solution

[0082] The biotin antibody solution was removed from the plate of the above 2)-1-4 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated five times. Thereafter, TMB (3,3',5,5'-Tetramethylbenzidine) solution (KPL) was added in an amount of 100 $\mu\text{l/well}$ to the reaction solution. The
15 obtained mixture was reacted at room temperature for 15 minutes, so that it was allowed to develop blue color.

2)-1-6 Reaction termination

[0083] A 2 N (2 normal) sulfuric acid solution (Wako Pure Chemical) was added in an amount of 100 $\mu\text{l/well}$ to the
20 reaction mixture, so that the solution was changed to yellow color as a result of termination of the reaction. Thereafter, the absorbance at 450 nm (reference wavelength: 570 nm) was measured using a microplate reader iMark (BIO-RAD).

2)-1-7 Results

25 **[0084]** Reactivity was observed in SHM41, 230-1, 57-1, 141-21, and 151-4, and among others, 230-1 exhibited the highest reactivity (Figure 1).

2)-2 Sandwich ELISA using anti-EPHA2 monoclonal antibody 230-1

30 2)-2-1 Coating of anti-EPHA2 monoclonal antibodies

[0085] In order to select an anti-EPHA2 monoclonal antibody that was to be combined with the anti-EPHA2 monoclonal antibody 230-1, the antibody 230-1 was labeled with biotin, and it was then used as a detection antibody. As capture antibodies, the antibodies 57-1, 80-21, 83-21, 113-1, 119-1, 131-1, 141-21, 148-1, 151-4, 240-4, 245-21 and the isotype IgG1 were each diluted with PBS to a concentration of 5 $\mu\text{g/ml}$, immediately before coating, and thereafter, the antibodies
35 were each added in an amount of 100 $\mu\text{l/well}$ to an EIA/RIA plate high binding type flat bottom 96-well plate. A plate seal was attached to the plate, and the antibodies were then adsorbed on the plate at 4°C for 16 hours or more, followed by performing a blocking treatment. For blocking, an assay solution was 5-fold diluted with deionized water and was then used, and the resultant was left at rest at 4°C overnight.

40

2)-2-2 Reference protein

[0086] The human EPHA2 reference protein was diluted to 4 stages of dilution concentrations, namely, 2000 pg/ml, 500 pg/ml, 125 pg/ml, and 0 pg/ml. After the removal of the blocking solution from the plate of the above 2)-2-1, each
45 concentration of EPHA2 reference protein solution was added in an amount of 100 $\mu\text{l/well}$ to the plate, and it was then reacted at room temperature for 2 hours.

2)-2-3 Biotinylation labeling

50 **[0087]** The monoclonal antibody 230-1 was subjected to biotinylation labeling using a biotin labeling kit (Dojindo Laboratories) in accordance with experimental procedures.

2)-2-4 Biotin-labeled detection antibody

55 **[0088]** The solution was removed from the plate of the above 2)-2-2 after completion of the reaction, and an ELISA washing solution was then added in an amount of 200 $\mu\text{l/well}$ to the plate. After the obtained mixture had been stirred using a plate mixer for 15 seconds, the washing solution was removed. This washing operation was repeated three times, and thereafter, a biotin-labeled anti-EPHA2 monoclonal antibody 230-1 that had been 1000-fold diluted with an

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assay solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 1 hour.

2)-2-5 Avidin enzyme solution

[0089] The biotin antibody solution was removed from the plate of the above 2)-2-4 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated four times. Thereafter, Streptavidin-HRP (BIOLEGEND) that had been 2000-fold diluted with an assay solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 45 minutes.

2)-2-6 Substrate solution

[0090] The biotin antibody solution was removed from the plate of the above 2)-2-5 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated five times. Thereafter, a TMB solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 15 minutes, so that it was allowed to develop blue color.

2)-2-7 Reaction termination

[0091] A 2 N sulfuric acid solution was added in an amount of 100 μ l/well to the reaction mixture, so that the solution was changed to yellow color as a result of termination of the reaction. Thereafter, the absorbance at 450 nm (reference wavelength: 570 nm) was measured using a microplate reader.

2)-2-8 Results

[0092] In the case of using the biotin-labeled antibody 230-1, it exhibited the highest reactivity, when it was combined with the antibody 57-1, among the examined 11 types of anti-EPHA2 monoclonal antibodies (Figure 2). 2)-3 Sandwich ELISA using anti-EPHA2 antibodies 230-1, 57-1 and SHM41 2)-3-1 Coating of anti-EPHA2 monoclonal antibodies

[0093] As coating antibodies used in sandwich ELISA for detection of EPHA2, the antibodies 57-1, 230-1, and SHM41 were each diluted with PBS to a concentration of 5 μ g/ml, and thereafter, the antibodies were each added in an amount of 100 μ l/well to an EIA/RIA plate high binding type flat bottom 96-well plate. A plate seal was attached to the plate, and the antibodies were then adsorbed on the plate at 4°C for 16 hours or more, followed by performing a blocking treatment. For blocking, an assay solution was 5-fold diluted with deionized water and was then used, and the resultant was left at rest at 4°C overnight.

2)-3-2 Reference protein

[0094] A human EPHA2 reference protein was serially (every 2-fold) diluted from a dilution concentration of 2000 pg/ml to 8 stages of concentrations (minimal concentration: 7.8 pg/ml). The blocking solution was removed from the plate of the above 2)-3-1, and each concentration of EPHA2 reference protein solution was added in an amount of 100 μ l/well to the plate, and it was then reacted at room temperature for 2 hours.

2)-3-3 Biotin-labeled detection antibody

[0095] The solution was removed from the plate of the above 2)-3-2 after completion of the reaction, and an ELISA washing solution was then added in an amount of 200 μ l/well to the plate. After the obtained mixture had been stirred for 15 seconds using a plate mixer, the washing solution was removed. This washing operation was repeated three times, and thereafter, a biotin-labeled anti-EPHA2 monoclonal antibody (57-1 or 230-1) that had been 1000-fold diluted with an assay solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 1 hour.

2)-3-4 Avidin enzyme solution

[0096] The biotin antibody solution was removed from the plate of the above 2)-3-3 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated four times. Thereafter, Streptavidin-HRP that had been 2000-fold diluted with an assay solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 45 minutes.

2)-3-5 Substrate solution

5 [0097] The biotin antibody solution was removed from the plate of the above 2)-3-4 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated five times. Thereafter, a TMB solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 15 minutes, so that it was allowed to develop blue color.

2)-3-6 Reaction termination

10 [0098] A 2 N sulfuric acid solution was added in an amount of 100 μ l/well to the reaction mixture, so that the solution was changed to yellow color as a result of termination of the reaction. Thereafter, the absorbance at 450 nm (reference wavelength: 570 nm) was measured using a microplate reader.

2)-3-7 Results

15 [0099] In a system in which SHM41 was used as a capture antibody and the biotin-labeled antibody 57-1 was used as a detection antibody, EPHA2 was hardly detected. In addition, in a system in which SHM41 was used as a capture antibody and the biotin-labeled antibody 230-1 was used as a detection antibody, EPHA2 was detected, but the background was high. On the other hand, in a system in which the antibody 57-1 or 230-1 was used as a capture antibody, and the biotin-labeled antibody 57-1 or the biotin-labeled antibody 230-1 was used as a detection antibody, it was possible to detect EPHA2, and the background was low. From these results, it was demonstrated that the combination of the antibody 57-1 and the antibody 230-1 was promising for detection of EPHA2 (Figure 3).

2)-4 Construction of EPHA2 sandwich ELISA system

25 [0100] In order to optimize an ELISA system of using the antibodies 57-1 and 230-1, a blocking solution, a diluted solution of the reference protein, and a diluted solution of the biotin-labeled antibody were changed.

2)-4-1 Coating of anti-EPHA2 monoclonal antibody

30 [0101] As coating antibodies used in sandwich ELISA for detection of EPHA2, the antibodies 57-1 and 230-1 were each diluted with PBS to a concentration of 5 μ g/ml, and thereafter, the antibodies were each added in an amount of 100 μ l/well to an EIA/RIA plate high binding type flat bottom 96-well plate. A plate seal was attached to the plate, and the antibodies were then adsorbed on the plate at 4°C for 16 hours or more, followed by performing a blocking treatment. For blocking, SuperBlock Blocking Solution (THERMO SCIENTIFIC) was used, and the resultant was left at rest at 4°C overnight.

2)-4-2 Reference protein

40 [0102] A human EPHA2 reference protein was serially (every 2-fold) diluted from a dilution concentration of 2000 pg/ml to 8 stages of concentrations (minimal concentration: 7.8 pg/ml), using Can Get Signal Solution #1 (TOYOBO LIFE SCIENCE). The blocking solution was removed from the plate of the above 2)-4-1, and each concentration of EPHA2 reference protein solution was added in an amount of 100 μ l/well to the plate, and it was then reacted at room temperature for 2 hours.

2)-4-3 Biotin-labeled detection antibody

50 [0103] The solution was removed from the plate of the above 2)-4-2 after completion of the reaction, and an ELISA washing solution was then added in an amount of 200 μ l/well to the plate. After the obtained mixture had been stirred for 15 seconds using a plate mixer, the washing solution was removed. This washing operation was repeated three times, and thereafter, a biotin-labeled anti-EPHA2 monoclonal antibody (57-1 or 230-1) that had been 1000-fold diluted with Can Get Signal Solution #2 (TOYOBO LIFE SCIENCE) was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 1 hour.

2)-4-4 Avidin enzyme solution

55 [0104] The biotin antibody solution was removed from the plate of the above 2)-4-3 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated four times. Thereafter,

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Streptavidin-HRP that had been 2000-fold diluted with an assay solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 45 minutes.

2)-4-5 Substrate solution

[0105] The biotin antibody solution was removed from the plate of the above 2)-4-4 after completion of the reaction, and thereafter, the operation to wash the solution with an ELISA washing solution was repeated five times. Thereafter, a TMB solution was added in an amount of 100 μ l/well to the reaction solution. The obtained mixture was reacted at room temperature for 15 minutes, so that it was allowed to develop blue color.

2)-4-6 Reaction termination

[0106] A 2 N sulfuric acid solution was added in an amount of 100 μ l/well to the reaction mixture, so that the solution was changed to yellow color as a result of termination of the reaction. Thereafter, the absorbance at 450 nm (reference wavelength: 570 nm) was measured using a microplate reader.

2)-4-7 Results

[0107] Both in a system in which the antibody 57-1 was used as a capture antibody and the biotin-labeled antibody 230-1 was used as a detection antibody, and in a system in which the antibody 230-1 was used as a capture antibody and the biotin-labeled antibody 57-1 was used as a detection antibody, it was possible for these ELISA systems to detect EPHA2, and the background was low. Moreover, in a system in which the antibody 230-1 was used as a capture antibody and the biotin-labeled antibody 57-1 was used as a detection antibody, a higher absorbance value was exhibited in a high concentration region (Figure 4).

2)-5 Calibration curve

[0108] In accordance with the method of Example 2)-4, the antibody 230-1 was used as a coating antibody (capture antibody) in sandwich ELISA, the biotin-labeled antibody 57-1 was used as a detection antibody, and a human EPHA2 reference protein that had been serially diluted from 2000 pg/ml to 7.8 pg/ml was measured. A calibration curve was produced using a cubic polynomial model of Prism 4 (version 4.03, Graph Pad Software, Inc.). As a result, the R^2 value was 0.9998, and the calibration curve showed favorable compatibility in the range from 7.8 pg/ml to 2000 pg/ml (Figure 5).

2)-6 Detection specificity

[0109] Using the method of Example 2)-4, other than the EPHA2 protein, EPHA1, EPHA3 and EPHA4 proteins (SINO BIOLOGICAL) were each diluted to 2000 pg/ml, 1000 pg/ml, 500 pg/ml, and 250 pg/ml in the same manner as described above, and were then measured according to sandwich ELISA. As a result, only EPHA2 was detected by this method, and no cross-reactivity was shown with EPHA1, EPHA3, and EPHA4 (Figure 6). From these results, it was demonstrated that this ELISA system has high specificity to EPHA2.

2)-7 Measurement of EPHA2 value in human serum

2)-7-1 Serum derived from cancer patients

[0110] Cryopreserved serums derived from gastric cancer patients (10 cases), cryopreserved serums derived from ovarian cancer patients (10 cases) and cryopreserved serums derived from healthy donors (10 cases) were acquired from BIOSERVE (agency: ReproCELL). All of the above-described serums were attended with IRB certificates proving the consent of the donors.

[0111] Cryopreserved serums derived from non-small-cell lung cancer patients (10 cases) and cryopreserved serums derived from healthy donors (10 cases) were acquired from ProteoGenex (agency: BizCom Japan, Inc.). All of the above-described serums were attended with IRB certificates proving the consent of the donors.

2)-7-2 Measurement of EPHA2 value in serum

[0112] In accordance with the method of Example 2)-4, various types of serums (from healthy donors, gastric cancer patients, and ovarian cancer patients) were 5-fold diluted with Can Get Signal Solution #1, and were then measured by sandwich ELISA.

2)-7-3 statistical analysis

[0113] A statistical analysis was carried out using Steel test (SAS System Release 9.2, SAS Institute Inc.).

5 2)-7-4 Results

[0114] The medians of the EPHA2 concentrations in the serums of healthy donors, gastric cancer patients, and ovarian cancer patients were 372 pg/ml, 647 pg/ml, and 600 pg/ml, respectively. The EPHA2 concentration in the blood of the gastric cancer patients was significantly higher than that in the healthy donors (P = 0.0142) (Figure 7-1).

10 **[0115]** The medians of the EPHA2 concentrations in the serums of healthy donors and non-small-cell lung cancer patients were 232 pg/ml and 645 pg/ml, respectively. In addition, the mean values thereof were 231 pg/ml and 1,031 pg/ml, respectively. The EPHA2 concentration in the blood of the non-small-cell lung cancer patients was significantly higher than that in the healthy donors (P = 0.0024) (Figure 7-2).

15 [Example 3]

Determination of nucleotide sequence of cDNA encoding variable region of mouse anti-EPHA2 monoclonal antibody

20 3)-1 Determination of nucleotide sequence of cDNA encoding variable region of mouse anti-EPHA2 antibody 57-1

3)-1-1 Preparation of total RNA from antibody 57-1 producing hybridomas

[0116] Total RNA was prepared from the antibody 57-1 producing hybridomas, using TRIzol Reagent (Ambion).

25 3)-1-2 Synthesis of cDNA (5'-RACE-Ready cDNA)

[0117] Using 1 µg of the total RNA prepared in Example 3)-1-1 and SMARTer RACE 5'/3' Kit (Clontech), cDNA (5'-RACE-Ready cDNA) was synthesized.

30 3)-1-3 Amplification of cDNA encoding heavy chain variable region of antibody 57-1 according to 5'-RACE PCR, and determination of nucleotide sequence thereof

[0118] In order to amplify cDNA encoding the heavy chain variable region of the antibody 57-1 according to PCR, the following primers were used:

35 UPM (Universal Primer A Mix: included with SMARTer RACE 5'/3' Kit), and
5'-CATCCCAGGGTCACCATGGAGTTAGTTTGG-3' (mG1VR1: SEQ ID NO: 12). The mG1VR1 was designed based on the sequence of the constant region of the mouse heavy chain (IgG1) shown in database.

40 **[0119]** Using these primers, and also using the cDNA (5'-RACE-Ready cDNA) synthesized in Example 3)-1-2 as a template, cDNA encoding the heavy chain variable region of the antibody 57-1 was amplified according to 5'-RACE PCR. This PCR was carried out using KOD-Plus- (TOYOBO) as polymerase, by the touchdown PCR program described in the instruction manual of SMARTer RACE 5'/3' Kit.

[0120] The amplified cDNA fragment was purified using MinElute PCR Purification Kit (QIAGEN), and was then cloned using Zero Blunt TOPO PCR Cloning Kit (Invitrogen, Thermo Fisher Scientific).

[0121] In order to determine the nucleotide sequence of the cloned cDNA fragment, the following sequencing primers were used:

50 5'-CATCCCAGGGTCACCATGGAGTTAGTTTGG-3' (mG1VR1: SEQ ID NO: 12); and
5'-AAGCAGTGGTATCAACGCAGAGT-3' (NUP: SEQ ID NO: 13).

[0122] The sequencing reaction was carried out using GeneAmp 9700 (Applied Biosystems, current Thermo Fisher Scientific), and the sequencing of the DNA was carried out using ABI PRISM 3700 DNA Analyzer (Applied Biosystems, current Thermo Fisher Scientific) or Applied Biosystems 3730xl Analyzer (Applied Biosystems, current Thermo Fisher Scientific).

55 **[0123]** The determined nucleotide sequence of the cDNA encoding the heavy chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 14 (Figure 8), and the amino acid sequence thereof is as set forth in SEQ ID NO: 15 (Figure 9).

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3)-1-4 Amplification of cDNA encoding light chain variable region of antibody 57-1 according to 5'-RACE PCR, and determination of nucleotide sequence thereof

5 **[0124]** In order to amplify cDNA encoding the light chain variable region of the antibody 57-1 according to PCR, the following primers were used:

UPM (Universal Primer A Mix: included with SMARTer RACE 5'/3' Kit), and
5'-AGTCCAACCTGTTTCAGGACGCCATTTTGTCTG-3'(mKVR2:SEQ ID NO: 16).

10 The mKVR2 was designed based on the sequence of the constant region of the mouse light chain shown in database.

[0125] Using these primers, and also using the cDNA (5'-RACE-Ready cDNA) synthesized in Example 3)-1-2 as a template, cDNA encoding the light chain variable region of the antibody 57-1 was amplified according to 5'-RACE PCR. This PCR was carried out using KOD-Plus- (TOYOBO) as polymerase, by the touchdown PCR program described in the instruction manual of SMARTer RACE 5'/3' Kit.

15 **[0126]** The amplified cDNA fragment was purified using MinElute PCR Purification Kit (QIAGEN), and was then cloned using Zero Blunt TOPO PCR Cloning Kit (Invitrogen, Thermo Fisher Scientific).

[0127] In order to determine the nucleotide sequence of the cloned cDNA fragment, the following sequencing primers were used:

20 5'-AGTCCAACCTGTTTCAGGACGCCATTTTGTCTG-3' (mKVR2: SEQ ID NO: 16); and
5'-AAGCAGTGGTATCAACGCAGAGT-3' (NUP: SEQ ID NO: 13).

25 **[0128]** The sequencing reaction was carried out using GeneAmp 9700 (Applied Biosystems, current Thermo Fisher Scientific), and the sequencing of the DNA was carried out using ABI PRISM 3700 DNA Analyzer (Applied Biosystems, current Thermo Fisher Scientific) or Applied Biosystems 3730xl Analyzer (Applied Biosystems, current Thermo Fisher Scientific).

[0129] The determined nucleotide sequence of the cDNA encoding the light chain variable region of the antibody 57-1 is as set forth in SEQ ID NO: 17 in the sequence listing (Figure 10), and the amino acid sequence thereof is as set forth in SEQ ID NO: 18 (Figure 11).

30 3)-2 Determination of nucleotide sequence of cDNA encoding variable region of mouse anti-EPHA2 antibody 230-1

3)-2-1 Preparation of total RNA from antibody 230-1 producing hybridomas

35 **[0130]** Total RNA was prepared from the antibody 230-1 producing hybridomas by the same method as that of Example 3)-1-1.

3)-2-2 Synthesis of cDNA (5'-RACE-Ready cDNA)

40 **[0131]** Using 1 µg of the total RNA prepared in Example 3)-2-1, cDNA (5'-RACE-Ready cDNA) was synthesized by the same method as that of Example 3)-1-2.

3)-2-3 Amplification of cDNA encoding heavy chain variable region of antibody 230-1 according to 5'-RACE PCR, and determination of nucleotide sequence thereof

45 **[0132]** Using the cDNA (5'-RACE-Ready cDNA) synthesized in Example 3)-2-2 as a template, cDNA encoding the heavy chain variable region of the antibody 230-1 was amplified by the same method as that of Example 3)-1-3, and the nucleotide sequence thereof was then determined.

50 **[0133]** The determined nucleotide sequence of the cDNA encoding the heavy chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 19 in the sequence listing (Figure 12), and the amino acid sequence thereof is as set forth in SEQ ID NO: 20 (Figure 13).

3)-2-4 Amplification of cDNA encoding light chain variable region of antibody 230-1 according to 5'-RACE PCR, and determination of nucleotide sequence thereof

55 **[0134]** Using the cDNA (5'-RACE-Ready cDNA) synthesized in Example 3)-2-2 as a template, cDNA encoding the light chain variable region of the antibody 230-1 was amplified by the same method as that of Example 3)-1-4, and the nucleotide sequence thereof was then determined.

[0135] The determined nucleotide sequence of the cDNA encoding the light chain variable region of the antibody 230-1 is as set forth in SEQ ID NO: 21 in the sequence listing (Figure 14), and the amino acid sequence thereof is as set forth in SEQ ID NO: 22 (Figure 15).

5 Industrial Applicability

[0136] The antibody of the present invention is suitable for measuring EPHA2 in a biological sample by a sandwich immunoassay, and can be utilized in detection of cancer, etc.

10 Sequence Listing Free Text

[0137] SEQ ID NOS: 1 to 4, 7 to 10, 12, 13 and 16 Primers

[0138] All publications, patents and patent applications cited in the present description are incorporated herein by reference in their entirety.

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							135					140					
35	Ile	Ala	Pro	Asp	Glu	Ile	Thr	Val	Ser	Ser	Asp	Phe	Glu	Ala	Arg	His	
	145					150					155					160	
40	Val	Lys	Leu	Asn	Val	Glu	Glu	Arg	Ser	Val	Gly	Pro	Leu	Thr	Arg	Lys	
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45	Gly	Phe	Tyr	Leu	Ala	Phe	Gln	Asp	Ile	Gly	Ala	Cys	Val	Ala	Leu	Leu	
				180					185					190			
50	Ser	Val	Arg	Val	Tyr	Tyr	Lys	Lys	Cys	Pro	Glu	Leu	Leu	Gln	Gly	Leu	
			195					200					205				
55	Ala	His	Phe	Pro	Glu	Thr	Ile	Ala	Gly	Ser	Asp	Ala	Pro	Ser	Leu	Ala	
							215					220					
60	Thr	Val	Ala	Gly	Thr	Cys	Val	Asp	His	Ala	Val	Val	Pro	Pro	Gly	Gly	
	225					230					235				240		
65	Glu	Glu	Pro	Arg	Met	His	Cys	Ala	Val	Asp	Gly	Glu	Trp	Leu	Val	Pro	
					245					250					255		
70	Ile	Gly	Gln	Cys	Leu	Cys	Gln	Ala	Gly	Tyr	Glu	Lys	Val	Glu	Asp	Ala	
				260					265					270			
75	Cys	Gln	Ala	Cys	Ser	Pro	Gly	Phe	Phe	Lys	Phe	Glu	Ala	Ser	Glu	Ser	
			275					280					285				

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Pro Cys Leu Glu Cys Pro Glu His Thr Leu Pro Ser Pro Glu Gly Ala
 290 295 300

5 Thr Ser Cys Glu Cys Glu Glu Gly Phe Phe Arg Ala Pro Gln Asp Pro
 305 310 315 320

Ala Ser Met Pro Cys Thr Arg Pro Pro Ser Ala Pro His Tyr Leu Thr
 10 325 330 335

Ala Val Gly Met Gly Ala Lys Val Glu Leu Arg Trp Thr Pro Pro Gln
 15 340 345 350

Asp Ser Gly Gly Arg Glu Asp Ile Val Tyr Ser Val Thr Cys Glu Gln
 355 360 365

20 Cys Trp Pro Glu Ser Gly Glu Cys Gly Pro Cys Glu Ala Ser Val Arg
 370 375 380

Tyr Ser Glu Pro Pro His Gly Leu Thr Arg Thr Ser Val Thr Val Ser
 25 385 390 395 400

Asp Leu Glu Pro His Met Asn Tyr Thr Phe Thr Val Glu Ala Arg Asn
 405 410 415

30 Gly Val Ser Gly Leu Val Thr Ser Arg Ser Phe Arg Thr Ala Ser Val
 420 425 430

Ser Ile Asn Gln Thr Glu Pro Pro Lys Val Arg Leu Glu Gly Arg Ser
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Thr Thr Ser Leu Ser Val Ser Trp Ser Ile Pro Pro Pro Gln Gln Ser
 40 450 455 460

Arg Val Trp Lys Tyr Glu Val Thr Tyr Arg Lys Lys Gly Asp Ser Asn
 465 470 475 480

45 Ser Tyr Asn Val Arg Arg Thr Glu Gly Phe Ser Val Thr Leu Asp Asp
 485 490 495

Leu Ala Pro Asp Thr Thr Tyr Leu Val Gln Val Gln Ala Leu Thr Gln
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Glu Gly Gln Gly Ala Gly Ser Lys Val His Glu Phe Gln Thr Leu Ser
 515 520 525

55 Pro Glu Gly Ser Gly Asn Leu Ala Val Ile Gly Gly Val Ala Val Gly
 530 535 540

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Val Val Leu Leu Leu Val Leu Ala Gly Val Gly Phe Phe Ile His Arg
 545 550 555 560
 5 Arg Arg Lys Asn Gln Arg Ala Arg Gln Ser Pro Glu Asp Val Tyr Phe
 565 570 575
 10 Ser Lys Ser Glu Gln Leu Lys Pro Leu Lys Thr Tyr Val Asp Pro His
 580 585 590
 15 Thr Tyr Glu Asp Pro Asn Gln Ala Val Leu Lys Phe Thr Thr Glu Ile
 595 600 605
 His Pro Ser Cys Val Thr Arg Gln Lys Val Ile Gly Ala Gly Glu Phe
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 20 Gly Glu Val Tyr Lys Gly Met Leu Lys Thr Ser Ser Gly Lys Lys Glu
 625 630 635 640
 25 Val Pro Val Ala Ile Lys Thr Leu Lys Ala Gly Tyr Thr Glu Lys Gln
 645 650 655
 Arg Val Asp Phe Leu Gly Glu Ala Gly Ile Met Gly Gln Phe Ser His
 660 665 670
 30 His Asn Ile Ile Arg Leu Glu Gly Val Ile Ser Lys Tyr Lys Pro Met
 675 680 685
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 Arg Glu Lys Asp Gly Glu Phe Ser Val Leu Gln Leu Val Gly Met Leu
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 40 Arg Gly Ile Ala Ala Gly Met Lys Tyr Leu Ala Asn Met Asn Tyr Val
 725 730 735
 45 His Arg Asp Leu Ala Ala Arg Asn Ile Leu Val Asn Ser Asn Leu Val
 740 745 750
 50 Cys Lys Val Ser Asp Phe Gly Leu Ser Arg Val Leu Glu Asp Asp Pro
 755 760 765
 Glu Ala Thr Tyr Thr Thr Ser Gly Gly Lys Ile Pro Ile Arg Trp Thr
 770 775 780
 55 Ala Pro Glu Ala Ile Ser Tyr Arg Lys Phe Thr Ser Ala Ser Asp Val
 785 790 795 800

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Trp Ser Phe Gly Ile Val Met Trp Glu Val Met Thr Tyr Gly Glu Arg
805 810 815

5 Pro Tyr Trp Glu Leu Ser Asn His Glu Val Met Lys Ala Ile Asn Asp
820 825 830

10 Gly Phe Arg Leu Pro Thr Pro Met Asp Cys Pro Ser Ala Ile Tyr Gln
835 840 845

15 Leu Met Met Gln Cys Trp Gln Gln Glu Arg Ala Arg Arg Pro Lys Phe
850 855 860

Ala Asp Ile Val Ser Ile Leu Asp Lys Leu Ile Arg Ala Pro Asp Ser
865 870 875 880

20 Leu Lys Thr Leu Ala Asp Phe Asp Pro Arg Val Ser Ile Arg Leu Pro
885 890 895

25 Ser Thr Ser Gly Ser Glu Gly Val Pro Phe Arg Thr Val Ser Glu Trp
900 905 910

30 Leu Glu Ser Ile Lys Met Gln Gln Tyr Thr Glu His Phe Met Ala Ala
915 920 925

Gly Tyr Thr Ala Ile Glu Lys Val Val Gln Met Thr Asn Asp Asp Ile
930 935 940

35 Lys Arg Ile Gly Val Arg Leu Pro Gly His Gln Lys Arg Ile Ala Tyr
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 <211> 348
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 30 20 25 30
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 35 35 40 45
 Ala Trp Ile Asn Thr Asp Thr Gly Glu Pro Ile Phe Val Glu Glu Phe
 50 55 60
 Lys Gly Arg Phe Ala Phe Ser Leu Glu Thr Ser Ala Ser Thr Ala Tyr
 40 65 70 75 80
 Leu Gln Ile Asn Asn Leu Thr Asn Glu Asp Thr Ala Thr Tyr Phe Cys
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catgaatctc caaggcttct catcaaatat gcttcccaat ccatctctgg gatcccctcc 180

aggttcagtg gcagtgatc aggtcagat ttcactctca ctatcaacag tgtggaacct 240

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35 Asp Arg Val Ser Leu Ser Cys Arg Ala Ser Gln Asn Ile Ser Asp Tyr
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40 Leu His Trp Tyr Gln Gln Lys Ser His Glu Ser Pro Arg Leu Leu Ile
35 40 45

Lys Tyr Ala Ser Gln Ser Ile Ser Gly Ile Pro Ser Arg Phe Ser Gly
50 55 60

45 Ser Gly Ser Gly Ser Asp Phe Thr Leu Thr Ile Asn Ser Val Glu Pro
65 70 75 80

50 Glu Asp Val Ala Met Tyr Tyr Cys Gln Asn Gly His Thr Phe Pro Thr
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 10 ccgaaaaaga ggctggagtg ggtcgcaacc attagtgatg atggtagttt caccactat 180
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 ctccaaatga gtagtctgaa gtctgacgac acagccatgt attactgtgc aagagacggc 300
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 30 Tyr Met Tyr Trp Val Arg Gln Thr Pro Glu Lys Arg Leu Glu Trp Val
 35 40 45
 Ala Thr Ile Ser Asp Asp Gly Ser Phe Thr His Tyr Leu Asp Ser Val
 50 55 60
 Lys Gly Arg Phe Thr Ile Ser Arg Asp Asn Ala Gln Asn Asn Leu Tyr
 65 70 75 80
 40 Leu Gln Met Ser Ser Leu Lys Ser Asp Asp Thr Ala Met Tyr Tyr Cys
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 50 Gly Thr Leu Val Thr Val Ser Ala
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 <213> Mus musculus

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 5 gggcaatctc ctaaactact gatttactgg gcatccaccc ggcacactgg agtccctgat 180
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 35 40 45

Tyr Trp Ala Ser Thr Arg His Thr Gly Val Pro Asp Arg Phe Thr Gly
 50 55 60

Ser Gly Ser Gly Thr Asp Tyr Ser Leu Thr Ile Ser Ser Val Gln Ala
 65 70 75 80

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 85 90 95

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 100 105

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<210> 24
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Gly

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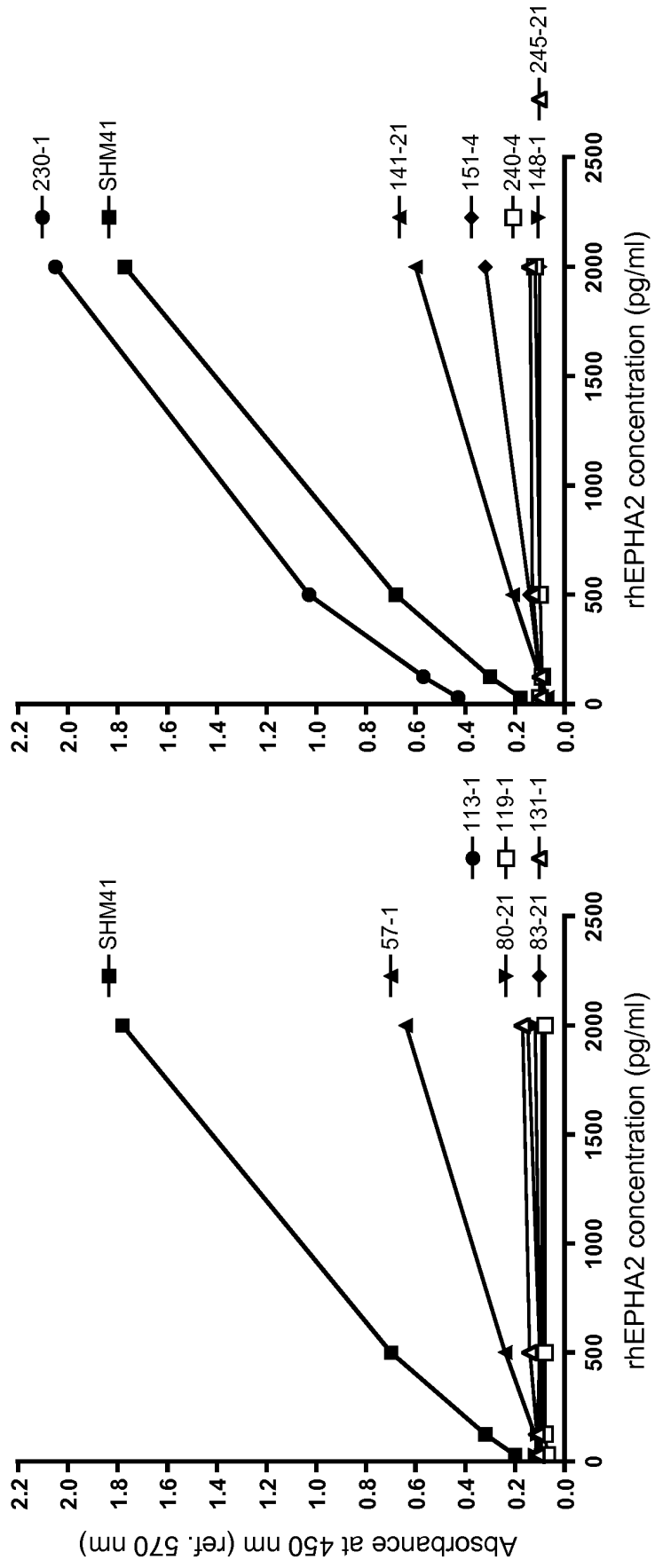
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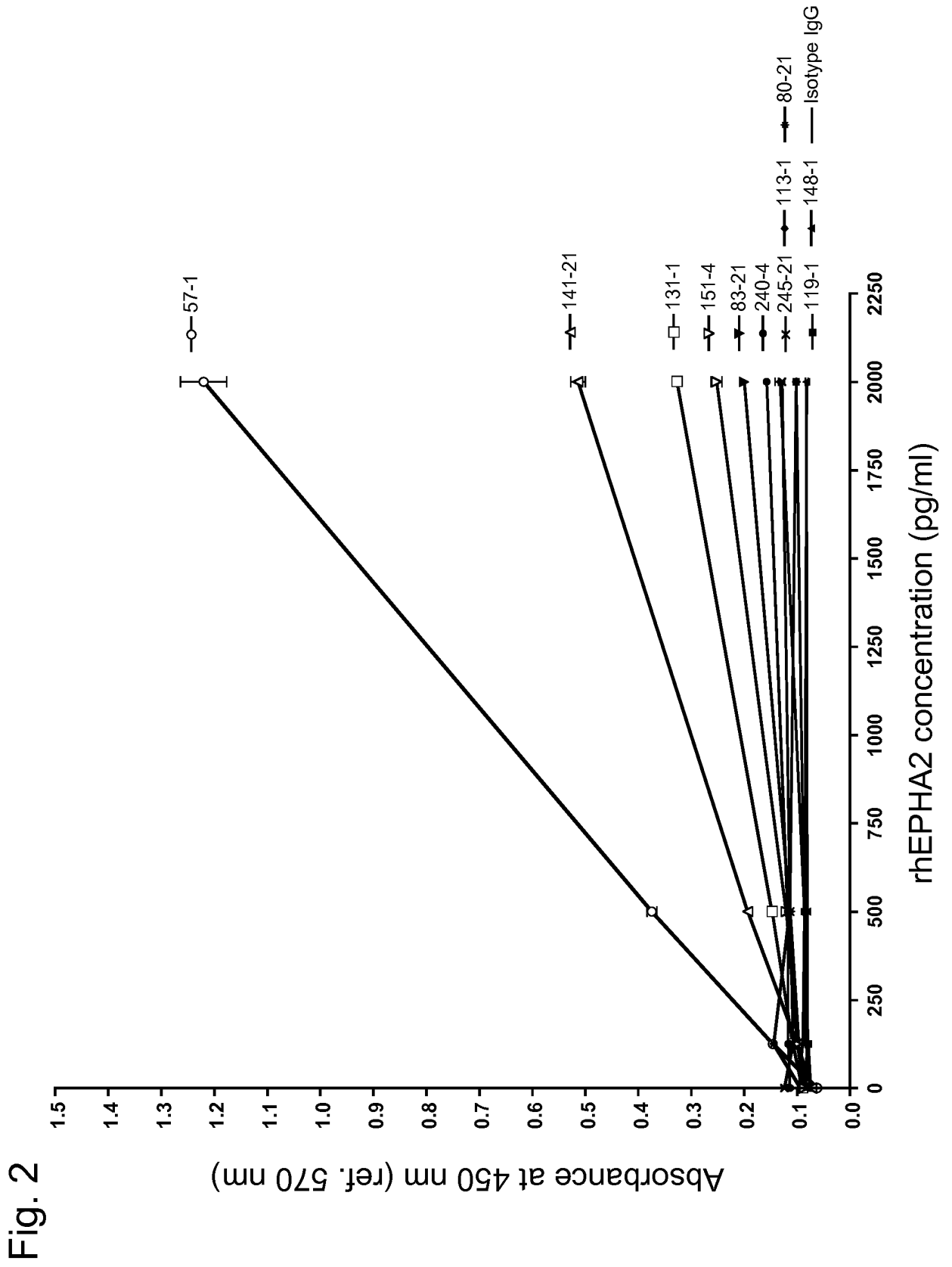
1. A monoclonal antibody specifically binding to EPHA2, comprising:
 - (a) a heavy chain CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 29,
 - (b) a heavy chain CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 30,
 - (c) a heavy chain CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 31,
 - (d) a light chain CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 32,
 - (e) a light chain CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 33, and
 - (f) a light chain CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 34, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
2. A monoclonal antibody specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 20 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 22, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
3. A monoclonal antibody specifically binding to EPHA2, comprising: a heavy chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 20, and having binding activity to human EPHA2; and a light chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 22, and having binding activity to human EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
4. A monoclonal antibody specifically binding to EPHA2, comprising:
 - (a) a heavy chain CDRH1 consisting of the amino acid sequence as set forth in SEQ ID NO: 23,
 - (b) a heavy chain CDRH2 consisting of the amino acid sequence as set forth in SEQ ID NO: 24,
 - (c) a heavy chain CDRH3 consisting of the amino acid sequence as set forth in SEQ ID NO: 25,
 - (d) a light chain CDRL1 consisting of the amino acid sequence as set forth in SEQ ID NO: 26,
 - (e) a light chain CDRL2 consisting of the amino acid sequence as set forth in SEQ ID NO: 27, and
 - (f) a light chain CDRL3 consisting of the amino acid sequence as set forth in SEQ ID NO: 28, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
5. A monoclonal antibody specifically binding to EPHA2, comprising a heavy chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 15 and a light chain variable region consisting of the amino acid sequence as set forth in SEQ ID NO: 18, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
6. A monoclonal antibody specifically binding to EPHA2, comprising: a heavy chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 15, and having binding activity to human EPHA2; and a light chain variable region consisting of an amino acid sequence having a sequence identity of 95% or more to the amino acid sequence as set forth in SEQ ID NO: 18, and having binding activity to human EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2.
7. A combination of two types of monoclonal antibodies; namely, the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 3, or a functional fragment of the monoclonal antibody specifically binding to EPHA2, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 4 to 6.
8. The combination according to claim 7, which is used in a method for detecting or measuring EPHA2 in a biological sample.
9. A method for specifically detecting EPHA2 contained in a biological sample according to an immunoassay, which uses the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 6.

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- 5
10. A method for specifically detecting EPHA2 contained in a biological sample according to a sandwich immunoassay, which uses two types of monoclonal antibodies; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 3, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 4 to 6.
11. The method according to claim 10, wherein the sandwich immunoassay is ELISA.
- 10
12. A method for detecting cancer, which comprises: measuring the concentration of EPHA2 in the blood of a subject according to an immunoassay, using the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 6; and evaluating that the subject suffers from cancer, when the concentration of EPHA2 in the blood of the subject is higher than the concentration of EPHA2 in the blood of a healthy donor.
- 15
13. A method for detecting cancer, which comprises: measuring the concentration of EPHA2 in the blood of a subject according to a sandwich immunoassay, using two types of monoclonal antibodies, namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 3, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 4 to 6; and evaluating that the subject suffers from cancer, when the concentration of EPHA2 in the blood of the subject is higher than the concentration of EPHA2 in the blood of a healthy donor.
- 20
14. The method according to claim 13, wherein the sandwich immunoassay is ELISA.
- 25
15. The method according to any one of claims 12 to 14, wherein the cancer is selected from the group consisting of gastric cancer, ovarian cancer, breast cancer, esophageal cancer, prostate cancer, non-small-cell lung cancer, colon cancer, pancreatic cancer, liver cancer, bladder cancer, cervical cancer, uterine cancer, kidney cancer, brain tumor, malignant melanoma, and head and neck cancer.
- 30
16. A kit for measuring EPHA2, comprising two types of monoclonal antibodies or functional fragments thereof; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 3, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 4 to 6.
- 35
17. A kit for detecting cancer, comprising two types of monoclonal antibodies or functional fragments thereof; namely, the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 1 to 3, and the monoclonal antibody specifically binding to EPHA2, or a functional fragment of the monoclonal antibody specifically binding to EPHA2 according to any one of claims 4 to 6.
- 40
18. The kit according to claim 16, wherein the cancer is selected from the group consisting of gastric cancer, ovarian cancer, breast cancer, esophageal cancer, prostate cancer, non-small-cell lung cancer, colon cancer, pancreatic cancer, liver cancer, bladder cancer, cervical cancer, uterine cancer, kidney cancer, brain tumor, malignant melanoma, and head and neck cancer.
- 45
- 50
- 55

Fig. 1





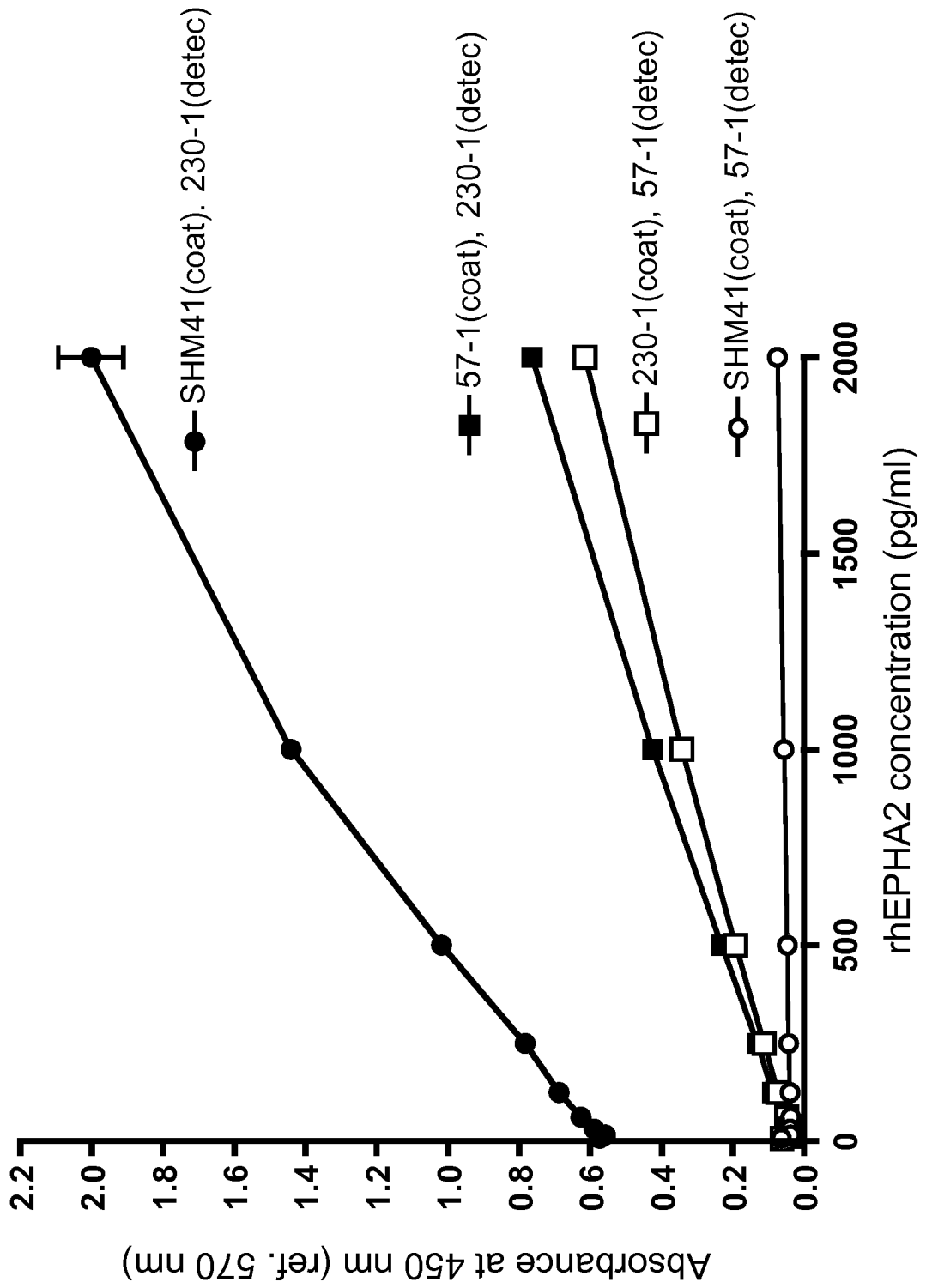


Fig. 3

Fig. 4

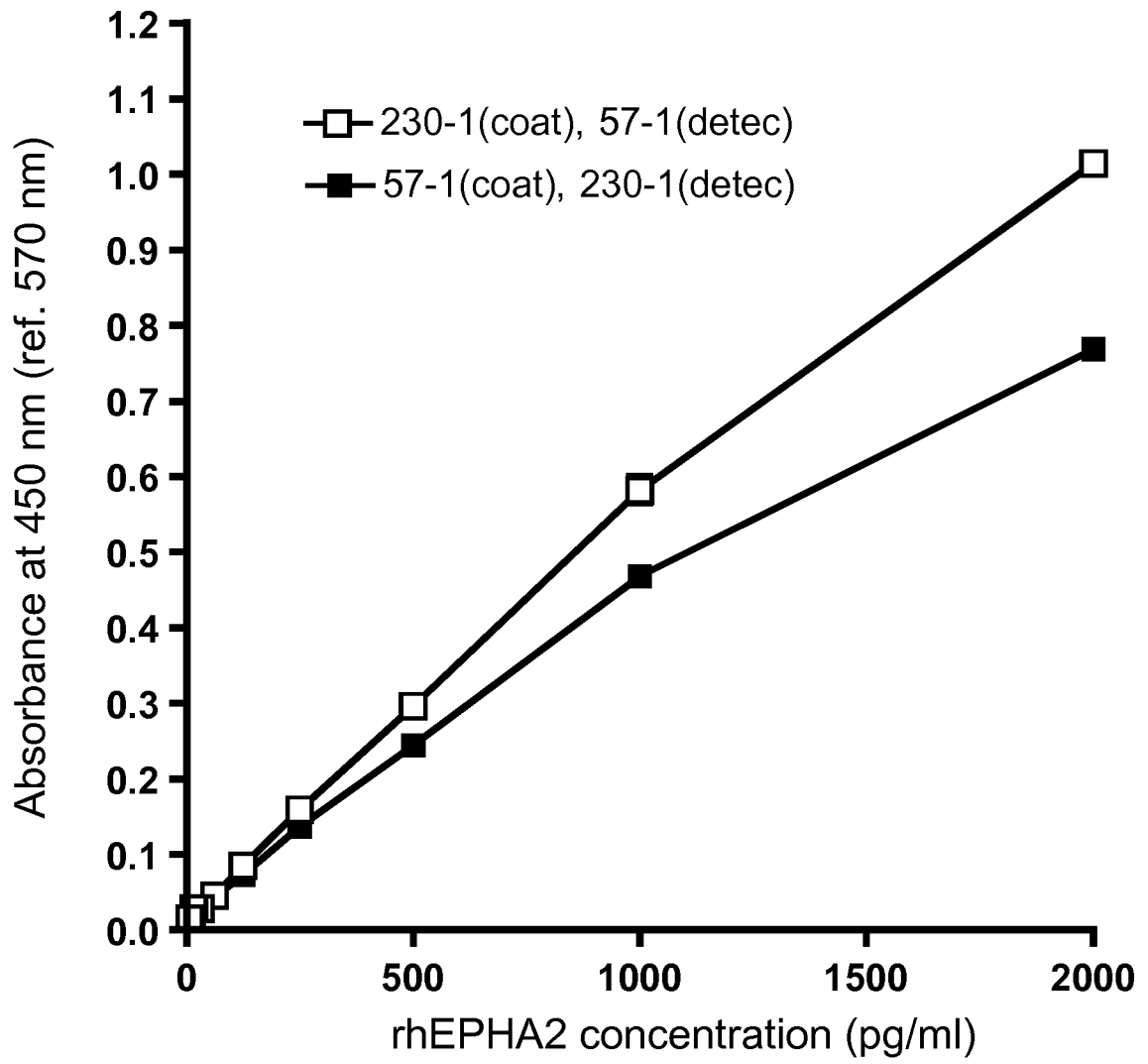


Fig. 5

$$y = -5.974E-11x^3 + 1.048E-07x^2 + 0.0006376x + 0.01477$$
$$R^2 = 0.9998$$

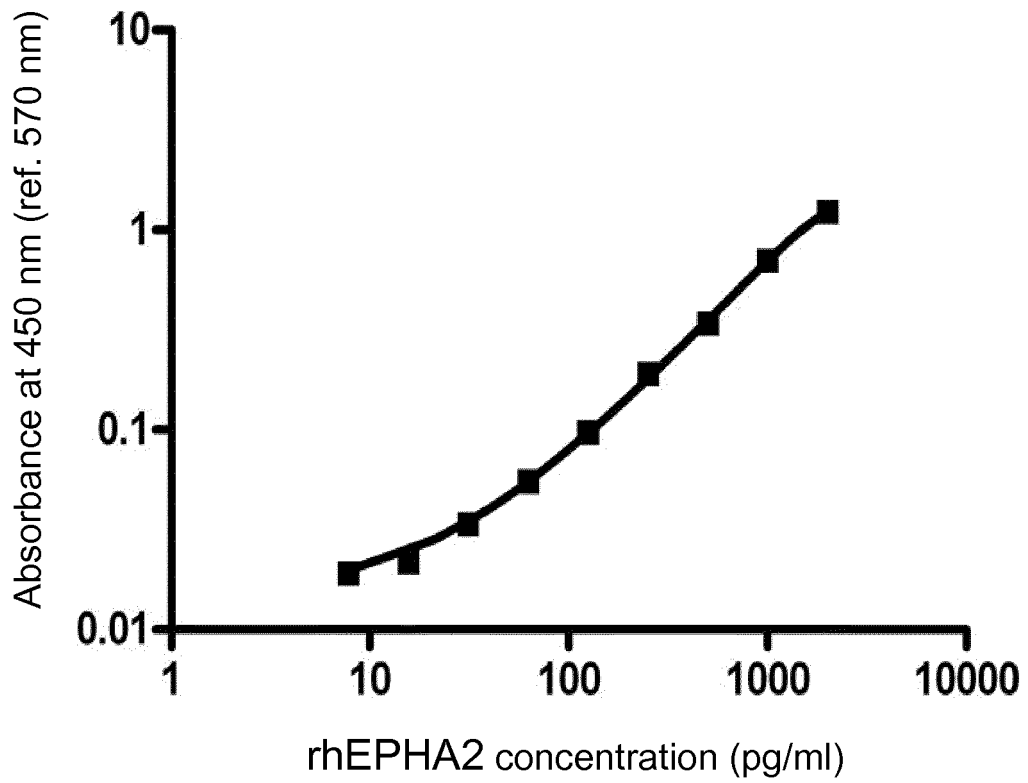


Fig. 6

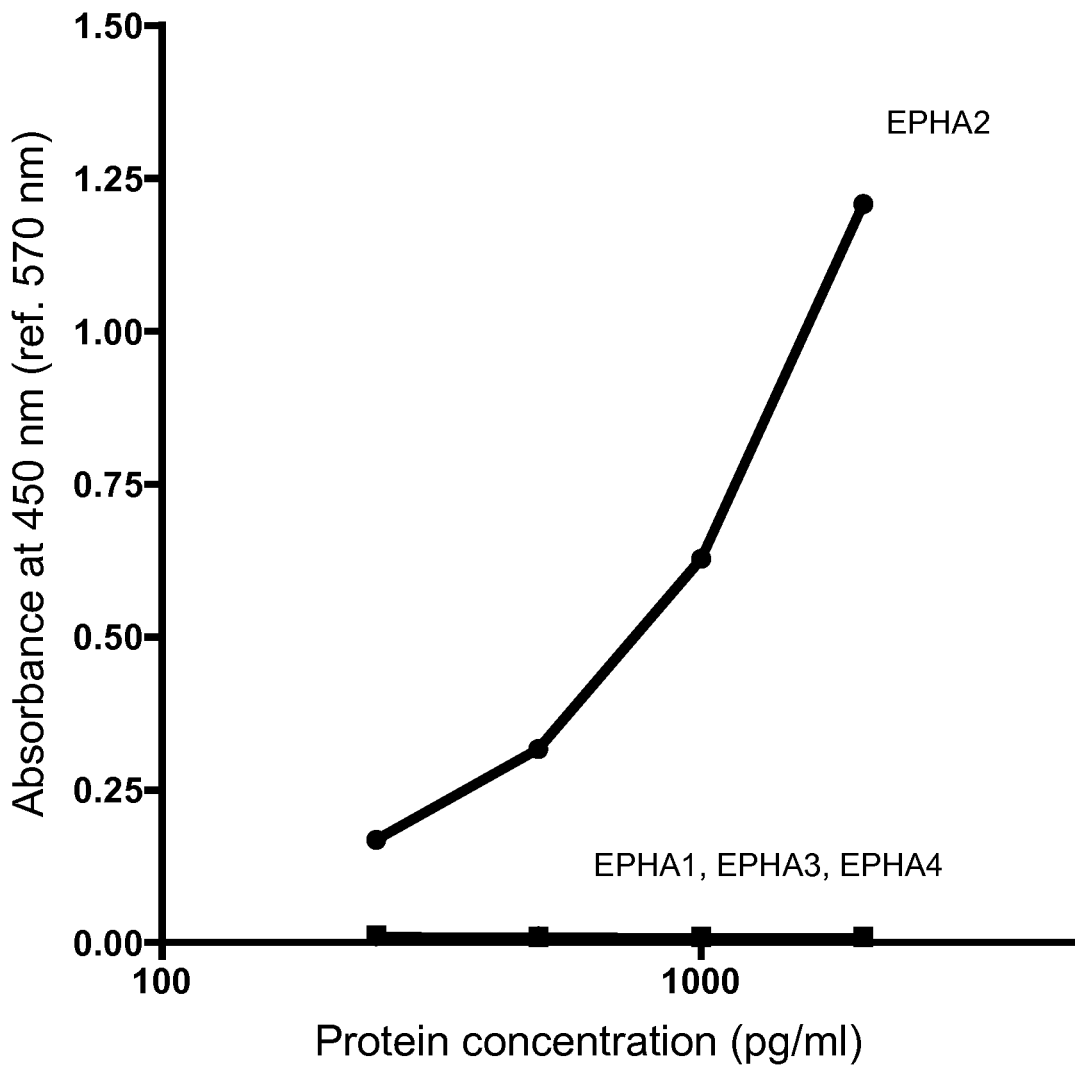


Fig. 7-1

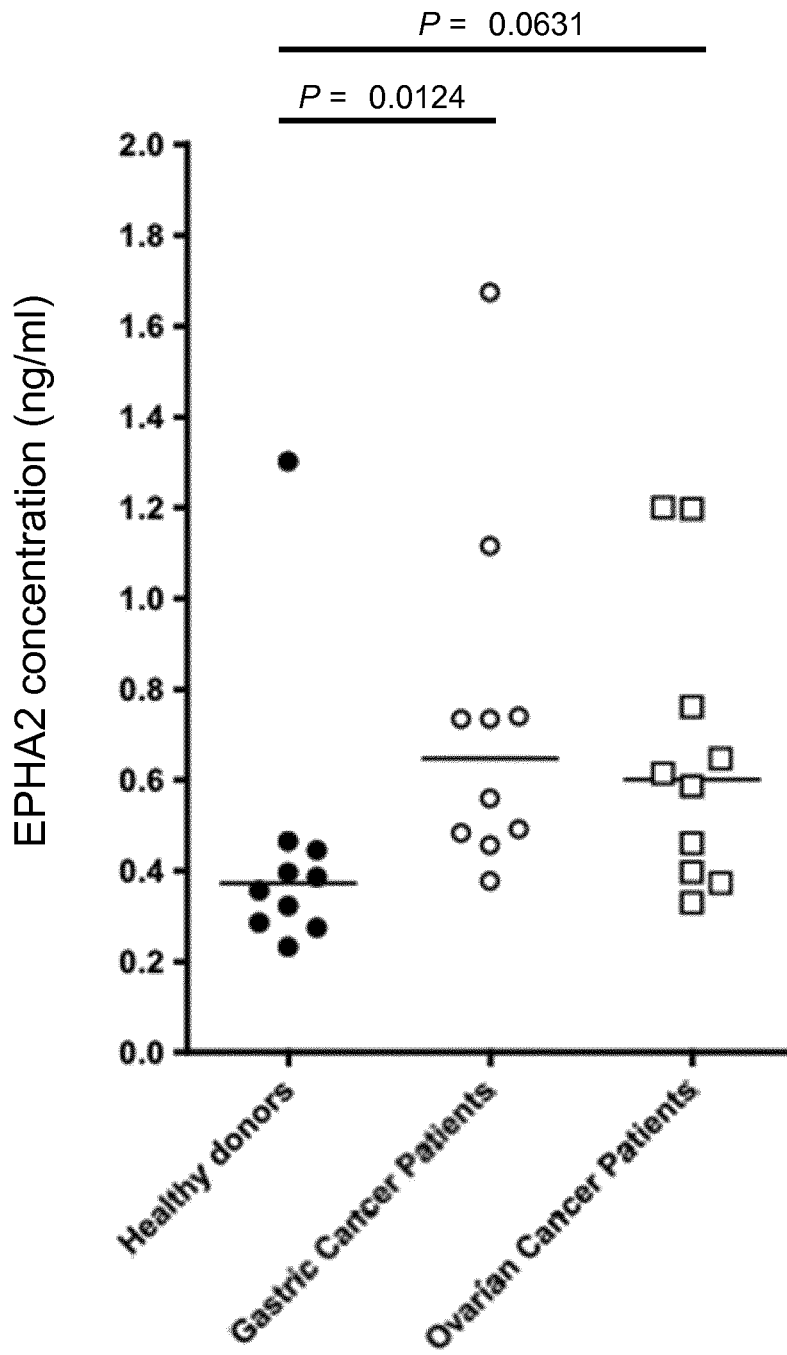


Fig. 7-2

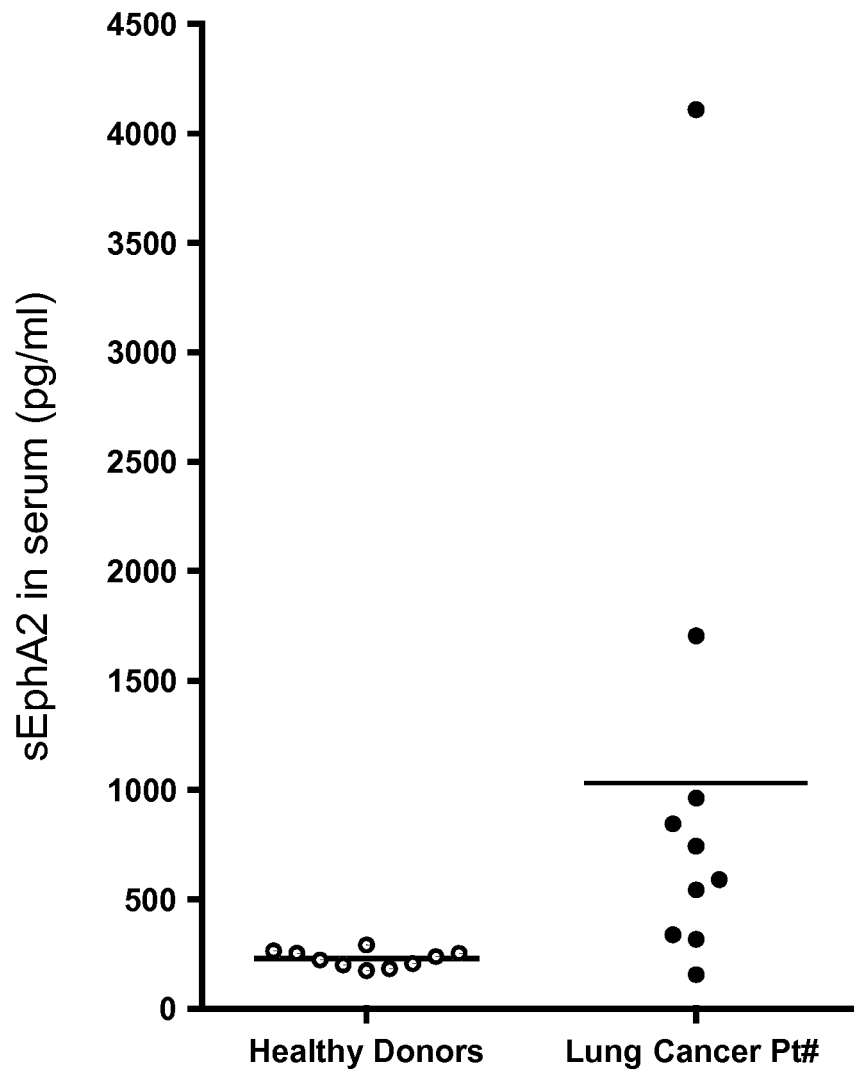


Fig. 8

Nucleotide sequence of cDNA encoding heavy chain variable region of mouse anti-EPHA2 antibody 57-1 (SEQ ID NO: 14)

```
cagatccagttggtgcagtctggacctgagctgaagaagcctggagagacagtcaagatc
tctgcaagggttctgggtataccttcacaaactatggaatgaactgggtgaagcaggct
ccaggaaagggtttaaagtggatggcctggataaacaccgacactggagagccaatattt
gttgaagagttcaagggacggtttgccttctctttggaaacctctgccagcactgcctat
ttgcagatcaacaacctcaciaatgaggacacggctacatatttctgtgcaagatctatg
gggggctttgctaactggggccaagggactctggtcactgtctctgca
```

Fig. 9

Amino acid sequence of heavy chain variable region of mouse anti-EPHA2 antibody 57-1 (SEQ ID NO: 15)

QIQLVQSGPELKKPGETVKISCKGSGYFTFTNYGMNWKQAPGKGLKWMWINTDTGEP
VEEFKGRFAFSLETSASTAYLQINNLTNEDTATYFCARSMGGFANWGQGLTVTSA

Fig. 10

Nucleotide sequence of cDNA encoding light chain variable region of mouse anti-EPHA2 antibody 57-1 (SEQ ID NO: 17)

```
gacattgtgatgactcagtctccagccaccctgtctgtgactccaggagatagagtctct  
cttcctgcagggccagccagaatattagcgactacttacactggtatcaacaaaaatca  
catgaatctccaaggcttctcatcaaataatgcttcccaatccatctctgggatcccctcc  
aggttcagtggcagtggatcagggtcagatttcactctcactatcaacagtggtggaacct  
gaagatgttgcaatgtattactgtcaaaatgggtcacacctttcccacggttcgggtgctggg  
accaagctggagctgaaacgggct
```

Fig. 11

Amino acid sequence of light chain variable region of mouse anti-EPHA2 antibody 57-1 (SEQ ID NO: 18)

DIVMTQSPATLSVTPGDRVSLSCRASQNI SDYLHWYQQKSHESPRLLIKYASQSIGIPS
RFSGSGSGSDFTLTINSVEPEDVAMYQCNGHTFPTFGAGTKLELKRA

Fig. 12

Nucleotide sequence of cDNA encoding heavy chain variable region of mouse anti-EPHA2 antibody 230-1 (SEQ ID NO: 19)

```
gaagtgcagctggtggagtctgggggaggcttagtgaagcctggaggggtcccttaactc
tcctgtgaagcctctggattcactttcagtgactattacatgtattgggttcggcagact
ccgaaaagaggctggagtgggtcgcaaccattagtgatgatggtagtttcacccactat
ctagacagtgtgaaggggcgattcaccatctccagagacaatgccagaacaacctgtac
ctccaaatgagtagtctgaagtctgacgacacagccatgtattactgtgcaagagacggc
tataggtacgacaggccgtttgcttactggggccaagggactctgggtcactgtctctgca
```

Fig. 13

Amino acid sequence of heavy chain variable region of mouse anti-EPHA2 antibody 230-1 (SEQ ID NO: 20)

EVQLVESGGGLVKPGGSLKLSCEASGFTFSDYYMYWVRQTPEKRLEWVATISDDGSFTHY
LDSVKGRFTISRDNAQNNLYLQMSLKSDDTAMYYCARDGYRYDRPFAYWGQGLTVTSA

Fig. 14

Nucleotide sequence of cDNA encoding light chain variable region of mouse anti-EPHA2 antibody 230-1 (SEQ ID NO: 21)

```
gacattgtgatgaccagcttcacaaattcatgtccacatcagtaggagacaggggccg  
atcacctgcaaggccagtcaggatgtgaatactgctgtagcctgggtatcaacaaaacca  
gggcaatctcctaaactactgatttactgggcatccacccggcacactggagtcctgat  
cgattcacaggcagtgatctgggacagattattctctcaccatcagcagtggtgcaggct  
gaagacctggcactttattactgtcaacaacattatagcactccgtacacggttcggaggg  
gggaccaagctggagataaaaacgggct
```

Fig. 15

Amino acid sequence of light chain variable region of mouse
anti-EPHA2 antibody 230-1 (SEQ ID NO: 22)

DIVMTQSHKFMSTSVGDRVRITCKASQDVNTAVAWYQQKPGQSPKLLIYWASTRHTGVPD
RFTGSGSGTDYSLTISSVQAEDLALYYCQQHYSTPYTFGGGTKLEIKRA

Fig. 16

SEQ ID NO: 23: Amino acid sequence of CDRH1 of mouse anti-EPHA2 antibody 57-1

NYGMN

SEQ ID NO: 24: Amino acid sequence of CDRH2 of mouse anti-EPHA2 antibody 57-1

WINTDTGEPFVVEEFGK

SEQ ID NO: 25: Amino acid sequence of CDRH3 of mouse anti-EPHA2 antibody 57-1

SMGGFAN

SEQ ID NO: 26: Amino acid sequence of CDRL1 of mouse anti-EPHA2 antibody 57-1

RASQNISDYLH

SEQ ID NO: 27: Amino acid sequence of CDRL2 of mouse anti-EPHA2 antibody 57-1

YASQSI

SEQ ID NO: 28: Amino acid sequence of CDRL3 of mouse anti-EPHA2 antibody 57-1

QNGHTFPT

Fig. 17

SEQ ID NO: 29: Amino acid sequence of CDRH1 of mouse anti-EPHA2 antibody 230-1

DYYMY

SEQ ID NO: 30: Amino acid sequence of CDRH2 of mouse anti-EPHA2 antibody 230-1

TISDDGSFTHYLDSVKG

SEQ ID NO: 31: Amino acid sequence of CDRH3 of mouse anti-EPHA2 antibody 230-1

DGYRYDRPFAY

SEQ ID NO: 32: Amino acid sequence of CDRL1 of mouse anti-EPHA2 antibody 230-1

KASQDVNTAVA

SEQ ID NO: 33: Amino acid sequence of CDRL2 of mouse anti-EPHA2 antibody 230-1

WASTRHT

SEQ ID NO: 34: Amino acid sequence of CDRL3 of mouse anti-EPHA2 antibody 230-1

QQHYSTPYT

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/001730

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. C07K16/28(2006.01)i, C07K16/46(2006.01)i, C12P21/08(2006.01)i,
G01N33/53(2006.01)i, G01N33/574(2006.01)i, C12N15/09(2006.01)n

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. C07K16/28, C07K16/46, C12P21/08, G01N33/53, G01N33/574, C12N15/09

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

JSTPlus/JMEDPlus/JST7580 (JDreamIII), CPlus/REGISTRY/MEDLINE/EMBASE/BIOSIS (STN), WPIDS/WPIX (STN)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2008-529497 A (RAVEN BIOTECHNOLOGIES INC.) 07 August 2008, claims 1-2, examples, paragraph [0155] & US 2006/0177453 A1, claims 1-2, examples, paragraph [0161]	1-18
Y	US 7402298 B1 (SCOTT, Kinch Michael et al.) 22 July 2008, claims 1-9, examples, example 4, table 5 (Family: none)	1-18

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
11 April 2018 (11.04.2018)

Date of mailing of the international search report
24 April 2018 (24.04.2018)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/001730

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2014/126160 A1 (THE UNIVERSITY OF TOKYO) 21 August 2014, claims 1-2, paragraphs [0026], [0033], [0057]-[0061] & US 2016/0103121 A, claims 1-2, paragraphs [0106], [0122], [0171]-[0177]	1-18
Y	WO 2009/028639 A1 (DAIICHI SANKYO CO., LTD.) 05 March 2009, claims 1-45, examples, etc. & US 2010/0183618 A1, claims 1-45, examples, etc.	1-18
Y	KONDO, Tadanori et al., Abstract 546: Soluble EphA2 is a potential serum biomarker for lung cancer, Cancer Research, August 2015, vol. 75 (15 Suppl), abstract nr 546, in particular, abstract	1-18

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/001730

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

(Invention 1) Claims 1-3, 7-8, 10-11, 13-14, 16-18, and parts concerning a "230-1" antibody in claims 9, 12, and 15

These claims and parts are an invention pertaining to a "230-1" antibody.

(Invention 2) Claims 4-6, and parts concerning a "57-1" antibody in claims 9, 12, and 15

These claims and parts are an invention pertaining to a "57-1" antibody.

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 2003094859 A [0011]
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- JP 2017009349 A [0019]

Non-patent literature cited in the description

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- EPHA2 (Human) Matched Antibody Pair (H00001969-AP11). Abnova [0012]
- EPHA2 (Human) Matched Antibody Pair (H00001969-AP51). Abnova [0012]
- **SAMBROOK, J. ; FRITSCH, E. F. ; MANIATIS, T.** *Molecular Cloning*. Cold Spring Harbor Laboratory Press, 1989 [0065]

专利名称(译)	抗-epha2抗体和EPHA2的免疫学检测		
公开(公告)号	EP3572426A1	公开(公告)日	2019-11-27
申请号	EP2018741009	申请日	2018-01-22
申请(专利权)人(译)	东洋大学		
当前申请(专利权)人(译)	东洋大学		
[标]发明人	KATO KAZUNORI AGATSUMA TOSHINORI HASEGAWA JUN		
发明人	KATO, KAZUNORI AGATSUMA, TOSHINORI HASEGAWA, JUN		
IPC分类号	C07K16/28 C07K16/46 C12P21/08 G01N33/53 G01N33/574 C12N15/09		
CPC分类号	C07K16/28 C07K16/46 C12N15/09 G01N33/53 G01N33/574 C07K16/2866 G01N33/563		
代理机构(译)	øYOUNG & CO LLP		
优先权	2017009349 2017-01-23 JP		
外部链接	Espacenet		

摘要(译)

特异性结合EPHA2的单克隆抗体，其包含由SEQ ID NO：20所示的氨基酸序列组成的重链可变区和由SEQ ID NO：22所示的氨基酸序列组成的轻链可变区。特异性结合EPHA2的单克隆抗体的功能性片段或特异性结合EPHA2的单克隆抗体，其包含由SEQ ID NO：15所示的氨基酸序列组成的重链可变区和轻链可变区由SEQ ID NO：18所示的氨基酸序列或与EPHA2特异性结合的单克隆抗体的功能片段组成。

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SEQUENCE LISTING
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using the antibody
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