# USE OF ERBB3 INHIBITORS IN THE TREATMENT OF TRIPLE NEGATIVE AND BASAL-LIKE BREAST CANCERS

## Cross-Reference to Related Application

This application claims priority to U.S. Provisional Patent Application No. 61/312895, filed March 11, 2010, entitled, "Use of ErbB3 Inhibitors in the Treatment of Triple Negative and Basal-Like Breast Cancers" which is hereby incorporated by reference in its entirety.

## Background

In women, breast cancer is among the most common cancers and is the fifth most common cause of cancer deaths. Due to the heterogeneity of breast cancers, 10-year progression free survival can vary widely with stage and type, from 98% to 10%. Different forms of breast cancers can have remarkably different biological characteristics and clinical behavior. Thus, classification of a patient's breast cancer has become a critical component for determining a treatment regimen. For example, along with classification of histological type and grade, breast cancers now are routinely evaluated for expression of hormone receptors (estrogen receptor (ER) and progesterone receptor (PR)) and for expression of HER2 (ErbB2), since a number of treatment modalities are currently available that target hormone receptors or the HER2 receptor. ER and PR are both nuclear receptors (they are predominantly located at cell nuclei, although they can also be found at the cell membrane) and small molecular inhibitors that target ER and/or PR have been developed. HER2, or human epidermal growth factor receptor type 2, is a receptor normally located on the cell surface and antibodies that target HER2 have been developed as therapeutics. HER2 is the only member of the EGFR family (which also includes HER1 (EGFR), HER3 (ErbB3) and HER4 (ErbB4) that is not capable of binding to an activating ligand on its own. Thus HER2 is only functional as a receptor when incorporated into a heterodimeric receptor complex with another EGFR family member, such as HER3. Cancers classified as expressing the estrogen receptor (estrogen receptor positive, or $ER^+$ tumors) may be treated with an ER antagonist such as tamoxifen. Similarly, breast cancers classified as expressing high levels the HER2 receptor may be treated with an anti-HER2 antibody, such as trastuzumab, or with a HER2-active receptor tyrosine kinase inhibitor such as lapatinib.

Triple negative (TN) breast cancer is a term used to designate a well-defined clinically relevant subtype of breast carcinomas that account for approximately 15% of all breast cancer cases. TN tumors score negative (*i.e.*, using conventional histopathology

methods and criteria) for expression of ER and PR and do not express amplified levels of HER2 (*i.e.*, they are $ER^-$, $PR^-$, $HER2^-$). TN breast cancer comprises primarily, but not exclusively, a molecularly and histopathologically distinct subtype of breast cancer known as the basal-like (BL) subtype. The BL subtype also is characterized by the expression of cytokeratins (*e.g.*, CK, CK5/6, CK14, CK17) and other proteins found in normal basal/myoepithelial cells of the breast. However, in addition to the BL subtype, certain other types of breast cancers, including some "normal breast-like", metaplastic carcinomas, medullary carcinomas and salivary gland-like tumors can also exhibit the triple negative (TN) phenotype. Furthermore, TN breast cancers occur more frequently in the presence of BRCA1 mutations and in pre-menopausal females of African-American or Hispanic descent. TN tumors typically display very aggressive behavior, with shorter post-relapse survival and poor overall survival rates relative to other breast cancer types.

Not all BL breast cancers are TN. Basal-like breast tumors are a heterogeneous tumor type that account for up to 15% of all breast cancers and exhibit aggressive clinical behavior that makes them particularly difficult to treat successfully. A majority of BL breast cancers are ER-, PR-, and HER2 low ($HER2^{1+}$ or HER2 negative). In addition, they typically express proteins usually found in normal breast basal (myoepithelial) cells. These include high molecular weight cytokeratins (e.g., 5/6, 8, 14, 17 and 18), p-cadherin, caveolins 1 and 2, nestin, αB crystalline, and EGFR. Furthermore, BL tumor cells typically lack the capacity for competent homologous recombination DNA repair.

Histologically, most BL breast cancers are of IDC-NST type, high histological grade, and exhibit very high mitotic indices. They also typically have central necrotic or fibrotic zones, pushing borders, conspicuous lymphocytic infiltrates, and typical/atypical medullary features, and generally exhibit features similar to those of human papilloma virus-induced squamous cell carcinoma of the head and neck.

A great majority of medullary and atypical medullary, metaplastic, secretory, myoepithelial, and adenoid cystic carcinomas of the breast also exhibit BL characteristics.

Given the lack of expression of hormone receptors or of significant amounts of HER2 in TN breast cancer cells, treatment options have been very limited as the tumors are not responsive to treatments that target ER (*e.g.*, tamoxifen, aromatase inhibitors) or HER2 (*e.g.*, trastuzumab). Instead these tumors are treated with conventional neoadjuvant and adjuvant chemotherapy regimens, which have limited efficacy and many cytotoxic side effects. Furthermore, such chemotherapy regimens can lead to drug resistance in tumors, and the risk

of recurrence of disease in TN breast cancers is higher within the first three years of treatment than for other types of breast cancers.

Basal-like breast cancers are also difficult to treat and are associated with poor prognoses, though BL adenoid cystic carcinomas generally are associated with better clinical outcomes.. use thereof for the manufacture

In view of the foregoing, a need remains for additional treatment options and methods for treating triple negative breast cancers and BL breast cancers.

## Summary

Provided herein are methods for treating triple negative breast cancers (*e.g.*, tumors) and basal-like breast cancers (*e.g.*, tumors), as well as pharmaceutical compositions that can be used in such methods. The methods and compositions are based, at least in part, on the discovery that ErbB3 inhibition can suppress the growth of TN breast cancer cells and BL breast cancer cells. In particular, administration of anti-ErbB3 antibody is demonstrated to suppress the growth of TN breast cancer cells *in vivo*.

Accordingly, use of an ErbB3 inhibitor (e.g., use thereof for the manufacture of a medicament) for the treatment of TN or BL breast cancer is provided. In another aspect, a method of suppressing growth of a TN breast cancer tumor or a BL breast cancer tumor is provided, the method comprising contacting the tumor with an effective amount of an ErbB3 inhibitor. In another aspect, a method of suppressing growth of a TN breast cancer tumor or BL breast cancer tumor in a patient is provided, the method comprising administering to the patient an effective amount of an ErbB3 inhibitor. In yet another aspect, a method of treating a patient for a TN breast cancer tumor or BL breast cancer tumor is provided, the method comprising administering to the patient an effective amount of an ErbB3 inhibitor. In still another aspect, a method of treating a breast cancer tumor or BL breast cancer tumor in a patient is provided, the method comprising: selecting a patient with a triple negative breast cancer tumor or a BL breast cancer tumor; and administering to the patient an effective amount of an ErbB3 inhibitor.

In an exemplary embodiment, the ErbB3 inhibitor is an anti-ErbB3 antibody. An exemplary anti-ErbB3 antibody is MM-121 (Ab #6), comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 1 and 2, respectively. Another exemplary anti-ErbB3 antibody is an antibody comprising, optionally in amino terminal to carboxy terminal order, $V_H$ CDR1, 2 and 3 sequences as shown in SEQ ID NOs: 3-5, respectively, and, optionally in amino terminal to carboxy terminal order, $V_L$ CDR1, 2 and 3 sequences as shown in SEQ ID NOs:

6-8, respectively. In other embodiments, the anti-ErbB3 antibody is Ab #3 (comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 9 and 10, respectively), Ab #14 (comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 17 and 18, respectively), Ab #17 (comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 25 and 26, respectively) or Ab #19 (comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 33 and 34, respectively). In still other embodiments, the anti-ErbB3 antibody is selected from the group consisting of mAb 1B4C3, mAb 2D1D12, AMG-888 and humanized mAb 8B8. In another embodiment, administration of the anti-ErbB3 antibody inhibits growth or invasiveness or metastasis of the tumor.

The methods provided herein can be used in the treatment of TN breast cancers of various different histopathological phenotypes. For example, in one embodiment, the triple negative breast cancer tumor is histopathologically characterized as having a basal-like phenotype. In another embodiment, the TN breast cancer tumor is histopathologically characterized as having a phenotype other than BL.

In each of the foregoing methods and compositions, the ErbB3 inhibitor may be comprised in a formulation comprising a pharmaceutically acceptable carrier.

In another aspect, the treatment methods provided herein further comprise administering to the patient at least one additional anti-cancer agent that is not an ErbB3 inhibitor. In one embodiment, the at least one additional anti-cancer agent comprises at least one chemotherapeutic drug, such as a drug(s) selected from the group consisting of platinum-based chemotherapy drugs, taxanes, tyrosine kinase inhibitors, and combinations thereof. It has now been observed that in the subset of TN breast cancers that test $HER2^{2+}$, treatment with anti-HER2 agents such as trastuzumab, pertuzumab or lapatinib may provide benefits when used in combination with anti-ErbB3 antibodies. Thus in another aspect the treatment methods provided herein further comprise administering to the patient an effective amount of at least one additional anti-cancer agent that is an anti-HER2 agent. Such anti-HER2 agents are well known and may include one or more of anti-ErbB2 antibodies such as C6.5 (and the numerous derivatives thereof) described in US patent 5,977,322, trastuzumab, as described in US patent 6,054,297, and pertuzumab, as described in US patent 6,949,245; as well as small molecule anti-HER2 agents such as lapatinib (which also inhibits EGFR tyrosine kinase) and AG879.

In another embodiment, the at least one additional anti-cancer agent comprises an EGFR inhibitor, such as an anti-EGFR antibody or a small molecule inhibitor of EGFR signaling. An exemplary anti-EGFR antibody comprises cetuximab. Other examples of anti-

EGFR antibodies include matuzumab, panitumumab, nimotuzumab and mAb 806. An exemplary small molecule inhibitor of EGFR signaling comprises gefitinib. Other examples of useful small molecule inhibitors of EGFR signaling include lapatinib, canertinib, erlotinib HCL, pelitinib, PKI-166, PD158780, and AG 1478.

In yet another embodiment, the at least one additional anti-cancer agent comprises a VEGF inhibitor. An exemplary VEGF inhibitor comprises an anti-VEGF antibody, such as the bevacizumab antibody.

In another embodiment, administration of the anti-ErbB3 antibody and the at least one additional anti-cancer agent inhibits growth or invasiveness or metastasis of the tumor.

In another aspect, methods of treating TN breast cancer or BL breast cancer in a patient comprise administering to said patient a combination comprising MM-121 and paclitaxel. In one embodiment the combination exhibits therapeutic synergy in the treatment of TN or BL breast cancers. In some examples, the combination effects a $\log_{10}$ cell kill of at least 2.8, at least 2.9 or at least 3.0. In other aspects, the combination provides an improvement in tumor growth inhibition that is at least about additive as compared to improvement obtained with each of the single agents of the combination.

In another embodiment, there is provided a composition comprising a combination of MM-121 and paclitaxel, wherein the combination exhibits therapeutic synergy in the treatment of TN or BL breast cancers. In some examples, the composition effects a $\log_{10}$ cell kill of at least 2.8, at least 2.9 or at least 3.0.

Kits containing the combination pharmaceutical compositions also are provided.

## Brief Description of the Drawings

**Figure 1** is a graph showing relative MAXF449 xenograft tumor volume (%) (Y axis - normalized to initial tumor volume) plotted against time in days following randomization (X axis) in NMRI nude mice treated with MM-121 or vehicle control. TGI = 200%.

**Figure 2** is a graph showing the percent change in MDA-MB-231 xenograft tumor volume (Y axis - normalized to initial tumor volume) plotted against time in days following injection of MDA-MB-231 cells (X axis) in Balb/c nude mice treated with MM-121 or vehicle control. Curves with open timepoint squares or circles indicate mice treated with MM-121. Curves with filled timepoint squares or circles indicate vehicle controls. In the inset, "mp" indicates that the MDA-MB-231 cells were injected into the mammary fat pad, while "sc" indicates that the MDA-MB-231 cells were injected subcutaneously in the flank.

**Figure 3** is a graph showing MDA-MB-231 tumor volume in $mm^3$ (Y axis) plotted against time in days (X-axis) starting at 28 days following injection of MDA-MB-231 cells into the mammary fat pads of Balb/c nude mice. Treatment was with MM-121 (150 µg/mouse), paclitaxel (5 mg/kg), a combination of MM-121 (150 µg/mouse) and paclitaxel (5 mg/kg), or vehicle control. Where used in the figures, "mpk" = mg/kg.

**Figure 4** presents graphs showing MDA-MB-231 tumor volume in $mm^3$ (Y axis) plotted against time in days (X-axis) starting at 28 days following injection of MDA-MB-231 cells into the mammary fat pads of Balb/c nude mice. **Figure 4A** depicts treatment with MM-121, cetuximab, or paclitaxel; MM-121 and cetuximab; and the triple combination MM-121 and cetuximab and paclitaxel. **Figure 4B** depicts treatment with MM-121, erlotinib, MM-121 and erlotinib, or the triple combination of MM-121 and erlotinib and paclitaxel.

## Detailed Description

Provided herein are methods for treating triple negative and basal-like breast cancers, as well as pharmaceutical compositions that can be used in practicing such methods. As described further in the Examples, it has now been demonstrated that an ErbB3 inhibitor, in particular an anti-ErbB3 antibody, is able to suppress the growth of TN breast cancer cells *in vivo*. Accordingly, methods for suppressing the growth of TN breast cancers and BL breast cancers, as well as methods of treating such breast cancers in patients, using an ErbB3 inhibitor are provided herein.

Definitions:

As used herein, the term "triple negative" or "TN" refers to tumors (e.g., carcinomas), typically breast tumors, in which the tumor cells score negative (*i.e.*, using conventional histopathology methods) for estrogen receptor (ER) and progesterone receptor (PR), both of which are nuclear receptors (i.e., they are predominantly located at cell nuclei), and the tumor cells are not amplified for epidermal growth factor receptor type 2 (HER2 or ErbB2), a receptor normally located on the cell surface. Tumor cells are considered negative for expression of ER and PR if less than 5% of the tumor cell nuclei are stained for ER and PR expression using standard immunohistochemical techniques. Tumor cells are considered highly amplified for HER2 ("$HER2^{3+}$") if, when tested with a HercepTest™ Kit (Code K5204, Dako North America, Inc., Carpinteria, CA), a semi-quantitative immunohistochemical assay using a polyclonal anti-HER2 primary antibody, they yield a test result score of 3+, or, the test HER2 positive by fluorescence *in-situ* hybridization (FISH).

As used herein, tumor cells are considered negative for HER2 overexpression if they yield a test result score of 0 or 1+, or 2+, or if they are HER2 FISH negative.

Furthermore, the term "triple negative breast cancer(s)" or "TN breast cancer(s)" encompasses carcinomas of differing histopathological phenotypes. For example, certain TN breast cancers are classified as "basal-like" ("BL"), in which the neoplastic cells express genes usually found in normal basal/myoepithelial cells of the breast, such as high molecular weight basal cytokeratins (CK, CK5/6, CK14, CK17), vimentin, p-cadherin, αB crystallin, fascin and caveolins 1 and 2. Certain other TN breast cancers, however, have a different histopathological phenotype, examples of which include high grade invasive ductal carcinoma of no special type, metaplastic carcinomas, medullary carcinomas and salivary gland-like tumors of the breast.

The terms "ErbB3," "HER3," "ErbB3 receptor," and "HER3 receptor," as used interchangeably herein, refer to human ErbB3 protein, as described in U.S. Pat. No. 5,480,968.

As used herein, the term "ErbB3 inhibitor" is intended to include therapeutic agents that inhibit, downmodulate, suppress or downregulate activity of ErbB3 . The term is intended to include chemical compounds, such as small molecule inhibitors, and biologic agents, such as antibodies, interfering RNA (shRNA, siRNA), soluble receptors and the like. An exemplary ErbB3 inhibitor is an anti-ErbB3 antibody.

An "antibody," as used herein is a protein consisting of one or more polypeptides comprising binding domains substantially encoded by immunoglobulin genes or fragments of immunoglobulin genes, wherein the protein immunospecifically binds to an antigen. The recognized immunoglobulin genes include the kappa, lambda, alpha, gamma, delta, epsilon and mu constant region genes, as well as myriad immunoglobulin variable region genes. Light chains are classified as either kappa or lambda. Heavy chains are classified as gamma, mu, alpha, delta, or epsilon, which in turn define the immunoglobulin classes, IgG, IgM, IgA, IgD and IgE, respectively. A typical immunoglobulin structural unit comprises a tetramer that is composed of two identical pairs of polypeptide chains, each pair having one "light" (about 25 kD) and one "heavy" chain (about 50-70 kD). "$V_L$" and "$V_H$" refer to these light and heavy chains respectively.

Antibodies include intact immunoglobulins as well as antigen-binding fragments thereof, which may be produced by digestion with various peptidases, or synthesized *de novo* either chemically or using recombinant DNA expression technology. Such fragments

include, for example, $F(ab)_2$ dimers and Fab monomers. Useful antibodies include single chain antibodies (antibodies that exist as a single polypeptide chain), *e.g.*, single chain Fv antibodies (scFv) in which a $V_H$ and a $V_L$ chain are joined together (directly or through a peptide linker) to form a continuous polypeptide.

"Immunospecific" or "immunospecifically" refer to antibodies that bind via domains substantially encoded by immunoglobulin genes or fragments of immunoglobulin genes to one or more epitopes of a protein of interest, but which do not substantially recognize and bind other molecules in a sample containing a mixed population of antigenic molecules. Typically, an antibody binds immunospecifically to a cognate antigen with a $K_d$ with a value of no greater than 50 nM, as measured by a surface plasmon resonance assay or a cell binding assay. The use of such assays is well known in the art, and is described in Example 3, below.

An "anti-ErbB3 antibody" is an antibody that immunospecifically binds to the ectodomain of ErbB3 and an "anti-ErbB2 antibody" is an antibody that immunospecifically binds to the ectodomain of ErbB2. The antibody may be an isolated antibody. Such binding to ErbB3 or ErB2 exhibits a $K_d$ with a value of no greater than 50 nM as measured by a surface plasmon resonance assay or a cell binding assay. An anti-ErbB3 antibody may be an isolated antibody. Exemplary anti-ErbB3 antibodies inhibit EGF-like ligand mediated phosphorylation of ErbB3. EGF-like ligands include EGF, TGFα, betacellulin, heparin-binding epidermal growth factor, biregulin, epigen, epiregulin, and amphiregulin, which typically bind to ErbB1 and induce heterodimerization of ErbB1 with ErbB3.

As used herein, the term "EGFR inhibitor" is intended to include therapeutic agents that inhibit, downmodulate, suppress or downregulate EGFR signaling activity. The term is intended to include chemical compounds, such as small molecule inhibitors (*e.g.*, small molecule tyrosine kinase inhibitors) and biologic agents, such as antibodies, interfering RNA (shRNA, siRNA), soluble receptors and the like.

As used herein, the term "VEGF inhibitor" is intended to include therapeutic agents that inhibit, downmodulate, suppress or downregulate VEGF signaling activity. The term is intended to include chemical compounds, such as small molecule inhibitors (*e.g.*, small molecule tyrosine kinase inhibitors) and biologic agents, such as antibodies, interfering RNA (shRNA, siRNA), soluble receptors and the like.

The terms "suppress", "suppression", "inhibit" and "inhibition" as used interchangeably herein, refer to any statistically significant decrease in biological activity (*e.g.*, tumor cell growth), including full blocking of the activity. For example, "inhibition"

can refer to a decrease of about 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, or 100% in biological activity.

The term "patient" includes a human or other mammalian animal that receives either prophylactic or therapeutic treatment.

The terms "treat," "treating," and "treatment," as used herein, refer to therapeutic or preventative measures such as those described herein. The methods of "treatment" employ administration to a patient of an ErbB3 inhibitor provided herein, for example, a patient having a TN or BL breast cancer tumor, in order to prevent, cure, delay, reduce the severity of, or ameliorate one or more symptoms of the disease or disorder or recurring disease or disorder, or in order to prolong the survival of a patient beyond that expected in the absence of such treatment.

The term "effective amount," as used herein, refers to that amount of an agent, such as an ErbB3 inhibitor, for example an anti-ErbB3 antibody, which is sufficient to effect treatment, prognosis or diagnosis of a TN or BL breast cancer, when administered to a patient. A therapeutically effective amount will vary depending upon the patient and disease condition being treated, the weight and age of the patient, the severity of the disease condition, the manner of administration and the like, which can readily be determined by one of ordinary skill in the art. The dosages for administration can range from, for example, about 1 ng to about 10,000 mg, about 5 ng to about 9,500 mg, about 10 ng to about 9,000 mg, about 20 ng to about 8,500 mg, about 30 ng to about 7,500 mg, about 40 ng to about 7,000 mg, about 50 ng to about 6,500 mg, about 100 ng to about 6,000 mg, about 200 ng to about 5,500 mg, about 300 ng to about 5,000 mg, about 400 ng to about 4,500 mg, about 500 ng to about 4,000 mg, about 1 μg to about 3,500 mg, about 5 μg to about 3,000 mg, about 10 μg to about 2,600 mg, about 20 μg to about 2,575 mg, about 30 μg to about 2,550 mg, about 40 μg to about 2,500 mg, about 50 μg to about 2,475 mg, about 100 μg to about 2,450 mg, about 200 μg to about 2,425 mg, about 300 μg to about 2,000, about 400 μg to about 1,175 mg, about 500 μg to about 1,150 mg, about 0.5 mg to about 1,125 mg, about 1 mg to about 1,100 mg, about 1.25 mg to about 1,075 mg, about 1.5 mg to about 1,050 mg, about 2.0 mg to about 1,025 mg, about 2.5 mg to about 1,000 mg, about 3.0 mg to about 975 mg, about 3.5 mg to about 950 mg, about 4.0 mg to about 925 mg, about 4.5 mg to about 900 mg, about 5 mg to about 875 mg, about 10 mg to about 850 mg, about 20 mg to about 825 mg, about 30 mg to about 800 mg, about 40 mg to about 775 mg, about 50 mg to about 750 mg, about 100 mg to about 725 mg, about 200 mg to about 700 mg, about 300 mg to about 675 mg, about 400 mg to about 650 mg, about 500 mg, or about 525 mg to about 625 mg, of an antibody or antigen

binding portion thereof, as provided herein. Dosing may be, *e.g.*, every week, every 2 weeks, every three weeks, every 4 weeks, every 5 weeks or every 6 weeks. Dosage regimens may be adjusted to provide the optimum therapeutic response. An effective amount is also one in which any toxic or detrimental effects (side effects) of the agent are minimized and/or outweighed by the beneficial effects. For MM-121, administration may be intravenous at exactly or about 6 mg/kg or 12 mg/kg weekly, or 12 mg/kg or 24 mg/kg biweekly. Additional dosing regimens are described below.

The terms "anti-cancer agent" and "antineoplastic agent" refer to drugs used to treat malignancies, such as cancerous growths. Drug therapy may be used alone, or in combination with other treatments such as surgery or radiation therapy.

Various aspects and embodiments are described in further detail in the following subsections.

I. ErbB3 Inhibitors

As described in further detail herein, the methods and compositions provided herein involve the use of one or more ErbB3 inhibitors.

In one embodiment, the ErbB3 inhibitor is an anti-ErbB3 antibody, *e.g.*, a monoclonal antibody. An exemplary anti-ErbB3 monoclonal antibody is MM-121, described further in WO 2008/100624 and US Patent No. 7,846,440, and having $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 1 and 2, respectively. Alternately, the anti-ErbB3 monoclonal antibody is an antibody that competes with MM-121 for binding to ErbB3. In another embodiment, the anti-ErbB3 antibody is an antibody comprising the $V_H$ and $V_L$ CDR sequences of MM-121, which are shown in SEQ ID NOs: 3-5 ($V_H$ CDR1, 2, 3) and 6-8 ($V_L$ CDR1, 2, 3), respectively. Other examples of anti-ErbB3 antibodies include Ab #3, Ab #14, Ab #17 and Ab #19, also described further in WO 2008/100624 and having $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 9 and 10, 17 and 18, 25 and 26, and 33 and 34 respectively. In another embodiment, the anti-ErbB3 antibody is an antibody comprising the $V_H$ and $V_L$ CDR sequences of Ab # 3 (shown in SEQ ID NOs: 11-13 and 14-18, respectively) or antibody comprising the $V_H$ and $V_L$ CDR sequences of Ab # 14 (shown in SEQ ID NOs: 19-21 and 22-24, respectively) or an antibody comprising the $V_H$ and $V_L$ CDR sequences of Ab # 17 (shown in SEQ ID NOs: 27-29 and 30-32, respectively) or an antibody comprising the $V_H$ and $V_L$ CDR sequences of Ab # 19 (shown in SEQ ID NOs: 35-37 and 38-40, respectively).

Alternately, the anti-ErbB3 antibody is a monoclonal antibody or antigen binding portion thereof which binds an epitope of human ErbB3 comprising residues 92-104 of SEQ

ID NO:41 and is characterized by inhibition of proliferation of a cancer cell expressing ErbB3. The cancer cell may be a MALME-3M cell, an AdrR cell, or an ACHN cell and the proliferation may be reduced by at least 10% relative to control. In an additional embodiment this isolated monoclonal antibody or antigen binding portion thereof binds an epitope comprising residues 92-104 and 129 of SEQ ID NO:41.

Other examples of useful anti-ErbB3 antibodies include the antibodies 1B4C3 and 2D1D12 (U3 Pharma AG), both of which are described in US Patent Application Publication No. 20040197332 by Ullrich *et al.*, and monoclonal antibodies (including humanized versions thereof), such as AMG-888 (U3 Pharma AG and Amgen) and 8B8, as described in U.S. Patent 5,968,511 by Akita *et al.*

In yet another embodiment, the anti-ErbB3 antibody can comprise a mixture, or cocktail, of two or more anti-ErbB3 antibodies, each of which binds to a different epitope on ErbB3. In one embodiment, the mixture, or cocktail, comprises three anti-ErbB3 antibodies, each of which binds to a different epitope on ErbB3.

In another embodiment, the ErbB3 inhibitor comprises a nucleic acid molecule, such as an RNA molecule, that inhibits the expression or activity of ErbB3. RNA antagonists of ErbB3 have been described in the art (see *e.g.*, US Patent Application Publication No. 20080318894). Moreover, interfering RNAs specific for ErbB3, such as shRNAs or siRNAs that specifically inhibits the expression and/or activity of ErbB3, have been described in the art.

In yet another embodiment, the ErbB3 inhibitor comprises a soluble form of the ErbB3 receptor that inhibits signaling through the ErbB3 pathway. Such soluble ErbB3 molecules have been described in the art (see e.g., U.S. Patent No. 7,390,632, U.S. Patent Application Publication No. 20080274504 and U.S. Patent Application Publication No. 20080261270, each by Maihle *et al.*, and U.S. Patent Application Publication No. 20080057064 by Zhou).

II. Methods

In one aspect, use of an ErbB3 inhibitor for the manufacture of a medicament for the treatment of TN breast cancer or BL breast cancer is provided.

In another aspect, a method of suppressing growth of a triple negative breast cancer cell is provided, the method comprising contacting the cell with an effective amount of an ErbB3 inhibitor.

In another aspect, a method of suppressing growth of a TN or BL breast cancer tumor in a patient is provided, the method comprising administering to the patient an effective amount of an ErbB3 inhibitor.

In yet another aspect, a method of treating a patient for a TNor BL breast cancer tumor is provided, the method comprising administering to the patient an effective amount of an ErbB3 inhibitor.

In still another aspect, a method of treating a breast cancer tumor in a patient is provided, the method comprising:

selecting a patient with a TN or BL breast cancer tumor; and

administering to the patient an effective amount of an ErbB3 inhibitor.

In another aspect, the patient with a TN or BL breast cancer tumor is a patient further selected by use of the selection methods disclosed in pending international application PCT/US2009/054051.

Identification of a triple negative breast cancer cells, or a patient having a triple negative breast cancer tumor, can be achieved through standard methods well known in the art. For example, immunohistochemical (IHC) staining is routinely used in biopsy analysis and permits the detection, localization and relative quantification of ER, PR, and HER2 within sections from formalin-fixed, paraffin-embedded tissues (*e.g.*, breast cancer tissues routinely processed for histological evaluation). In the context of identifying TN tumors, staining of less than 5% of tumor cell nuclei is considered negative for each of for ER and PR. The primary antibody used for IHC staining of ER is *e.g.*, 1D5 (Chemicon, Temecula CA, catalog # IHC2055). The primary antibody used for IHC staining of PR is *e.g.*, PgR636 (Thermo Fisher Scientific, Fremont, CA, catalog # MS-1882-R7) or PgR 1294 (Dako North America, Inc., Carpinteria, CA, Code M3568). The ErbB2 IHC assay used is *e.g.*, the HercepTest™ Kit (Dako North America, Inc., Carpinteria, CA, Code K5204), a semi-quantitative IHC assay using a polyclonal anti-HER2 primary antibody to determine HER2 protein overexpression in breast cancer tissues routinely processed for histological evaluation, which is used according to the manufacturer's directions. In the context of identifying TN tumors, a test result of 0 to 1+ is considered Her2 negative.

In one embodiment, the triple negative breast cancer tumor is histopathologically characterized as having a basal-like phenotype. In another embodiment, the triple negative breast cancer tumor is histopathologically characterized as having a phenotype other than basal-like. Examples of TN breast cancer histopathological phenotypes that are other than

BL include high grade invasive ductal carcinoma of no special type, metaplastic carcinomas, medullary carcinomas and salivary gland-like tumors of the breast.

In one aspect, the TN or BL breast cancer to be treated with ErbB3 inhibitor coexpresses ErbB1 (EGFR), ErbB3, and heregulin (HRG). Expression of EGFR and HRG can be identified by RT-PCR or by standard immunoassay techniques, such as ELISA assay or immunohistochemical staining of formalin-fixed, paraffin-embedded tissues (e.g., breast cancer tissues routinely processed for histological evaluation), using an anti-EGFR antibody, anti-ErbB3 antibody or an anti-HRG antibody. Additional characteristics of tumors for treatment in accordance with the disclosure herein are set forth in pending U.S. Patent Publication No. 20110027291, which claims priority to PCT application No. PCT/US2009/054051.

In one embodiment, the ErbB3 inhibitor administered to the patient is an anti-ErbB3 antibody. An exemplary anti-ErbB3 antibody is MM-121, comprising $V_H$ and $V_L$ sequences as shown in SEQ ID NOs: 1 and 2, respectively, or an antibody comprising $V_H$ CDR1, 2 and 3 sequences as shown in SEQ ID NOs: 3-5, respectively, and $V_L$ CDR1, 2 and 3 sequences as shown in SEQ ID NOs: 6-8, respectively (i.e., the $V_H$ and $V_L$ CDRs of MM-121). Additional non-limiting exemplary anti-ErbB3 antibodies and other forms of ErbB3 inhibitors are described in detail in Subsection I above.

The ErbB3 inhibitor can be administered to the patient by any route suitable for the effective delivery of the inhibitor to the patient. For example, many small molecule inhibitors are suitable for oral administration. Antibodies and other biologic agents typically are administered parenterally, e.g., intravenously, intraperitoneally, subcutaneously or intramuscularly. Various routes of administration, dosages and pharmaceutical formulations suitable for use in the methods provided herein are described in further detail below.

III. Pharmaceutical Compositions

In another aspect, pharmaceutical compositions are provided that can be used in the methods disclosed herein, *i.e.*, pharmaceutical compositions for treating TN or BL breast cancer tumors.

In one embodiment, the pharmaceutical composition for treating TN breast cancer comprises an ErbB3 inhibitor and a pharmaceutical carrier. The ErbB3 inhibitor can be formulated with the pharmaceutical carrier into a pharmaceutical composition. Additionally, the pharmaceutical composition can include, for example, instructions for use of the composition for the treatment of patients for TN or BL breast cancer tumors.

In one embodiment, the ErbB3 inhibitor in the composition is an anti-ErbB3 antibody, *e.g.*, MM-121 or an antibody comprising the $V_H$ and $V_L$ CDRs of MM-121 positioned in the antibody in the same relative order as they are present in MM-121 so as to provide immunospecific binding of ErbB3. Additional non-limiting exemplary anti-ErbB3 antibodies and other forms of ErbB3 inhibitors are described in detail in Subsection I above.

As used herein, "pharmaceutically acceptable carrier" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, buffers, and other excipients that are physiologically compatible. Preferably, the carrier is suitable for parenteral, oral, or topical administration. Depending on the route of administration, the active compound, *e.g.*, small molecule or biologic agent, may be coated in a material to protect the compound from the action of acids and other natural conditions that may inactivate the compound.

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

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

Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions provided herein include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, and injectable organic esters, such as ethyl oleate. When required, proper fluidity can 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. In many

cases, it will be useful to include isotonic agents, for example, sugars, polyalcohols such as mannitol, sorbitol, or sodium chloride in the composition. Prolonged absorption of the injectable compositions can be brought about by including in the composition an agent that delays absorption, for example, monostearate salts and gelatin.

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

Therapeutic compositions typically must be sterile, non-pyrogenic, and stable under the conditions of manufacture and storage. The composition can be formulated as a solution, microemulsion, liposome, or other ordered structure suitable to high drug concentration.

Sterile injectable solutions can be prepared by incorporating the active compound in the required amount in an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by sterilization, *e.g.*, by microfiltration. Generally, dispersions are prepared by incorporating the active compound into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, methods of preparation include 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 active agent(s) may be mixed under sterile conditions with additional pharmaceutically acceptable carrier(s), and with any preservatives, buffers, or propellants which may be required.

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

Pharmaceutical compositions comprising an ErbB3 inhibitor can be administered alone or in combination therapy. For example, the combination therapy can include a composition provided herein comprising an ErbB3 inhibitor and at least one or more additional therapeutic agents, such as one or more chemotherapeutic agents known in the art, discussed in further detail in Subsection IV below. Pharmaceutical compositions can also be administered in conjunction with radiation therapy and/or surgery.

Dosage regimens are adjusted to provide the optimum desired response (*e.g.*, a therapeutic response). For example, a single bolus may be administered, several divided doses may be administered over time or the dose may be proportionally reduced or increased as indicated by the exigencies of the therapeutic situation.

Exemplary dosage ranges for administration of an antibody include: 10-1000 mg (antibody)/kg (body weight of the patient), 10-800 mg/kg, 10-600 mg/kg, 10-400 mg/kg, 10-200 mg/kg, 30-1000 mg/kg, 30-800 mg/kg, 30-600 mg/kg, 30-400 mg/kg, 30-200 mg/kg, 50-1000 mg/kg, 50-800 mg/kg, 50-600 mg/kg, 50-400 mg/kg, 50-200 mg/kg, 100-1000 mg/kg, 100-900 mg/kg, 100-800 mg/kg, 100-700 mg/kg, 100-600 mg/kg, 100-500 mg/kg, 100-400 mg/kg, 100-300 mg/kg and 100-200 mg/kg. Exemplary dosage schedules include once every three days, once every five days, once every seven days (*i.e.*, once a week), once every 10 days, once every 14 days (*i.e.*, once every two weeks), once every 21 days (*i.e.*, once every three weeks), once every 28 days (*i.e.*, once every four weeks) and once a month.

It may be advantageous to formulate parenteral compositions in unit dosage form for ease of administration and uniformity of dosage. Unit dosage form as used herein refers to physically discrete units suited as unitary dosages for the patients to be treated; each unit contains a predetermined quantity of active agent calculated to produce the desired therapeutic effect in association with any required pharmaceutical carrier. The specification for unit dosage forms are dictated by and directly dependent on (a) the unique characteristics of the active compound and the particular therapeutic effect to be achieved, and (b) the limitations inherent in the art of compounding such an active compound for the treatment of sensitivity in individuals.

Actual dosage levels of the active ingredients in the pharmaceutical compositions disclosed herein 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. "Parenteral" as used herein in the context of administration means modes of administration other than enteral and topical administration, usually by injection, and includes, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion.

The phrases "parenteral administration" and "administered parenterally" as used herein refer to modes of administration other than enteral (*i.e.*, via the digestive tract) and topical administration, usually by injection or infusion, and includes, without limitation,

intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion. Intravenous injection and infusion are often (but not exclusively) used for antibody administration.

When agents provided herein are administered as pharmaceuticals, to humans or animals, they can be given alone or as a pharmaceutical composition containing, for example, 0.001 to 90% (*e.g.*, 0.005 to 70%, *e.g.*, 0.01 to 30%) of active ingredient in combination with a pharmaceutically acceptable carrier.

IV. Combination Therapy

In certain embodiments, the methods and uses provided herein for suppressing growth of TN breast cancer cells or for treating a patient with a TN breast tumor or BL breast tumor can comprise administration of an ErbB3 inhibitor and at least one additional anti-cancer agent that is not an ErbB3 inhibitor.

In one embodiment, the at least one additional anti-cancer agent comprises at least one chemotherapeutic drug. Non-limiting examples of such chemotherapeutic drugs include platinum-based chemotherapy drugs (*e.g.*, cisplatin, carboplatin), taxanes (*e.g.*, paclitaxel (Taxol®), docetaxel (Taxotere®), EndoTAG-1™ (a formulation of paclitaxel encapsulated in positively charged lipid-based complexes; MediGene), Abraxane® (a formulation of paclitaxel bound to albumin)), tyrosine kinase inhibitors (*e.g.*, imatinib/Gleevec®, sunitinib/Sutent®, dasatinib/Sprycel®), and combinations thereof.

In another embodiment, the at least one additional anti-cancer agent comprises an EGFR inhibitor, such as an anti-EGFR antibody or a small molecule inhibitor of EGFR signaling. An exemplary anti-EGFR antibody is cetuximab (Erbitux®). Cetuximab is commercially available from ImClone Systems Incorporated. Other examples of anti-EGFR antibodies include matuzumab (EMD72000), panitumumab (Vectibix®; Amgen); nimotuzumab (TheraCIM™) and mAb 806. An exemplary small molecule inhibitor of the EGFR signaling pathway is gefitinib (Iressa®), which is commercially available from AstraZeneca and Teva. Other examples of small molecule inhibitors of the EGFR signaling pathway include erlotinib HCL (OSI-774; Tarceva®, OSI Pharma); lapatinib (Tykerb®, GlaxoSmithKline); canertinib (canertinib dihydrochloride, Pfizer); pelitinib (Pfizer); PKI-166 (Novartis); PD158780; and AG 1478 (4-(3-Chloroanillino)-6,7-dimethoxyquinazoline).

In yet another embodiment, the at least one additional anti-cancer agent comprises a VEGF inhibitor. An exemplary VEGF inhibitor comprises an anti-VEGF antibody, such as bevacizumab (Avastatin®; Genentech).

In still another embodiment, the at least one additional anti-cancer agent comprises an anti-ErbB2 antibody. Suitable anti-ErbB2 antibodies include trastuzumab and pertuzumab.

In one aspect, the improved effectiveness of a combination according to the invention can be demonstrated by achieving therapeutic synergy.

The term "therapeutic synergy" is used when the combination of two products at given doses is more efficacious than the best of each of the two products alone at the same doses. In one example, therapeutic synergy can be evaluated by comparing a combination to the best single agent using estimates obtained from a two-way analysis of variance with repeated measurements (e.g., time factor) on parameter tumor volume.

The term "additive" refers to when the combination of two or more products at given doses is equally efficacious than the sum of the efficacies obtained with of each of the two or more products, whilst the term "superadditive" refers to when the combination is more efficacious than the sum of the efficacies obtained with of each of the two or more products.

Another measure by which effectiveness (including effectiveness of combinations) can be quantified is by calculating the $\log_{10}$ cell kill, which is determined according to the following equation:

$$\log_{10} \text{ cell kill} = \text{T-C (days)}/3.32 \times T_d$$

in which T-C represents the delay in growth of the cells, which is the average time, in days, for the tumors of the treated group (T) and the tumors of the control group (C) to have reached a predetermined value (1 g, or 10 mL, for example), and $T_d$ represents the time, in days necessary for the volume of the tumor to double in the control animals. When applying this measure, a product is considered to be active if $\log_{10}$ cell kill is greater than or equal to 0.7 and a product is considered to be very active if $\log_{10}$ cell kill is greater than 2.8.

Using this measure, a combination, used at its own maximum tolerated dose, in which each of the constituents is present at a dose generally less than or equal to its maximum tolerated dose, exhibits therapeutic synergy when the $\log_{10}$ cell kill is greater than the value of the $\log_{10}$ cell kill of the best constituent when it is administered alone. In an exemplary case, the $\log_{10}$ cell kill of the combination exceeds the value of the $\log_{10}$ cell kill of the best constituent of the combination by at least one log cell kill.

## Examples

### Example 1: MM-121 effects on triple negative human breast cancer xenograft MAXF449

An analysis of the anti-tumor efficacy and tolerability of MM-121 treatment of tumor-bearing mice is carried out using triple negative human mammary carcinoma xenograft MAXF449 (ONCOTEST GmbH, Frieburg, Germany) in NMRI nude mice. MAXF449 is a Human tumor explant (histologically described upon explant as solid invasive ductal, and poorly defined) established via subcutaneous injection in serial passages in nude mice. The MAXF449 cells used in these experiments have been passaged 22 times. NMRI nude mice are obtained from Taconic farms, Charles River Laboratories International, or Harlan Laboratories. The mice are housed in Tecniplast Individually Ventilated polycarbonate (Macrolon) Cages (IVC) set in climate-controlled rooms and have free access to food and acidified water.

To investigate anti-tumor efficacy in monotherapy, MM-121 or vehicle control (100µL) is given to tumor-bearing mice at 600µg per mouse (MM-121 as a 6 mg/mL solution in PBS) by IP injection every three days. Control mice receive the PBS vehicle only. Efficacy is determined by comparing tumor growth between the antibody-treated mice and the vehicle control mice and is expressed as the experimental to control ratio of median relative tumor volumes (T/C value). A minimum T/C value below 50% is a prerequisite for rating a treatment as effective. The control and experimental groups each contain 10 mice bearing one tumor each. To obtain 30 mice bearing tumors of similar sizes for randomization, 40 mice per tumor are implanted unilaterally.

Mice are randomized and therapy begins when a sufficient number of individual tumors have grown to a volume of approximately 200 mm3. Tumors are measured (L x W) by digital caliper measurement and the tumor volume is calculated using the formula Pi/6 (W2 x L). The first dose is administered either on Day 0 (day of randomization) or one day later.

Approximately 24 hours after administration of the final dose all mice are bled to prepare serum; in addition, tumors are collected from the same mice for flash-freezing and FFPE (1/2 tumor each).

According to regulations for animal experiments, mice are sacrificed if the tumor volume exceeds 1800 $mm^3$ (one tumor per mouse). Mice are monitored and dosed until their tumors

have grown to that size but no longer than 60 days. Thereafter, they are sacrificed for sample collection.

At the end of the study, approximately 24 hours after administration of the final dose, all mice on study are bled sublingually to obtain a maximum amount of blood for the preparation of serum. Serum is aliquoted in 2 tubes with approximately 250 μL in each.

In addition, tumors from all mice are excised without delay for snap-freezing in liquid nitrogen (1/2 tumor, COVARIS bags for the storage of samples are provided) and for fixation in 10% buffered formalin for <24 hours, subsequent dehydration and paraffin embedding (FFPE, 1/2 tumor).

Animal weights and tumor diameters (W and L) are measured twice weekly and tumor volumes are calculated using the formula Pi/6 (W2xL). Tumor growth curves are plotted. Tumor inhibition and absolute growth delay for 2 and 4 doubling times are calculated.

Results of experiments that were carried out substantially as described are presented in Figure 1. MM-121 treatment inhibited or stopped tumor growth, and in some cases reduced tumor size. TGI (tumor growth inhibition) in these human triple negative tumor xenografts was calculated to be approximately 200%.

**Example 2: MM-121 effects on triple-negative human breast cancer xenograft MDA-MB-231**

Balb/c nude mice are injected under general anesthesia with $10^7$ MDA-MB-231 human triple negative breast cancer cells (ATCC) either subcutaneously in the flank or into the mammary fat pad. Mice with established tumors (i.e., after 7-10 days of tumor growth following injection of cells) are then treated IP with either PBS or MM-121 every 3 days with 600 ug MM-121 per mouse as described in Example 1. Tumor volume is measured twice a week as described in Example 1.

Results of experiments carried out substantially as described are presented in Figure 2. MM-121 treatment stopped human triple negative breast cancer tumor growth essentially completely in these experiments.

**Example 3: Measurement of Binding Affinity ($K_D$ )**

The dissociation constants of anti-ErbB antibodies may be measured using either or both of two independent techniques, a Surface Plasmon Resonance Assay and a cell binding assay.

Surface Plasmon Resonance Assay

The Surface Plasmon Resonance Assay is performed as described in Wassaf *et al.* (2006) *Analytical Biochem.*, 351:241-253. One implementation uses a BIACORE 3000 instrument (GE Healthcare) using a recombinant ErbB protein as the analyte and the anti-ErbB antibody as the ligand The $K_D$ value is calculated based on the formula $K_D = K_d/K_a$.

Cell Binding Assay

A cell binding assay is performed using MALME-3M cells (ATCC ) for ErbB3 binding. The assay is performed substantially as follows.

Cells are detached with 2 mLs trypsin-EDTA + 2 mLs RMPI + 5mM EDTA at room temperature for 5 minutes. Complete RPMI (10 mLs) is added immediately to the trypsinized cells, resuspended gently and spun down in a Beckman tabletop centrifuge at 1100 rpm for 5 minutes. Cells are resuspended in BD stain buffer (PBS + 2% FBS + 0.1% sodium azide, Becton Dickinson) at a concentration of 2 x $10^6$ cells per ml and 50 µl (1 x $10^5$ cells) aliquots are plated in a 96-well titer plate.

A 150 µl solution of 200 nM anti-ErbB antibody in BD stain buffer is prepared and serially diluted 2-fold into 75 µl BD stain buffer. The concentrations of the diluted antibody ranged from 200 nM to 0.4 nM. 50 µl aliquots of the different protein dilutions are then added directly to the 50 ul cell suspension giving the final concentrations of 100 nM, 50 nM, 25 nM, 12 nM, 6 nM, 3 nM, 1.5 nM, 0.8 nM, 0.4 nM and 0.2 nM of the antibody.

Aliquoted cells in the 96-well plate are incubated with the protein dilutions for 30 minutes at room temperature on a platform shaker and washed 3 times with 300 µl BD stain buffer. Cells are then incubated with 100 µl of secondary antibody (e.g., a 1:750 dilution of Alexa 647-labeled goat anti-human IgG in BD stain buffer) for 45 minutes on a platform shaker in the cold room. Finally, cells are washed twice, pelleted and resuspended in 250 µl BD stain buffer + 0.5 µg/ml propidium iodide. Analysis of 10,000 cells is done in a FACSCALIBUR flow cytometer using the FL4 channel. MFI values and the corresponding concentrations of the anti-ErbB-antibody are plotted on the y-axis and x-axis, respectively. The $K_D$ of the molecule is determined using GraphPad PRISM software using the one-site binding model for a non-linear regression curve.

The $K_D$ value is calculated based on the formula $Y=Bmax* X/ K_D + X$ (Bmax = fluorescence at saturation. X= antibody concentration. Y = degree of binding).

**Example 4: Inhibition of tumor growth *in vivo* by combination treatment with MM-121 and paclitaxel**

Methods:

Balb/c nude mice (female, 4-5 weeks old from Charles River lab) are implanted orthotopically with 10 x 106 cells in mammary pad. Tumors are allowed to reach average of 100 $mm^3$ in size before randomization into 4 groups of 10 mice, containing mice with a similar size distribution of tumors. Each group of mice is treated with 1) MM-121 (150ug/mouse, ip., Q3D) or 2) vehicle control (PBS, ip.) or 3) paclitaxel (5mg/kg LC Labs) or 4) paclitaxel (5mg/kg) and MM-121 (150ug/mouse). Treatment is continued for 4 weeks. Tumors are measured twice weekly and tumor volume is calculated as $p/6 \times length \times width^2$, where the width is the shorter measurement.

Results:

The combination of MM-121 with paclitaxel was investigated *in vivo* in the MDA-MB-231 triple negative breast cancer xenograft model using the methods described above or minor variations thereof. Mice were treated with sub-optimal doses of MM-121, paclitaxel, a combination of MM-121 and paclitaxel, or vehicle control (Figure 3). While both MM-121 and paclitaxel each inhibited tumor growth *in vivo*, mice receiving a combination therapy of MM-121 and paclitaxel exhibited an improvement of tumor growth inhibition when compared to that obtained with each of the individual treatments. The improvement in tumor growth inhibition exhibited therapeutic synergy and was at least about additive as compared to the improvement obtained with each of the single agents of the combination.

Table 1 shows data used to generate Figure 3. Table 2 shows the mean % change in tumor volumes using data from the same experiments shown in Figure 3, normalized to initial tumor volume.

**TABLE 1:** data used to generate Figure 3 - mean tumor volumes in $mm^3$

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Vehicle** | **Mean** | **104.4** | **137.1** | **144.5** | **229.5** | **253.7** | **291.0** |
| **MM121 150µg** | **Mean** | **99.4** | **115.5** | **137.5** | **180.4** | **187.2** | **242.7** |
| **paclitaxel 5mg/kg** | **Mean** | **97.9** | **113.5** | **144.6** | **166.2** | **178.8** | **202.2** |
| **MM121 150µg+paclitaxel 5mg/kg** | **Mean** | **96.2** | **100.8** | **98.3** | **104.1** | **113.0** | **121.6** |

**Example 5: MM-121 combination with targeted and chemotherapies *in vivo***

Methods:

Balb/c nude mice (female, 4-5 weeks old from Charles River lab) are implanted orthotopically with 10 x 106 cells in mammary pad. Tumors are allowed to reach average of 150 $mm^3$ in size before randomization into 9 groups of 8 mice, containing mice with a similar size distribution of tumors. Each group of mice is treated with a dose of 1) MM-121(300ug/mouse, ip., Q3D) or 2) vehicle control (PBS, ip.) or 3) paclitaxel (10mg/kg LC Labs) or 4) erlotinib (50mg/kg PO 5XQD) or 5) cetuximab (2mg/kg Q3D) or combination therapy with: 6) erlotinib (50mg/kg) and MM-121 (300ug/mouse), or 7) cetuximab (2mg/kg) and MM-121 (300ug/mouse), or 8) erlotinib (50mg/kg) and MM-121 (300ug/mouse) and paclitaxel (10mg/kg), or 9) cetuximab (2mg/kg) and MM121 (300ug/mouse) and paclitaxel (10mg/kg). Treatment is continued for 4 weeks. Tumors are measured twice weekly and tumor volume is calculated as $p/6 \times length \times width^2$, where the width is the shorter measurement.

Results: In order to test the efficacy of MM-121 to inhibit tumor growth when used in combination with other agents, these combinations were tested *in vivo* in the MDA-MB-231 triple negative breast cancer xenograft model using the methods described above or minor variations thereof. Mice were treated with MM-121 (administered at sub-optimal doses in the combinations), cetuximab, paclitaxel, MM-121 and cetuximab, and the triple combination MM-121 and cetuximab and paclitaxel. As shown in figure 4A, combination therapy with MM-121 and cetuximab inhibited tumor growth to a greater extent than either agent alone and essentially stopped tumor growth until at least day 39. The decreased rate of growth showed therapeutic synergy and, in certain cases represented at least about an additive decrease in growth compared to the decreased rates obtained with any of the single therapies. Addition of paclitaxel did not enhance the effect of MM-121 and cetuximab. Mice were then treated with MM-121, erlotinib, MM-121 and erlotinib, or the triple combination of MM-121 and erlotinib and paclitaxel. As shown in Figure 4B, MM-121 in combination with erlotinib did not have a statistically significant effect on the rate of tumor growth compared with treatment with either agent alone. Conversely, treatment with the triple combination of MM-121, erlotinib, and paclitaxel resulted in a clearly decreased rate of tumor growth and essentially stopped tumor growth until at least day 39. The decreased rate of growth showed therapeutic synergy and, in certain cases represented at least about an additive decrease in growth compared to the decreased rates obtained with any of the single or double therapies.

Table 3 shows data used to generate Figures 4A and 4B. Table 4 shows the mean % change in tumor volume using data from the same experiments shown in Figures 4A and 4B, normalized to initial tumor volume.

**TABLE 2**. Data used to generate Figures 4A and 4B - mean tumor volumes in $mm^3$.

| Day | 28 | 32 | 36 | 39 | 43 | 46 | 49 | 53 |
|---|---|---|---|---|---|---|---|---|
| PBS | 163.7 | 199.0 | 242.8 | 304.5 | 369.4 | 423.4 | 458.4 | 490.7 |
| MM121 300ug | 178.6 | 197.3 | 219.1 | 257.8 | 269.4 | 291.4 | 351.3 | 425.0 |
| erlotinib 50mg/kg | 172.1 | 182.1 | 216.1 | 273.2 | 252.8 | 245.6 | 303.1 | 327.4 |
| cetuximab 2mg/kg | 172.4 | 210.6 | 245.0 | 269.2 | 296.3 | 279.7 | 283.5 | 358.1 |
| MM121 + erlotinib | 170.6 | 215.5 | 221.8 | 261.7 | 272.5 | 255.3 | 305.2 | 378.3 |
| paclitaxel 10mg/kg | 155.2 | 167.0 | 182.4 | 216.6 | 228.1 | 247.0 | 292.6 | 383.5 |
| MM121 + cetuximab | 152.5 | 149.6 | 171.6 | 169.1 | 196.6 | 171.2 | 182.9 | 241.2 |
| MM121 + erlotinib + paclitaxel | 164.8 | 149.3 | 139.8 | 146.5 | 156.7 | 163.4 | 202.9 | 264.5 |
| MM121 + cetuximab + paclitaxel | 176.3 | 158.5 | 147.8 | 160.4 | 154.4 | 163.4 | 203.4 | 247.7 |

Equivalents

Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents of the specific embodiments described herein. Such equivalents are intended to be encompassed by the following claims. Any combinations of the embodiments disclosed in the dependent claims are contemplated to be within the scope of the invention.

Incorporation by Reference

Each and every, issued patent, patent application and publication referred to herein is hereby incorporated herein by reference in its entirety.

## SUMMARY OF SEQUENCE LISTING

MM-121 $V_H$ amino acid sequence (SEQ ID NO:1)
EVQLLESGGGLVQPGGSLRLSCAASGFTFSHYVMAWVRQAPGKGLEWVSSISSSGG
WTLYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCTRGLKMATIFDYWGQ
GTLVTVSS

MM-121 $V_L$ amino acid sequence (SEQ ID NO:2)
QSALTQPASVSGSPGQSITISCTGTSSDVGSYNVVSWYQQHPGKAPKLIIYEVSQRPSG
VSNRFSGSKSGNTASLTISGLQTEDEADYYCCSYAGSSIFVIFGGGTKVTVL

MM-121 $V_H$ CDR1 (SEQ ID NO:3)
HYVMA

MM-121 $V_H$ CDR2 (SEQ ID NO:4)
SISSSGGWTLYADSVKG

MM-121 $V_H$ CDR3 (SEQ ID NO:5)
GLKMATIFDY

MM-121 $V_L$ CDR1 (SEQ ID NO:6)
TGTSSDVGSYNVVS

MM-121 $V_L$ CDR2 (SEQ ID NO:7)
EVSQRPS

MM-121 $V_L$ CDR3 (SEQ ID NO:8)
CSYAGSSIFVI

Ab # 3 $V_H$ amino acid sequence (SEQ ID NO:9)
EVQLLESGGGLVQPGGSLRLSCAASGFTFSAYNMRWVRQAPGKGLEWVSVIYPSGG
ATRYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCARGYYYYGMDVWGQ
GTLVTVSS

Ab # 3 $V_L$ amino acid sequence (SEQ ID NO:10)
QSVLTQPPSASGTPGQRVTISCSGSDSNIGRNYIYWYQQFPGTAPKLLIYRNNQRPSG
VPDRISGSKSGTSASLAISGLRSEDEAEYHCGTWDDSLSGPVFGGGTKLTVL

Ab # 3 $V_H$ CDR1 (SEQ ID NO:11)
AYNMR

Ab # 3 $V_H$ CDR2 (SEQ ID NO:12)
VIYPSGGATRYADSVKG

Ab # 3 $V_H$ CDR3 (SEQ ID NO:13)
GYYYYGMDV

Ab # 3 $V_L$ CDR1 (SEQ ID NO:14)
SGSDSNIGRNYIY

Ab # 3 $V_L$ CDR2 (SEQ ID NO:15)
RNNQRPS

Ab # 3 $V_L$ CDR3 (SEQ ID NO:16)
GTWDDSLSGPV

Ab # 14 $V_H$ amino acid sequence (SEQ ID NO:17)
EVQLLESGGGLVQPGGSLRLSCAASGFTFSAYGMGWVRQAPGKGLEWVSYISPSGG
HTKYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAKVLETGLLVDAFDIW
GQGTMVTVSS

Ab # 14 $V_L$ amino acid sequence (SEQ ID NO: 18)
QYELTQPPSVSVYPGQTASITCSGDQLGSKFVSWYQQRPGQSPVLVMYKDKRRPSEI
PERFSGSNSGNTATLTISGTQAIDEADYYCQAWDSSTYVFGTGTKVTVL

Ab # 14 $V_H$ CDR1 (SEQ ID NO:19)
AYGMG

Ab # 14 $V_H$ CDR2 (SEQ ID NO:20)
YISPSGGHTKYADSVKG

Ab # 14 $V_H$ CDR3 (SEQ ID NO:21)
VLETGLLVDAFDI

Ab # 14 $V_L$ CDR1 (SEQ ID NO:22)
SGDQLGSKFVS

Ab # 14 $V_L$ CDR2 (SEQ ID NO:23)
YKDKRRPS
Ab # 14 $V_L$ CDR3 (SEQ ID NO:24)
QAWDSSTYV

Ab # 17 $V_H$ amino acid sequence (SEQ ID NO:25)
EVQLLESGGGLVQPGGSLRLSCAASGFTFSWYGMGWVRQAPGKGLEWVSYISPSGG
ITVYADSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCARLNYYYGLDVWGQG
TTVTVSS

Ab # 17 $V_L$ amino acid sequence (SEQ ID NO:26)
QDIQMTQSPSSLSASVGDRITITCQASQDIGDSLNWYQQKPGKAPRLLIYDASNLETG
VPPRFSGSGSGTDFTFTFRSLQPEDIATYFCQQSANAPFTFGPGTKVDIK

Ab # 17 $V_H$ CDR1 (SEQ ID NO:27)
WYGMG

Ab # 17 $V_H$ CDR2 (SEQ ID NO:28)
YISPSGGITVYADSVKG

Ab # 17 $V_H$ CDR3 (SEQ ID NO:29)
LNYYYGLDV

Ab # 17 $V_L$ CDR1 (SEQ ID NO:30)
QASQDIGDSLN

Ab # 17 $V_L$ CDR2 (SEQ ID NO:31)
DASNLET

Ab # 17 $V_L$ CDR3 (SEQ ID NO:32)
QQSANAPFT

Ab # 19 $V_H$ amino acid sequence (SEQ ID NO:33)
EVQLLESGGGLVQPGGSLRLSCAASGFTFSRYGMWWVRQAPGKGLEWVSYIGSSGG
PTYYVDSVKGRFTISRDNSKNTLYLQMNSLRAEDTAVYYCAGGRGTPYYFDSWGQ
GTLVTVSS

Ab # 19 $V_L$ amino acid sequence (SEQ ID NO:34)
QYELTQPASVSGSPGQSITISCTGTSSDIGRWNIVSWYQQHPGKAPKLMIYDVSNRPS
GVSNRF
SGSKSGNTASLTISGLQAEDEADYYCSSYTSSSTWVFGGGTKLTVL

Ab # 19 $V_H$ CDR1 (SEQ ID NO:35)
RYGMW

Ab # 19 $V_H$ CDR2 (SEQ ID NO:36)
YIGSSGGPTYYVDSVKG

Ab # 19 $V_H$ CDR3 (SEQ ID NO:37)
GRGTPYYFDS

Ab # 19 $V_L$ CDR1 (SEQ ID NO:38
TGTSSDIGRWNIVS

Ab # 19 $V_L$ CDR2 (SEQ ID NO:39)
DVSNRPS

Ab # 19 $V_L$ CDR3 (SEQ ID NO:40)
SSYTSSSTWV

ErbB3 (SEQ ID NO:41)
SEVGNSQAVCPGTLNGLSVTGDAENQYQTLYKLYERCEVVMGNLEIVLTGHNADLS
FLQWIREVTGYVLVAMNEFSTLPLPNLRVVRGTQVYDGKFAIFVMLNYNTNSSHAL
RQLRLTQLTEILSGGVYIEKNDKLCHMDTIDWRDIVRDRDAEIVVKDNGRSCPPCHE
VCKGRCWGPGSEDCQTLTKTICAPQCNGHCFGPNPNQCCHDECAGGCSGPQDTDCF
ACRHFNDSGACVPRCPQPLVYNKLTFQLEPNPHTKYQYGGVCVASCPHNFVVDQTS
CVRACPPDKMEVDKNGLKMCEPCGGLCPKACEGTGSGSRFQTVDSSNIDGFVNCTK
ILGNLDFLITGLNGDPWHKIPALDPEKLNVFRTVREITGYLNIQSWPPHMHNFSVFSN
LTTIGGRSLYNRGFSLLIMKNLNVTSLGFRSLKEISAGRIYISANRQLCYHHSLNWTK
VLRGPTEERLDIKHNRPRRDCVAEGKVCDPLCSSGGCWGPGPGQCLSCRNYSRGGV
CVTHCNFLNGEPREFAHEAECFSCHPECQPMEGTATCNGSGSDTCAQCAHFRDGPH
CVSSCPHGVLGAKGPIYKYPDVQNECRPCHENCTQGCKGPELQDCLGQTLVLIGKTH
LTMALTVIAGLVVIFMMLGGTFLYWRGRRIQNKRAMRRYLERGESIEPLDPSEKANK
VLARIFKETELRKLKVLGSGVFGTVHKGVWIPEGESIKIPVCIKVIEDKSGRQSFQAVT
DHMLAIGSLDHAHIVRLLGLCPGSSLQLVTQYLPLGSLLDHVRQHRGALGPQLLLNW
GVQIAKGMYYLEEHGMVHRNLAARNVLLKSPSQVQVADFGVADLLPPDDKQLLYS
EAKTPIKWMALESIHFGKYTHQSDVWSYGVTVWELMTFGAEPYAGLRLAEVPDLLE
KGERLAQPQICTIDVYMVMVKCWMIDENIRPTFKELANEFTRMARDPPRYLVIKRES
GPGIAPGPEPHGLTNKKLEEVELEPELDLDLDLEAEEDNLATTTLGSALSLPVGTLNR
PRGSQSLLSPSSGYMPMNQGNLGESCQESAVSGSSERCPRPVSLHPMPRGCLASESSE
GHVTGSEAELQEKVSMCRSRSRSRSPRPRGDSAYHSQRHSLLTPVTPLSPPGLEEEDV
NGYVMPDTHLKGTPSSREGTLSSVGLSSVLGTEEEDEDEEYEYMNRRRRHSPPHPPR
PSSLEELGYEYMDVGSDLSASLGSTQSCPLHPVPIMPTAGTTPDEDYEYMNRQRDGG
GPGGDYAAMGACPASEQGYEEMRAFQGPGHQAPHVHYARLKTLRSLEATDSAFDN
PDYWHSRLFPKANAQRT

CLAIMS

1. Use of an ErbB3 inhibitor for the manufacture of a medicament for the treatment of triple negative breast cancer.

2. The use of claim 1, wherein the ErbB3 inhibitor comprises an anti-ErbB3 antibody.

3. The use of claim 2, wherein the anti-ErbB3 antibody comprises, in amino terminal to carboxy terminal order, a $V_H$ CDR1 sequence as shown in SEQ ID NO:3, a $V_H$ CDR2 sequence as shown in SEQ ID NO:4 and a $V_H$ CDR3 sequence as shown in SEQ ID NO:5, and, in amino terminal to carboxy terminal order, a $V_L$ CDR1 sequence as shown in SEQ ID NO:6, a $V_L$ CDR2 sequence as shown in SEQ ID NO:7 and a $V_L$ CDR3 sequence as shown in SEQ ID NO:8.

4. The use claim 2, wherein the anti-ErbB3 antibody is selected from the group consisting of:
(a) an antibody comprising a $V_H$ sequence as shown in SEQ ID NO:1 and a $V_L$ sequence as shown in SEQ ID NO:2;
(b) an antibody comprising a $V_H$ sequence as shown in SEQ ID NO:9 and a $V_L$ sequence as shown in SEQ ID NO:10;
(c) an antibody comprising a $V_H$ sequence as shown in SEQ ID NO:17 and a $V_L$ sequence as shown in SEQ ID NO:18; and
(d) an antibody comprising a $V_H$ sequence as shown in SEQ ID NO:25 and a $V_L$ sequence as shown in SEQ ID NO:26.

5. The use of any one of claims 1 to 4, wherein the triple negative breast cancer tumor is histopathologically characterized as having a basal-like phenotype.

6. The use of any one of claims 1 to 4, wherein the triple negative breast cancer tumor is histopathologically characterized as having a phenotype other than basal-like.

7. The use of any one of claims 1 to 4, wherein the medicament is for use in administering to a patient in combination with an effective amount of at least one additional anti-cancer agent.

8. The use of claim 7, wherein the at least one additional anti-cancer agent is selected from the group consisting of platinum-based chemotherapy drugs, taxanes, tyrosine kinase inhibitors, anti-EGFR antibodies, anti-ErbB2 antibodies, and combinations thereof.

9. The use of claim 8, wherein the at least one additional anti-cancer agent is paclitaxel.

10. The use of claim 7, wherein the at least one additional anti-cancer agent comprises an EGFR inhibitor.

11. The use of claim 10, wherein the EGFR inhibitor comprises an anti-EGFR antibody.

12. The use of claim 11, wherein the anti-EGFR antibody is selected from the group consisting of cetuximab, matuzumab, panitumumab, nimotuzumab and mAb 806.

13. The use of claim 10, wherein the EGFR inhibitor is a small molecule inhibitor of EGFR signaling selected from the group consisting of gefitinib, lapatinib, canertinib, pelitinib, erlotinib HCL, PKI-166, PD158780, and AG 1478.

14. The use or method of claim 7, wherein the at least one additional anti-cancer agent comprises a VEGF inhibitor.

15. The use or method of claim 14, wherein the VEGF inhibitor comprises bevacizumab.

16. The use of any one of claims 1 to 4, wherein the triple negative breast cancer tumor is a tumor in which the tumor cells score negative for estrogen receptor (ER) and progesterone receptor and yield a test result for HER2 of 0, 1+, or 2+ using a semi-quantitative immunohistochemical assay using a polyclonal anti-HER2 primary antibody.

17. The use or method of claim 16, wherein the tumor cells are FISH negative for HER2 gene amplification.

18. Use of an ErbB3 inhibitor for the manufacture of a medicament for the treatment of basal-like breast cancer.

19. The use of claim 18, wherein the ErbB3 inhibitor comprises an anti-ErbB3 antibody that comprises, in amino terminal to carboxy terminal order, a $V_H$ CDR1 sequence as shown in SEQ ID NO:3, a $V_H$ CDR2 sequence as shown in SEQ ID NO:4 and a $V_H$ CDR3 sequence as shown in SEQ ID NO:5, and, in amino terminal to carboxy terminal order, a $V_L$ CDR1 sequence as shown in SEQ ID NO:6, a $V_L$ CDR2 sequence as shown in SEQ ID NO:7 and a $V_L$ CDR3 sequence as shown in SEQ ID NO:8, or wherein the anti-ErbB3 antibody comprises an antibody comprising a $V_H$ sequence as shown in SEQ ID NO:1 and a $V_L$ sequence as shown in SEQ ID NO:2.

20. The use claim 19, wherein the medicament is for use in administering to a patient in combination with an effective amount of at least one additional anti-cancer agent.

21. The use of claim 20, wherein the at least one additional anti-cancer agent is paclitaxel.

22. Use of an ErbB3 inhibitor of claim 1 or 18, wherein the medicament is for use in administering to a patient in combination with at least one additional anti-cancer agent that is not an ErbB3 inhibitor.

23. The use of claim 22, wherein the at least one additional anti-cancer agent is selected from the group consisting of paclitaxel, trastuzumab, pertuzumab, cetuximab, matuzumab, panitumumab, nimotuzumab, mAb 806, gefitinib, lapatinib, canertinib, pelitinib, erlotinib, HCL, PK1-166, PD158780, and AG 1478.