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(54) Title: MONOCLONAL ANTIBODIES AGAINST HER2 EPITOPE

(57) Abstract: Isolated monoclonal antibodies which bind to human epidermal growth factor receptor 2 (HER2), and related antibody-based compositions and molecules, are disclosed. Pharmaceutical compositions comprising the antibodies and therapeutic and diagnostic methods for using the antibodies are also disclosed.



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MONOCLONAL ANTIBODIES AGAINST HER2 EPI TOPE

FIELD OF THE INVENTION

The present invention relates to monoclonal antibodies directed to human epidermal growth factor receptor 2 (HER2) and to uses of such antibodies, in particular their use in the treatment of cancer.

BACKGROUND OF THE INVENTION

HER2 is a 185-kDa cell surface receptor tyrosine kinase and member of the epidermal growth factor receptor (EGFR) family that comprises four distinct receptors: EGFR/ErbB-1, HER2/ErbB-2, HER3/ErbB-3, and HER4/ErbB-4. Both homo- and heterodimers are formed by the four members of the EGFR family, with HER2 being the preferred and most potent dimerization partner for other ErbB receptors (Graus-Porta *et al.*, *Embo J* 1997;16:1647-1655; Tao *et al.*, *J Cell Sci* 2008;121:3207-3217). HER2 can be activated by overexpression or by heterodimerization with other ErbBs that can be activated by ligand binding (Riese and Stern, *Bioessays* 1998;20:41-48). For HER2, no ligand has been identified. HER2 activation leads to receptor phosphorylation, which triggers a cascade of downstream signals through multiple signaling pathways, such as MAPK, phosphoinositol 3-kinase/AKT, JAK/STAT and PKC, which ultimately results in the regulation of multiple cellular functions, such as growth, survival and differentiation (Huang *et al.*, *Expert Opin Biol Ther* 2009;9:97-110).

Much of the attention on HER2 in tumors has been focused on its role in breast cancer, in which HER2 overexpression is reported in approximately 20% of the cases and is correlated with poor prognosis (Reese *et al.*, *Stem Cells* 1997;15:1-8; Andrechek *et al.*, *Proc Natl Acad Sci U S A* 2000;97:3444-3449; and Slamon *et al.*, *Science* 1987;235:177-182). Besides breast cancer, HER2 expression has also been associated with other human carcinoma types, including prostate cancer, non-small cell lung cancer, bladder cancer, ovarian cancer, gastric cancer, colon cancer, esophageal cancer and squamous cell carcinoma of the head & neck (Garcia de Palazzo *et al.*, *Int J Biol Markers* 1993;8:233-239; Ross *et al.*, *Oncologist* 2003;8:307-325; Osman *et al.*, *J Urol* 2005;174:2174-2177; Kapitanovic *et al.*, *Gastroenterology* 1997;112:1103-1113; Turken *et al.*, *Neoplasma* 2003;50:257-261; and Oshima *et al.*, *Int J Biol Markers* 2001;16:250-254).

Trastuzumab (Herceptin[®]) is a recombinant, humanized monoclonal antibody directed against domain IV of the HER2 protein, thereby blocking ligand-independent HER2 homodimerization, and to a lesser extend heterodimerization of HER2 with other family members in cells with high HER2 overexpression (Cho *et al.*, *Nature* 2003;421:756-760 and

Wehrman *et al.*, Proc Natl Acad Sci U S A 2006;103:19063-19068). In cells with modest HER2 expressing levels, trastuzumab was found to inhibit the formation of HER2/EGFR heterodimers (Wehrman *et al.*, (2006), *supra*; Schmitz *et al.*, Exp Cell Res 2009;315:659-670). Trastuzumab mediates antibody-dependent cellular cytotoxicity (ADCC) and prevents ectodomain shedding, which would otherwise result in the formation of a truncated constitutively active protein in HER2 overexpressing cells. Also inhibition of both *in vitro* and *in vivo* proliferation of tumor cells expressing high levels of HER2 has been reported for trastuzumab (reviewed in Nahta and Esteva, Oncogene 2007;26:3637-3643). Herceptin® has been approved both for first-line and adjuvant treatment of HER2 overexpressing metastatic breast cancer, either in combination with chemotherapy, or as a single agent following one or more chemotherapy regimens. Trastuzumab has been found to be effective only in 20-50% of HER2 overexpressing breast tumor patients and many of the initial responders show relapse after a few months (Dinh *et al.*, Clin Adv Hematol Oncol 2007;5:707-717).

Pertuzumab (Omnitarg™) is another humanized monoclonal antibody directed against domain II of the HER2 protein, resulting in inhibition of ligand-induced heterodimerization (i.e., HER2 dimerizing with another member of the ErbB family to which a ligand has bound); a mechanism reported to not strictly require high HER2 expression levels (Franklin *et al.*, Cancer Cell 2004;5:317-328.). Although pertuzumab also mediates ADCC, the main mechanism of action of pertuzumab relies on its dimerization blockade (Hughes *et al.*, Mol Cancer Ther 2009;8:1885-1892). Moreover, pertuzumab was found to enhance EGFR internalization and downregulation by inhibiting the formation of EGFR/HER2 heterodimers, which otherwise tethers EGFR at the plasma membrane (Hughes *et al.*, 2009, *supra*). This correlates with the observation that EGFR homodimers internalize more efficient than EGFR/HER2 dimers (Pedersen *et al.*, Mol Cancer Res 2009;7:275-284. The complementary mechanisms of action of pertuzumab and trastuzumab reportedly results in enhanced anti-tumor effects and efficacy when combined in patients who progressed during prior trastuzumab therapy (Baselga *et al.*, J Clin Oncol 2010;28:1138-1144), and a phase III trial to evaluate this antibody combination together with Docetaxel in previously untreated HER2-positive metastatic breast cancer is underway.

An alternative approach to improve targeted antibody therapy is by delivering cytotoxic cells or drugs specifically to the antigen-expressing cancer cells. For example, the so-called trifunctional antibodies are bispecific antibodies, targeting with one arm the antigen on the tumor cell and with the other arm for instance CD3 on T cells. Upon binding, a complex of T cells, tumor cells and effector cells that bind Fc is formed, leading to killing of the tumor cells (Muller and Kontermann, BioDrugs 2010;24:89-98.). Ertumaxomab is one

such trifunctional antibody against HER2, which induces cytotoxicity in cell lines with low HER2 expression and which is in Phase II clinical development in metastatic breast cancer (Jones *et al.*, Lancet Oncol 2009;10:1179-1187 and Kiewe *et al.*, Clin Cancer Res 2006;12:3085-3091).

A HER2 antibody drug conjugate (ADC) is currently in clinical development. T-DM1 consists of trastuzumab conjugated to the fungal toxin maytansine. In Phase II trials, responses in a heavily pretreated patient cohort including prior trastuzumab and/or lapatinib therapy were reported (Krop *et al.*, J Clin Oncol. 2010 (published on-line ahead of print) and Lewis Phillips *et al.*, Cancer Res 2008;68:9280-9290). A Phase III trial to evaluate T-DM1 efficacy and safety versus capecitabine + lapatinib in patients with HER2-positive locally advanced or metastatic breast cancer who received prior trastuzumab therapy is ongoing.

While many factors are involved in selecting a suitable antibody for HER2 targeted therapy, it is typically an advantage for an ADC approach if the HER2-antibody complex efficiently internalizes upon antibody binding. Studies on murine HER2 antibodies have shown that certain combinations of antibodies instigate HER2 endocytosis (Ben-Kasus *et al.*, PNAS 2009;106:3294-9). Human HER2 antibodies F5 and C1 have been reported to internalize relatively rapidly on their own and to bind the same epitope (WO 99/55367 and WO 2006/116107). As compared to EGFR, however, internalization of HER2 is impaired. Indeed, EGFR homodimers internalize much more efficiently than HER2 homodimers (Dinh *et al.*, Clin Adv Hematol Oncol 2007;5:707-717). EGFR, and also HER3, can increase endocytosis of HER2 by the formation of EGFR/HER2 and HER3/HER2 heterodimers, respectively (Baulida *et al.*, J Biol Chem 1996;271:5251-5257; Pedersen NM, *et al.*, Mol Cancer Res 2009;7:275-84).

The complex mechanisms regulating the function of HER2 warrant further research on new and optimized therapeutic strategies against this proto-oncogene. Accordingly, there remains a need for effective and safe products for treating HER2-related diseases, such as cancer.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide novel highly specific and effective monoclonal HER2 antibodies for medical use. The antibodies of the invention exhibit HER2 binding characteristics that differ from antibodies described in the art. Particularly, the antibodies of the invention bind to a different segment of HER2, in that they cross-block each other but not trastuzumab, pertuzumab or F5/C1 from binding to HER2. Further, as opposed to the known antibodies, the antibodies of the invention can internalize efficiently into HER2-expressing cells without promoting cell proliferation.

In preferred embodiments, the antibodies of the invention are fully human, bind to novel epitopes and/or have other favorable properties for therapeutic use in human patients. Exemplary properties include, but are not limited to, favorable binding characteristics to cancer cells expressing human HER2 at high or low levels, specific binding to rhesus epithelial cells expressing a HER2 ortholog, efficient internalization upon binding to HER2, high capacity for killing cancer cells expressing high or low levels of HER2 when administered as an antibody drug conjugate (ADC), no substantial agonistic effect on the proliferation of HER2-expressing cancer cells, and provide for effective ADCC-mediated killing of HER2-expressing cells, as well as any combination of the foregoing properties.

These and other aspects of the invention are described in further detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1: Alignment of HuMab heavy chain variable region (VH) sequences with germline (reference) sequences (A-D). In each VH sequence, the amino acids that differ from those of the germline (reference) at specific positions are highlighted. Consensus VH sequences are shown, where "X" indicates positions at which alternative amino acids (selected from those aligned at the indicated position) are possible. The CDR1, CDR2, and CDR3 sequences are underlined in each VH sequence. The consensus CDR sequences are further defined in Table 4.

Figure 2: Alignment of HuMab light chain variable region (VL) sequences with germline (reference) sequences (A-B). In each VL sequence, the amino acids that differ from those of the germline (reference) at specific positions are highlighted. In Figure 2A, all VL sequences derived from the same V-segment (IgKV3-20-01), but the closest J-segment differed between antibodies. Consensus VL sequences are shown, where "X" indicates positions at which alternative amino acids (selected from those aligned at the indicated position) are possible. The CDR1, CDR2, and CDR3 sequences are underlined in each VL sequence. The consensus CDR sequences are further defined in Table 4.

Figure 3: Binding curves of HER2 antibodies to (A) high (AU565) and (B) low (A431) HER2 expressing cell lines, determined as described in Example 12. Data shown are mean fluorescence intensities (MFI) of one representative experiment for each cell line. The EC₅₀ values indicate the apparent affinities.

Figure 4: Binding of HER2 antibodies to HER2 expressed on Rhesus epithelial cells. Data shown are mean fluorescence intensities (MFI) of one experiment, described in Example 13.

Figure 5: Chromium-release (ADCC) assay of HER2 antibodies, showing PBMC-mediated lysis of ⁵¹Cr-labeled SK-BR-3 cells after incubation with HER2 antibody. Values depicted are the mean maximum percentages ⁵¹Cr-release ± the standard deviation from one representative *in vitro* ADCC experiment with SK-BR-3 cells. See Example 15 for details.

Figure 6: Effect of HER2 antibodies on the proliferation of AU565 cells, as compared to untreated cells (set to 100%). Data shown are percentages proliferation of AU565 cells compared to untreated cells measured in three independent experiments $\pm$ the standard deviation. See Example 16 for details.

Figure 7: ADC assay, showing killing of AU565 cells (A) or A431 cells (B) via anti-kappa-ETA'-conjugated HER2 antibodies. (A) Data shown are mean fluorescence intensities (MFI) of one representative experiment with AU565 cells treated with non-conjugated and anti-kappa-ETA'-conjugated HER2 antibodies. (B) Data shown are mean fluorescence intensities (MFI) of one representative experiment with A431 cells treated with non-conjugated and anti-kappa-ETA'-conjugated HER2 antibodies. See Example 17 for details.

Figure 8: Antibody induced downmodulation of HER2. Relative percentage of HER2 expressed in AU565 cell lysate after 3 days incubation with 10 μ g/mL antibody. The amount of HER2 was quantified using a HER2-specific capture ELISA and plotted as a percentage relative to untreated cells. Data shown are mean of three experiments $\pm$ standard deviation. See example 19 for details.

Figure 9: Colocalization analysis of HER2 antibodies (FITC) with lysosomal marker LAMP1 (Cy5), showing FITC pixel intensity overlapping with Cy5 for various monospecific HER2 antibodies. FITC pixel intensity in LAMP1/Cy5 positive pixels of three different images is plotted for each antibody. Antibody 005 shows higher FITC pixel intensities in the LAMP1/Cy5 positive compartments compared to antibodies Herceptin and pertuzumab. See example 20 for details.

Figure 10: HER2 antibody binding to CHO-S cells transfected with different HER2 ECD construct analyzed by means of flow cytometry. Hu-HER2 = fully human HER2, Hu-HER2-ch(I) CR1 = hu-HER2 with chicken domain I, Hu-HER2-ch(II) = hu-HER2 with chicken domain II, hu-HER2-ch(III) = hu-HER2 with chicken domain III and Hu-HER2-ch(IV) = hu-HER2 with chicken domain IV. Data shown are mean fluorescence intensities (MFI) of one representative antibody, 106. See example 21 for details.

Figure 11: In vivo effect of HER2-HuMab 005 in the NCI-N87 human gastric carcinoma xenograft model in female CB.17 severe combined immunodeficiency (SCID) mice. Data shown are mean tumorsize $\pm$ S.E.M. per group (n = 10 mice per group) (A) and survival (B). See example 22 for details.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

The term "HER2" (also known as ErbB-2, NEU, HER-2, and CD340), when used herein, refers to human epidermal growth factor receptor 2 (SwissProt P04626) and includes any variants, isoforms and species homologs of HER2 which are naturally expressed by cells,

including tumor cells, or are expressed on cells transfected with the HER2 gene. Species homologs include rhesus monkey HER2 (macaca mulatta; Genbank accession No. GI:109114897).

The term "immunoglobulin" refers to a class of structurally related glycoproteins consisting of two pairs of polypeptide chains, one pair of light (L) low molecular weight chains and one pair of heavy (H) chains, all four inter-connected by disulfide bonds. The structure of immunoglobulins has been well characterized. See for instance Fundamental Immunology Ch. 7 (Paul, W., ed., 2nd ed. Raven Press, N.Y. (1989)). Briefly, each heavy chain typically is comprised of a heavy chain variable region (abbreviated herein as V_H or VH) and a heavy chain constant region. The heavy chain constant region typically is comprised of three domains, C_{H1} , C_{H2} , and C_{H3} . Each light chain typically is comprised of a light chain variable region (abbreviated herein as V_L or VL) and a light chain constant region. The light chain constant region typically is comprised of one domain, C_L . The V_H and V_L regions may be further subdivided into regions of hypervariability (or hypervariable regions which may be hypervariable in sequence and/or form of structurally defined loops), also termed complementarity determining regions (CDRs), interspersed with regions that are more conserved, termed framework regions (FRs). Each V_H and V_L is typically composed of three CDRs and four FRs, arranged from amino-terminus to carboxy-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4 (see also Chothia and Lesk J. Mol. Biol. 196, 901-917 (1987)). Unless otherwise stated or contradicted by context, CDR sequences herein are identified according to IMGT rules (Brochet X., Nucl Acids Res. 2008;36:W503-508 and Lefranc MP., Nucleic Acids Research 1999;27:209-212; see also internet http://imgt.cines.fr/IMGT_vquest/vquest?livret=0&Option=humanIg). However, the numbering of amino acid residues in an antibody sequence can also be performed by the method described in Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991) (phrases such as "variable domain residue numbering as in Kabat", "Kabat position" or "according to Kabat" herein refer to this numbering system). Particularly, for numbering of amino acids in the constant region, the EU index numbering system according to Kabat *et al*, *supra*, can be used. The Kabat numbering of residues may be determined for a given antibody by alignment at regions of homology of the sequence of the antibody with a "standard" Kabat numbered sequence.

The term "antibody" (Ab) in the context of the present invention refers to an immunoglobulin molecule, a fragment of an immunoglobulin molecule, or a derivative of either thereof, which has the ability to specifically bind to an antigen under typical physiological conditions with a half life of significant periods of time, such as at least about

30 minutes, at least about 45 minutes, at least about one hour, at least about two hours, at least about four hours, at least about 8 hours, at least about 12 hours, about 24 hours or more, about 48 hours or more, about 3, 4, 5, 6, 7 or more days, etc., or any other relevant functionally-defined period (such as a time sufficient to induce, promote, enhance, and/or modulate a physiological response associated with antibody binding to the antigen and/or time sufficient for the antibody to recruit an effector activity). The variable regions of the heavy and light chains of the immunoglobulin molecule contain a binding domain that interacts with an antigen. The constant regions of the antibodies (Abs) may mediate the binding of the immunoglobulin to host tissues or factors, including various cells of the immune system (such as effector cells) and components of the complement system such as C1q, the first component in the classical pathway of complement activation. A HER2 antibody may also be a bispecific antibody, diabody, or similar molecule (see for instance PNAS USA 90(14), 6444-8 (1993) for a description of diabodies). Indeed, bispecific antibodies, diabodies, and the like, provided by the present invention may bind any suitable target in addition to a portion of HER2. As indicated above, the term antibody herein, unless otherwise stated or clearly contradicted by context, includes fragments of an antibody that are antigen-binding fragments, i.e., retain the ability to specifically bind to the antigen. It has been shown that the antigen-binding function of an antibody may be performed by fragments of a full-length antibody. Examples of antigen-binding fragments encompassed within the term "antibody" include (i) a Fab' or Fab fragment, a monovalent fragment consisting of the V_L, V_H, C_L and C_H1 domains, or a monovalent antibody as described in WO2007059782 (Genmab); (ii) F(ab')₂ fragments, bivalent fragments comprising two Fab fragments linked by a disulfide bridge at the hinge region; (iii) a Fd fragment consisting essentially of the V_H and C_H1 domains; (iv) a Fv fragment consisting essentially of the V_L and V_H domains of a single arm of an antibody, (v) a dAb fragment (Ward *et al.*, Nature 341, 544-546 (1989)), which consists essentially of a V_H domain and also called domain antibodies (Holt *et al.*; Trends Biotechnol. 2003 Nov;21(11):484-90); (vi) camelid or nanobodies (Revets *et al.*; Expert Opin Biol Ther. 2005 Jan;5(1):111-24) and (vii) an isolated complementarity determining region (CDR). Furthermore, although the two domains of the Fv fragment, V_L and V_H, are coded for by separate genes, they may be joined, using recombinant methods, by a synthetic linker that enables them to be made as a single protein chain in which the V_L and V_H regions pair to form monovalent molecules (known as single chain antibodies or single chain Fv (scFv), see for instance Bird *et al.*, Science 242, 423-426 (1988) and Huston *et al.*, PNAS USA 85, 5879-5883 (1988)). Such single chain antibodies are encompassed within the term antibody unless otherwise noted or clearly indicated by context. Although such fragments are generally included within the

meaning of antibody, they collectively and each independently are unique features of the present invention, exhibiting different biological properties and utility. These and other useful antibody fragments in the context of the present invention, as well as bispecific formats of such fragments, are discussed further herein. It also should be understood that the term antibody, unless specified otherwise, also includes polyclonal antibodies, monoclonal antibodies (mAbs), antibody-like polypeptides, such as chimeric antibodies and humanized antibodies, and antibody fragments retaining the ability to specifically bind to the antigen (antigen-binding fragments) provided by any known technique, such as enzymatic cleavage, peptide synthesis, and recombinant techniques. An antibody as generated can possess any isotype.

As used herein, "isotype" refers to the immunoglobulin class (for instance IgG1, IgG2, IgG3, IgG4, IgD, IgA, IgE, or IgM) that is encoded by heavy chain constant region genes.

The term "monovalent antibody" means in the context of the present invention that an antibody molecule is capable of binding a single molecule of the antigen, and thus is not able of antigen crosslinking.

An "antibody deficient in effector function" or an "effector-function-deficient antibody" refers to an antibody which has a significantly reduced or no ability to activate one or more effector mechanisms, such as complement activation or Fc receptor binding. Thus, effector-function deficient antibodies have significantly reduced or no ability to mediate antibody-dependent cell-mediated cytotoxicity (ADCC) and/or complement-dependent cytotoxicity (CDC). An example of such an antibody is IgG4.

A "HER2 antibody" or "anti-HER2 antibody" is an antibody as described above, which binds specifically to the antigen HER2.

The term "human antibody", as used herein, is intended to include antibodies having variable and constant regions derived from human germline immunoglobulin sequences. The human antibodies of the invention may include amino acid residues not encoded by human germline immunoglobulin sequences (*e.g.*, mutations introduced by random or site-specific mutagenesis *in vitro* or by somatic mutation *in vivo*). However, the term "human antibody", as used herein, is not intended to include antibodies in which CDR sequences derived from the germline of another mammalian species, such as a mouse, have been grafted onto human framework sequences.

As used herein, a human antibody is "derived from" a particular germline sequence if the antibody is obtained from a system using human immunoglobulin sequences, for instance by immunizing a transgenic mouse carrying human immunoglobulin genes or by screening a human immunoglobulin gene library, and wherein the selected human antibody

is at least 90%, such as at least 95%, for instance at least 96%, such as at least 97%, for instance at least 98%, or such as at least 99% identical in amino acid sequence to the amino acid sequence encoded by the germline immunoglobulin gene. Typically, outside the heavy chain CDR3, a human antibody derived from a particular human germline sequence will display no more than 20 amino acid differences, e.g. no more than 10 amino acid differences, such as no more than 9, 8, 7, 6 or 5, for instance no more than 4, 3, 2, or 1 amino acid difference from the amino acid sequence encoded by the germline immunoglobulin gene.

In a preferred embodiment, the antibody of the invention is isolated. An "isolated antibody," as used herein, is intended to refer to an antibody which is substantially free of other antibodies having different antigenic specificities (for instance an isolated antibody that specifically binds to HER2 is substantially free of antibodies that specifically bind antigens other than HER2). An isolated antibody that specifically binds to an epitope, isoform or variant of HER2 may, however, have cross-reactivity to other related antigens, for instance from other species (such as HER2 species homologs). Moreover, an isolated antibody may be substantially free of other cellular material and/or chemicals. In one embodiment of the present invention, two or more "isolated" monoclonal antibodies having different antigen-binding specificities are combined in a well-defined composition.

When used herein in the context of two or more antibodies, the term "competes with" or "cross-competes with" indicates that the two or more antibodies compete for binding to HER2, e.g. compete for HER2 binding in the assay described in Example 14. An antibody "blocks" or "cross-blocks" one or more other antibodies from binding to HER2 if the antibody competes with the one or more other antibodies 25% or more, with 25%-74% representing "partial block" and 75%-100% representing "full block", preferably as determined using the assay of Example 14. For some pairs of antibodies, competition or blocking in the assay of the Examples is only observed when one antibody is coated on the plate and the other is used to compete, and not vice versa. Unless otherwise defined or negated by context, the terms "competes with", "cross-competes with", "blocks" or "cross-blocks" when used herein is also intended to cover such pairs of antibodies.

The term "epitope" means a protein determinant capable of specific binding to an antibody. Epitopes usually consist of surface groupings of molecules such as amino acids or sugar side chains and usually have specific three dimensional structural characteristics, as well as specific charge characteristics. Conformational and nonconformational epitopes are distinguished in that the binding to the former but not the latter is lost in the presence of denaturing solvents. The epitope may comprise amino acid residues directly involved in the binding (also called immunodominant component of the epitope) and other amino acid

residues, which are not directly involved in the binding, such as amino acid residues which are effectively blocked by the specifically antigen binding peptide (in other words, the amino acid residue is within the footprint of the specifically antigen binding peptide).

The term "monoclonal antibody" as used herein refers to a preparation of antibody molecules of single molecular composition. A monoclonal antibody composition displays a single binding specificity and affinity for a particular epitope. Accordingly, the term "human monoclonal antibody" refers to antibodies displaying a single binding specificity which have variable and constant regions derived from human germline immunoglobulin sequences. The human monoclonal antibodies may be generated by a hybridoma which includes a B cell obtained from a transgenic or transchromosomal nonhuman animal, such as a transgenic mouse, having a genome comprising a human heavy chain transgene and a light chain transgene, fused to an immortalized cell.

As used herein, the term "binding" in the context of the binding of an antibody to a predetermined antigen typically is a binding with an affinity corresponding to a K_D of about 10^{-7} M or less, such as about 10^{-8} M or less, such as about 10^{-9} M or less, about 10^{-10} M or less, or about 10^{-11} M or even less when determined by for instance surface plasmon resonance (SPR) technology in a BIAcore 3000 instrument using the antigen as the ligand and the antibody as the analyte, and binds to the predetermined antigen with an affinity corresponding to a K_D that is at least ten-fold lower, such as at least 100 fold lower, for instance at least 1,000 fold lower, such as at least 10,000 fold lower, for instance at least 100,000 fold lower than its affinity for binding to a non-specific antigen (e.g., BSA, casein) other than the predetermined antigen or a closely-related antigen. The amount with which the affinity is lower is dependent on the K_D of the antibody, so that when the K_D of the antibody is very low (that is, the antibody is highly specific), then the amount with which the affinity for the antigen is lower than the affinity for a non-specific antigen may be at least 10,000 fold.

The term " k_d " (sec^{-1}), as used herein, refers to the dissociation rate constant of a particular antibody-antigen interaction. Said value is also referred to as the k_{off} value.

The term " k_a " ($\text{M}^{-1} \times \text{sec}^{-1}$), as used herein, refers to the association rate constant of a particular antibody-antigen interaction.

The term " K_D " (M), as used herein, refers to the dissociation equilibrium constant of a particular antibody-antigen interaction.

The term " K_A " (M^{-1}), as used herein, refers to the association equilibrium constant of a particular antibody-antigen interaction and is obtained by dividing the k_a by the k_d .

As used herein, the term "inhibits proliferation" (e.g. referring to cells, such as tumor cells) is intended to include any substantial decrease in the cell proliferation when contacted

with a HER2 antibody as compared to the proliferation of the same cells not in contact with a HER2 antibody, *e.g.*, the inhibition of proliferation of a cell culture by at least about 10%, at least about 20% or at least about 30%, or at least as much as a reference antibody such as trastuzumab, *e.g.*, as determined by an assay in the Examples.

As used herein, the term "promotes proliferation" (*e.g.* referring to cells, such as tumor cells) is intended to include any substantial increase in the cell proliferation when contacted with a HER2 antibody as compared to the proliferation of the same cells not in contact with a HER2 antibody, *e.g.*, the promotion of proliferation of a cell culture by at least about 10%, at least about 20% or at least about 30%, or at least as much as a reference antibody as F5, *e.g.*, as determined by an assay in the Examples.

As used herein, "internalization", when used in the context of a HER2 antibody includes any mechanism by which the antibody is internalized into a HER2-expressing cell from the cell-surface and/or from surrounding medium, *e.g.*, via endocytosis. The internalization of an antibody can be evaluated using a direct assay measuring the amount of internalized antibody (such as, *e.g.*, the fab-CypHer5E assay described in Example 18), or an indirect assay where the effect of an internalized antibody-toxin conjugate is measured (such as, *e.g.*, the anti-kappa-ETA' assay of Example 17).

The present invention also provides antibodies comprising functional variants of the VL region, VH region, or one or more CDRs of the antibodies of the examples. A functional variant of a VL, VH, or CDR used in the context of a HER2 antibody still allows the antibody to retain at least a substantial proportion (at least about 50%, 60%, 70%, 80%, 90%, 95% or more) of the affinity/avidity and/or the specificity/selectivity of the parent antibody and in some cases such a HER2 antibody may be associated with greater affinity, selectivity and/or specificity than the parent antibody.

Such functional variants typically retain significant sequence identity to the parent antibody. The percent identity between two sequences is a function of the number of identical positions shared by the sequences (*i.e.*, % homology = # of identical positions/total # of positions x 100), taking into account the number of gaps, and the length of each gap, which need to be introduced for optimal alignment of the two sequences. The percent identity between two nucleotide or amino acid sequences may *e.g.* be determined using the algorithm of E. Meyers and W. Miller, *Comput. Appl. Biosci* 4, 11-17 (1988) which has been incorporated into the ALIGN program (version 2.0), using a PAM120 weight residue table, a gap length penalty of 12 and a gap penalty of 4. In addition, the percent identity between two amino acid sequences may be determined using the Needleman and Wunsch, *J. Mol. Biol.* 48, 444-453 (1970) algorithm.

Exemplary variants include those which differ from a parent antibody VH and/or VL sequence shown in Figures 1 and 2 at one or more "variant" amino acid positions, denoted "X" in the corresponding consensus sequence. Preferred variants are those in which the new amino acid is selected from those at the corresponding position in one of the aligned sequences in Figure 1 or 2 (for details on CDR sequence variants, see Table 4). Alternatively or additionally, the sequence of VH, VL or CDR variants may differ from the sequence of the VH, VL or CDR of the parent antibody sequences mainly by conservative substitutions; for instance at least 10, such as at least 9, 8, 7, 6, 5, 4, 3, 2 or 1 of the substitutions in the variant are conservative amino acid residue replacements. In the context of the present invention, conservative substitutions may be defined by substitutions within the classes of amino acids reflected in the following table:

Amino acid residue classes for conservative substitutions

Acidic Residues	Asp (D) and Glu (E)
Basic Residues	Lys (K), Arg (R), and His (H)
Hydrophilic Uncharged Residues	Ser (S), Thr (T), Asn (N), and Gln (Q)
Aliphatic Uncharged Residues	Gly (G), Ala (A), Val (V), Leu (L), and Ile (I)
Non-polar Uncharged Residues	Cys (C), Met (M), and Pro (P)
Aromatic Residues	Phe (F), Tyr (Y), and Trp (W)

The term "recombinant host cell" (or simply "host cell"), as used herein, is intended to refer to a cell into which an expression vector has been introduced, e.g. an expression vector encoding an antibody of the invention. Recombinant host cells include, for example, transfectomas, such as CHO cells, HEK293 cells, NS/0 cells, and lymphocytic cells.

The term "transgenic non-human animal" refers to a non-human animal having a genome comprising one or more human heavy and/or light chain transgenes or transchromosomes (either integrated or non-integrated into the animal's natural genomic DNA) and which is capable of expressing fully human antibodies. For example, a transgenic mouse can have a human light chain transgene and either a human heavy chain transgene or human heavy chain transchromosome, such that the mouse produces human HER2 antibodies when immunized with HER2 antigen and/or cells expressing HER2. The human heavy chain transgene may be integrated into the chromosomal DNA of the mouse, as is the case for transgenic mice, for instance HuMAb mice, such as HCo7, HCo12, or HCo17 mice, or the human heavy chain transgene may be maintained extrachromosomally, as is

the case for transchromosomal KM mice as described in WO02/43478. Similar mice, having a larger human Ab gene repertoire, include HCo7 and HCo20 (see e.g. WO2009097006). Such transgenic and transchromosomal mice (collectively referred to herein as "transgenic mice") are capable of producing multiple isotypes of human monoclonal antibodies to a given antigen (such as IgG, IgA, IgM, IgD and/or IgE) by undergoing V-D-J recombination and isotype switching. Transgenic, nonhuman animal can also be used for production of antibodies against a specific antigen by introducing genes encoding such specific antibody, for example by operatively linking the genes to a gene which is expressed in the milk of the animal.

"Treatment" refers to the administration of an effective amount of a therapeutically active compound of the present invention with the purpose of easing, ameliorating, arresting or eradicating (curing) symptoms or disease states.

An "effective amount" refers to an amount effective, at dosages and for periods of time necessary, to achieve a desired therapeutic result. A therapeutically effective amount of a HER2 antibody may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the HER2 antibody to elicit a desired response in the individual. A therapeutically effective amount is also one in which any toxic or detrimental effects of the antibody or antibody portion are outweighed by the therapeutically beneficial effects.

An "anti-idiotypic" antibody is an antibody which recognizes unique determinants generally associated with the antigen-binding site of an antibody.

Further aspects and embodiments of the invention

As described above, in a first aspect, the invention relates to a monoclonal antibody which binds HER2.

Monoclonal antibodies of the present invention may be produced, e.g., by the hybridoma method first described by Kohler *et al.*, Nature 256, 495 (1975), or may be produced by recombinant DNA methods. Monoclonal antibodies may also be isolated from phage antibody libraries using the techniques described in, for example, Clackson *et al.*, Nature 352, 624-628 (1991) and Marks *et al.*, J. Mol. Biol. 222, 581-597 (1991).

Monoclonal antibodies may be obtained from any suitable source. Thus, for example, monoclonal antibodies may be obtained from hybridomas prepared from murine splenic B cells obtained from mice immunized with an antigen of interest, for instance in form of cells expressing the antigen on the surface, or a nucleic acid encoding an antigen of interest. Monoclonal antibodies may also be obtained from hybridomas derived from antibody-

expressing cells of immunized humans or non-human mammals such as rats, dogs, primates, etc.

In one embodiment, the antibody of the invention is a human antibody. Human monoclonal antibodies directed against HER2 may be generated using transgenic or transchromosomal mice carrying parts of the human immune system rather than the mouse system. Such transgenic and transchromosomal mice include mice referred to herein as HuMAb mice and KM mice, respectively, and are collectively referred to herein as "transgenic mice".

The HuMAb mouse contains a human immunoglobulin gene miniloci that encodes unrearranged human heavy (μ and γ) and κ light chain immunoglobulin sequences, together with targeted mutations that inactivate the endogenous μ and κ chain loci (Lonberg, N. *et al.*, Nature 368, 856-859 (1994)). Accordingly, the mice exhibit reduced expression of mouse IgM or κ and in response to immunization, the introduced human heavy and light chain transgenes, undergo class switching and somatic mutation to generate high affinity human IgG, κ monoclonal antibodies (Lonberg, N. *et al.* (1994), *supra*; reviewed in Lonberg, N. Handbook of Experimental Pharmacology 113, 49-101 (1994) , Lonberg, N. and Huszar, D., Intern. Rev. Immunol. Vol. 13 65-93 (1995) and Harding, F. and Lonberg, N. Ann. N.Y. Acad. Sci 764 536-546 (1995)). The preparation of HuMAb mice is described in detail in Taylor, L. *et al.*, Nucleic Acids Research 20, 6287-6295 (1992), Chen, J. *et al.*, International Immunology 5, 647-656 (1993), Tuailon *et al.*, J. Immunol. 152, 2912-2920 (1994), Taylor, L. *et al.*, International Immunology 6, 579-591 (1994), Fishwild, D. *et al.*, Nature Biotechnology 14, 845-851 (1996). See also US 5,545,806, US 5,569,825, US 5,625,126, US 5,633,425, US 5,789,650, US 5,877,397, US 5,661,016, US 5,814,318, US 5,874,299, US 5,770,429, US 5,545,807, WO 98/24884, WO 94/25585, WO 93/1227, WO 92/22645, WO 92/03918 and WO 01/09187.

The HCo7, HCo12, HCo17 and HCo20 mice have a JKD disruption in their endogenous light chain (kappa) genes (as described in Chen *et al.*, EMBO J. 12, 821-830 (1993)), a CMD disruption in their endogenous heavy chain genes (as described in Example 1 of WO 01/14424), and a KCo5 human kappa light chain transgene (as described in Fishwild *et al.*, Nature Biotechnology 14, 845-851 (1996)). Additionally, the HCo7 mice have a HCo7 human heavy chain transgene (as described in US 5,770,429), the HCo12 mice have a HCo12 human heavy chain transgene (as described in Example 2 of WO 01/14424), the HCo17 mice have a HCo17 human heavy chain transgene (as described in Example 2 of WO 01/09187) and the HCo20 mice have a HCo20 human heavy chain transgene. The resulting mice express human immunoglobulin heavy and kappa light chain transgenes in a

background homozygous for disruption of the endogenous mouse heavy and kappa light chain loci.

In the KM mouse strain, the endogenous mouse kappa light chain gene has been homozygously disrupted as described in Chen et al., EMBO J. 12, 811-820 (1993) and the endogenous mouse heavy chain gene has been homozygously disrupted as described in Example 1 of WO 01/09187. This mouse strain carries a human kappa light chain transgene, KCo5, as described in Fishwild et al., Nature Biotechnology 14, 845-851 (1996). This mouse strain also carries a human heavy chain transchromosome composed of chromosome 14 fragment hCF (SC20) as described in WO 02/43478. HCo12-Balb/C mice can be generated by crossing HCo12 to KCo5[J/K](Balb) as described in WO 097006. Splenocytes from these transgenic mice may be used to generate hybridomas that secrete human monoclonal antibodies according to well known techniques.

Further, human antibodies of the present invention or antibodies of the present invention from other species may be identified through display-type technologies, including, without limitation, phage display, retroviral display, ribosomal display, and other techniques, using techniques well known in the art and the resulting molecules may be subjected to additional maturation, such as affinity maturation, as such techniques are well known in the art (see for instance Hoogenboom et al., J. Mol. Biol. 227, 381 (1991) (phage display), Vaughan et al., Nature Biotech 14, 309 (1996) (phage display), Hanes and Plutchau, PNAS USA 94, 4937-4942 (1997) (ribosomal display), Parmley and Smith, Gene 73, 305-318 (1988) (phage display), Scott TIBS 17, 241-245 (1992), Cwirla et al., PNAS USA 87, 6378-6382 (1990), Russel et al., Nucl. Acids Research 21, 1081-1085 (1993), Hogenboom et al., Immunol. Reviews 130, 43-68 (1992), Chiswell and McCafferty TIBTECH 10, 80-84 (1992), and US 5,733,743). If display technologies are utilized to produce antibodies that are not human, such antibodies may be humanized.

In one aspect the HER2 antibody of the invention binds to domain III of human HER2. The inventors of the present invention have shown that antibodies 005, 006, 059, 060, 106 and 111 show enhanced internalization, lysosomal degradation and toxicity in the anti-kappa-ETA' model system. Thus without being bound by any theory binding of an antibody to domain III of HER2 may be important for internalization of the antibody and therefore useful for antibody drug conjugates (ADCs). Antibodies 005, 006, 059, 060, 106 and 111 recognize an epitope that resides in HER2 domain III, which has no known function in heterodimerization of HER2. Whereas HER2 domain IV (bound by Herceptin) has been reported to be involved in ligand independent heterodimerization of HER2 (Juntilla *et al.*, Cancer Cell 2009;15:429-440), and HER2 domain II (bound by pertuzumab) has been

reported to be involved in ligand induced heterodimerization of HER2 (Landgraf et al., Breast Cancer Research 2007;9:202). We hypothesize that the formation of HER2/ErbB heterodimers is critical to get sufficient internalization and degradation of HER2 antibody/receptor complexes. Therefore, HER2 antibodies that utilize HER2 heterodimer driven internalization and degradation seem very attractive for future HER2-targeted ADC therapeutics. In particular, on tumor cells that do not overexpress HER2 at extremely high levels, the formation of HER2/ErbB heterodimers may represent an attractive approach for HER2 antibodies to deliver an ADC.

In one aspect of the HER2 antibody of the invention, the antibody does not block the binding to soluble HER2 of a second antibody, optionally in immobilized form, comprising the VH and VL sequences of any of trastuzumab, pertuzumab, F1, and C5, when determined as described in Example 14.

In an additional or alternative aspect of the antibody of the invention, the antibody blocks or cross-blocks the binding to soluble HER2 of one or more of the novel human antibodies described herein.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**), preferably wherein the antibody is fully blocking when determined as described in Example 14.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:12 (**006**), preferably wherein the antibody is fully-blocking when determined as described in Example 14.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**), preferably wherein the antibody is fully-blocking when determined as described in Example 14.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ

ID NO:26 (**060**), preferably wherein the antibody is fully-blocking when determined as described in Example 14.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**), preferably wherein the antibody is fully-blocking when determined as described in Example 14.

In one embodiment, the antibody blocks the binding to soluble HER2 of a reference antibody, optionally immobilized, wherein the reference antibody comprises a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**), preferably wherein the antibody is fully-blocking when determined as described in Example 14.

In separate and specific embodiments, the antibody blocks the binding of two, three, four, five, or six reference antibodies of the preceding embodiment, such as, e.g., antibodies 005 and 111, antibodies 005 and 006; antibodies 059 and 106; antibodies 006 and 059; antibodies 059, 106, 005 and 060; antibodies 006, 59, 060, and 111; or antibodies 059, 106, 005, 060, 111 and 006.

In one embodiment, the antibody competes for at least 25%, preferably at least 50% for binding to soluble HER2 with all of the following:

- a reference antibody, optionally immobilized, comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);

- a reference antibody, optionally immobilized, comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);

- a reference antibody, optionally immobilized, comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);

- a reference antibody, optionally immobilized, comprising a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**);

- a reference antibody, optionally immobilized, comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**),

when determined as described in Example 14.

In one embodiment, the antibody, when immobilized, blocks the binding to soluble HER2 of at least one antibody selected from the group consisting of:

an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);

an antibody comprising a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:12 (**006**);

an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);

an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);

an antibody comprising a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**); and

an antibody comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**),

preferably wherein the immobilized antibody is fully-blocking when determined as described in Example 14.

In one embodiment, the antibody, when immobilized, competes for binding to soluble HER2 with all antibodies defined in the preceding embodiment for 25% or more, preferably 50% or more, when determined as described in Example 14.

In one aspect of the antibody of the invention, the antibody binds the same epitope on HER2 as one or more of the novel human antibodies described herein.

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**).

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:12 (**006**).

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**).

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**).

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**).

In one embodiment, the antibody binds the same epitope as an antibody comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

In one embodiment, the antibody binds to the same epitope as at least one antibody selected from the group consisting of:

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:43 and a VL region comprising the sequence of SEQ ID NO:44 (**041**)
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:45 and a VL region comprising the sequence of SEQ ID NO:46 (**150**), and
- c) an antibody comprising a VH region comprising the sequence of SEQ ID NO:47 and a VL region comprising the sequence of SEQ ID NO:48 (**067**);
- d) an antibody comprising a VH region comprising the sequence of SEQ ID NO:49 and a VL region comprising the sequence of SEQ ID NO:50 (**072**);
- e) an antibody comprising a VH region comprising the sequence of SEQ ID NO:51 and a VL region comprising the sequence of SEQ ID NO:52 (**163**);
- f) an antibody comprising a VH region comprising the sequence of SEQ ID NO:53 and a VL region comprising the sequence of SEQ ID NO:54 (**093**);
- g) an antibody comprising a VH region comprising the sequence of SEQ ID NO:55 and a VL region comprising the sequence of SEQ ID NO:56 (**044**).

In another additional or alternative aspect of the antibody of the invention, the antibody binds to HER2 and comprises a VH CDR3, VH region and/or VL region sequence similar or identical to a sequence of the novel antibodies described herein.

In one embodiment, the antibody comprises a VH CDR3 region having an amino acid sequence selected from the group consisting of

SEQ ID No:59, such as the sequence of SEQ ID No:4, 25, 32 (**005, 060, 106**), optionally wherein the VH region is derived from the IgHV5-51-1 germline;

SEQ ID No:62, such as the sequence of SEQ ID NO:11 (**006**), optionally wherein the VH region is derived from the IgHV3-23-1 germline sequence;

SEQ ID NO:65, such as the sequence of SEQ ID NO:18 (**059**), optionally wherein the VH region is derived from the IgHV1-18-1 germline sequence; or

SEQ ID NO:67, such as the sequence of SEQ ID NO:39 (**111**), optionally wherein the VH region is derived from the IgHV1-69-4 germline sequence.

In one embodiment, the antibody comprises a VH CDR3 region comprising the amino acid sequence of SEQ ID NO: 59, wherein X1=Q, H, or L; X2 = R, A, T, or K; X3=G; X4=D; X5=R or none; X6=G or none; X7=Y or F; X8=Y or D; X9=Y, F, or H; X10=Y, D, S, F, or N; X11=M or L; and X12=V or I; preferably, wherein X1=Q, X2=R or A; X5=X6=none; X7=Y or F; X8=Y; X9=F; X10=Y; and X12=V. In a particular embodiment the antibody comprises a VH CDR3 region comprising the amino acid sequence of SEQ ID NO: 59, wherein X1=Q, X2=R or A; X3=G; X4=D, X5=X6=none; X7=Y or F; X8=Y; X9=F; X10=Y; and X12=V. In one embodiment the antibody comprises a VH CDR3 region comprising the amino acid sequence of SEQ ID NO: 59, wherein X1=Q, X2=K; X3=G; X4=D, X5=X6=none; X7=F; X8=Y; X9=X10=F; X11=L; and X12=V; or wherein X1=Q, X2=A; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=Y; X10=N; X11=M; and X12=V; or wherein X1=Q, X2=K; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=H; X10=Y; X11=L; and X12=V; or wherein X1=Q, X2=K; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=F; X10=N; X11=L; and X12=V; or wherein X1=Q, X2=R; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=F; X10=N; X11=L; and X12=V; or wherein X1=Q, X2=R; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=X10=F; X11=L; and X12=I; or wherein X1=Q, X2=A; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=Y; X10=N; X11=M; and X12=V.

In one embodiment, the antibody comprises a VH CDR3 region of one of antibodies 041, 150, 067, 072, 163, or 093, as shown in Figure 1, optionally wherein the VH region is derived from an IgHV5-51-1 germline.

In one embodiment, the antibody comprises a VH region selected from the group consisting of

- a) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:57, 58 and 59, such as
 - a. a CDR1 sequence selected from SEQ ID NOs:2, 23, and 30; a CDR2 sequence selected from 3, 24, and 31; and a CDR3 sequence selected from 4, 25, and 32 (**005, 060, 106**),
 - b. the CDR1, CDR2, and CDR3 sequences of SEQ ID NOs:2, 3 and 4, respectively (**005**),
 - c. the CDR1, CDR2, and CDR3 sequences of SEQ ID NOs:23, 24 and 25, respectively (**060**),
 - d. the CDR1, CDR2, and CDR3 sequences of SEQ ID NOs:32, 33 and 34, respectively (**106**),

- optionally where the VH region is derived from an IgHV5-51-1 germline;
- b) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:60, 61 and 62, such the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:9, 10, and 11, respectively (**006**), optionally where the VH region is derived from an IgHV3-23-1 germline; and
 - c) a VH region comprising the CDR1, CDR2, and CDR3 sequences of SEQ ID NOs:63, 64, and 65, such as the CRD1, CDR2, and CDR3 sequences of SEQ ID NOs: 16, 17 and 18 (**059**), respectively, optionally where the VH region is derived from an IgHV1-18-1 germline; and
 - d) a VH region comprising the CDR1, CDR2, and CDR3 sequences of SEQ ID NOs:66, 38 and 67, such as the CRD1, CDR2, and CDR3 sequences of SEQ ID NOs: 37, 38 and 39 (**111**), respectively, optionally where the VH region is derived from an IgHV1-69-4 germline.

In one embodiment, the antibody comprises a VH region selected from the preceding embodiments (a), (c) or (d) and a VL region comprising the CDR1, CDR2, and CDR3 sequences of SEQ ID NO:68, GAS, and SEQ ID No:69, respectively, such as a CDR1 sequence selected from SEQ ID Nos: 6, 20, 27, 34 and 41, a CDR2 which is GAS, and a CDR3 sequence selected from 7, 21, 28, 35 and 42 (**005, 059, 060, 106, 111**); respectively, optionally where the VL region is derived from an IgKV3-20-01 germline.

In one embodiment, the antibody comprises a VH region which is the preceding embodiment (b) and a VL region comprising the CDR1, CDR2, and CDR3 sequences of SEQ ID NO:13, DAS, and SEQ ID NO:14 (**006**), respectively, optionally where the VL region is derived from IgKV3-11-01.

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:2, 3 and 4, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:6, GAS, and SEQ ID NO:7, respectively (**005**).

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:9, 10 and 11, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:13, DAS, and SEQ ID NO:14, respectively (**006**).

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:16, 17 and 18, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:20, GAS, and SEQ ID NO:21, respectively (**059**).

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:23, 24 and 25, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:27, GAS, and SEQ ID NO:28, respectively (**060**).

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:30, 31 and 32, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:34, GAS, and SEQ ID NO:35, respectively (**106**).

In one embodiment, the antibody comprises a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:37, 38 and 39, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:41, GAS, and SEQ ID NO:42, respectively (**111**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=S; X2=T and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=H and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q, X2=K; X3=G; X4=D, X5=X6=none; X7=F; X8=Y; X9=X10=F; X11=L; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=X4=none and X5=L (**041**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=S; X2=T and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=H, and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q, X2=A; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=Y; X10=N; X11=M; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=X4=none and X5=L (**150**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=S; X2=T and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=D, and the CDR3 sequence of SEQ ID NO:59, X1=Q, X2=K; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=H; X10=Y; X11=L; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=P, X4=R and X5=L (**067**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=S; X2=T and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=D, and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q,

X2=K; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=F; X10=N; X11=L; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=P, X4=R and X5=L (**072**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=R; X2=I and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=D, and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q, X2=R; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=F; X10=N; X11=L; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=X4=none and X5=L (**163**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=S; X2=T and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=Y and X2=D, and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q, X2=R; X3=G; X4=D, X5=X6=none; X7=Y; X8=Y; X9=X10=F; X11=L; and X12=I; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=X4=none and X5=L (**093**).

In one embodiment, the antibody comprises a VH region comprising the CDR1 sequence of SEQ ID NO:57, wherein X1=R; X2=S and X3=S; the CDR2 sequence of SEQ ID NO:58, wherein X1=F and X2=D, and the CDR3 sequence of SEQ ID NO:59, wherein X1=Q, X2=A; X3=G; X4=D, X5=X6=none; X7=X8=Y; X9=Y; X10=N; X11=M; and X12=V; and a VL region comprising the CDR1 sequence of SEQ ID NO:68, wherein X1=X2=S; the CDR2 sequence GAS; and the CDR3 sequence of SEQ ID NO: 69, wherein X1=Q, X2=S, X3=X4=none and X5=L (**044**).

In separate embodiments, the antibody comprises:

- a) a VH region comprising the sequence of SEQ ID NO:1 and, preferably, a VL region comprising the sequence of SEQ ID NO:5 (**005**)
- b) a VH region comprising the sequence of SEQ ID NO:8 and, preferably, a VL region comprising the sequence of SEQ ID NO:11 (**006**)
- c) a VH region comprising the sequence of SEQ ID NO:15 and, preferably, a VL region comprising the sequence of SEQ ID NO:19 (**059**)
- d) a VH region comprising the sequence of SEQ ID NO:22 and, preferably, a VL region comprising the sequence of SEQ ID NO:26 (**060**)

- e) a VH region comprising the sequence of SEQ ID NO:29 and, preferably, a VL region comprising the sequence of SEQ ID NO:33 (**106**)
- f) a VH region comprising the sequence of SEQ ID NO:36 and, preferably, a VL region comprising the sequence of SEQ ID NO:40 (**111**)
- g) a VH region comprising the sequence of SEQ ID NO:43 and, preferably, a VL region comprising the sequence of SEQ ID NO:44 (**041**)
- h) a VH region comprising the sequence of SEQ ID NO:45 and, preferably, a VL region comprising the sequence of SEQ ID NO:46 (**150**),
- i) a VH region comprising the sequence of SEQ ID NO:47 and, preferably, a VL region comprising the sequence of SEQ ID NO:48 (**067**),
- j) a VH region comprising the sequence of SEQ ID NO:49 and, preferably, a VL region comprising the sequence of SEQ ID NO:50 (**072**),
- k) a VH region comprising the sequence of SEQ ID NO:51 and, preferably, a VL region comprising the sequence of SEQ ID NO:52 (**163**),
- l) a VH region comprising the sequence of SEQ ID NO:53 and, preferably, a VL region comprising the sequence of SEQ ID NO:54 (**093**),
- m) a VH region comprising the sequence of SEQ ID NO:55 and, preferably, a VL region comprising the sequence of SEQ ID NO:56 (**044**),
- n) a variant of any of said antibodies, wherein said variant preferably has at most 1,2 or 3 amino-acid modifications, more preferably amino-acid substitutions, such as conservative amino acid substitutions and substitutions where the new amino acid is one at the same position in an aligned sequence in Figures 1 or 2, particularly at positions indicated by "X" in the corresponding consensus sequence.

In another aspect of the antibody of the invention, the antibody partially or completely cross-blocks the binding to soluble HER2 of one or more of the novel antibodies described herein, preferably when determined as described in Example 14; and is further characterized by one or more properties determined as described in Examples 12, 13, 15, 16, 17 and 18.

In one embodiment, the HER2 antibody has a lower EC₅₀ value (half maximal effective concentration) than trastuzumab in binding to A431 cells, preferably an EC₅₀ value lower than 0.80, 0.50 or 0.30 µg/ml, when determined as described in Example 12, and cross-blocks at least one antibody selected from the group consisting of

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);

- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**); and
- c) an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 006, 059, or a combination thereof.

In an additional or alternative embodiment, the HER antibody specifically binds HER2-positive Rhesus epithelial cells, when determined as described in Example 13, and cross-blocks at least one antibody selected from the group consisting of:

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**)
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**)
- c) an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**)
- d) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**)
- e) an antibody comprising a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**)
- f) an antibody comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 006, 059, 060, 106, 111, or a combination thereof.

In an additional or alternative embodiment, the HER2 antibody specifically binds HER2-expressing AU565 cells but promotes ligand-independent proliferation of the cells less than F5, preferably promoting proliferation less than 30%, more preferably by less than 20%, when determined as described in Example 16, and cross-blocks at least one antibody selected from:

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**); and
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 060, or a combination thereof.

In an additional or alternative embodiment, the antibody, when conjugated directly or indirectly to a therapeutic moiety such as a truncated form of the pseudomonas-exotoxin A, is more effective than trastuzumab in killing AU565 cells, A431 cells, or both AU565 and A431 cells, when determined as described in Example 17.

In one embodiment, the conjugated antibody kills at least 60%, preferably at least 70% AU565 cells or A431 cells, when determined as described in Example 17, and cross-blocks at least one antibody selected from

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**)
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**)
- c) an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**), and
- d) an antibody comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 060, 059, 111, or a combination thereof.

In an additional or alternative embodiment, the antibody, when conjugated directly or indirectly to a therapeutic moiety, is capable of killing tumor cells expressing a lower average amount of HER2 copies per cell than AU565 cells, such as an average of about 500,000 or less, 100,000 or less, or 30,000 or less copies of HER2 per cell (when determined, e.g., as referred to in Example 12), at concentrations where non-conjugated antibody does not induce killing of the cells, preferably when determined as described in Example 17.

In one embodiment, the antibody of the preceding embodiment kills at least 80% of A431 cells when determined as described in Example 17, and cross-blocks at least one antibody selected from

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**), and

- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 060, or a combination thereof.

In an additional or alternative embodiment, the antibody is internalized by tumor cells expressing HER2, such as AU565 cells, more than trastuzumab is, preferably more than twice or three times the amount of internalized trastuzumab, preferably when determined according to Example 18, and cross-blocks at least one antibody selected from the group consisting of:

- a) an antibody comprising a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**)
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**)
- c) an antibody comprising a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**)
- d) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**)
- e) an antibody comprising a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**)
- f) an antibody comprising a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

In separate and specific embodiments, the antibody of the preceding embodiment fully cross-blocks, preferably bind to the same epitope as, antibody 005, 006, 059, 060, 106, 111, or a combination thereof.

In a further embodiment, the antibody promotes proliferation of HER2 expressing tumor cells less than F5, and is internalized more than trastuzumab into HER2 expressing tumor cells, preferably when determined as described in the Examples.

Antibody formats

The present invention provides HER2 antibodies which efficiently bind to and internalize into HER2-expressing tumor cells, typically without significantly promoting ligand-independent proliferation of the cells. Depending on the desired functional properties for a particular use, particular antibodies can be selected from the set of antibodies provided in the present

invention and/or their format can be adapted to change these properties, as described below.

The antibody of the invention can be of any isotype. The choice of isotype typically will be guided by the desired effector functions, such as ADCC induction. Exemplary isotypes are IgG1, IgG2, IgG3, and IgG4. Either of the human light chain constant regions, kappa or lambda, may be used. If desired, the class of a HER2 antibody of the present invention may be switched by known methods. For example, an antibody of the present invention that was originally IgM may be class switched to an IgG antibody of the present invention. Further, class switching techniques may be used to convert one IgG subclass to another, for instance from IgG1 to IgG2. Thus, the effector function of the antibodies of the present invention may be changed by isotype switching to, e.g., an IgG1, IgG2, IgG3, IgG4, IgD, IgA, IgE, or IgM antibody for various therapeutic uses. In one embodiment an antibody of the present invention is an IgG1 antibody, for instance an IgG1, κ .

In a further embodiment, the antibody of the invention is glyco-engineered to reduce fucose and thus enhance ADCC, e.g. by addition of compounds to the culture media during antibody production as described in US2009317869 or as described in van Berkel *et al.* (2010) *Biotechnol. Bioeng.* 105:350 or by using FUT8 knockout cells, e.g. as described in Yamane-Ohnuki *et al.* (2004) *Biotechnol. Bioeng.* 87:614. ADCC may alternatively be optimized using the method described by Umaña *et al.* (1999) *Nature Biotech* 17:176.

In a further embodiment, the antibody of the invention has been engineered to enhance complement activation, e.g. as described in Natsume *et al.* (2009) *Cancer Sci.* 100:2411.

In one embodiment, the antibody of the invention is a full-length antibody, preferably an IgG1 antibody, in particular an IgG1, κ antibody. In another embodiment, the antibody of the invention is an antibody fragment or a single-chain antibody.

Antibody fragments may e.g. be obtained by fragmentation using conventional techniques, and the fragments screened for utility in the same manner as described herein for whole antibodies. For example, F(ab')₂ fragments may be generated by treating an antibody with pepsin. The resulting F(ab')₂ fragment may be treated to reduce disulfide bridges with a reducing agent, such as dithiothreitol, to produce Fab' fragments. Fab fragments may be obtained by treating an antibody with papain. A F(ab')₂ fragment may also be produced by binding Fab' fragments via a thioether bond or a disulfide bond. Antibody fragments may also be generated by expression of nucleic acids encoding such fragments in recombinant cells (see for instance Evans *et al.*, *J. Immunol. Meth.* 184, 123-38 (1995)). For example, a chimeric gene encoding a portion of an F(ab')₂ fragment could include DNA sequences encoding the C_H1 domain and hinge region of the H chain,

followed by a translational stop codon to yield such a truncated antibody fragment molecule.

As explained above, in one embodiment, the HER2 antibody of the invention is a bivalent antibody.

In another embodiment, the HER2 antibody of the invention is a monovalent antibody.

In one embodiment, the antibody of the invention is a Fab fragment or a one-armed antibody, such as described in US20080063641 (Genentech) or other monovalent antibody, e.g. such as described in WO2007048037 (Amgen).

In a preferred embodiment, a monovalent antibody has a structure as described in WO2007059782 (Genmab) (incorporated herein by reference) having a deletion of the hinge region. Accordingly, in one embodiment, the antibody is a monovalent antibody, wherein said HER2 antibody is constructed by a method comprising:

i) providing a nucleic acid construct encoding the light chain of said monovalent antibody, said construct comprising a nucleotide sequence encoding the VL region of a selected antigen specific HER2 antibody and a nucleotide sequence encoding the constant CL region of an Ig, wherein said nucleotide sequence encoding the VL region of a selected antigen specific antibody and said nucleotide sequence encoding the CL region of an Ig are operably linked together, and wherein, in case of an IgG1 subtype, the nucleotide sequence encoding the CL region has been modified such that the CL region does not contain any amino acids capable of forming disulfide bonds or covalent bonds with other peptides comprising an identical amino acid sequence of the CL region in the presence of polyclonal human IgG or when administered to an animal or human being;

ii) providing a nucleic acid construct encoding the heavy chain of said monovalent antibody, said construct comprising a nucleotide sequence encoding the VH region of a selected antigen specific antibody and a nucleotide sequence encoding a constant CH region of a human Ig, wherein the nucleotide sequence encoding the CH region has been modified such that the region corresponding to the hinge region and, as required by the Ig subtype, other regions of the CH region, such as the CH3 region, does not comprise any amino acid residues which participate in the formation of disulphide bonds or covalent or stable non-covalent inter-heavy chain bonds with other peptides comprising an identical amino acid sequence of the CH region of the human Ig in the presence of polyclonal human IgG or when administered to an animal human being, wherein said nucleotide sequence encoding the VH region of a selected antigen specific antibody and said nucleotide sequence encoding the CH region of said Ig are operably linked together;

iii) providing a cell expression system for producing said monovalent antibody;

iv) producing said monovalent antibody by co-expressing the nucleic acid constructs of (i) and (ii) in cells of the cell expression system of (iii).

Similarly, in one embodiment, the HER2 antibody is a monovalent antibody, which comprises

(i) a variable region of an antibody of the invention as described herein or an antigen binding part of the said region, and

(ii) a C_H region of an immunoglobulin or a fragment thereof comprising the C_H2 and C_H3 regions, wherein the C_H region or fragment thereof has been modified such that the region corresponding to the hinge region and, if the immunoglobulin is not an IgG4 subtype, other regions of the C_H region, such as the C_H3 region, do not comprise any amino acid residues, which are capable of forming disulfide bonds with an identical C_H region or other covalent or stable non-covalent inter-heavy chain bonds with an identical C_H region in the presence of polyclonal human IgG.

In a further embodiment hereof, the heavy chain of the monovalent HER2 antibody has been modified such that the entire hinge has been deleted.

In another further embodiment, said monovalent antibody is of the IgG4 subtype, but the C_H3 region has been modified so that one or more of the following amino acid substitutions have been made:

Numbering of CH3 mutations

KABAT*	EU index G4*	Mutations
E378	E357	E357A or E357T or E357V or E357I
S387	S364	S364R or S364K
T389	T366	T366A or T366R or T366K or T366N
L391	L368	L368A or L368V or L368E or L368G or L368S or L368T
D427	D399	D399A or D399T or D399S
F436	F405	F405A or F405L or F405T or F405D or F405R or F405Q or F405K or F405Y
Y438	Y407	Y407A or Y407E or Y407Q or Y407K or Y407F
F436 and Y438	F405 and Y407	(F405T and Y407E) or (F405D and Y407E) (D399S and Y407Q) or (D399S and Y407K) or (D399S D427 and Y438 D399 and Y407 and Y407E)

*KABAT indicates amino acid numbering according to Kabat (Kabat et al., *Sequences of Proteins of Immunological Interest*, 5th Ed. Public Health Service, National Institutes of Health, Bethesda, MD. (1991). EU index indicates amino acid numbering according to EU index as outlined in Kabat et al., (supra).

In another further embodiment, the sequence of said monovalent antibody has been modified so that it does not comprise any acceptor sites for N-linked glycosylation.

HER2 antibodies of the invention also include single chain antibodies. Single chain antibodies are peptides in which the heavy and light chain Fv regions are connected. In one embodiment, the present invention provides a single-chain Fv (scFv) wherein the heavy and light chains in the Fv of a HER2 antibody of the present invention are joined with a flexible peptide linker (typically of about 10, 12, 15 or more amino acid residues) in a single peptide chain. Methods of producing such antibodies are described in for instance US 4,946,778, Pluckthun in *The Pharmacology of Monoclonal Antibodies*, vol. 113, Rosenberg and Moore eds. Springer-Verlag, New York, pp. 269-315 (1994), Bird *et al.*, *Science* 242, 423-426 (1988), Huston *et al.*, *PNAS USA* 85, 5879-5883 (1988) and McCafferty *et al.*, *Nature* 348, 552-554 (1990). The single chain antibody may be monovalent, if only a single V_H and V_L are used, bivalent, if two V_H and V_L are used, or polyvalent, if more than two V_H and V_L are used.

In one embodiment, the HER2 antibody of the invention is an effector-function-deficient antibody. In one embodiment, the effector-function-deficient HER2 antibody is a stabilized IgG4 antibody, which has been modified to prevent Fab-arm exchange (van der Neut Kofschoten *et al.* (2007) *Science* 317(5844):1554-7). Examples of suitable stabilized IgG4 antibodies are antibodies, wherein arginine at position 409 in a heavy chain constant region of human IgG4, which is indicated in the EU index as in Kabat *et al.*, is substituted with lysine, threonine, methionine, or leucine, preferably lysine (described in WO2006033386 (Kirin)) and/or wherein the hinge region has been modified to comprise a Cys-Pro-Pro-Cys sequence.

In one embodiment, the stabilized IgG4 HER2 antibody is an IgG4 antibody comprising a heavy chain and a light chain, wherein said heavy chain comprises a human IgG4 constant region having a residue selected from the group consisting of: Lys, Ala, Thr, Met and Leu at the position corresponding to 409 and/or a residue selected from the group consisting of: Ala, Val, Gly, Ile and Leu at the position corresponding to 405, and wherein said antibody optionally comprises one or more further substitutions, deletions and/or insertions, but does not comprise a Cys-Pro-Pro-Cys sequence in the hinge region. Preferably, said antibody comprises a Lys or Ala residue at the position corresponding to 409 or the CH3 region of the antibody has been replaced by the CH3 region of human IgG1, of human IgG2 or of human IgG3. See also WO2008145142 (Genmab).

In an even further embodiment, the stabilized IgG4 HER2 antibody is an IgG4 antibody comprising a heavy chain and a light chain, wherein said heavy chain comprises a

human IgG4 constant region having a residue selected from the group consisting of: Lys, Ala, Thr, Met and Leu at the position corresponding to 409 and/or a residue selected from the group consisting of: Ala, Val, Gly, Ile and Leu at the position corresponding to 405, and wherein said antibody optionally comprises one or more further substitutions, deletions and/or insertions and wherein said antibody comprises a Cys-Pro-Pro-Cys sequence in the hinge region. Preferably, said antibody comprises a Lys or Ala residue at the position corresponding to 409 or the CH3 region of the antibody has been replaced by the CH3 region of human IgG1, of human IgG2 or of human IgG3.

In a further embodiment, the effector-function-deficient HER2 antibody is an antibody of a non-IgG4 type, e.g. IgG1, IgG2 or IgG3 which has been mutated such that the ability to mediate effector functions, such as ADCC, has been reduced or even eliminated. Such mutations have e.g. been described in Dall'Acqua WF *et al.*, J Immunol. 177(2):1129-1138 (2006) and Hezareh M, J Virol. ;75(24):12161-12168 (2001).

Conjugates

In a further embodiment, the present invention provides a HER2 antibody conjugated to a therapeutic moiety, such as a cytotoxin, a chemotherapeutic drug, a cytokine, an immunosuppressant, or a radioisotope. Such conjugates are referred to herein as "immunoconjugates". Immunoconjugates which include one or more cytotoxins are referred to as "immunotoxins".

A cytotoxin or cytotoxic agent includes any agent that is detrimental to (e.g., kills) cells. Suitable therapeutic agents for forming immunoconjugates of the present invention include taxol, cytochalasin B, gramicidin D, ethidium bromide, emetine, mitomycin, etoposide, teniposide, vincristine, vinblastine, colchicin, doxorubicin, daunorubicin, dihydroxy anthracin dione, maytansine or an analog or derivative thereof, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, glucocorticoids, procaine, tetracaine, lidocaine, propranolol, and puromycin,; calicheamicin or analogs or derivatives thereof; antimetabolites (such as methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, fludarabine, 5-fluorouracil, decarbazine, hydroxyurea, asparaginase, gemcitabine, cladribine), alkylating agents (such as mechlorethamine, thioepa, chlorambucil, melphalan, carmustine (BSNU), lomustine (CCNU), cyclophosphamide, busulfan, dibromomannitol, streptozotocin, dacarbazine (DTIC), procarbazine, mitomycin C, cisplatin and other platinum derivatives, such as carboplatin; as well as duocarmycin A, duocarmycin SA, CC-1065 (a.k.a. rachelmycin), or analogs or derivatives of CC-1065), antibiotics (such as dactinomycin (formerly actinomycin), bleomycin, daunorubicin (formerly daunomycin), doxorubicin, idarubicin, mithramycin, mitomycin, mitoxantrone, plicamycin, anthramycin

(AMC)), anti-mitotic agents (e.g., tubulin-inhibitors) such as monomethyl auristatin E, monomethyl auristatin F, or other analogs or derivatives of dolastatin 10; diphtheria toxin and related molecules (such as diphtheria A chain and active fragments thereof and hybrid molecules); ricin toxin (such as ricin A or a deglycosylated ricin A chain toxin), cholera toxin, a Shiga-like toxin (SLT-I, SLT-II, SLT-IIIV), LT toxin, C3 toxin, Shiga toxin, pertussis toxin, tetanus toxin, soybean Bowman-Birk protease inhibitor, *Pseudomonas* exotoxin, alorin, saporin, modeccin, gelanin, abrin A chain, modeccin A chain, alpha-sarcin, Aleurites fordii proteins, dianthin proteins, *Phytolacca americana* proteins (PAPI, PAPII, and PAP-S), momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, and enomycin toxins. Other suitable conjugated molecules include antimicrobial/lytic peptides such as CLIP, Magainin 2, mellitin, Cecropin, and P18; ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, diphtherin toxin, and *Pseudomonas* endotoxin. See, for example, Pastan *et al.*, *Cell* **47**, 641 (1986) and Goldenberg, *Calif. A Cancer Journal for Clinicians* **44**, 43 (1994). Therapeutic agents that may be administered in combination with a HER2 antibody of the present invention as described elsewhere herein, such as, e.g., anti-cancer cytokines or chemokines, are also candidates for therapeutic moieties useful for conjugation to an antibody of the present invention.

In one embodiment, a HER2 antibody of the invention comprises a conjugated nucleic acid or nucleic acid-associated molecule. In one such embodiment, the conjugated nucleic acid is a cytotoxic ribonuclease, an antisense nucleic acid, an inhibitory RNA molecule (e.g., a siRNA molecule) or an immunostimulatory nucleic acid (e.g., an immunostimulatory CpG motif-containing DNA molecule). In another embodiment, a HER2 antibody of the invention is conjugated to an aptamer or a ribozyme.

In one embodiment, HER2 antibodies comprising one or more radiolabeled amino acids are provided. A radiolabeled HER2 antibody may be used for both diagnostic and therapeutic purposes (conjugation to radiolabeled molecules is another possible feature). Non-limiting examples of labels for polypeptides include ^3H , ^{14}C , ^{15}N , ^{35}S , ^{90}Y , ^{99}Tc , and ^{125}I , ^{131}I , and ^{186}Re .

In one embodiment, the antibody is conjugated to a radioisotope or to a radioisotope-containing chelate. For example, the antibody can be conjugated to a chelator linker, e.g. DOTA, DTPA or tiuxetan, which allows for the antibody to be complexed with a radioisotope. The antibody may also or alternatively comprise or be conjugated to one or more radiolabeled amino acids or other radiolabeled molecule. A radiolabeled CD74 antibody may be used for both diagnostic and therapeutic purposes. Non-limiting examples of radioisotopes include ^3H , ^{14}C , ^{15}N , ^{35}S , ^{90}Y , ^{99}Tc , ^{125}I , ^{111}In , ^{131}I , ^{186}Re , ^{213}Bs , ^{225}Ac and ^{227}Th .

HER2 antibodies may also be chemically modified by covalent conjugation to a polymer to for instance increase their circulating half-life. Exemplary polymers, and methods to attach them to peptides, are illustrated in for instance US 4,766,106, US 4,179,337, US 4,495,285 and US 4,609,546. Additional polymers include polyoxyethylated polyols and polyethylene glycol (PEG) (e.g., a PEG with a molecular weight of between about 1,000 and about 40,000, such as between about 2,000 and about 20,000).

Any method known in the art for conjugating the HER2 antibody to the conjugated molecule(s), such as those described above, may be employed, including the methods described by Hunter *et al.*, Nature 144, 945 (1962), David *et al.*, Biochemistry 13, 1014 (1974), Pain *et al.*, J. Immunol. Meth. 40, 219 (1981) and Nygren, J. Histochem. and Cytochem. 30, 407 (1982). Such antibodies may be produced by chemically conjugating the other moiety to the N-terminal side or C-terminal side of the HER2 antibody or fragment thereof (e.g., a HER2 antibody H or L chain) (see, e.g., Antibody Engineering Handbook, edited by Osamu Kanemitsu, published by Chijin Shokan (1994)). Such conjugated antibody derivatives may also be generated by conjugation at internal residues or sugars, where appropriate.

The agents may be coupled either directly or indirectly to a HER2 antibody of the present invention. One example of indirect coupling of a second agent is coupling via a spacer moiety to cysteine or lysine residues in the antibody. In one embodiment, a HER2 antibody is conjugated to a prodrug molecule that can be activated *in vivo* to a therapeutic drug via a spacer or linker. After administration, the spacers or linkers are cleaved by tumor-cell associated enzymes or other tumor-specific conditions, by which the active drug is formed. Examples of such prodrug technologies and linkers are described in WO02083180, WO2004043493, WO2007018431, WO2007089149, and WO2009017394 by Syntarga BV, *et al.* Suitable antibody-prodrug technology and duocarmycin analogs can also be found in U.S. Patent No. 6,989,452 (Medarex).

In one embodiment, the HER2 antibody of the present invention is attached to a chelator linker, e.g. tiuxetan, which allows for the antibody to be conjugated to a radioisotope.

Bispecific antibodies

In a further aspect, the invention relates to a bispecific molecule comprising a first antigen binding site from a HER2 antibody of the invention as described herein above and a second antigen binding site with a different binding specificity, such as a binding specificity for a

human effector cell, a human Fc receptor, a T cell receptor, a B cell receptor or a binding specificity for a non-overlapping epitope of HER2, i.e. a bispecific antibody wherein the first and second antigen binding sites do not cross-block each other for binding to HER2, e.g. when tested as described in Example 14.

Exemplary bispecific antibody molecules of the invention comprise (i) two antibodies, one with a specificity to HER2 and another to a second target that are conjugated together, (ii) a single antibody that has one chain or arm specific to HER2 and a second chain or arm specific to a second molecule, (iii) a single chain antibody that has specificity to HER2 and a second molecule, e.g., via two scFvs linked in tandem by an extra peptide linker; (iv) a dual-variable-domain antibody (DVD-Ig), where each light chain and heavy chain contains two variable domains in tandem through a short peptide linkage (Wu *et al.*, Generation and Characterization of a Dual Variable Domain Immunoglobulin (DVD-IgTM) Molecule, In: Antibody Engineering, Springer Berlin Heidelberg (2010)); (v) a chemically-linked bispecific (Fab')₂ fragment; (vi) a Tandab, which is a fusion of two single chain diabodies resulting in a tetravalent bispecific antibody that has two binding sites for each of the target antigens; (vii) a flexibody, which is a combination of scFvs with a diabody resulting in a multivalent molecule; (viii) a so called "dock and lock" molecule, based on the "dimerization and docking domain" in Protein Kinase A, which, when applied to Fabs, can yield a trivalent bispecific binding protein consisting of two identical Fab fragments linked to a different Fab fragment; (ix) a so-called Scorpion molecule, comprising, e.g., two scFvs fused to both termini of a human Fc-region; and (x) a diabody. In one embodiment, the bispecific antibody of the present invention is a diabody.

In one embodiment, the second molecule is a cancer antigen/tumor-associated antigen such as carcinoembryonic antigen (CEA), prostate specific antigen (PSA), RAGE (renal antigen), α -fetoprotein, CAMEL (CTL-recognized antigen on melanoma), CT antigens (such as MAGE-B5, -B6, -C2, -C3, and D; Mage-12; CT10; NY-ESO-1, SSX-2, GAGE, BAGE, MAGE, and SAGE), mucin antigens (e.g., MUC1, mucin-CA125, etc.), ganglioside antigens, tyrosinase, gp75, c-Met, C-myc, Mart1, MelanA, MUM-1, MUM-2, MUM-3, HLA-B7, Ep-CAM or a cancer-associated integrin, such as $\alpha 5 \beta 3$ integrin. In another embodiment, the second molecule is a T cell and/or NK cell antigen, such as CD3 or CD16. In another embodiment, the second molecule is an angiogenic factor or other cancer-associated growth factor, such as a vascular endothelial growth factor, a fibroblast growth factor, epidermal growth factor, angiogenin or a receptor of any of these, particularly receptors associated with cancer progression (for instance another one of the HER receptors; HER1, HER3, or HER4). In one embodiment, the second antigen-binding site binds a different, preferably non-blocking, site on HER2 than the one bound by the antibody of the invention. For example, the second

molecule may be derived from, or cross-block HER2-binding of, trastuzumab, pertuzumab, F5, or C1.

Nucleic acid sequences, vectors and host cells

In a further aspect, the invention relates to nucleic acid sequences, such as DNA sequences, encoding heavy and light chains of an antibody of the invention.

In one embodiment, the nucleic acid sequence encodes an amino acid sequence selected from the group consisting of: SEQ ID NO: 1, 5, 8, 12, 15, 19, 22, 26, 29, 33, 36, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, and 56.

In another particular embodiment, the nucleic acid sequence encodes a VH amino acid sequence selected from the group consisting of: SEQ ID NO: 1, 8, 15, 22, 29, 36, 43, 45, 47, 49, 51, 53, and 55.

In another particular embodiment, the nucleic acid sequence encodes a VL amino acid sequence selected from the group consisting of: SEQ ID NO: 5, 12, 19, 26, 33, 40, 44, 46, 48, 50, 52, 54, and 56.

In an even further aspect, the invention relates to an expression vector, or a set of expression vectors, encoding an antibody of the invention. The heavy and light chain of the antibody may be encoded by the same vector or by different vector.

Such expression vectors may be used for recombinant production of antibodies of the invention.

In one embodiment, the expression vector of the invention comprises a nucleotide sequence encoding one or more of the amino acid sequences selected from the group consisting of: SEQ ID NO: 1, 5, 8, 12, 15, 19, 22, 26, 29, 33, 36, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, and 56.

In another particular embodiment, the expression vector of the invention comprises a nucleotide sequence encoding one or more of the VH amino acid sequences selected from the group consisting of: SEQ ID NO: 1, 8, 15, 22, 29, 36, 43, 45, 47, 49, 51, 53, and 55.

In another particular embodiment, the expression vector of the invention comprises a nucleotide sequence encoding one or more of the VL amino acid sequences selected from the group consisting of: SEQ ID NO: 5, 12, 19, 26, 33, 40, 44, 46, 48, 50, 52, 54, and 56.

In a further embodiment, the expression vector further comprises a nucleotide sequence encoding the constant region of a light chain, a heavy chain or both light and heavy chains of an antibody, e.g. a human antibody.

An expression vector in the context of the present invention may be any suitable vector, including chromosomal, non-chromosomal, and synthetic nucleic acid vectors (a nucleic acid sequence comprising a suitable set of expression control elements). Examples of such vectors include derivatives of SV40, bacterial plasmids, phage DNA, baculovirus, yeast plasmids, vectors derived from combinations of plasmids and phage DNA, and viral nucleic acid (RNA or DNA) vectors. In one embodiment, a HER2 antibody-encoding nucleic acid is comprised in a naked DNA or RNA vector, including, for example, a linear expression element (as described in for instance Sykes and Johnston, *Nat Biotech* 17, 355-59 (1997)), a compacted nucleic acid vector (as described in for instance US 6,077, 835 and/or WO 00/70087), a plasmid vector such as pBR322, pUC 19/18, or pUC 118/119, a "midge" minimally-sized nucleic acid vector (as described in for instance Schakowski et al., *Mol Ther* 3, 793-800 (2001)), or as a precipitated nucleic acid vector construct, such as a CaP04-precipitated construct (as described in for instance WO 00/46147, Benvenisty and Reshef, *PNAS USA* 83, 9551-55 (1986), Wigler et al., *Cell* 14, 725 (1978), and Coraro and Pearson, *Somatic Cell Genetics* 7, 603 (1981)). Such nucleic acid vectors and the usage thereof are well known in the art (see for instance US 5,589,466 and US 5,973,972).

Exemplary expression vectors for the antibodies of the invention are also described in Examples 2 and 3.

In one embodiment, the vector is suitable for expression of the HER2 antibody in a bacterial cell. Examples of such vectors include expression vectors such as BlueScript (Stratagene), pIN vectors (Van Heeke & Schuster, *J Biol Chem* 264, 5503-5509 (1989), pET vectors (Novagen, Madison WI) and the like).

An expression vector may also or alternatively be a vector suitable for expression in a yeast system. Any vector suitable for expression in a yeast system may be employed. Suitable vectors include, for example, vectors comprising constitutive or inducible promoters such as alpha factor, alcohol oxidase and PGH (reviewed in: F. Ausubel *et al.*, ed. *Current Protocols in Molecular Biology*, Greene Publishing and Wiley InterScience New York (1987), and Grant *et al.*, *Methods in Enzymol* 153, 516-544 (1987)).

An expression vector may also or alternatively be a vector suitable for expression in mammalian cells, e.g. a vector comprising glutamine synthetase as a selectable marker, such as the vectors described in Bebbington (1992) *Biotechnology (NY)* 10:169-175.

A nucleic acid and/or vector may also comprises a nucleic acid sequence encoding a secretion/localization sequence, which can target a polypeptide, such as a nascent polypeptide chain, to the periplasmic space or into cell culture media. Such sequences are known in the art, and include secretion leader or signal peptides.

In an expression vector of the invention, HER2 antibody-encoding nucleic acids may comprise or be associated with any suitable promoter, enhancer, and other expression-facilitating elements. Examples of such elements include strong expression promoters (e. g., human CMV IE promoter/enhancer as well as RSV, SV40, SL3-3, MMTV, and HIV LTR promoters), effective poly (A) termination sequences, an origin of replication for plasmid product in *E. coli*, an antibiotic resistance gene as selectable marker, and/or a convenient cloning site (e.g., a polylinker). Nucleic acids may also comprise an inducible promoter as opposed to a constitutive promoter such as CMV IE.

In one embodiment, the HER2 antibody-encoding expression vector may be positioned in and/or delivered to the host cell or host animal via a viral vector.

In an even further aspect, the invention relates to a recombinant eukaryotic or prokaryotic host cell, such as a transfectoma, which produces an antibody of the invention as defined herein. Examples of host cells include yeast, bacterial, and mammalian cells, such as CHO or HEK cells. For example, in one embodiment, the present invention provides a cell comprising a nucleic acid stably integrated into the cellular genome that comprises a sequence coding for expression of a HER2 antibody of the present invention. In another embodiment, the present invention provides a cell comprising a non-integrated nucleic acid, such as a plasmid, cosmid, phagemid, or linear expression element, which comprises a sequence coding for expression of a HER2 antibody of the invention.

In a further aspect, the invention relates to a hybridoma which produces an antibody of the invention as defined herein. In an even further aspect, the invention relates to a transgenic non-human animal or plant comprising nucleic acids encoding a human heavy chain and a human light chain, wherein the animal or plant produces an antibody of the invention of the invention.

In a further aspect, the invention relates to a method for producing a HER2 antibody of the invention, said method comprising the steps of

- a) culturing a hybridoma or a host cell of the invention as described herein above, and
- b) purifying the antibody of the invention from the culture media.

Compositions

In a further main aspect, the invention relates to a pharmaceutical composition comprising:

- a HER2 antibody as defined herein, and
- a pharmaceutically-acceptable carrier.

The pharmaceutical composition of the present invention may contain one antibody of the present invention or a combination of different antibodies of the present invention.

The pharmaceutical compositions may be formulated in accordance with conventional techniques such as those disclosed in Remington: The Science and Practice of Pharmacy, 19th Edition, Gennaro, Ed., Mack Publishing Co., Easton, PA, 1995. A pharmaceutical composition of the present invention may e.g. include diluents, fillers, salts, buffers, detergents (e. g., a nonionic detergent, such as Tween-20 or Tween-80), stabilizers (e. g., sugars or protein-free amino acids), preservatives, tissue fixatives, solubilizers, and/or other materials suitable for inclusion in a pharmaceutical composition.

Pharmaceutically acceptable carriers include any and all suitable solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonicity agents, antioxidants and absorption delaying agents, and the like that are physiologically compatible with a compound of the present invention. Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions of the present invention include water, saline, phosphate buffered saline, ethanol, dextrose, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, carboxymethyl cellulose colloidal solutions, tragacanth gum and injectable organic esters, such as ethyl oleate, and/or various buffers. Pharmaceutically acceptable carriers include sterile aqueous solutions or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion. Proper fluidity may be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

Pharmaceutical compositions of the present invention may also comprise pharmaceutically acceptable antioxidants for instance (1) water soluble antioxidants, such as ascorbic acid, cysteine hydrochloride, sodium bisulfate, sodium metabisulfite, sodium sulfite and the like; (2) oil-soluble antioxidants, such as ascorbyl palmitate, butylated hydroxyanisole, butylated hydroxytoluene, lecithin, propyl gallate, alpha-tocopherol, and the like; and (3) metal chelating agents, such as citric acid, ethylenediamine tetraacetic acid (EDTA), sorbitol, tartaric acid, phosphoric acid, and the like.

Pharmaceutical compositions of the present invention may also comprise isotonicity agents, such as sugars, polyalcohols, such as mannitol, sorbitol, glycerol or sodium chloride in the compositions.

The pharmaceutical compositions of the present invention may also contain one or more adjuvants appropriate for the chosen route of administration such as preservatives, wetting agents, emulsifying agents, dispersing agents, preservatives or buffers, which may enhance the shelf life or effectiveness of the pharmaceutical composition. The compounds of the present invention may be prepared with carriers that will protect the compound against

rapid release, such as a controlled release formulation, including implants, transdermal patches, and microencapsulated delivery systems. Such carriers may include gelatin, glyceryl monostearate, glyceryl distearate, biodegradable, biocompatible polymers such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid alone or with a wax, or other materials well known in the art. Methods for the preparation of such formulations are generally known to those skilled in the art.

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

The actual dosage levels of the active ingredients in the pharmaceutical compositions may be varied so as to obtain an amount of the active ingredient which is effective to achieve the desired therapeutic response for a particular patient, composition, and mode of administration, without being toxic to the patient. The selected dosage level will depend upon a variety of pharmacokinetic factors including the activity of the particular compositions of the present invention employed, or the amide thereof, the route of administration, the time of administration, the rate of excretion of the particular compound being employed, the duration of the treatment, other drugs, compounds and/or materials used in combination with the particular compositions employed, the age, sex, weight, condition, general health and prior medical history of the patient being treated, and like factors well known in the medical arts.

The pharmaceutical composition may be administered by any suitable route and mode. In one embodiment, a pharmaceutical composition of the present invention is administered parenterally. "Administered parenterally" as used herein means modes of administration other than enteral and topical administration, usually by injection, and include epidermal, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, intratendinous, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, intracranial, intrathoracic, epidural and intrasternal injection and infusion.

In one embodiment that pharmaceutical composition is administered by intravenous or subcutaneous injection or infusion.

Uses

In a further main aspect, the invention relates to a HER2 antibody of the invention for use as a medicament.

The HER2 antibodies of the invention may be used for a number of purposes. In particular, the antibodies of the invention may be used for the treatment of various forms of cancer, including metastatic cancer and refractory cancer.

In one embodiment, the HER2 antibodies of the invention are used for the treatment of breast cancer, including primary, metastatic, and refractory breast cancer.

In one embodiment, the HER2 antibodies of the invention are used for the treatment of a form of cancer selected from the group consisting of prostate cancer, non-small cell lung cancer, bladder cancer, ovarian cancer, gastric cancer, colorectal cancer, esophageal cancer, squamous cell carcinoma of the head & neck, cervical cancer, pancreatic cancer, testis cancer, malignant melanoma and a soft-tissue cancer (e.g. synovial sarcoma).

In one embodiment the invention relates to A method for inhibiting growth and/or proliferation of one or more tumor cells expressing HER2, comprising administration, to an individual in need thereof, of an antibody according to the invention.

In one embodiment the antibody is conjugated to another moiety.

In one embodiment the one or more tumor cell co-expresses HER2 and EGFR and/or HER3.

The present invention also relates to a method for treating cancer, comprising

- a) selecting a subject suffering from a cancer comprising tumor cells co-expressing HER2 and EGFR and/or HER3, and
- b) administering to the subject the antibody according to any one of claims 1-35.

In one embodiment the cancer is selected from the group consisting of breast cancer, colorectal cancer, endometrial/cervical cancer, lung cancer, malignant melanoma, ovarian cancer, pancreatic cancer, prostate cancer, testis cancer, a soft-tissue tumor such as synovial sarcoma, and bladder cancer.

Similarly, the invention relates to a method for killing a tumor cell expressing HER2, comprising administration, to an individual in need thereof, of an effective amount of an antibody of the invention, such as an antibody drug-conjugate (ADC).

In one embodiment, said tumor cell is involved in a form of cancer selected from the group consisting of: breast cancer, prostate cancer, non-small cell lung cancer, bladder cancer, ovarian cancer, gastric cancer, colorectal cancer, esophageal cancer and squamous cell carcinoma of the head & neck, cervical cancer, pancreatic cancer, testis cancer, malignant melanoma, and a soft-tissue cancer (e.g., synovial sarcoma).

In one embodiment, the tumor cell is one that co-expresses HER2 and at least one other member of the EGFR family, preferably EGFR, HER3, or both of EGFR and HER3, and is a tumor cell involved in breast cancer, colorectal cancer, endometrial/cervical cancer, lung cancer, malignant melanoma, ovarian cancer, pancreatic cancer, prostate cancer, testis cancer, a soft-tissue tumor (e.g., synovial sarcoma), or bladder cancer.

In one aspect, the invention relates to a method for treating cancer in a subject, comprising selecting a subject suffering from a cancer comprising tumor cells co-expressing HER2 and EGFR and/or HER3, and administering to the subject an antibody of the invention, optionally in the form of an antibody conjugated to a cytotoxic agent or drug. In one embodiment, the subject suffers from a cancer selected from the group consisting of breast cancer, colorectal cancer, endometrial/cervical cancer, lung cancer, malignant melanoma, ovarian cancer, pancreatic cancer, prostate cancer, testis cancer, a soft-tissue tumor (e.g., synovial sarcoma), or bladder cancer.

Also, the invention relates to the use of a monoclonal antibody that binds to human HER2 for the preparation of a medicament for the treatment of cancer, such as one of the specific cancer indications mentioned above.

The invention further relates to a monoclonal antibody for use in the treatment of cancer, such as one of the cancer indications mentioned above.

In a further embodiment of the methods of treatment of the present invention, the efficacy of the treatment is being monitored during the therapy, e.g. at predefined points in time, by determining tumor burden or HER2 expression levels on the relevant tumor cells.

Dosage regimens in the above methods of treatment and uses are adjusted to provide the optimum desired response (e.g., a therapeutic response). For example, a single bolus may be administered, several divided doses may be administered over time or the dose may be proportionally reduced or increased as indicated by the exigencies of the therapeutic situation. Parenteral compositions may be formulated in dosage unit form for ease of administration and uniformity of dosage.

The efficient dosages and the dosage regimens for the HER2 antibodies depend on the disease or condition to be treated and may be determined by the persons skilled in the art. An exemplary, non-limiting range for a therapeutically effective amount of a compound of the present invention is about 0.1-100 mg/kg, such as about 0.1-50 mg/kg, for example about 0.1-20 mg/kg, such as about 0.1-10 mg/kg, for instance about 0.5, about such as 0.3, about 1, about 3, about 5, or about 8 mg/kg.

A physician or veterinarian having ordinary skill in the art may readily determine and prescribe the effective amount of the pharmaceutical composition required. For example, the physician or veterinarian could start doses of the HER2 antibody employed in the

pharmaceutical composition at levels lower than that required in order to achieve the desired therapeutic effect and gradually increase the dosage until the desired effect is achieved. In general, a suitable daily dose of a composition of the present invention will be that amount of the compound which is the lowest dose effective to produce a therapeutic effect. Administration may e.g. be parenteral, such as intravenous, intramuscular or subcutaneous. In one embodiment, the HER2 antibodies may be administered by infusion in a weekly dosage of from 10 to 500 mg/m², such as of from 200 to 400 mg/m². Such administration may be repeated, e.g., 1 to 8 times, such as 3 to 5 times. The administration may be performed by continuous infusion over a period of from 2 to 24 hours, such as of from 2 to 12 hours. In one embodiment, the HER2 antibodies may be administered by slow continuous infusion over a long period, such as more than 24 hours, in order to reduce toxic side effects.

In one embodiment the HER2 antibodies may be administered in a weekly dosage of from 250 mg to 2000 mg, such as for example 300 mg, 500 mg, 700 mg, 1000 mg, 1500 mg or 2000 mg, for up to 8 times, such as from 4 to 6 times. Such regimen may be repeated one or more times as necessary, for example, after 6 months or 12 months. The dosage may be determined or adjusted by measuring the amount of compound of the present invention in the blood upon administration by for instance taking out a biological sample and using anti-idiotypic antibodies which target the antigen binding region of the HER2 antibodies of the present invention.

In one embodiment, the HER2 antibodies may be administered by maintenance therapy, such as, e.g., once a week for a period of 6 months or more.

A HER2 antibody may also be administered prophylactically in order to reduce the risk of developing cancer, delay the onset of the occurrence of an event in cancer progression, and/or reduce the risk of recurrence when a cancer is in remission.

HER2 antibodies may also be administered in combination therapy, i.e., combined with other therapeutic agents relevant for the disease or condition to be treated. Accordingly, in one embodiment, the antibody-containing medicament is for combination with one or more further therapeutic agent, such as a cytotoxic, chemotherapeutic or anti-angiogenic agent.

Such combined administration may be simultaneous, separate or sequential. For simultaneous administration the agents may be administered as one composition or as separate compositions, as appropriate. The present invention thus also provides methods for treating a disorder involving cells expressing HER2 as described above, which methods comprise administration of a HER2 antibody of the present invention combined with one or more additional therapeutic agents as described below.

In one embodiment, the present invention provides a method for treating a disorder involving cells expressing HER2 in a subject, which method comprises administration of a therapeutically effective amount of a HER2 antibody of the present invention and at least one additional therapeutic agent to a subject in need thereof.

In one embodiment, the present invention provides a method for treating or preventing cancer, which method comprises administration of a therapeutically effective amount of a HER2 antibody of the present invention and at least one additional therapeutic agent to a subject in need thereof.

In one embodiment, such an additional therapeutic agent may be selected from an antimetabolite, such as methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, fludarabine, 5-fluorouracil, decarbazine, hydroxyurea, asparaginase, gemcitabine or cladribine.

In another embodiment, such an additional therapeutic agent may be selected from an alkylating agent, such as mechlorethamine, thioepa, chlorambucil, melphalan, carmustine (BSNU), lomustine (CCNU), cyclophosphamide, busulfan, dibromomannitol, streptozotocin, dacarbazine (DTIC), procarbazine, mitomycin C, cisplatin and other platinum derivatives, such as carboplatin.

In another embodiment, such an additional therapeutic agent may be selected from an anti-mitotic agent, such as taxanes, for instance docetaxel, and paclitaxel, and vinca alkaloids, for instance vindesine, vincristine, vinblastine, and vinorelbine.

In another embodiment, such an additional therapeutic agent may be selected from a topoisomerase inhibitor, such as topotecan or irinotecan, or a cytostatic drug, such as etoposide and teniposide.

In another embodiment, such an additional therapeutic agent may be selected from a growth factor inhibitor, such as an inhibitor of ErbB1 (EGFR) (such as an EGFR antibody, e.g. zalutumumab, cetuximab, panitumumab or nimotuzumab or other EGFR inhibitors, such as gefitinib or erlotinib), another inhibitor of ErbB2 (HER2/neu) (such as a HER2 antibody, e.g. trastuzumab, trastuzumab-DM1 or pertuzumab) or an inhibitor of both EGFR and HER2, such as lapatinib).

In another embodiment, such an additional therapeutic agent may be selected from a tyrosine kinase inhibitor, such as imatinib (Glivec, Gleevec STI571) or lapatinib, PTK787/ZK222584.

In another embodiment, the present invention provides a method for treating a disorder involving cells expressing HER2 in a subject, which method comprises administration of a therapeutically effective amount of an HER2 antibody of the present

invention and at least one inhibitor of angiogenesis, neovascularization, and/or other vascularization to a subject in need thereof

Examples of such angiogenesis inhibitors are urokinase inhibitors, matrix metalloprotease inhibitors (such as marimastat, neovastat, BAY 12-9566, AG 3340, BMS-275291 and similar agents), inhibitors of endothelial cell migration and proliferation (such as TNP-470, squalamine, 2-methoxyestradiol, combretastatins, endostatin, angiostatin, penicillamine, SCH66336 (Schering-Plough Corp, Madison, NJ), R115777 (Janssen Pharmaceutica, Inc, Titusville, NJ) and similar agents), antagonists of angiogenic growth factors (such as such as ZD6474, SU6668, antibodies against angiogenic agents and/or their receptors (such as VEGF (e.g. bevacizumab), bFGF, and angiopoietin-1), thalidomide, thalidomide analogs (such as CC-5013), Sugen 5416, SU5402, antiangiogenic ribozyme (such as angiozyme), interferon α (such as interferon α 2a), suramin and similar agents), VEGF-R kinase inhibitors and other anti-angiogenic tyrosine kinase inhibitors (such as SU011248), inhibitors of endothelial-specific integrin/survival signaling (such as vitaxin and similar agents), copper antagonists/chelators (such as tetrathiomolybdate, captopril and similar agents), carboxyamido-triazole (CAI), ABT-627, CM101, interleukin-12 (IL-12), IM862, PNU145156E as well as nucleotide molecules inhibiting angiogenesis (such as antisense-VEGF-cDNA, cDNA coding for angiostatin, cDNA coding for p53 and cDNA coding for deficient VEGF receptor-2).

Other examples of such inhibitors of angiogenesis, neovascularization, and/or other vascularization are anti-angiogenic heparin derivatives (e.g., heparinase III), temozolomide, NK4, macrophage migration inhibitory factor, cyclooxygenase-2 inhibitors, inhibitors of hypoxia-inducible factor 1, anti-angiogenic soy isoflavones, oltipraz, fumagillin and analogs thereof, somatostatin analogues, pentosan polysulfate, tecogalan sodium, dalteparin, tumstatin, thrombospondin, NM-3, combrestatin, canstatin, avastatin, antibodies against other targets, such as anti- α -v/ β -3 integrin and anti-kininostatin antibodies.

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be an anti-cancer immunogen, such as a cancer antigen/tumor-associated antigen (e.g., epithelial cell adhesion molecule (EpCAM/TACSTD1), mucin 1 (MUC1), carcinoembryonic antigen (CEA), tumor-associated glycoprotein 72 (TAG-72), gp100, Melan-A, MART-1, KDR, RCAS1, MDA7, cancer-associated viral vaccines (e.g., human papillomavirus vaccines) or tumor-derived heat shock proteins,

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be an anti-cancer cytokine, chemokine, or combination thereof. Examples of suitable cytokines and growth factors include IFN γ , IL-2, IL-4, IL-6, IL-7, IL-10, IL-12, IL-13, IL-15, IL-18, IL-23, IL-24, IL-27,

IL-28a, IL-28b, IL-29, KGF, IFN α (e.g., IFN α 2b), IFN β , GM-CSF, CD40L, Flt3 ligand, stem cell factor, ancestim, and TNF α . Suitable chemokines may include Glu-Leu-Arg (ELR)-negative chemokines such as IP-10, MCP-3, MIG, and SDF-1 α from the human CXC and C-C chemokine families. Suitable cytokines include cytokine derivatives, cytokine variants, cytokine fragments, and cytokine fusion proteins.

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be a cell cycle control/apoptosis regulator (or "regulating agent"). A cell cycle control/apoptosis regulator may include molecules that target and modulate cell cycle control/apoptosis regulators such as (i) cdc-25 (such as NSC 663284), (ii) cyclin-dependent kinases that overstimulate the cell cycle (such as flavopiridol (L868275, HMR1275), 7-hydroxystaurosporine (UCN-01, KW-2401), and roscovitine (R-roscovitine, CYC202)), and (iii) telomerase modulators (such as BIBR1532, SOT-095, GRN163 and compositions described in for instance US 6,440,735 and US 6,713,055). Non-limiting examples of molecules that interfere with apoptotic pathways include TNF-related apoptosis-inducing ligand (TRAIL)/apoptosis-2 ligand (Apo-2L), antibodies that activate TRAIL receptors, IFNs, and anti-sense Bcl-2.

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be a hormonal regulating agent, such as agents useful for anti-androgen and anti-estrogen therapy. Examples of such hormonal regulating agents are tamoxifen, idoxifene, fulvestrant, droloxifene, toremifene, raloxifene, diethylstilbestrol, ethinyl estradiol/estinyl, an antiandrogene (such as flutaminde/eulexin), a progestin (such as such as hydroxyprogesterone caproate, medroxy-progesterone/provera, megestrol acepate/megace), an adrenocorticosteroid (such as hydrocortisone, prednisone), luteinizing hormone-releasing hormone (and analogs thereof and other LHRH agonists such as buserelin and goserelin), an aromatase inhibitor (such as anastrozole/arimidex, aminoglutethimide/cytraden, exemestane) or a hormone inhibitor (such as octreotide/sandostatin).

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be an anti-anergic agent, such as compounds are molecules that block the activity of CTLA-4, e.g. ipilimumab.

In one embodiment, a therapeutic agent for use in combination with a HER2 antibody for treating the disorders as described above may be an anti-cancer nucleic acid or an anti-cancer inhibitory RNA molecule.

Examples of other anti-cancer agents, which may be relevant as therapeutic agents for use in combination with a HER2 antibody for treating the disorders as described above are differentiation inducing agents, retinoic acid analogues (such as all trans retinoic acid,

13-cis retinoic acid and similar agents), vitamin D analogues (such as seocalcitrol and similar agents), inhibitors of ErbB3, ErbB4, IGF-IR, insulin receptor, PDGFR α , PDGFR β , Flk2, Flt4, FGFR1, FGFR2, FGFR3, FGFR4, TRKA, TRKC, RON (such as an anti-RON antibody), Sea, Tie, Tie2, Eph, Ret, Ros, Alk, LTK, PTK7 and similar agents.

Examples of other anti-cancer agents, which may be relevant as therapeutic agents for use in combination with a HER2 antibody for treating the disorders as described above are estramustine and epirubicin.

Examples of other anti-cancer agents, which may be relevant as therapeutic agents for use in combination with a HER2 antibody for treating the disorders as described above are a HSP90 inhibitor like 17-allyl amino geldanamycin, antibodies directed against a tumor antigen such as PSA, CA125, KSA, integrins, e.g. integrin β 1, or inhibitors of VCAM.

Examples of other anti-cancer agents, which may be relevant as therapeutic agents for use in combination with a HER2 antibody for treating the disorders as described above are calcineurin-inhibitors (such as valspodar, PSC 833 and other MDR-1 or p-glycoprotein inhibitors), TOR-inhibitors (such as sirolimus, everolimus and rapamycin). and inhibitors of "lymphocyte homing" mechanisms (such as FTY720), and agents with effects on cell signaling such as adhesion molecule inhibitors (for instance anti-LFA).

In one embodiment, the HER2 antibody of the invention is for use in combination with one or more other therapeutic antibodies, such as ofatumumab, zanolimumab, daratumumab, ranibizumab, Zenapax, Simulect, Remicade, Humira, Tysabri, Xolair, raptiva and/or rituximab.

In another embodiment, two or more different antibodies of the invention as described herein are used in combination for the treatment of disease. Particularly interesting combinations include two or more non-blocking antibodies. Such combination therapy may lead to binding of an increased number of antibody molecules per cell, which may give increase efficacy, e.g. via activation of complement-mediated lysis.

In addition to the above, other embodiments of combination therapies of the invention include the following:

For the treatment of breast cancer, a HER2 antibody or a therapeutic conjugate thereof, in combination with methotrexate, paclitaxel, doxorubicin, carboplatin, cyclophosphamide, daunorubicin, epirubicin, 5-fluorouracil, gemcitabine, ixabepilone, mutamycin, mitoxantrone, vinorelbine, docetaxel, thiotepa, vincristine, capecitabine, an EGFR antibody (e.g. zalutumumab, cetuximab, panitumumab or nimotuzumab) or other EGFR inhibitor (such as gefitinib or erlotinib), another HER2 antibody or -conjugate (such as, e.g., trastuzumab, trastuzumab-DM1 or pertuzumab), an inhibitor of both EGFR and HER2 (such as lapatinib), and/or in combination with a HER3 inhibitor.

For the treatment of non-small-cell lung cancer, a HER2 antibody in combination with EGFR inhibitors, such as an EGFR antibody, e.g. zalutumumab, cetuximab, panitumumab or nimotuzumab or other EGFR inhibitors (such as gefitinib or erlotinib), or in combination with an another HER2 agent (such as a HER2 antibody, e.g. trastuzumab, trastuzumab-DM1 or pertuzumab) or in combination with an inhibitor of both EGFR and HER2, such as lapatinib, or in combination with a HER3 inhibitor.

For the treatment of colorectal cancer a HER2 antibody in combination with one or more compounds selected from: gemcitabine, bevacizumab, FOLFOX, FOLFIRI, XELOX, IFL, oxaliplatin, irinotecan, 5-FU/LV, Capecitabine, UFT, EGFR targeting agents, such as cetuximab, panitumumab, zalutumumab; VEGF inhibitors, or tyrosine kinase inhibitors such as sunitinib.

For the treatment of prostate cancer a HER2 antibody in combination with one or more compounds selected from: hormonal/antihormonal therapies; such as antiandrogens, Luteinizing hormone releasing hormone (LHRH) agonists, and chemotherapeutics such as taxanes, mitoxantrone, estramustine, 5FU, vinblastine, and ixabepilone.

Radiotherapy - surgery

In one embodiment, the present invention provides a method for treating a disorder involving cells expressing HER2 in a subject, which method comprises administration of a therapeutically effective amount of a HER2 antibody, such as a HER2 antibody of the present invention, and radiotherapy to a subject in need thereof.

In one embodiment, the present invention provides a method for treating or preventing cancer, which method comprises administration of a therapeutically effective amount of a HER2 antibody, such as a HER2 antibody of the present invention, and radiotherapy to a subject in need thereof.

In one embodiment, the present invention provides the use of a HER2 antibody, such as a HER2 antibody of the present invention, for the preparation of a pharmaceutical composition for treating cancer to be administered in combination with radiotherapy.

Radiotherapy may comprise radiation or associated administration of radiopharmaceuticals to a patient is provided. The source of radiation may be either external or internal to the patient being treated (radiation treatment may, for example, be in the form of external beam radiation therapy (EBRT) or brachytherapy (BT)). Radioactive elements that may be used in practicing such methods include, e.g., radium, cesium-137, iridium-192, americium-241, gold-198, cobalt-57, copper-67, technetium-99, iodide-123, iodide-131, and indium-111.

In a further embodiment, the present invention provides a method for treating or preventing cancer, which method comprises administration to a subject in need thereof of a therapeutically effective amount of a HER2 antibody, such as a HER2 antibody of the present invention, in combination with surgery.

Diagnostic uses

The HER2 antibodies of the invention may also be used for diagnostic purposes. Thus, in a further aspect, the invention relates to a diagnostic composition comprising a HER2 antibody as defined herein.

In one embodiment, the HER2 antibodies of the present invention may be used *in vivo* or *in vitro* for diagnosing diseases wherein activated cells expressing HER2 play an active role in the pathogenesis, by detecting levels of HER2, or levels of cells which contain HER2 on their membrane surface. This may be achieved, for example, by contacting a sample to be tested, optionally along with a control sample, with the HER2 antibody under conditions that allow for formation of a complex between the antibody and HER2.

Thus, in a further aspect, the invention relates to a method for detecting the presence of HER2 antigen, or a cell expressing HER2, in a sample comprising:

- contacting the sample with a HER2 antibody of the invention under conditions that allow for formation of a complex between the antibody and HER2; and
- analyzing whether a complex has been formed.

In one embodiment, the method is performed *in vitro*.

More specifically, the present invention provides methods for the identification of, and diagnosis of invasive cells and tissues, and other cells targeted by HER2 antibodies of the present invention, and for the monitoring of the progress of therapeutic treatments, status after treatment, risk of developing cancer, cancer progression, and the like.

Suitable labels for the HER2 antibody and/or secondary antibodies used in such techniques are well-known in the art.

In a further aspect, the invention relates to a kit for detecting the presence of HER2 antigen, or a cell expressing HER2, in a sample comprising

- a HER2 antibody of the invention or a bispecific molecule of the invention; and
- instructions for use of the kit.

In one embodiment, the present invention provides a kit for diagnosis of cancer comprising a container comprising a HER2 antibody, and one or more reagents for detecting binding of the HER2 antibody to HER2. Reagents may include, for example, fluorescent tags, enzymatic tags, or other detectable tags. The reagents may also include secondary or

tertiary antibodies or reagents for enzymatic reactions, wherein the enzymatic reactions produce a product that may be visualized.

Anti-idiotypic antibodies

In a further aspect, the invention relates to an anti-idiotypic antibody which binds to a HER2 antibody of the invention as described herein.

An anti-idiotypic (Id) antibody is an antibody which recognizes unique determinants generally associated with the antigen-binding site of an antibody. An Id antibody may be prepared by immunizing an animal of the same species and genetic type as the source of a HER2 mAb with the mAb to which an anti-Id is being prepared. The immunized animal typically can recognize and respond to the idiotypic determinants of the immunizing antibody by producing an antibody to these idiotypic determinants (the anti-Id antibody).

An anti-Id antibody may also be used as an "immunogen" to induce an immune response in yet another animal, producing a so-called anti-anti-Id antibody. An anti-anti-Id may be epitopically identical to the original mAb, which induced the anti-Id. Thus, by using antibodies to the idiotypic determinants of a mAb, it is possible to identify other clones expressing antibodies of identical specificity.

The present invention is further illustrated by the following examples, which should not be construed as limiting the scope of the invention.

EXAMPLES

Example 1 - Expression constructs for HER2 and HER2 variants

Fully codon-optimized constructs for expression of full length HER2 (1255 aa, Swissprot P04626), the extracellular domain (ECD) of HER2 (Her2-ECDHis, aa 1-653 with a C-terminal His6 tag), the naturally occurring HER2 splice variant (Her2-delex16, resulting from exon 16 deletion and lacking aa 633-648) and a truncated form of the HER2 receptor (Her2-stumpy, aa 648-1256), were generated. The construct contained suitable restriction sites for cloning and an optimal Kozak sequence (Kozak, M., *Gene* 1999;234(2):187-208.). The constructs were cloned in the mammalian expression vector pEE13.4 (Lonza Biologics; Bebbington, C.R., *et al.*, *Biotechnology* (N Y) 1992;10(2):169-75) and fully sequenced to confirm the correctness of the construct.

Example 2 - Expression constructs for pertuzumab, C1 and F5

Fully codon-optimized constructs for expression of the heavy chain (HC) and the light chain (LC) of the IgG1 antibodies pertuzumab, C1 and F5 in HEK cells, were generated. The variable regions encoded by these constructs are identical to those described in U.S. Patent

No. 6,949,245 for pertuzumab heavy chain and light chain and U.S. Patent No. 7,244,826 for C1 and F5 heavy and light chain. For C1 and F5, the mammalian expression vectors p33G1f and p33K or p33L (pcDNA3.3 (Invitrogen)) containing the fully codon optimized constant region for the human IgG1 heavy chain (allotype f), the human kappa light chain or the human lambda light chain, respectively, were used. For pertuzumab, the mammalian expression vectors pG1f (pEE12.4 (Lonza Biologics)) and pKappa (pEE6.4 (Lonza Biologics)), containing the fully codon-optimized constant region for the human IgG1 heavy chain (allotype f) and the human kappa light chain, respectively, were used.

Trastuzumab (Herceptin[®]) can be produced in the same manner, using the heavy and light chain sequences described in, e.g., U.S. Patent No. 7,632,924.

Example 3 - Transient expression in HEK-293 or CHO cells

Freestyle[™] 293-F (a HEK-293 subclone adapted to suspension growth and chemically defined Freestyle medium, (HEK-293F)) cells were obtained from Invitrogen and transfected with the appropriate plasmid DNA, using 293fectin (Invitrogen) according to the manufacturer's instructions. In the case of antibody expression, the appropriate heavy chain and light chain expression vectors were co-expressed.

pEE13.4Her2, pEE13.4Her2-delex16 and pEE13.4Her2-stumpy were transiently transfected in the Freestyle[™] CHO-S (Invitrogen) cell line using Freestyle MAX transfection reagent (Invitrogen). Expression of HER2 and Her2-delex16 was tested by means of FACS analysis as described below.

Example 4 - Stable polyclonal pool expression in NS0

pEE13.4Her2, pEE13.4Her2-delex16 and pEE13.4Her2-stumpy were stably transfected in NS0 cells by nucleofection (Amaxa). A pool of stably transfected cells was established after selection on glutamine dependent growth, based on the integrated glutamine synthetase selection marker (Barnes, L.M., *et al.*, Cytotechnology 2000;32(2):109-123).

Example 5 - Purification of His-tagged HER2

Her2ECDHis was expressed in HEK-293F cells. The His-tag in Her2ECDHis enabled purification with immobilized metal affinity chromatography, since the His-tagged protein binds strongly to the resin beads, while other proteins present in the culture supernatant do not bind strongly.

In this process, a chelator fixed onto the chromatographic resin was charged with Co²⁺ cations. Her2ECDHis containing supernatant was incubated with the resin in batch mode (i.e. solution). After incubation, the beads were retrieved from the supernatant and

packed into a column. The column was washed in order to remove weakly bound proteins. The strongly bound Her2ECDHis proteins were then eluted with a buffer containing imidazole, which competes with the binding of His to Co^{2+} . The eluent was removed from the protein by buffer exchange on a desalting column.

Example 6 - Immunization procedure of transgenic mice

Antibodies 005, 006, 041, 044, 059, 060, 067, 072, 093, 106 and 111 were derived from the following immunization procedure: two female HCo12 mice, one female and one male HCo12-Balb/C mouse, one female and one male HCo17 mouse, and two male HCo20 mice (Medarex, San José, CA, USA) were immunized every fortnight, alternating between 5×10^6 NS0 cells transiently transfected with Her2ECD intraperitoneal (IP) and 20 μg Her2ECDHis protein coupled to the hapten Keyhole Limpet Hemocyanin (KLH) subcutaneous (SC) at the tail base. A maximum of eight immunizations was performed per mouse (four IP and four SC immunizations). The first immunization with cells was done in complete Freund's adjuvant (CFA; Difco Laboratories, Detroit, MI, USA). For all other immunizations, cells were injected IP in PBS and KLH coupled Her2ECD was injected SC using incomplete Freund's adjuvant (IFA; Difco Laboratories, Detroit, MI, USA).

Antibody 150 was derived from immunization of one female HCo17 mouse (Medarex) alternating with 5×10^6 NS0 cells transiently transfected with Her2delex16 IP and 20 μg Her2ECDHis protein coupled to the hapten Keyhole Limpet Hemocyanin (KLH) SC at the tail base, with an interval of fourteen days. A maximum of eight immunizations was performed (four IP and four SC immunizations). The first immunization with cells was done in complete Freund's adjuvant (CFA; Difco Laboratories, Detroit, MI, USA). For all other immunizations, cells were injected IP in PBS and KLH coupled Her2ECD was injected SC using incomplete Freund's adjuvant (IFA; Difco Laboratories, Detroit, MI, USA).

Antibody 163 was derived from immunization of one male HCo20 mouse (Medarex) with 20 μg Her2ECDHis protein coupled to the hapten Keyhole Limpet Hemocyanin (KLH), alternating IP and SC at the tailbase with an interval of fourteen days. A maximum of eight immunizations was performed (four IP and four SC immunizations). The first immunization was done IP in complete Freund's adjuvant (CFA; Difco Laboratories, Detroit, MI, USA). The other immunizations were injected using incomplete Freund's adjuvant (IFA; Difco Laboratories, Detroit, MI, USA).

Mice with at least two sequential titers against TC1014-Her2, TC1014-Her2delex16 or TC1014-Her2stumpy in the antigen specific FMAT screening assay (as described in Example 7), were considered positive and fused.

Example 7 - Homogeneous antigen specific screening assay

The presence of HER2 antibodies in sera of immunized mice or HuMab (human monoclonal antibody) hybridoma or transfectoma culture supernatant was determined by homogeneous antigen specific screening assays (four quadrant) using Fluorometric Micro volume Assay Technology (FMAT; Applied Biosystems, Foster City, CA, USA). For this, a combination of 4 cell based assays was used. Binding to TC1014-Her2 (HEK-293F cells transiently expressing the HER2 receptor; produced as described above), TC1014-Her2delex16 (HEK-293F cells transiently expressing the extracellular domain of Her2-delex (a 16 amino acid deletion mutant of the HER2 receptor; produced as described above) and TC1014-Her2stumpy (HEK-293F cells transiently expressing the extracellular stumpy domain of the HER2 receptor; produced as described above) as well as HEK293 wild type cells (negative control cells which do not express HER2) was determined. Samples were added to the cells to allow binding to HER2. Subsequently, binding of HuMab was detected using a fluorescent conjugate (Goat anti-Human IgG-Cy5; Jackson ImmunoResearch). TH1014-Pertuzumab (produced in HEK-293F cells) was used as a positive control and HuMab-mouse pooled serum and HuMab-KLH were used as negative controls. The samples were scanned using an Applied Biosystems 8200 Cellular Detection System (8200 CDS) and 'counts x fluorescence' was used as read-out. Samples were stated positive when counts were higher than 50 and counts x fluorescence were at least three times higher than the negative control.

Example 8 - HuMab hybridoma generation

HuMab mice with sufficient antigen-specific titer development (defined as above) were sacrificed and the spleen and lymph nodes flanking the abdominal aorta and vena cava were collected. Fusion of splenocytes and lymph node cells to a mouse myeloma cell line was done by electrofusion using a CEEF 50 Electrofusion System (Cyto Pulse Sciences, Glen Burnie, MD, USA), essentially according to the manufacturer's instructions. Next, the primary wells were sub cloned using the ClonePix system (Genetix, Hampshire, UK). To this end specific primary well hybridoma's were seeded in semisolid medium made from 40% CloneMedia (Genetix, Hampshire, UK) and 60% HyQ 2x complete media (Hyclone, Waltham, USA). The sub clones were retested in the antigen-specific binding assay as described in Example 7 and IgG levels were measured using an Octet (Fortebio, Menlo Park, USA) in order to select the most specific and best producing clone per primary well for further expansion. Further expansion and culturing of the resulting HuMab hybridomas were done based upon standard protocols (e.g. as described in Coligan J.E., Bierer, B.E., Margulies, D.H., Shevach, E.M. and Strober, W., eds. Current Protocols in Immunology, John Wiley & Sons, Inc., 2006). Clones derived by this process were designated PC1014.

Example 9 - Mass Spectrometry of purified antibodies

Small aliquots of 0.8 mL antibody containing supernatant from 6-well or Hyperflask stage were purified using PhyTip columns containing Protein G resin (PhyNexus Inc., San Jose, USA) on a Sciclone ALH 3000 workstation (Caliper Lifesciences, Hopkinton, USA). The PhyTip columns were used according to manufacturer's instructions, although buffers were replaced by: Binding Buffer PBS (B.Braun, Medical B.V., Oss, Netherlands) and Elution Buffer 0.1M Glycine-HCl pH 2.7 (Fluka Riedel-de Haën, Buchs, Germany). After purification, samples were neutralized with 2M Tris-HCl, pH 9.0 (Sigma-Aldrich, Zwijndrecht, Netherlands). Alternatively, in some cases larger volumes of culture supernatant were purified using MabSelect SuRe.

After purification, the samples were placed in a 384-well plate (Waters, 100 μ l square well plate, part# 186002631). Samples were deglycosylated overnight at 37°C with N-glycosidase F (Roche cat no 11365177001. DTT (15 mg/mL) was added (1 μ L/well) and incubated for 1 h at 37°C. Samples (5 or 6 μ L) were desalted on an Acquity UPLC™ (Waters, Milford, USA) with a BEH300 C18, 1.7 μ m, 2.1x 50 mm column at 60 °C. MQ water and LC-MS grade acetonitrile (Biosolve, cat no 01204101, Valkenswaard, The Netherlands) with both 0.1% formic acid (Fluka, cat no 56302, Buchs, Germany), were used as Eluents A and B, respectively. Time-of-flight electrospray ionization mass spectra were recorded on-line on a micrOTOF™ mass spectrometer (Bruker, Bremen, Germany) operating in the positive ion mode. Prior to analysis, a 900-3000 m/z scale was calibrated with ES tuning mix (Agilent Technologies, Santa Clara, USA). Mass spectra were deconvoluted with DataAnalysis™ software v. 3.4 (Bruker) using the Maximal Entropy algorithm searching for molecular weights between 5 and 80 kDa.

After deconvolution, the resulting heavy and light chain masses for all samples were compared in order to find duplicate antibodies. This was sometimes due to the presence of an extra light chain, but in the comparison of the heavy chains, the possible presence of C-terminal lysine variants was also taken into account. This resulted in a list of unique antibodies, i.e., a unique combination of specific heavy and light chains. In case duplicate antibodies were found, one unique antibody was selected based on results from other tests.

Example 10 - Sequence analysis of the HER2 antibody variable domains and cloning in expression vectors

Total RNA of the HER2 HuMabs was prepared from 5x10⁶ hybridoma cells and 5'-RACE-Complementary DNA (cDNA) was prepared from 100 ng total RNA, using the SMART RACE cDNA Amplification kit (Clontech), according to the manufacturer's instructions. VH and VL

coding regions were amplified by PCR and cloned directly, in frame, in the pG1f and pKappa expression vectors, by ligation independent cloning (Aslanidis, C. and P.J. de Jong, *Nucleic Acids Res* 1990;18(20): 6069-74). Clones derived by this process were designated TH1014. For each antibody, 16 VL clones and 8 VH clones were sequenced. Clones which predicted heavy and light chain mass in agreement with the mass of the hybridoma derived material of the same antibody (as determined by mass spectrometry) were selected for further study and expression.

The resulting sequences are shown in Figures 1 and 2 and in the Sequence Listing. Selected sequences are also described in more detail below. CDR sequences were defined according to IMGT (Lefranc MP. *et al.*, *Nucleic Acids Research*, 27, 209-212, 1999 and Brochet X. *Nucl. Acids Res.* 36, W503-508 (2008)). Table 1, Table 2 and Table 3 give an overview of antibody sequence information or germline sequences, and Table 4 shows consensus sequences.

Table 1: Heavy chain variable region (VH), light chain variable region (VL) and CDR sequences of HuMabs 005, 006, 059, 060, 106, and 111.

SEQ ID No: 1	VH 005	EVQLVQSGAEVKKPGESLKISCKASGYSFHFYWIGW VRQMPGKGLEWMGSIYPGDS TRYRPSFQGQVTISA DKSISTAYLQWTS LKASDTAIYYCARQRGDYYYFYGM DVWGQGTTVTVSS
SEQ ID No: 2	VH 005, CDR1	GYSFHFYW
SEQ ID No: 3	VH 005, CDR2	IYPGDS DT
SEQ ID No: 4	VH 005, CDR3	ARQRGDYYYFYGM DV
SEQ ID No: 5	VL 005	EIVLTQSPGTL SLSPGERATL SCRASQSVSSYLAWY QQKPGQVPRLLIYGASSRATGIPDRFSGSGSGTDFTL TISRLEPEDFAVYYCQYQGSS-LTFGGG TKVEIK
SEQ ID No: 6	VL 005, CDR1	QSVSSSY
	VL 005, CDR2	GAS
SEQ ID No: 7	VL 005, CDR3	QQYGS SLT
SEQ ID No: 8	VH 006	EVQLLES GGLVQPGGSLRLS CAASGFTFSNYALI WV RQAPGKGLEWVSIIRGGAGSTYYADSVKGRFTISR D NSKNTLYLQMNSLRAEDTAVYYCAKARIWG PLFDYW GQGT LVT VSS
SEQ ID No: 9	VH 006, CDR1	GFTFSNYA
SEQ ID No: 10	VH 006, CDR2	IRGGAGST
SEQ ID No: 11	VH 006, CDR3	AKARIWG PLFDY
SEQ ID No: 12	VL 006	EIVLTQSPATL SLSPGERATL SCRASQSVSSYLAWYQ QKPGQAPRLLIYDASN RATGIPARFSGSGSGTDFTL TI SSLEPEDFAVYYCQQR SNWPPLTFGGG TKVEIK

SEQ ID No: 13	VL 006, CDR1	QSVSSY
	VL 006, CDR2	DAS
SEQ ID No: 14	VL 006, CDR3	QQRSNWPPLT
SEQ ID No: 15	VH 059	QVQLVQSGAEVKKPGASVRVPCKASGYTFTRYGISW VRQAPGQGLEWMGWISAYNGKTYAQLQGRVTMT TDTSTSTAYMELRSLRSDDTAVYYCARSPLLWFEELY FDYWGGQGLTVTVSS
SEQ ID No: 16	VH 059, CDR1	GYTFTRYG
SEQ ID No: 17	VH 059, CDR2	ISAYNGKT
SEQ ID No: 18	VH 059, CDR3	ARSPLLWFEELYFDY
SEQ ID No: 19	VL 059	EIVLTQSPGTLSPGERATLSCRASQSVSSYLA WYQQKPGQAPRLLIYGASSRATGIPDRFSGSGSGTDFTL TISRLEPEDFAVYYCQQYGTSLSFTFGPGTKVDIK
SEQ ID No: 20	VL 059, CDR1	QSVSSY
	VL 059, CDR2	GAS
SEQ ID No: 21	VL 059, CDR3	QQYGTSLSFT
SEQ ID No: 22	VH 060	EVQLVQSGAEVKKPGESLKISCKGSGYRFTSYWIGW VRQMPGKGLEWMGSIYPGDSYTRNPSFQGGVTISA DKSIATAYLQWNSLKASDTAMYYCARHAGDFYFDG LDVWGGQGTTVTVSS
SEQ ID No: 23	VH 060, CDR1	GYRFTTSYW
SEQ ID No: 24	VH 060, CDR2	IYPGDSYT
SEQ ID No: 25	VH 060, CDR3	ARHAGDFYFDGLDV
SEQ ID No: 26	VL 060	EIVLTQSPGTLSPGERATLSCRASQSVSSYLA WYQQKPGQAPRLLIYGASSRATGIPDRFSGSGSGTDFTL TISRLEPEDFAVYYCQQYGSSPPITFGQGTTRLEIK
SEQ ID No: 27	VL 060, CDR1	QSVSSY
	VL 060, CDR2	GAS
SEQ ID No: 28	VL 060, CDR3	QQYGSSPPIT
SEQ ID No: 29	VH 106	EVQLVQSGAEVKKPGESLKISCKGSGYSFTRYWIGW VRQMPGKGLEWMGIIYPGDSYTRYSPSFQGGVTISA DKSISTAYLQWSSLKASDTAMYYCARLTGDRGFDY SGMDVWGGQGTTVTVSS
SEQ ID No: 30	VH 106, CDR1	GYSFTRYW
SEQ ID No: 31	VH 106, CDR2	IYPGDSYT
SEQ ID No: 32	VH 106, CDR3	ARLTGDRGFDYSGMDV
SEQ ID No: 33	VL 106	EIVLTQSPGTLSPGERATLSCRASQSVSSYLA WYQQKPGQAPRLLIYGASSRATGIPDRFSGSGSGTDFTL TISRLEPEDFAVYYCQQYGSS-FTFGPGTKVDIK
SEQ ID No: 34	VL 106, CDR1	QSVSSY
	VL 106, CDR2	GAS
SEQ ID No: 35	VL 106, CDR3	QQYGSSFT

SEQ ID No: 36	VH 111	QVQLVQSGAEVKKPGSSVKVSKASGGTFSSYGISW VRQAPGPGLEWMGRIIPILGIANYAQKFQGRVTITAD KSTNTAYMELSSLRSED TAVYYCARDQEYSSNWYYW GGGTLVTVSS
SEQ ID No: 37	VH 111, CDR1	GGTFSSYG
SEQ ID No: 38	VH 111, CDR2	IIPILGIA
SEQ ID No: 39	VH 111, CDR3	ARDQEYSSNWYY
SEQ ID No: 40	VL 111	EIVLTQSPGTLSPGERATLSCRASQSVRSSLAWY QQKPGQAPRLLIYGASSRATGIPDRFSGSGSGTDFTL TISRLEPEDFAVYYCQLYGSSPTFGPGTKVDIK
SEQ ID No: 41	VL 111, CDR1	QSVRSSY
	VL 111, CDR2	GAS
SEQ ID No: 42	VL 111, CDR3	QLYGSSPT

Table 2: Mouse origin and heavy and light chain sequence homologies of HuMabs 005, 006, 059, 060, 106, and 111.

HuMab:	Mouse:	Strain:	Germline VH:	Germline VL:
005	350611	HCo12- BalbC	IgHV5-51-1	IgKV3-20-01
006	350611	HCo12- BalbC	IgHV3-23-1	IgKV3-11-01
059	350654	HCo17	IgHV1-18-1	IgKV3-20-01
060	350654	HCo17	IgHV5-51-1	IgKV3-20-01
106	350660	HCo17	IgHV5-51-1	IgKV3-20-01
111	350660	HCo17	IgHV1-69-4	IgKV3-20-01

Table 3: Heavy chain variable region (VH), light chain variable region (VL) sequences of HuMabs 041, 150, 067, 072, 163, 093, and 044. The respective CDRs correspond to those underlined in Figures 1 and 2, for VH and VL sequences, respectively.

SEQ ID No: 43	VH 041	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGL EWMGSIYPGDSHTRYRPSFQQQVTISADKSISTAYLQWSSLKASD TAMYYCARQKGDFFYFFGLDVWGQGTAITVSS
SEQ ID No: 44	VL 041	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSLTFGGGGTKVEIK
SEQ ID No: 45	VH 150	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGL EWMGSIYPGDSHTRYRPSFQQQVTISADKSISTAYLQWSSLKASD TAMYYCARQAGDYYYYNGMDVWGQGTITVTVSS

SEQ ID No: 46	VL 150	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLTWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSLTFGGGGTKVEIK
SEQ ID No: 47	VH 067	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGL EWMGIIYPGDS DTRYSPSFQGQVTISVDKSISTAYLQWSSLKASDT AMYYCARQKGDYYYHYGLDVWGQGTTVTVSS
SEQ ID No: 48	VL 067	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSPRLTFGGGGTKVEIK
SEQ ID No: 49	VH 072	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGL EWMGIIYPGDS DTRYSPSFQGQVTISADKSISTAYLQWSSLKASDT AMYYCARQKGDYYYFNGLDVWGQGTTVTVSS
SEQ ID No: 50	VL 072	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSPRLTFGGGGTKVEIK
SEQ ID No: 51	VH 163	EVQLVQSGAEVKKPGESLKISCKGSGYRFISYWIGWVRQMPGKGL EWMGRIYPGDS DTRYSPSFQGQVTISVDKSISTAYLQWSSLKASD TAMYYCARQRGDYYYFNGLDVWGQGTTVTVSS
SEQ ID No: 52	VL 163	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSLTFGGGGTKVEIK
SEQ ID No: 53	VH 093	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGL EWMGRIYPGDS DTRYSPSFQGQVTISADKSITTAYLQWSSLRASDT AMYYCARQRGDYYYFFGLDIWGQGTTVTVSL
SEQ ID No: 54	VL 093	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSLTFGGGGTKVEIK
SEQ ID No: 55	VH 044	EVQLVQSGAEVKKPGESLKISCKGSGYRFSSYWIGWVRQMPGKGL EWMGSIFPGDS DTRYSPSFQGQVTISADKSITTAYLQWSSLKASDT AMYYCARQAGDYYYNGMDVWGQGTTVTVSS
SEQ ID No: 56	VL 044	EIVLTQSPGTLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPR LLIYGASSRATGIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYG SSLTFGGGGTKVEIK

Table 4: Consensus CDRs based on sequence alignments shown in Figures 1 and 2.

SEQ ID No: 57 005-060-106-041- 150-067-072-163- 093-044	IgHV5- 51-1	VH CDR1	GYX1FX2X3YW	wherein X1=S or R; X2=S, T, H, or I; and X3=S, R, or F; preferably, wherein X2=H or T
SEQ ID No: 58 005-060-106-041- 150-067-072-163- 093-044	IgHV5- 51-1	VH CDR2	IX1PGDSX2T	wherein X1=Y or F; X2=D, Y, or H preferably, wherein X2=D or Y

SEQ ID No: 59 005-060-106-041- 150-067-072-163- 093-044	IgHV5- 51-1	VH CDR3	ARX1X2X3X4X5X 6X7X8YX9X10GX 11DX12	wherein X1=Q, H, or L; X2= R, A, T, or K; X3=G; X4=D; X5=R or none; X6=G or none; X7=Y or F; X8=Y or D; X9=Y, F, or H; X10=Y, D, S, F, or N; X11=M or L; and X12=V or I; preferably, wherein X1=Q, X2= R or A; X5=X6=none; X7=Y or F; X8=Y; X9=F; X10=Y; and X12=V
SEQ ID No: 60 006	IgHV3- 23-1	VH CDR1	GFTFSXYA	wherein X=N or S, preferably N
SEQ ID No: 61 006	IgHV3- 23-1	VH CDR2	IX1GX2X3GST	wherein X1=R or S; X2=G or S; and X3=A or G, preferably wherein X1=R; X2=G; and X3=A
SEQ ID No: 62 006	IgHV3- 23-1	VH CDR3	AKRIWGPXFDY	wherein X=L or Y, preferably L
SEQ ID No: 63 059	IgHV1- 18-1	VH CDR1	GYTFTXYG	wherein X=R or S, preferably R
SEQ ID No: 64 059	IgHV1- 18-1	VH CDR2	ISAYNGXT	wherein X=K or N, preferably K
SEQ ID No: 65 059	IgHV1- 18-1	VH CDR3	ARSPLLWFEELYF DY	
SEQ ID No: 66 111	IgHV1- 69-4	VH CDR1	GGTFSSYX	wherein X=G or A, preferably G
SEQ ID No: 38 111	IgHV1- 69-4	VH CDR2	IIPILGIA	
SEQ ID No: 67 111	IgHV1- 69-4	VH CDR3	ARDQEYSSX1X2 X3	wherein X1=N or Y; X2=W or F; and X3=Y or D, preferably wherein X1=N; X2=W; and X3=Y

SEQ ID No: 68 005-059-060-106- 111-041-150-067- 072-163-093-044	IgKV3- 20-01	VL CDR1	QSVX1SX2Y	wherein X1=S or R and X2=S or T
005-059-060-106- 111-041-150-067- 072-163-093-044	IgKV3- 20-01	VL CDR2	GAS	
SEQ ID No: 69 005-059-060-106- 111-041-150-067- 072-163-093-044	IgKV3- 20-01	VL CDR3	QX1YGX2SX3X4 X5T	wherein X1=Q or L; X2=S or T; X3=P or none; X4=P, L, R, or none; and X5=L, F, I, or none; preferably, wherein X4=P, L, or none
SEQ ID No: 13 006	IgKV3- 11-01	VL CDR1	QSVSSY	
006	IgKV3- 11-01	VL CDR2	DAS	
SEQ ID No: 14 006	IgKV3- 11-01	VL CDR3	QQRSNWPPLT	

Example 11 - Purification of antibodies

Culture supernatant was filtered over 0.2 µm dead-end filters, loaded on 5 ml MabSelect SuRe columns (GE Health Care) and eluted with 0.1 M sodium citrate-NaOH, pH 3. The eluate was immediately neutralized with 2M Tris-HCl, pH 9 and dialyzed overnight to 12.6 mM NaH₂PO₄, 140 mM NaCl, pH 7.4 (B.Braun). Alternatively, subsequent to purification, the eluate was loaded on a HiPrep Desalting column and the antibody was exchanged into 12.6 mM NaH₂PO₄, 140 mM NaCl, pH 7.4 (B.Braun) buffer. After dialysis or exchange of buffer, samples were sterile filtered over 0.2 µm dead-end filters. Purity was determined by SDS-PAGE and concentration was measured by nephelometry and absorbance at 280 nm. Purified antibodies were stored at 4°C. Mass spectrometry was performed to identify the molecular mass of the antibody heavy and light chains expressed by the hybridomas as described in Example 9.

Example 12 – Binding of HER2 clones to tumor cells expressing membrane-bound HER2 measured by means of FACS analysis

The binding of HER2 antibodies to AU565 cells (purchased at ATCC, CRL-2351) and A431 cells (purchased at ATCC, CRL-1555), was tested using flow cytometry (FACS Canto II, BD Biosciences). Qifi analysis (Dako, Glostrup, Denmark) revealed that the AU565 cells expressed on average 1,000,000 copies of HER2 protein per cell, whereas A431 cells expressed on average 15,000 copies per cell. Binding of HER2 antibodies was detected using a Phycoerythrin (PE)-conjugated goat-anti-human IgG antibody (Jackson). Clinical grade Herceptin® (Roche) was used as a positive control, and an isotype control antibody was used as negative control. EC₅₀ values were determined by means of non-linear regression (sigmoidal dose-response with variable slope) using GraphPad Prism V4.03 software (GraphPad Software, San Diego, CA, USA).

As shown in Figure 3, all tested HER2 antibodies bound to HER2 expressed on both AU565 and A431 cells in a dose-dependent manner. The EC₅₀ values for binding varied between 0.304-2.678 µg/mL for AU565 cells and 0.106-1.982 µg/mL for A431 cells. Especially on A431 cells, large differences in EC₅₀ values were observed between the tested antibodies. Some differences in maximum binding levels were also observed between different antibodies. In particular, antibodies 005 and 006 demonstrated higher maximum binding levels on A431 as compared to other HER2 antibodies.

Example 13 - Binding of HER2 antibodies to membrane-bound HER2 expressed on Rhesus epithelial cells measured by means of FACS analysis

To determine cross-reactivity with Rhesus HER2, the binding of HER2 antibodies to HER2-positive Rhesus epithelial cells (4MBr-5; purchased at ATCC) was tested using flow cytometry (FACS Canto II, BD Biosciences). A Phycoerythrin-conjugated goat-anti-human IgG antibody (Jackson) was used as a secondary conjugate. An isotype control antibody was used as negative control antibody.

As shown in Figure 4, all tested HER2 antibodies were cross-reactive with Rhesus monkey HER2. At both tested concentrations (1 µg/mL and 10 µg/mL), the HER2 antibodies were able to bind specifically to Rhesus monkey HER2. No binding was observed with the isotype control antibody.

Example 14 - Competition of HER2 antibodies for binding to soluble Her2ECDHis measured in sandwich-ELI SA

The optimal coating concentrations of the tested HER2 antibodies and optimal Her2ECDHis concentration were determined in the following manner: ELISA wells were coated overnight

at 4°C with HER2 HuMabs serially diluted in PBS (0.125-8 µg/mL in 2-fold dilutions). Next, the ELISA wells were washed with PBST (PBS supplemented with 0.05% Tween-20 [Sigma-Aldrich, Zwijndrecht, The Netherlands]) and blocked for one hour at room temperature (RT) with PBSTC (PBST supplemented 2% [v/v] chicken serum [Gibco, Paisley, Scotland]). The ELISA wells were then washed with PBST and incubated for one hour at RT with Her2ECDHis serially diluted in PBSTC (0.25-2 µg/mL in 2-fold dilutions). Unbound Her2ECDHis was washed away with PBST, and bound Her2ECDHis was incubated for one hour at RT with 0.25 µg/mL biotinylated rabbit-anti-6xhis-biot (Abcam, Cambridge, UK). The plate was thereafter washed with PBST and incubated for one hour with 0.1 µg/mL Streptavidin-poly-*HRP* (Sanquin, Amsterdam, The Netherlands) diluted in PBST. After washing, the reaction was visualized through a 15 minutes incubation with 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid (ABTS: one ABTS tablet diluted in 50 mL ABTS buffer (Roche Diagnostics, Almere, The Netherlands)) at RT (room temperature) protected from light. The colorization was stopped by adding an equal volume of oxalic acid (Sigma-Aldrich, Zwijndrecht, The Netherlands). Fluorescence at 405 nm was measured on a microtiter plate reader (Biotek Instruments, Winooski, USA). The antibody concentrations that resulted in sub-optimal binding of each antibody were determined and used for the following cross-block experiments.

Each HER2 antibody was coated to the ELISA wells at the sub-optimal dose that was determined as described above. After blocking of the ELISA wells, the wells were incubated with the predetermined concentration of 1 µg/mL biotinylated Her2ECDHis in the presence or absence of an excess of a second (competitor) HER2 antibody. The ELISA was then performed as described above. Residual binding of Her2ECDHis to the coated antibody was expressed as a percentage relative to the binding observed in the absence of competitor antibody. Percentage competition for each antibody combination was then determined as 100 minus the percentage of inhibition. 75% competition represented full block, with 25-74% competition representing partial block, and 0-24% competition no block.

As shown in Table 5, all HER2 antibodies competed for binding to Her2ECDHis, at least partially, with themselves. Trastuzumab (clinical grade Herceptin®) and pertuzumab (TH1014-pert, transiently produced in HEK-293 cells) could only compete with themselves, and not with any of the other listed HER2 antibodies. C1 and F5 (both transiently produced in HEK-293 cells) competed with each other for binding to Her2ECDHis, but did not compete with other HER2 antibodies.

Antibodies 005, 006, 059, 060, 106 and 111 all competed with each other for binding to Her2ECDHis, but did not cross-block with trastuzumab, pertuzumab, C1 or F5. Clones 005, 059, 060 and 106 only blocked 006 when 006 was the competitor antibody. In

the reverse reaction where 006 was immobilized, no blocking was found with 005, 059, 060 or 106. This was possibly a result of the higher apparent affinity of clone 006 compared to 005, 059, 060, 106 and 111, shown in Figures 3A and 3B. Values higher than 100% can be explained by avidity effects and the formation of antibody-Her2ECDHis complexes containing two non-blocking antibodies.

Table 5: Competition and blocking of HER2 antibodies for binding to Her2ECDHis

	Competing mAb: →									
Immobilized mAb ↓	Tras	Pert	C1	F5	106	111	005	006	059	060
Trastuzumab	6	100	103	99	114	166	137	110	120	119
TH1014-pert	104	9	106	125	115	145	151	125	132	118
TH1014-C1	89	85	65	58	84	86	98	99	89	93
TH1014-F5	197	178	70	21	129	183	178	192	165	185
PC1014-106	323	275	471	495	26	21	25	25	25	23
PC1014-111	110	102	122	119	75	14	51	10	65	36
PC1014-005	126	115	157	227	54	32	18	15	22	12
PC1014-006	163	136	136	153	127	47	148	20	129	125
PC1014-059	117	107	78	128	23	12	13	11	12	11
PC1014-060	106	99	108	126	37	35	30	6	14	19
Cross-block group	1	2	3	3	4	4	4	4	4	4

75 – 100% competition

25 – 74% competition

0 – 24% competition

Depicted values are mean percentages inhibition of binding relative to the binding observed in the absence of competitor antibody, of two independent experiments. Competition experiments with HEK-produced C1 and F5 (TH1014-C1 and TH1014-F5) were performed once. Trastuzumab (clinical grade Herceptin®) and HEK-produced pertuzumab (TH1014-pert) were also tested twice.

Example 15 - Antibody-dependent cell-mediated cytotoxicity (ADCC)

SK-BR-3 cells (purchased at ATCC, HTB-30) were harvested (5×10^6 cells), washed (twice in PBS, 1500 rpm, 5 min) and collected in 1 mL RPMI 1640 medium supplemented with 10% cosmic calf serum (CCS) (HyClone, Logan, UT, USA), to which 200 μ Ci ^{51}Cr (Chromium-51;

Amersham Biosciences Europe GmbH, Roosendaal, The Netherlands) was added. The mixture was incubated in a shaking water bath for 1.5 hours at 37°C. After washing of the cells (twice in PBS, 1500 rpm, 5 min), the cells were resuspended in RPMI 1640 medium supplemented with 10% CCS, counted by trypan blue exclusion and diluted to a concentration of 1×10^5 cells/mL.

Meanwhile, peripheral blood mononuclear cells (PBMCs) were isolated from fresh buffy coats (Sanquin, Amsterdam, The Netherlands) using standard Ficoll density centrifugation according to the manufacturer's instructions (lymphocyte separation medium; Lonza, Verviers, France). After resuspension of cells in RPMI 1640 medium supplemented with 10% CCS, cells were counted by trypan blue exclusion and concentrated to 1×10^7 cells/mL.

For the ADCC experiment, 50 μ L ^{51}Cr -labeled SK-BR-3 cells (5.000 cells) were pre-incubated with 15 $\mu\text{g}/\text{mL}$ HER2 antibody (IgG1, κ) in a total volume of 100 μ L RPMI medium supplemented with 10% CCS in a 96-well microtiter plate. After 15 min at RT, 50 μ L PBMCs (500.000 cells) were added, resulting in an effector to target ratio of 100:1. The maximum amount of cell lysis was determined by incubating 50 μ L ^{51}Cr -labeled SK-BR-3 cells (5.000 cells) with 100 μ L 5% Triton-X100. The amount of spontaneous lysis was determined by incubating 5.000 ^{51}Cr -labeled SK-BR-3 cells in 150 μ L medium, without any antibody or effector cells. The level of antibody-independent cell lysis was determined by incubating 5.000 SK-BR-3 cells with 500.000 PBMCs without antibody. Subsequently, the cells were incubated 4 hr at 37°C, 5% CO₂. To determine the amount of cell lysis, the cells were centrifuged (1200 rpm, 3 min) and 75 μ L of supernatant was transferred to micronic tubes, after which the released ^{51}Cr was counted using a gamma counter. The measured counts per minute (cpm) were used to calculate the percentage of antibody-mediated lysis as follows:

$$(\text{cpm sample} - \text{cpm Ab-independent lysis}) / (\text{cpm max. lysis} - \text{cpm spontaneous lysis}) \times 100\%$$

As shown in Figure 5, all HER2 antibodies induced efficient lysis of SK-BR-3 cells through ADCC. The average percentage lysis by the different antibodies varied between 15% and 28%, except for trastuzumab (Herceptin®), which showed on average 41% lysis. Without being bound by theory, the higher percentage lysis by trastuzumab possibly resulted from an increased non-core fucosylation grade (12.4%) due to its CHO production, compared to ~4% non-core fucosylation on the other HEK-produced HER2 antibodies, or by recognizing an epitope that induces less internalization of the HER2 receptor-antibody complexes.

Example 16 - Inhibition of ligand-independent proliferation of AU565 cells

HER2 antibodies were tested for their ability to inhibit proliferation of AU565 cells *in vitro*. Due to the high HER2 expression levels on AU565 cells (~1.000.000 copies per cell as described in Example 12), HER2 is constitutively active in these cells and thus not dependent on ligand-induced heterodimerization.

In a 96-well tissue culture plate (Greiner bio-one, Frickenhausen, Germany). 9.000 AU565 cells were seeded per well in the presence of 10 µg/mL HER2 antibody in serum-free cell culture medium. As a control, cells were seeded in serum-free medium without antibody. After 3 days, the amount of viable cells was quantified with Alamarblue (BioSource International, San Francisco, US) according to the manufacturer's instructions. Fluorescence was monitored using the EnVision 2101 Multilabel reader (PerkinElmer, Turku, Finland) with standard Alamarblue settings. The Alamarblue signal of antibody-treated cells was plotted as a percentage relative to untreated cells. Dunnett's test was applied for statistical analysis.

The results are depicted in Figure 6, showing the percentage proliferation of AU565 cells after HER2 antibody treatment compared to untreated cells, which was set to 100%. Herceptin apparently inhibited AU565 cell proliferation, but this effect was not statistically significant. TH1014-F5 significantly enhanced proliferation of AU565 cells indicating that this is an agonistic antibody, whereas none of the other antibodies tested (005, 060 and pertuzumab) had a substantial effect on AU565 proliferation. For trastuzumab (Herceptin®) and pertuzumab, this was in accordance with the results described by Juntilla *et al.* (Cancer Cell 2009;15(5):353–355).

Table 6: Average percentage proliferation of AU565 cells after HER2 antibody treatment compared to untreated cells, which was set to 100%.

antibody	% proliferation
PC1014-005	103
PC1014-060	104
TH1014-F5	180
TH1014-pert	101
Herceptin	83
isotype-control	101

Example 17 - Anti-kappa-ETA' assay

To investigate the suitability of HER2 antibodies for an antibody-drug conjugate approach, a generic *in vitro* cell-based killing assay using kappa-directed pseudomonas-exotoxin A (anti-kappa-ETA') was developed. The assay makes use of a high affinity anti-kappa domain

antibody conjugated to a truncated form of the pseudomonas-exotoxin A. Upon internalization, the anti-kappa-ETA' domain antibody undergoes proteolysis and disulfide-bond reduction, separating the catalytic from the binding domain. The catalytic domain is transported from the Golgi to the endoplasmic reticulum via the KDEL retention motif, and subsequently translocated to the cytosol where it inhibits protein synthesis and induces apoptosis (Kreitman RJ, *BioDrugs* 2009;23(1):1-13). In this assay, to identify HER2 antibodies that enable internalization and killing through the toxin, HER2 antibodies are pre-conjugated with the anti-kappa-ETA' before incubation with HER2-positive cells. As noted above, AU565 cells express a high number of Her2 molecules per cell ($\sim 10^6$ molecules/cell), whereas A431 cells express a low number of Her2 molecules per cell ($\sim 30,000$ molecules/cell).

First, the optimal concentration of anti-kappa-ETA' was determined for each cell line, i.e. the maximally tolerate dose that does not lead to induction of non-specific cell death. AU565 cells (7500 cells/well) and A431 cells (2500 cells/well) were seeded in normal cell culture medium in 96-wells tissue culture plate (Greiner bio-one) and allowed to adhere for at least 4 hours. Next, cells were incubated with 100, 10, 1, 0.1, 0.01, 0.001 and 0 $\mu\text{g/mL}$ anti-kappa-ETA' dilutions in normal cell culture medium. After 3 days, the amount of viable cells was quantified with Alamarblue (BioSource International, San Francisco, US) according to the manufacturer's instruction. Fluorescence was monitored using the EnVision 2101 Multilabel reader (PerkinElmer, Turku, Finland) with standard Alamarblue settings. The highest concentration anti-kappa-ETA' that did not kill the cells by itself was used for following experiments (0.5 $\mu\text{g/mL}$ for AU565 and 1 $\mu\text{g/mL}$ for A431).

Next, antibody-mediated internalization and killing by the toxin was tested for different HER2 antibodies. Cells were seeded as described above. Dilution-series of HER2 antibodies were pre-incubated for 30 minutes with the predetermined concentration anti-kappa-ETA' before adding them to the cells. After 3 days of incubation, the amount of viable cells was quantified as described above. The Alamarblue signal of cells treated with anti-kappa-ETA' conjugated antibodies was plotted compared to cells treated with antibody alone. 23.4 $\mu\text{g/mL}$ Staurosporin was used as positive control for cell killing. An isotype control antibody was used as negative control.

As shown in Figure 7A and Table 7, all anti-kappa-ETA'-conjugated HER2 antibodies were able to kill AU565 cells in a dose-dependent manner. Anti-kappa-ETA'-conjugated-Herceptin killed only 32% of the AU565 cells, whereas all other conjugated antibodies induced 50-72% cell killing. Moreover, antibodies 005 and 111 demonstrated more than three times improved EC_{50} values (resp. 15.13 and 24.20 ng/mL) compared to trastuzumab

(78.49 ng/mL). Except for trastuzumab, non-conjugated HER2 antibodies did not induce killing of AU565 cells at the concentrations tested.

Table 7: Killing of AU565 cells by anti-kappa-ETA'-conjugated HER2 antibodies. Data shown are EC₅₀ values and maximal percentage cell kill of AU565 cells treated with anti-kappa-ETA'-conjugated HER2 antibodies, measured in one representative experiment. Cell kill induced by Staurosporin was set as 100% and MFI of untreated cells was set as 0%. "Ndet" means not detected.

antibody	% cells killed	EC50 ng/mL
PC1014-111	72.0	24.2
PC1014-005	69.7	15.13
PC1014-059	67.0	67.65
PC1014-060	64.3	79.38
PC1014-106	59.1	107.9
PC1014-006	50.4	45.14
Trastuzumab	31.9	78.49
isotype control	Ndet	Ndet

As shown in Figure 7B and Table 8, antibodies 005 and 060 were able to induce effective killing of A431 cells ($\geq 85\%$) when conjugated to anti-kappa-ETA', whereas anti-kappa-ETA'-conjugated-Herceptin and isotype control antibody did not induce killing of A431 cells. Moreover, antibodies 005 and 111 demonstrated killing of A431 cells already at low antibody concentrations (10 ng/mL) with EC₅₀ values of ~ 10 ng/mL. No cell kill was observed with non-conjugated HER2 antibodies.

Table 8: Killing of A431 cells by anti-kappa-ETA'-conjugated HER2 antibodies. Data shown are EC₅₀ values and maximal percentage cell kill of A431 cells treated with anti-kappa-ETA'-conjugated HER2 antibodies, measured in one representative experiment. Cell kill induced by Staurosporin was set as 100% and MFI of untreated cells was set as 0%.

antibody	% cells killed	EC50 ng/mL
PC1014-005	88.5	~ 10.07
PC1014-060	85.0	~ 10.03
Trastuzumab	NDet	NDet
isotype control	NDet	NDet

Example 18 - Internalization of HER2 antibodies measured with an FMAT-based fab-CypHer5E assay

To investigate whether the enhanced killing of AU565 cells observed in the kappa-toxin-ETA' assay described in the previous Example correlated with enhanced internalization of HER2 antibodies, a fab-CypHer5E-based internalization assay was performed. CypHer5E is a pH-sensitive dye which is non-fluorescent at basic pH (extracellular: culture medium) and fluorescent at acidic pH (intracellular: lysosomes), with an acid dissociation constant (pKa) of 7.3.

AU565 cells were seeded in a 384-wells tissue culture plates (Greiner bio-one), at a density of 3000 cells/well in normal cell culture medium supplemented with 240 ng/mL fab-CypHer5E (in house conjugation of Goat-fab-anti-Human IgG [Jackson] with CypHer5E [GE Healthcare, Eindhoven, The Netherlands] according to manufacturer's instructions). Next, HER2 antibodies were serially diluted in normal cell culture medium, added to the cells and left at room temperature for 9 hours. Mean fluorescent intensities (MFI) of intracellular CypHer5E were measured using the 8200 FMAT (Applied Biosystems, Nieuwerkerk A/D IJssel, The Netherlands) and 'counts x fluorescence' was used as read-out. An isotype control antibody was used as negative control antibody. EC₅₀ values and maximal MFI were determined by means of non-linear regression (sigmoidal dose-response with variable slope) using GraphPad Prism V4.03 software (GraphPad Software, San Diego, CA, USA).

The results are shown in Table 9, depicting the EC₅₀ values and maximal MFI for all tested HER2 antibodies in the CypHer5E internalization assay with AU565 cells. The maximal MFI values reflect how many HER2 antibodies were internalized upon binding. All human HER2 antibodies showed higher maximal MFI values (130.529-57.428) than trastuzumab (35.000) and TH1014-pert (35.323), indicating that these antibodies induced enhanced receptor internalization. The enhanced internalization of TH1014-F5 may be a result from its agonistic activity and the induction of HER2-HER2 dimerization (see Example 16).

Table 9: Cypher-5-based internalization assay of HER2 antibodies. Data shown are MFI and EC₅₀ values of one representative experiment from two experiments with AU565 cells treated with fab-CypHer5E labeled HER2 antibodies.

Cypher 5		
Antibody	EC ₅₀ ng/ mL	Maximal MFI
PC1014-006	23.08	130829
PC1014-005	21.37	95117
PC1014-111	35.22	81680
PC1014-059	14.77	77123

PC1014-060	36.16	68184
PC1014-106	68.60	57428
TH1014-F5	22.65	113116
TH1014-pert	~1041	35323
Trastuzumab	21.70	35000

Example 19 - HER2 downmodulation

To investigate if enhanced HER2 internalization induced by the antibodies of the present invention also results in enhanced receptor downmodulation, 005 was selected as representative antibody and tested for its ability to induce downmodulation of HER2. To this end, AU565 cells were incubated 3 days with HER2 antibodies, and analyzed for presence of HER2. AU565 cells were seeded in a 24-wells tissue culture plate (100.000 cells/well) in normal cell culture medium and cultured for 3 days at 37°C in the presence of 10 µg/mL HER2 antibody. After washing with PBS, cells were lysed by incubating 30 min at room temperature with 25 µL Surefire Lysis buffer (Perkin Elmer, Turku, Finland). Total protein levels were quantified using bicinchoninic acid (BCA) protein assay reagent (Pierce) according to the the manufacturer's protocol. HER2 protein levels in the lysates were analyzed using a HER2-specific sandwich ELISA. Rabbit-anti-human HER2 intracellular domain antibody (Cell Signaling) was used to capture HER2 and biotinylated goat-anti-human HER2 polyclonal antibody (R&D), followed by streptavidin-poly-HRP, were used to detect bound HER2. The reaction was visualized using 2,2'-azino-bis 3-ethylbenzothiazoline-6-sulfonic acid (ABTS: dilute one ABTS tablet in 50 mL ABTS buffer [Roche Diagnostics, Almere, The Netherlands]) and stopped with oxalic acid (Sigma-Aldrich, Zwijndrecht, The Netherlands). Fluorescence at 405 nm was measured on a microtiter plate reader (Biotek Instruments, Winooski, USA) and the amount of HER2 was expressed as a percentage relative to untreated cells.

The results are shown in Figure 8 and Table 10 below depicting the amount of HER2 expressed as a percentage compared to untreated cells. The results in Figure 8 and Table 10 demonstrate that antibody 005 induced approximately 30% HER2 downmodulation, while Herceptin induced approximately 20% HER2 downmodulation. This was in line with enhanced internalization observed by antibody 005.

Table 10: Antibody induced downmodulation of HER2 depicted as percentage HER2 compared to untreated cells

antibody	% HER2 compared to untreated cells
Herceptin	80
IgG1-1014-005	70
isotype control	108

Example 20 - Colocalization of HER2 antibodies with lysosomal marker LAMP1 analyzed by confocal microscopy.

The HER2 downmodulation assay as described in example 19 and the CypHer-5E based internalization assay indicated that HER2 antibodies of the present invention were more efficiently internalized and targeted towards lysosomes. To confirm these findings, confocal microscopy technology was applied. AU565 cells were grown on glass coverslips (thickness 1.5 micron, Thermo Fisher Scientific, Braunschweig, Germany) in standard tissue culture medium at 37°C for 3 days. Cells were pre-incubated for 1 hour with 50 µg/mL leupeptin (Sigma) to block lysosomal activity, after which 10 µg/mL HER2 antibody were added. The cells were incubated for an additional 3 or 18 hours at 37°C. Hereafter they were washed with PBS and incubated for 30 min. at RT (room temperature) with 4% formaldehyde (Klinipath). Slides were washed with blocking buffer (PBS supplemented with 0.1% saponin [Roche] and 2% BSA [Roche]) and incubated for 20 min with blocking buffer containing 20 mM NH₄Cl to quench formaldehyde. Slides were washed again with blocking buffer and incubated for 45 min at RT with mouse-anti-human CD107a (LAMP1) (BD Pharmingen) to identify lysosomes. Following washing with blocking buffer the slides were incubated 30 min at RT with a cocktail of secondary antibodies; goat-anti-mouse IgG-Cy5 (Jackson) and goat-anti-human IgG-FITC (Jackson). Slides were washed again with blocking buffer and mounted on microscope slides using 20 µL mounting medium (6 gram Glycerol [Sigma] and 2.4 gram Mowiol 4-88 [Omnilabo] was dissolved in 6 mL distilled water to which 12 mL 0.2M Tris [Sigma] pH8.5 was added followed by incubation for 10 min at 50-60°C. Mounting medium was aliquoted and stored at -20°C.). Slides were imaged with a Leica SPE-II confocal microscope (Leica Microsystems) equipped with a 63x 1.32-0.6 oil immersion objective lens and LAS-AF software. To allow for quantification of overlapping pixel intensities, laser intensity, gain and offset were adjusted to visualize antibodies without pixel saturation. These settings were kept the same for all confocal slides.

12-bit grayscale TIFF images were analyzed for colocalisation using MetaMorph® software (version Meta Series 6.1, Molecular Devices Inc, Sunnyvale California, USA). FITC and Cy5 images were imported as stacks and background was subtracted. Identical thresholds

settings were used (manually set) for all FITC images and all Cy5 images. Colocalisation was depicted as the pixel intensity of FITC in the region of overlap (ROI), where the ROI is composed of all Cy5 positive regions. To compare different slides stained with several HER2 antibodies, the images were normalized using the pixel intensity of Cy5. Goat-anti-mouse IgG-Cy5 was used to stain the lysosomal marker LAMP1 (CD107a). The pixel intensity of LAMP1 should not differ between various HER2 antibodies tested.

Normalized values for colocalization of FITC and Cy5 =

$$\frac{(\text{Total Pixel Intensity FITC} \times \text{percentage FITC-Cy5 colocalization} / 100)}{\text{Total Pixel Intensity Cy5}}$$

The results are shown in Figure 9 and Table 11 below, and depict the FITC pixel intensity overlapping with Cy5 for various HER2 antibodies. For each antibody, three different images were analyzed from one slide containing ~ 1, 3 or >5 cells. Significant variation was observed between the different images within each slide. Still, it was evident that antibody 005 demonstrated increased colocalisation with the lysosomal marker LAMP1, when compared with Herceptin and pertuzumab. These results indicate that once internalized, HER2 antibody 005 is efficiently sorted towards lysosomal compartments, making it especially interesting for an antibody drug conjugate approach.

Table 11 : Mean FITC pixel intensities overlapping with Cy5 depicted as arbitrary units

antibody	FITC pixel intensity in lysosomes [arbitrary units]
TH1014-005	0.619
TH1014-pert	0.214
Herceptin	0.236

Example 21 - HER2 extracellular domain shuffle human-to-chicken

To further define the HER2 binding regions recognized by antibodies of the present invention, a HER2 extracellular domain shuffle experiment was performed. To this end, a small gene-synthesis library with five constructs was generated, swapping the sequences of domain I, II, III or IV of the extracellular domain of human HER2 to the corresponding sequence of chicken HER2 (Gallus gallus isoform B NCBI: NP_001038126.1): 1) fully human HER2 (Uniprot P04626) hereafter named hu-HER2, 2) hu-HER2 with chicken domain I (replacing amino acids (aa) 1-203 of the human Her2 with the corresponding chicken Her2 region) hereafter named hu-HER2-ch(I), 3) hu-HER2 with chicken domain II (replacing amino acids (aa) 204-330 of the human Her2 with the corresponding chicken Her2 region)

hereafter named hu-HER2-ch(II), 4) hu-HER2 with chicken domain III (replacing aa 331-507 of the human Her2 with the corresponding chicken Her2 region) hereafter named hu-HER2-ch(III) and 5) hu-HER2 with chicken domain IV (replacing aa 508-651 of the human Her2 with the corresponding chicken Her2 region) hereafter named hu-HER2-ch(IV). The human and chicken HER2 orthologs show 67% homology in their extracellular domain with 62% homology in domain I, 72% homology in domain II, 63% homology in domain III and 68% homology in domain IV. The constructs were transiently transfected in the Freestyle™ CHO-S (Invitrogen) cell line using Freestyle MAX transfection reagent (Invitrogen) according to the instructions of the manufacturer, and transfected cells were cultured for 20 hours. HER2 antibody binding to the transfected cells was analyzed by means of flow cytometry:

The transfected CHO-S cells were harvested, washed with FACS buffer and incubated with 10 µg/mL HER2 antibody (30 minutes on ice). Binding of HER2 antibodies was detected using a Phycoerythrin (PE)-conjugated goat-anti-human IgG antibody (Jackson). To check if expression between different batches was the same, cells were fixed and permeabilized using Cytofix/Cytoperm solution (BD) according manufacturer's instruction and stained with a rabbit-anti-human intracellular HER2 antibody (DAKO) in combination with a secondary PE-conjugated goat-anti-rabbit antibody (Jackson). An isotype control antibody was used as negative control. Fluorescence was measured on a FACSCanto-II (BD) and binding curves were made by means of non-linear regression (sigmoidal dose-response with variable slope) using GraphPad Prism V4.03 software (GraphPad Software, San Diego, CA, USA). Loss of binding was used as read out to identify which HER2 domains were recognized by the different antibodies.

Exemplary binding curves for antibody 106 are shown in figure 10. All binding results are shown in Table 12. Herceptin showed loss of binding to Hu-HER2-ch(IV), but not to the proteins with one of the remaining domains shuffled, confirming that the epitopes of Herceptin resides in HER2 domain IV. Pertuzumab showed only loss of binding to Hu-HER2-ch(II), confirming that its epitope resides in HER2 domain II. Antibodies 005, 006, 060 and 111 showed loss of binding upon substitution of HER2 domain III, which demonstrated that the epitope resides in HER2 domain III. Interestingly, antibodies 059 and 106 demonstrated loss of binding to both hu-HER2-ch(III) and hu-HER2-ch(I), implying that antibodies 059 and 106 recognize a conformational epitope within these two domains.

Table 12: Summary of HER2 antibody binding to different HER2ECD receptor constructs. FL; hu-HER2, I; hu-HER2-ch(I), II; hu-HER2-ch(II), III; hu-HER2-ch(III), IV; hu-HER2-ch(IV). +++ indicates normal binding, + indicates reduced binding compared to binding observed to hu-HER2, - indicates no binding detected.

Antibody	HER2-domain shuffled				
	FL	I	II	III	IV
Herceptin	+++	+++	+++	+++	+++
Pertuzumab	+++	+++	+	+++	+++
005	+++	+++	+++	-	+++
006	+++	+++	+++	-	+++
059	+++	-	+++	-	+++
060	+++	+++	+++	-	+++
106	+++	-	+++	-	+++
111	+++	+++	+++	-	+++

Example 22 - In vivo efficacy of HER2 HuMab 005 in NCI-N87 human gastric carcinoma xenografts in SCID mice

The in vivo effect of HER2-HuMab 005 on tumor growth and survival in a NCI-N87 human gastric carcinoma xenograft model in female CB.17 severe combined immunodeficiency (SCID) mice was determined. 10×10^6 NCI-N87 tumor cells in 50% matrigel were injected s.c. in female SCID mice, 10 mice per group. Eight days after tumor inoculation, intravenous treatment with HER2-HuMabs 005 or control antibody HuMab-HepC was started. In figure 11 this is indicated as day 1, day of treatment initiation. The first dose was at 40 mg/kg, followed by 10 mg/kg on days 4, 8, 11, 15, 18, 22 and 25 after treatment initiation.

Tumor volume was determined at least 2 times per week. Volumes (mm^3) were calculated from caliper (PLEXX) measurements as $(\text{width}^2 \times \text{length})/2$. Tumors were calipered twice weekly and each animal was euthanized when its tumor reached the predetermined endpoint volume (800 mm^3).

As shown in Figure 11A and 11B the mice administered with HuMab 005 demonstrated slower tumor growth (A) and better survival (B), respectively than the mice that received negative control antibody HuMab-HepC.

CLAIMS

1. A monoclonal antibody which blocks the binding of a reference antibody to soluble human epidermal growth factor receptor 2 (HER2), wherein the reference antibody comprises heavy chain variable (VH) and light chain variable (VL) regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);
 - b) a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:12 (**006**);
 - c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);
 - d) a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);
 - e) a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**); and
 - f) a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**);
- optionally when determined as described in Example 14.

2. The antibody of claim 1, which blocks the binding of at least two, preferably at least three of the reference antibodies in (a) to (f).

3. The antibody of claim 1, which blocks the binding of the reference antibodies in (a) to (f).

4. The antibody of claim 1, which blocks the binding of the reference antibody in (a), the reference antibody in (f), or both.

5. The antibody of any of claims 1 to 4, wherein the reference antibody is immobilized.

6. The antibody of any of claims 1 to 5, which fully blocks the binding of the reference antibody.

7. The antibody of any preceding claim which binds to the same epitope on HER2 as a reference antibody comprising the VH and VL regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);
- b) a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:12 (**006**);
- c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);
- d) a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);
- e) a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**);
- f) a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**);
- g) a VH region comprising the sequence of SEQ ID NO:43 and a VL region comprising the sequence of SEQ ID NO:44 (**041**);
- h) a VH region comprising the sequence of SEQ ID NO:45 and a VL region comprising the sequence of SEQ ID NO:46 (**150**);
- i) a VH region comprising the sequence of SEQ ID NO:47 and a VL region comprising the sequence of SEQ ID NO:48 (**067**);
- j) a VH region comprising the sequence of SEQ ID NO:49 and a VL region comprising the sequence of SEQ ID NO:50 (**072**);
- k) a VH region comprising the sequence of SEQ ID NO:51 and a VL region comprising the sequence of SEQ ID NO:52 (**163**);
- l) a VH region comprising the sequence of SEQ ID NO:53 and a VL region comprising the sequence of SEQ ID NO:54 (**093**); and
- m) a VH region comprising the sequence of SEQ ID NO:55 and a VL region comprising the sequence of SEQ ID NO:56 (**044**).

8. The antibody of claim 7, which binds to the same epitope on HER2 as the reference antibody in (a) or (f).

9. The antibody of any preceding claim, which comprises a VH region comprising a CDR3 sequence selected from the group consisting of

- a) SEQ ID NO:59, such as a sequence selected from SEQ ID Nos:4, 25 and 32 (**005**, **060**, **106**);
- b) SEQ ID NO:62, such as SEQ ID NO:11 (**006**);
- c) SEQ ID NO:65, such as SEQ ID NO:18 (**059**); and

- d) SEQ ID NO:67, such as SEQ ID NO:39 (**111**).
10. An antibody which comprises a VH region comprising a CDR3 sequence selected from the group consisting of
- a) SEQ ID NO:59, such as a sequence selected from SEQ ID Nos:4, 25 and 32 (**005**, **060**, **106**);
 - b) SEQ ID NO:62, such as SEQ ID NO:11 (**006**);
 - c) SEQ ID NO:65, such as SEQ ID NO:18 (**059**); and
 - d) SEQ ID NO:67, such as SEQ ID NO:39 (**111**).
11. The antibody of claim 9 or 10, which comprises a VH region comprising CDR1, CDR2, CDR3 sequences selected from the group consisting of:
- a) SEQ ID NOs:57, 58 and 59, respectively, where the VH region is optionally derived from an IgHV5-51-1 germline;
 - b) SEQ ID NOs:60, 61 and 62, respectively, where the VH region is optionally derived from an IgHV3-23-1 germline;
 - c) SEQ ID NOs:63, 64, and 65, respectively, where the VH region is optionally derived from an IgHV1-18-1 germline; and
 - d) SEQ ID NOs:66, 38 and 67, respectively, where the VH region is optionally derived from an IgHV1-69-4 germline.
12. The antibody of claim 11, which comprises a VH region comprising CDR1, CDR2, CDR3 sequences selected from the group consisting of:
- a) SEQ ID NOs:2, 3 and 4, respectively (**005**);
 - b) SEQ ID NOs:23, 24 and 25, respectively (**060**);
 - c) SEQ ID NOs:30, 31 and 32, respectively (**106**);
 - d) SEQ ID NOs:9, 10, and 11, respectively (**006**);
 - e) SEQ ID NOs: 16, 17 and 18, respectively (**059**); and
 - f) SEQ ID NOs: 37, 38 and 39, respectively (**111**).
13. The antibody of claim 12, comprising a VH region and a VL region selected from the groups consisting of:
- a) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:2, 3 and 4, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:6, GAS, and SEQ ID NO:7, respectively (**005**);

- b) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:9, 10 and 11, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:13, DAS, and SEQ ID NO:14, respectively (**006**);
- c) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:16, 17 and 18, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:20, GAS, and SEQ ID NO:21, respectively (**059**);
- d) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:23, 24 and 25, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:27, GAS, and SEQ ID NO:28, respectively (**060**);
- e) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:30, 31 and 32, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:34, GAS, and SEQ ID NO:35, respectively (**106**); and
- f) a VH region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:37, 38 and 39, respectively; and a VL region comprising the CDR1, CDR2 and CDR3 sequences of SEQ ID NOs:41, GAS, and SEQ ID NO:42, respectively (**111**).

14. The antibody of any preceding claim, comprising a VH region and a VL region selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and, preferably, a VL region comprising the sequence of SEQ ID NO:5 (**005**);
- b) a VH region comprising the sequence of SEQ ID NO:8 and, preferably, a VL region comprising the sequence of SEQ ID NO:11 (**006**);
- c) a VH region comprising the sequence of SEQ ID NO:15 and, preferably, a VL region comprising the sequence of SEQ ID NO:19 (**059**);
- d) a VH region comprising the sequence of SEQ ID NO:22 and, preferably, a VL region comprising the sequence of SEQ ID NO:26 (**060**);
- e) a VH region comprising the sequence of SEQ ID NO:29 and, preferably, a VL region comprising the sequence of SEQ ID NO:33 (**106**);
- f) a VH region comprising the sequence of SEQ ID NO:36 and, preferably, a VL region comprising the sequence of SEQ ID NO:40 (**111**);
- g) a VH region comprising the sequence of SEQ ID NO:43 and, preferably, a VL region comprising the sequence of SEQ ID NO:44 (**041**);
- h) a VH region comprising the sequence of SEQ ID NO:45 and, preferably, a VL region comprising the sequence of SEQ ID NO:46 (**150**);
- i) a VH region comprising the sequence of SEQ ID NO:47 and, preferably, a VL region comprising the sequence of SEQ ID NO:48 (**067**),

- j) a VH region comprising the sequence of SEQ ID NO:49 and, preferably, a VL region comprising the sequence of SEQ ID NO:50 (**072**),
- k) a VH region comprising the sequence of SEQ ID NO:51 and, preferably, a VL region comprising the sequence of SEQ ID NO:52 (**163**),
- l) a VH region comprising the sequence of SEQ ID NO:53 and, preferably, a VL region comprising the sequence of SEQ ID NO:54 (**093**),
- m) a VH region comprising the sequence of SEQ ID NO:55 and, preferably, a VL region comprising the sequence of SEQ ID NO:56 (**044**), and
- n) a variant of any of said antibodies, wherein said variant preferably has at most 1,2 or 3 amino-acid modifications, more preferably amino-acid substitutions, such as conservative amino acid substitutions and substitutions where the new amino acid is one at the same position in an aligned sequence in Figures 1 or 2, particularly at positions indicated by "X" in the corresponding consensus sequence.

15. A human antibody which does not block the binding of a reference antibody to soluble HER2 when determined as described in Example 14, wherein reference antibody comprises the VH and VL sequences of any of trastuzumab, pertuzumab, F1, and C5.

16. The antibody of any preceding claim, which has an EC₅₀ value for binding to HER2-expressing cells lower than 0.80 µg/ml, preferably lower than 0.50 µg/ml, when determined as described in Example 12, and preferably blocks the binding to soluble HER2 of a reference antibody comprising VH and VL regions selected from the group consisting of

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);
- b) a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**); and
- c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**).

17. The antibody of any preceding claim, which specifically binds HER2-positive Rhesus epithelial cells, when determined as described in Example 13, and preferably blocks the binding to soluble HER2 of a reference antibody comprising VH and VL regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);

- b) a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**);
- c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);
- d) a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);
- e) a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**); and
- f) a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

18. The antibody of any preceding claim, which specifically binds HER2-expressing AU565 cells but promotes ligand-independent proliferation of the cells less than F5 when determined as described in Example 16, and preferably blocks the binding to soluble HER2 of at a reference antibody comprising VH and VL regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**); and
- b) a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**).

19. The antibody of any preceding claim, wherein the antibody, when conjugated to a therapeutic moiety such as a truncated form of the pseudomonas-exotoxin A kills at least 60%, preferably at least 70% of a HER2-expressing tumor cell-line when determined as described in Example 17, and preferably blocks the binding to soluble HER2 of a reference antibody comprising the VH and VL regions selected from the groups consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**)
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**)
- c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**), and
- d) a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

20. The antibody of claim 19, wherein the HER2-expressing tumor cell-line expresses less than an average of about 30000 HER2 molecules per cell, and wherein the antibody preferably blocks the binding to soluble HER2 of a reference antibody comprising the VH and VL regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**); and
- b) an antibody comprising a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**).

21. The antibody of any preceding claim, wherein a higher amount of the antibody than trastuzumab is internalized by a HER2-expressing tumor cell-line when determined according to Example 18, and wherein the antibody preferably cross-blocks a reference antibody comprising VH and VL regions selected from the group consisting of:

- a) a VH region comprising the sequence of SEQ ID NO:1 and a VL region comprising the sequence of SEQ ID NO:5 (**005**);
- b) a VH region comprising the sequence of SEQ ID NO:8 and a VL region comprising the sequence of SEQ ID NO:11 (**006**);
- c) a VH region comprising the sequence of SEQ ID NO:15 and a VL region comprising the sequence of SEQ ID NO:19 (**059**);
- d) a VH region comprising the sequence of SEQ ID NO:22 and a VL region comprising the sequence of SEQ ID NO:26 (**060**);
- e) a VH region comprising the sequence of SEQ ID NO:29 and a VL region comprising the sequence of SEQ ID NO:33 (**106**); and
- f) a VH region comprising the sequence of SEQ ID NO:36 and a VL region comprising the sequence of SEQ ID NO:40 (**111**).

22. The antibody of any of claims 16-21, which fully blocks the reference antibody from binding to soluble HER2, preferably, wherein the antibody binds the same epitope as the reference antibody.

23. The antibody of any one of the preceding claims, wherein the antibody is a bivalent antibody.

24. The antibody of any one of the preceding claims, wherein the antibody is an antigen-binding fragment.

25. The antibody of any one of the preceding claims, wherein the antibody is a full-length antibody, preferably an IgG1 antibody, in particular an IgG1, κ antibody.

26. The antibody of any one of the preceding claims, wherein the antibody is an effector-function-deficient antibody, e.g. a stabilized human IgG4 antibody, such as an antibody wherein arginine at position 409 in the heavy chain constant region of human IgG4 is substituted with lysine, threonine, methionine, or leucine, preferably lysine and/or wherein the hinge region comprises a Cys-Pro-Pro-Cys sequence.

27. The antibody of any one of the preceding claims, wherein the antibody is a monovalent antibody.

28. The antibody of claim 27, wherein the monovalent antibody comprises

- (i) a variable region of an antibody of claims 1 to 25 or an antigen binding part of the said region, and
- (ii) a C_H region of an immunoglobulin or a fragment thereof comprising the C_H2 and C_H3 regions, wherein the C_H region or fragment thereof has been modified such that the region corresponding to the hinge region and, if the immunoglobulin is not an IgG4 subtype, other regions of the C_H region, such as the C_H3 region, do not comprise any amino acid residues, which are capable of forming disulfide bonds with an identical C_H region or other covalent or stable non-covalent inter-heavy chain bonds with an identical C_H region in the presence of polyclonal human IgG.

29. The antibody of claim 28, wherein the immunoglobulin referred to in step ii) is of the IgG4 subtype.

30. The antibody of claim 29, wherein the heavy chain has been modified such that the entire hinge region has been deleted.

31. The antibody of any one of the preceding claims, wherein the antibody is a bispecific antibody, comprising an first antigen-binding region of an antibody as defined in any one of the preceding claims, and a second antigen-binding site having a different binding specificity, such as a binding specificity for a human effector cell, a human Fc receptor, a B cell receptor or a non-blocking epitope of HER2.

32. The antibody of any one of the preceding claims, wherein the antibody is conjugated to another moiety, such as a cytotoxic moiety, a radioisotope, a drug, or a cytokine.

33. The antibody of claim 32, wherein the cytotoxic moiety is selected from the group consisting of taxol; cytochalasin B; gramicidin D; ethidium bromide; emetine; mitomycin; etoposide; tenoposide; vincristine; vinblastine; colchicin; doxorubicin; daunorubicin; dihydroxy anthracin dione; a tubulin-inhibitor such as maytansine or an analog or derivative thereof; mitoxantrone; mithramycin; actinomycin D; 1-dehydrotestosterone; a glucocorticoid; procaine; tetracaine; lidocaine; propranolol; puromycin; calicheamicin or an analog or derivative thereof an antimetabolite such as methotrexate, 6 mercaptopurine, 6 thioguanine, cytarabine, fludarabine, 5 fluorouracil, decarbazine, hydroxyurea, asparaginase, gemcitabine, or cladribine; an alkylating agent such as mechlorethamine, thioepa, chlorambucil, melphalan, carmustine (BSNU), lomustine (CCNU), cyclophosphamide, busulfan, dibromomannitol, streptozotocin, dacarbazine (DTIC), procarbazine, mitomycin C, cisplatin, carboplatin, duocarmycin A, duocarmycin SA, rachelmycin (CC-1065), or an analog or derivative thereof; an antibiotic such as dactinomycin, bleomycin, daunorubicin, doxorubicin, idarubicin, mithramycin, mitomycin, mitoxantrone, plicamycin, anthramycin (AMC)); an antimitotic agent such as monomethyl auristatin E or F or an analog or derivative thereof; diphtheria toxin and related molecules such as diphtheria A chain and active fragments thereof and hybrid molecules, ricin toxin such as ricin A or a deglycosylated ricin A chain toxin, cholera toxin, a Shiga-like toxin such as SLT I, SLT II, SLT IIV, LT toxin, C3 toxin, Shiga toxin, pertussis toxin, tetanus toxin, soybean Bowman-Birk protease inhibitor, Pseudomonas exotoxin, alorin, saporin, modeccin, gelanin, abrin A chain, modeccin A chain, alpha-sarcin, Aleurites fordii proteins, dianthin proteins, Phytolacca americana proteins such as PAPI, PAPII, and PAP S, momordica charantia inhibitor, curcin, crotin, sapaonaria officinalis inhibitor, gelonin, mitogellin, restrictocin, phenomycin, and enomycin toxins; ribonuclease (RNase); DNase I, Staphylococcal enterotoxin A; pokeweed antiviral protein; diphtherin toxin; and Pseudomonas endotoxin.

34. The antibody of claim 32, which is conjugated to a cytotoxic moiety selected from the group consisting of maytansine, calicheamicin, duocarmycin, rachelmycin (CC-1065), monomethyl auristatin E, or an analog, derivative, or prodrug of any thereof.

35. The antibody of claim 32, which is conjugated to a cytokine selected from the group consisting of IL-2, IL-4, IL-6, IL-7, IL-10, IL-12, IL-13, IL-15, IL-18, IL-23, IL-24, IL-27,

IL-28a, IL-28b, IL-29, KGF, IFN α , IFN β , IFN γ , GM-CSF, CD40L, Flt3 ligand, stem cell factor, anacardic acid, and TNF α .

36. The antibody of claim 32, which is conjugated to a radioisotope.

37. A nucleotide sequence encoding one or more of the amino acid sequences selected from the group consisting of SEQ ID NO: 1, 5, 8, 12, 15, 19, 22, 26, 29, 33, 36, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, and 56.

38. An expression vector comprising a nucleotide sequence according to claim 37, wherein the vector further encodes an operably-linked constant region of a light chain, constant region of a heavy chain or both light and heavy chains of an antibody.

39. A recombinant eukaryotic or prokaryotic host cell which produces an antibody as defined in any one of claims 1 to 31.

40. A pharmaceutical composition comprising an antibody as defined in any of claims 1 to 31 and a pharmaceutically acceptable carrier.

41. A pharmaceutical comprising an antibody as defined in any one of claims 32 to 36, and a pharmaceutically acceptable carrier.

42. The antibody of any one of claims 1 to 31 for use as a medicament.

43. The antibody of any one of claims 32 to 36 for use as a medicament.

44. The antibody of any one of claims 1 to 31 for use in the treatment of cancer.

45. The antibody of any one of claims 32 to 36 for use in the treatment of cancer.

46. The antibody for the use in any of claims 44 and 45, wherein the cancer is selected from the group consisting of breast cancer, prostate cancer, non-small cell lung cancer, bladder cancer, ovarian cancer, gastric cancer, colorectal cancer, esophageal cancer, squamous cell carcinoma of the head and neck, cervical cancer, pancreatic cancer, testis cancer, malignant melanoma and soft-tissue cancer.

47. The antibody for the use in any one of claims 44 to 46, wherein the antibody is for the treatment of cancer in combination with one or more further therapeutic agent, such as a chemotherapeutic agent.

48. Use of the antibody of any one of the claims 1 to 36 for the manufacture of a medicament for treatment of cancer, optionally comprising the further features of claim 46 and/or 47.

49. A method for inhibiting growth and/or proliferation of one or more tumor cells expressing HER2, comprising administration, to an individual in need thereof, of an antibody according to any one of claims 1 to 36.

50. The method of claim 49, wherein the antibody comprises the features of any one of claims 31 to 36, and the one or more tumor cell co-expresses HER2 and EGFR and/or HER3.

51. A method for treating cancer, comprising

- a) selecting a subject suffering from a cancer comprising tumor cells co-expressing HER2 and EGFR and/or HER3, and
- b) administering to the subject the antibody according to any one of claims 1-36.

52. The method of claim 51, wherein the cancer is selected from the group consisting of breast cancer, colorectal cancer, endometrial/cervical cancer, lung cancer, malignant melanoma, ovarian cancer, pancreatic cancer, prostate cancer, testis cancer, a soft-tissue tumor such as synovial sarcoma, and bladder cancer.

53. A method for producing an antibody of any of claims 1 to 36, said method comprising the steps of

- a) culturing a host cell of claim 39, and
- b) purifying the antibody from the culture media.

54. A method for detecting the presence of HER2 in a sample, comprising:

- contacting the sample with an antibody of any one of claims 1 to 36 under conditions that allow for formation of a complex between the antibody and HER2; and
- analyzing whether a complex has been formed.

55. A kit for detecting the presence of HER2 in a sample comprising

- an antibody of any of claims 1 to 36; and
- instructions for use of the kit.

Figure 1A

IgHV5-51-1 / IGJH6-02 – VH alignment

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IgHV5-51-1  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIYPGDS DTRYSPSFQ
TH1014-005 EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ
TH1014-060 EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ
TH1014-106 EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIYPGDS DTRYSPSFQ
VH1014-041  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ
VH1014-150  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ
VH1014-067  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIYPGDS DTRYSPSFQ
VH1014-072  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIYPGDS DTRYSPSFQ
VH1014-163  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGRIYPGDS DTRYSPSFQ
VH1014-093  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGRIYPGDS DTRYSPSFQ
VH1014-044  EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ
Consensus   EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGSIYPGDS DTRYSPSFQ

IgHV5-51-1  GQVTISADKSI TAYLQWSSLKASDTAMYYCAR-----GMDVWGQGTITVTVSS
TH1014-005 GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYFYGMDVWGQGTITVTVSS
TH1014-060 GQVTISADKSI TAYLQWSSLKASDTAMYYCARHAGD--FYFDGLDVGQGTITVTVSS
TH1014-106 GQVTISADKSI TAYLQWSSLKASDTAMYYCARLTGDRGFDYSGMDVWGQGTITVTVSS
VH1014-041  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--FYFDGLDVGQGTITVTVSS
VH1014-150  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYYYNGMDVWGQGTITVTVSS
VH1014-067  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYFYGLDVGQGTITVTVSS
VH1014-072  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYFYGLDVGQGTITVTVSS
VH1014-163  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYFYGLDVGQGTITVTVSS
VH1014-093  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYFYGLDVGQGTITVTVSS
VH1014-044  GQVTISADKSI TAYLQWSSLKASDTAMYYCARQAGD--YYYYNGMDVWGQGTITVTVSS
Consensus   GQVTISADKSI TAYLQWSSLKASDTAMYYCARXXXXXXXXXXGXDVGQGTITVTVSS

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Figure 1BIgHV3-23-1 / IGHJ4-02 – VH alignment

IgHV3-23-1 EVQLLES~~GGGLVQ~~PGGSLRLSCAASGFTFSSYAMSWVRQAPGKGLEWVSAISGSGGSTYYADSVKG
TH1014-006 EVQLLES~~GGGLVQ~~PGGSLRLSCAASGFTFSS~~NYALTI~~WVRQAPGKGLEWVSI~~IRGGAG~~STYYADSVKG
 Consensus EVQLLES~~GGGLVQ~~PGGSLRLSCAASGFTFSS~~YAXXX~~WVRQAPGKGLEWVS~~XIXXXX~~STYYADSVKG

 IgHV3-23-1 RFTISRDN SKNTLYLQMNSLRAEDTAVYYCAK-----YFDYWGQGT~~LVTVSS~~
TH1014-006 RFTISRDN SKNTLYLQMNSLRAEDTAVYYCAKARIWGP~~EF~~YDWGQGT~~LVTVSS~~
 Consensus RFTISRDN SKNTLYLQMNSLRAEDTAVYYCAKARIWGP~~EF~~YDWGQGT~~LVTVSS~~

Figure 1CIgHV1-18-1 / IGHJ4-02 – VH alignment

IgHV1-18-1 QVQLVQSGAEVKKPGASVKVSCASGYTFTSYGISWVRQAPGQGLEWMGWISAYNGNTNYAQKLQG
TH1014-059 QVQLVQSGAEVKKPGASV~~VE~~CKASGYTFT~~RY~~GISWVRQAPGQGLEWMGWISAYNG~~NT~~Y~~Y~~AQKLQG
 Consensus QVQLVQSGAEVKKPGASV~~V~~CKASGYTFT~~RY~~GISWVRQAPGQGLEWMGWISAYNG~~NT~~Y~~Y~~AQKLQG

 IgHV1-18-1 RVTMTTDTSTSTAYMELRSLRSDDTAVYYCAR-----YFDYWGQGT~~LVTVSS~~
TH1014-059 RVTMTTDTSTSTAYMELRSLRSDDTAVYYCAR~~SPLLW~~FEELYFDYWGQGT~~LVTVSS~~
 Consensus RVTMTTDTSTSTAYMELRSLRSDDTAVYYCAR~~SPLLW~~FEELYFDYWGQGT~~LVTVSS~~

Figure 1DIgHV1-69-4 / IGHJ4-02 – VH alignment

IgHV1-69-4 QVQLVQSGAEVKKPGSSVKVSCASGGTFSSY~~AI~~SWVRQAPGQGLEWMGRIIPILGIAN~~YA~~QKFQG
TH1014-111 QVQLVQSGAEVKKPGSSVKVSCASGGTFSSY~~GI~~SWVRQAPG~~Q~~GLEWMGRIIPILGIAN~~YA~~QKFQG
 Consensus QVQLVQSGAEVKKPGSSVKVSCASGGTFSSY~~AI~~SWVRQAPG~~Q~~GLEWMGRIIPILGIAN~~YA~~QKFQG

 IgHV1-69-4 RVTITADKSTSTAYMELSSLRSEDTAVYYCAR-----YFDYWGQGT~~LVTVSS~~
TH1014-111 RVTITADKST~~IT~~AYMELSSLRSEDTAVYYCARDQEYSS~~NT~~YWGQGT~~LVTVSS~~
 Consensus RVTITADKST~~IT~~AYMELSSLRSEDTAVYYCARDQEYSS~~NT~~YWGQGT~~LVTVSS~~

Figure 2A

IgKV3-20-01 / IGKJ4-01 – VL alignment

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IgKV3-20-01  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-005  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-059  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-060  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-106  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-111  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-041  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-150  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-067  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-072  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-163  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-093  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
VL1014-044  EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS
Consensus   EIVLTQSPGTLSLSPGERATLSCRASQSVSSSYLAWYQQKPGQAPRLLIYGASSRATGIPDRFSGS

IgKV3-20-01  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-005  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-059  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-060  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-106  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-111  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-041  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-150  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-067  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-072  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-163  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-093  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
VL1014-044  GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK
Consensus   GSGTDFLTISRLEPEDFAVYYCQYQSSP-LTFGGGTKVEIK

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Figure 2BIgKV3-11-01 / IGKJ4-01 – VL alignment

IgKV3-11-01	EIVLTQSPATLSLSPGERATLSCRASQSVSSYLAWYQQKPGQAPRLLIYDASNRATGIPARFSGS
VL1014-006	EIVLTQSPATLSLSPGERATLSCRAS <u>QSVSSYLAWYQQKPGQAPRLLIYDASNRATGIPARFSGS</u>
Consensus	EIVLTQSPATLSLSPGERATLSCRAS <u>QSVSSYLAWYQQKPGQAPRLLIYDASNRATGIPARFSGS</u>
IgKV3-11-01	GSGTDFLTITISLEPEDFAVYYCQQRSNWPPLTFGGGTKVEIK
VL1014-006	GSGTDFLTITISLEPEDFAVYYC <u>QQRSNWPPLTFGGGTKVEIK</u>
Consensus	GSGTDFLTITISLEPEDFAVYYC <u>QQRSNWPPLTFGGGTKVEIK</u>

Figure 3A

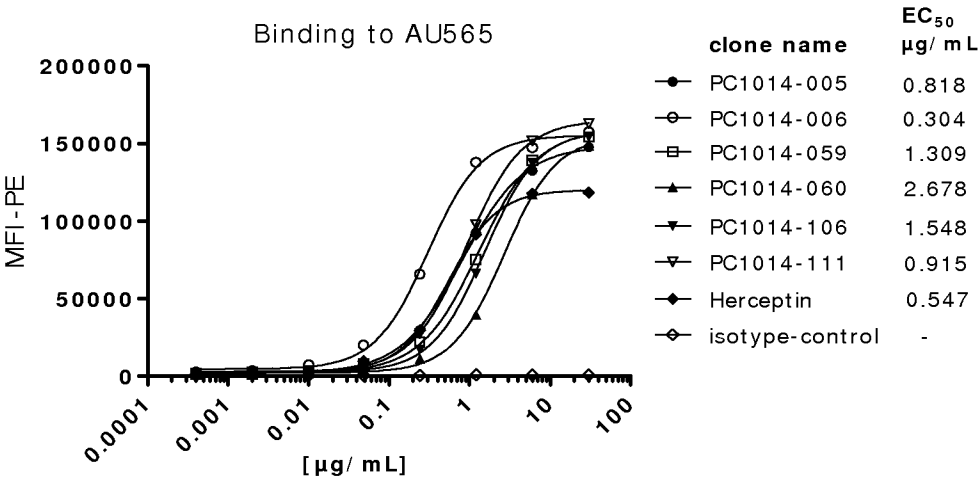


Figure 3B

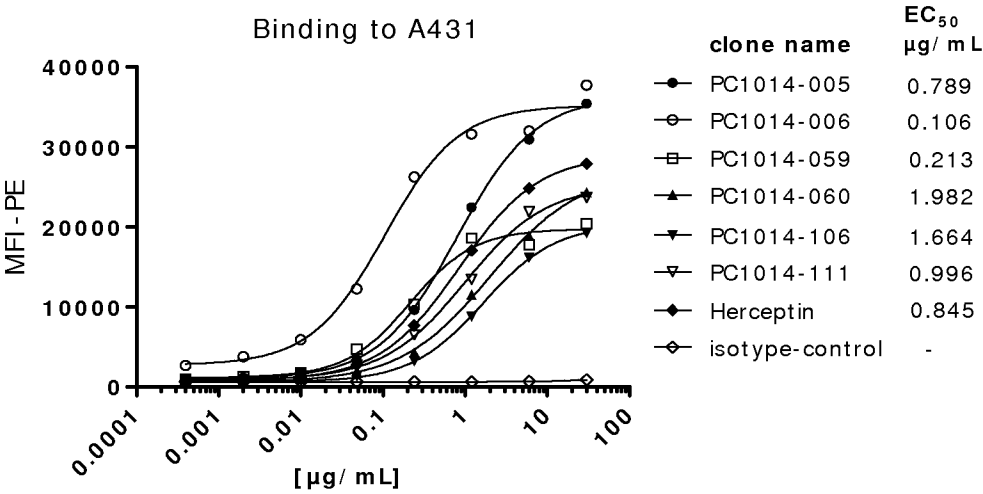


Figure 4

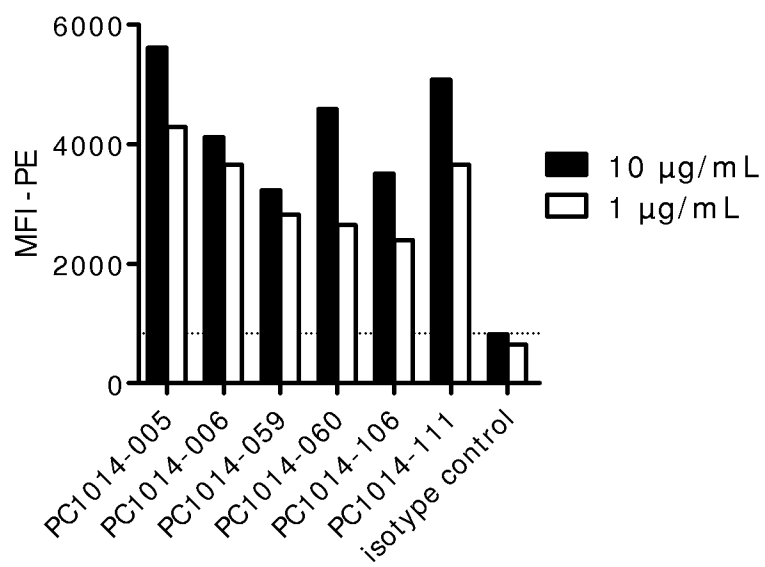


Figure 5

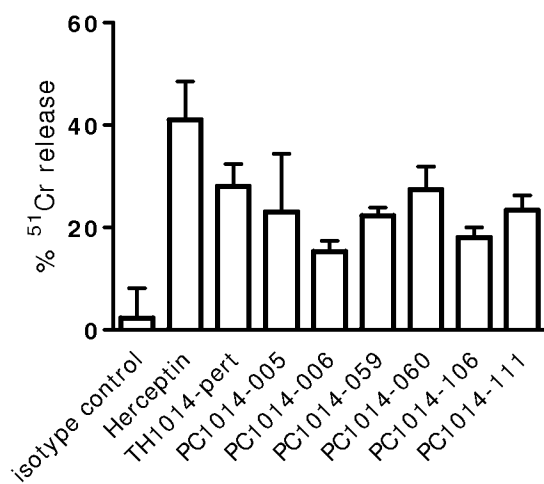


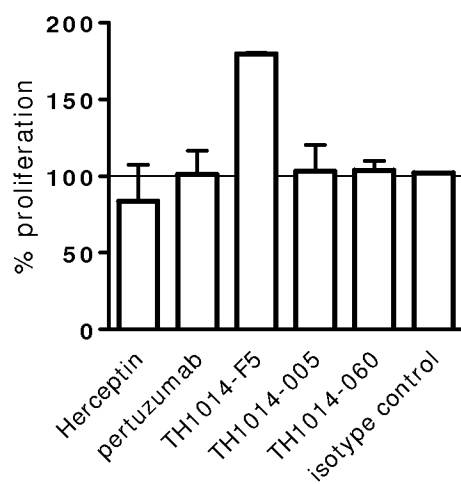
Figure 6

Figure 7A

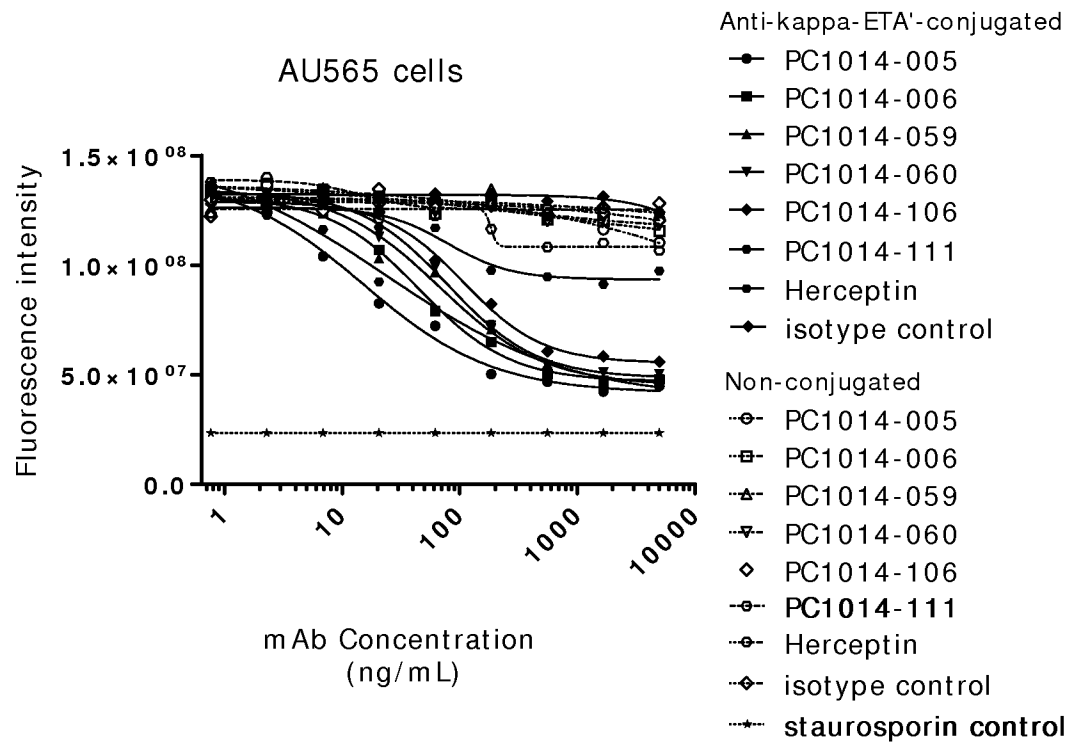


Figure 7B

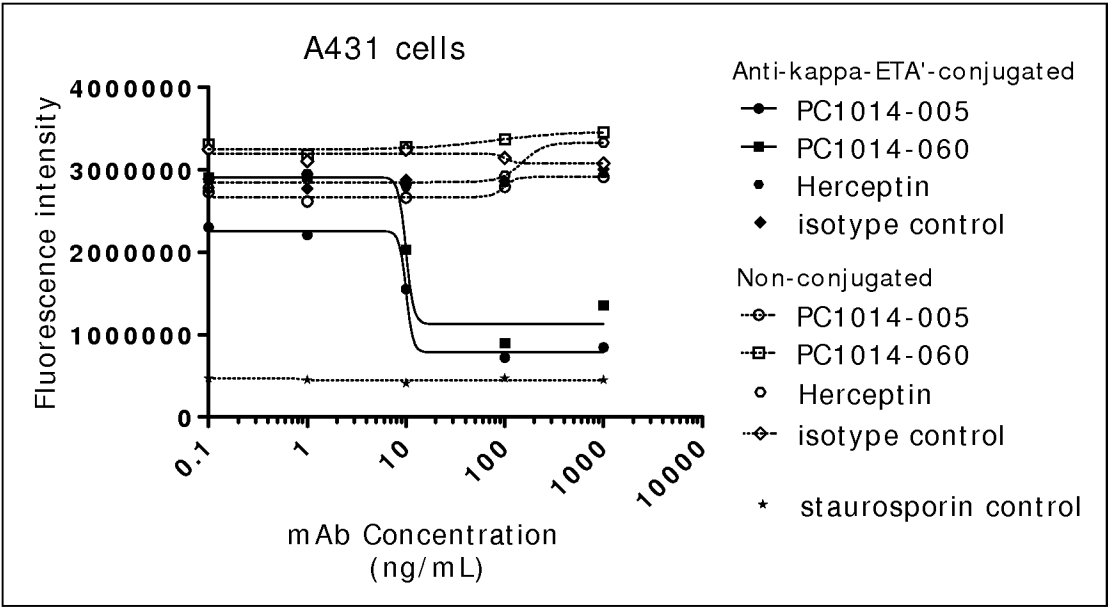


Figure 8

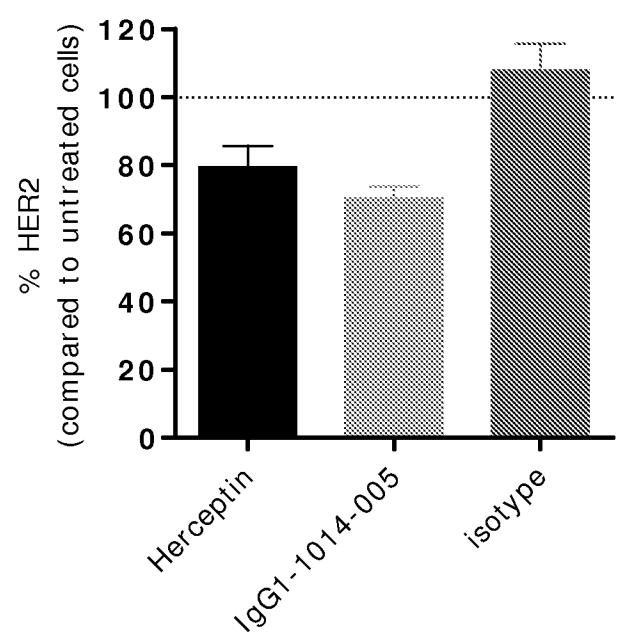


Figure 9

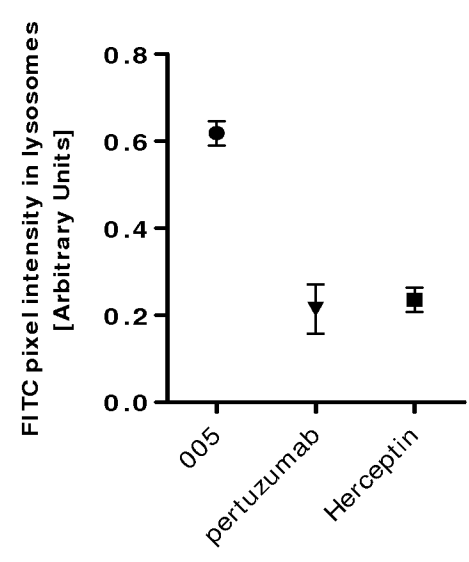


Figure 10

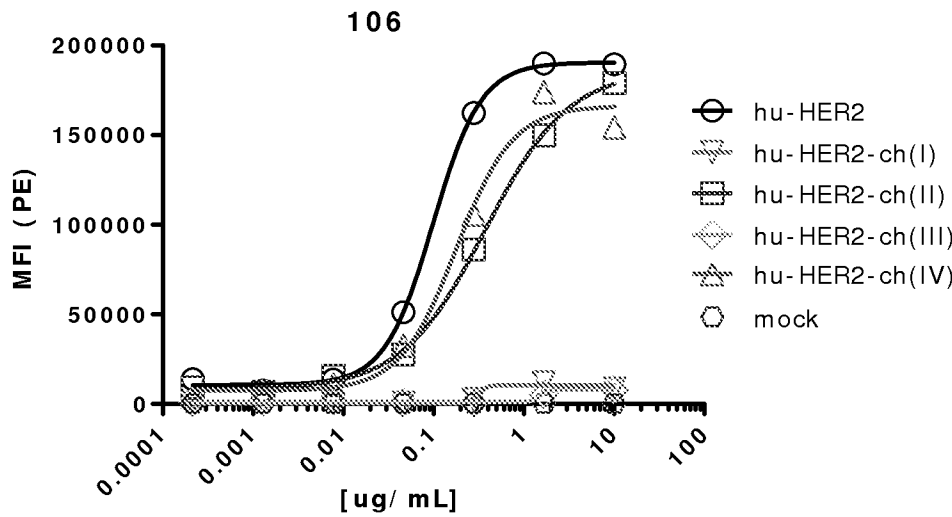


Figure 11A

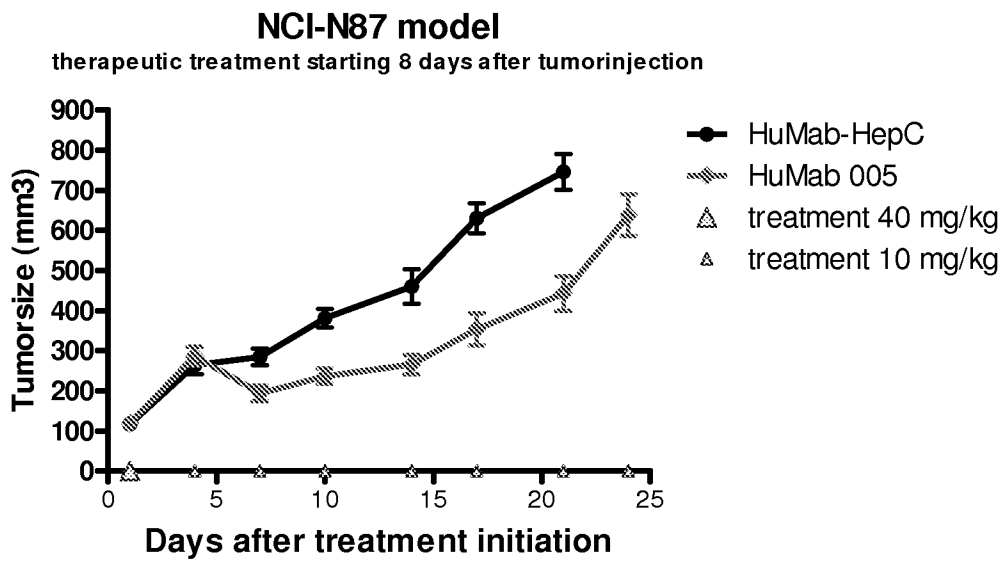


Figure 11B

