

ANTI-5T4 ANTIBODIES AND USES THEREOF

RELATED APPLICATIONS

Priority is claimed to U.S. Provisional Application No. 60/891,248, filed February 23, 2007, and to U.S. Provisional Application No. 60/781,346, filed March 10, 2006, each of which is incorporated by reference in its entirety herein.

FIELD OF THE INVENTION

The present invention generally relates to anti-5T4 antibodies and antibody/drug conjugates (*i.e.*, immunoconjugates) for the diagnosis and/or treatment of neoplastic or malignant disorders. The present invention also relates to isolated variable region nucleic acids and polypeptides for preparing anti-5T4 antibodies and antibody/drug conjugates.

BACKGROUND OF THE INVENTION

The availability of high affinity monoclonal antibodies has enabled the development of targeted immunotherapies. According to this approach, a therapeutic agent is coupled to an antibody with binding specificity for a defined target cell population. Therapeutic agents that have been conjugated to monoclonal antibodies include cytotoxins, biological response modifiers, enzymes (*e.g.*, ribonucleases), apoptosis-inducing proteins and peptides, and radioisotopes. Antibody/cytotoxin conjugates are generally referred to as immunocytotoxins. Antibodies coupled to low-molecular-weight drugs such as methothrexate are typically called chemoantibody/drug conjugates. Conjugates described as immunomodulators contain biological response modifiers such as lymphokines, growth factors, and complement-activating cobra venom factor (CVF). Radiolabeled antibodies include radioactive isotopes that may be used for radiotherapy as well as imaging.

Antibody-mediated drug delivery to tumor cells augments drug efficacy by minimizing its uptake in normal tissues. See *e.g.*, Reff et al. (2002) *Cancer Control* 9:152-66; Sievers (2000) *Cancer Chemother. Pharmacol.* 46 Suppl:S18-22; Goldenberg (2001) *Crit. Rev. Oncol. Hematol.* 39:195-201. MYLOTARG® (gemtuzumab ozogamicin) is a commercially available targeted immunotherapy that works according to this principle and which is approved for the treatment of acute

myeloid leukemia in elderly patients. See Sievers et al. (1999) *Blood* 93: 3678-84. In this case, the targeting molecule is an anti-CD33 monoclonal antibody that is conjugated to calicheamicin.

Targeted immunotherapy in humans has nevertheless been limited, in part due to adverse responses to non-human monoclonal antibodies. Early clinical trials using rodent antibodies revealed human anti-mouse antibody (HAMA) and human anti-rat antibody (HARA) responses, which result in rapid antibody clearance. Less immunogenic antibodies have since been developed, including chimeric antibodies, humanized antibodies, PRIMATIZED® antibodies, and human antibodies prepared using transgenic mice or phage display libraries. See Morrison et al. (1984) *Proc. Natl. Acad. Sci. USA* 81:6851-5; Queen et al. (1989) *Proc. Natl. Acad. Sci. USA* 86:10029-33; Newman et al. (1992) *Biotechnology (NY)* 10:1455-60; Green et al. (1994) *Nat. Genet.* 7:13-21; Marks et al. (1991) *J. Mol. Biol.* 222:581-97. Avoidance of a HAMA response permits high dose and repeated dose administration to achieve a therapeutic response.

Candidate antibodies for drug targeting include antibodies that recognize oncofetal antigens, *i.e.*, antigens present on fetal cells and neoplastic cells, and which are largely absent from normal adult cells. See *e.g.*, Magdelenat (1992) *J. Immunol. Methods* 150: 133-43. The 5T4 oncofetal antigen is a 72 kDa highly glycosylated transmembrane glycoprotein comprising a 42 kDa non-glycosylated core (Hole et al. (1988) *Br. J. Cancer* 57: 239-46, Hole et al. (1990) *Int. J. Cancer* 45: 179-84; PCT International Publication No. WO89/07947; U.S. Patent No. 5,869,053). 5T4 includes an extracellular domain characterized by two leucine-rich repeats (LRRs) and an intervening hydrophilic region, which is an accessible site for targeted therapy (Myers et al. (1994) *J. Biol. Chem.* 269: 9319-24).

Human 5T4 is expressed in numerous cancer types, including carcinomas of the bladder, breast, cervix, endometrium, lung, esophagus, ovary, pancreas, stomach, and testes, and is substantially absent from normal tissues, except for syncytiotrophoblast in placenta (*see, e.g.*, Southall et al. (1990) *Br. J. Cancer* 61: 89-95 (immunohistological distribution of 5T4 antigen in normal and malignant tissues); Mieke et al. (1997) *Clin. Cancer Res.* 3: 1923-1930 (low intercellular adhesion molecule 1 and high 5T4 expression on tumor cells correlate with reduced disease-free survival in colorectal carcinoma patients); Starzynska et al. (1994) *Br. J. Cancer* 69: 899-902 (prognostic significance of 5T4 oncofetal antigen expression in

colorectal carcinoma); Starzynska et al. (1992) *Br. J. Cancer* 66: 867-869 (expression of 5T4 antigen in colorectal and gastric carcinoma); Jones et al. (1990) *Br. J. Cancer* 61: 96-100 (expression of 5T4 antigen in cervical cancer); Connor and Stern (199) *Int. J. Cancer* 46: 1029-1034 (loss of MHC class-I expression in cervical carcinomas); Ali et al. (2001) *Oral Oncology* 37: 57-64 (pattern of expression of the 5T4 oncofoetal antigen on normal, dysplastic and malignant oral mucosa); PCT International Publication No. WO89/07947; U.S. Patent No. 5,869,053). For example, tissues reported to have no expression of 5T4 include the liver, skin, spleen, thymus, central nervous system (CNS), adrenal gland, and ovary. Tissues reported to have focal or low expression of 5T4 include the liver, skin, spleen, lymph node, tonsil, thyroid, prostate, and seminal vesicles. Weak-moderate diffuse expression of 5T4 has been reported in the kidney, lung, pancreas, pharynx, and gastro-intestinal tract. The only tissue reported to have high expression of 5T4 is syncytiotrophoblast; 5T4 was also absent from normal serum or the serum of pregnant women (*i.e.*, levels < 10 ng/ml). Overexpression of 5T4 in tumors has been correlated with disease progression, and assessment of 5T4 expression has been suggested as a useful approach for identifying patients with short-term prognosis (Mulder et al. (1997) *Clin. Cancer Res.* 3: 1923-30, Naganuma et al. (2002) *Anticancer Res.* 22: 1033-1038, Starzynska et al. (1994) *Br. J. Cancer* 69: 899-902, Starzynska et al. (1998) *Eur. J. Gastroenterol. Hepatol.* 10: 479-484, Wrigley et al. (1995) *Int. J. Gynecol. Cancer* 5: 269-274).

Several anti-5T4 antibodies have been described, including mAb5T4, also called the H8 antibody, which recognizes a conformational epitope of the 5T4 antigen (Shaw et al. (2002) *Biochem. J.* 363: 137-45, PCT International Publication No. WO98/55607), a rat monoclonal antibody (Woods et al. (2002) *Biochem. J.* 366: 353-65), and a mouse monoclonal antibody called 5T4 (U.S. Patent No. 5,869,053). Single chain anti-5T4 antibodies have also been described, as well as fusion proteins that include anti-5T4 antibody sequences fused to a therapeutic molecule. For example, anti-5T4 antibody sequences fused to the human IgG1 constant domain or to the extracellular domain of murine B7.1 induces cytotoxicity of 5T4-expressing tumor cell lines (Myers et al. (2002) *Cancer Gene Ther.* 9: 884-896, Shaw et al. (2000) *Biochim. Biophys. Acta.* 1524: 238-246; U.S. Patent Application Publication No. 2003/0018004). Similarly, a single chain anti-5T4 antibody fused to a superantigen may stimulate T cell-dependent cytotoxicity of non-small cell lung

carcinoma cells *in vitro* (Forsberg et al. (2001) *Br. J. Cancer* 85: 129-136). A phase I clinical trial using PNU-214936, a murine Fab fragment of the monoclonal antibody 5T4 fused to a mutated superantigen staphylococcal enterocytotoxin A (SEA), showed limited toxicity and some anti-tumor response (Cheng et al. (2004) *J. Clin. Oncol.* 22(4):602-9). As an alternate therapeutic approach, recombinant 5T4 vaccines are also suggested for the treatment of cancers (Mulryan et al. (2002) *Mol. Cancer Ther.* 1: 1129-37; UK Patent Application Publication Nos. 2,370,571 and 2,378,704; EP Patent Application Publication Nos. EP 1,160,323 and 1,152,060).

The present invention provides novel anti-5T4 antibodies, anti-5T4/drug conjugates, methods for producing the disclosed antibodies and antibody/drug conjugates, and methods for their diagnostic and therapeutic use.

SUMMARY OF THE INVENTION

The present invention provides novel anti-5T4 antibodies, conjugates thereof, and methods for using the same. Also provided are isolated anti-5T4 polypeptides and isolated nucleic acids encoding the same.

Anti-5T4 antibodies of the invention include antibodies that specifically bind human 5T4 antigen, wherein the antibody (a) comprises an antigen binding domain of murine A1, A2, or A3 antibodies; (b) competes for 5T4 binding with murine A1, A2, or A3 antibodies; (c) binds a 5T4 epitope bound by A1, A2, or A3 antibodies; or (d) comprises a 5T4-binding fragment of an antibody of (a)-(c). The anti-5T4 antibodies of the invention may be chimeric, humanized, single chain, an Fab fragment, a F(ab)₂ fragment, a Fv fragment, tetrameric, tetravalent, multispecific, domain-specific, a single domain antibody, a fusion protein, or a murine monoclonal. For example, humanized anti-5T4 antibodies of the invention include antibodies comprising at least one heavy chain variable region or at least one light chain variable region, wherein the humanized antibody or antibody fragment: (a) comprises an antigen binding domain of murine A1, A2, or A3 antibodies; (b) competes for 5T4 binding with murine A1, A2, or A3 antibodies; (c) binds a 5T4 epitope bound by A1, A2, or A3 antibodies; or (d) a 5T4-binding fragment of an antibody of (a)-(c).

The anti-5T4 antibodies of the invention have a binding affinity for human 5T4 antigen of at least about 1×10^{-7} M to about 1×10^{-12} M. The disclosed anti-5T4

antibodies and conjugates thereof may also show specific binding by targeting of 5T4-expressing cells *in vivo*.

Representative anti-5T4 antibodies of the invention include antibodies comprising a heavy chain variable region comprising (a) an amino acid sequence of residues 20-138 of SEQ ID NO:2; (b) an amino acid sequence that is at least 85% identical to residues 20-138 of SEQ ID NO:2; (c) an amino acid sequence of residues 19-135 of SEQ ID NO:6; (d) an amino acid sequence that is at least 86% identical to residues 19-135 of SEQ ID NO:6; (e) an amino acid sequence of residues 20-141 of SEQ ID NO:10; (f) an amino acid sequence that is at least 91% identical to residues 20-141 of SEQ ID NO:10; (g) an amino acid sequence of any one of SEQ ID NOs:49, 51, 52, 54, 56, 77, 78, 81, or 82; (h) an amino acid sequence that is at least 91% identical to SEQ ID NO:51; (i) an amino acid sequence that is at least 78% identical to SEQ ID NO:54; (j) an amino acid sequence that is at least 89% identical to SEQ ID NO:77; (k) an amino acid sequence that is at least 79% identical to SEQ ID NO:78; (l) an amino acid sequence that is at least 80% identical to SEQ ID NO:81; or (m) an amino acid sequence that is at least 78% identical to SEQ ID NO:82.

Representative anti-5T4 antibodies of the invention include antibodies comprising a light chain variable region comprising (a) an amino acid sequence of residues 21-127 of SEQ ID NO:4; (b) an amino acid sequence that is at least 94% identical to residues 21-127 of SEQ ID NO:4; (c) an amino acid sequence of residues 23-130 of SEQ ID NO:8; (d) an amino acid sequence that is at least 96% identical to residues 23-130 of SEQ ID NO:8; (e) an amino acid sequence of residues 21-127 of SEQ ID NO:12; (f) an amino acid sequence that is at least 98% identical to residues 21-127 of SEQ ID NO:12; (g) an amino acid sequence of any one of SEQ ID NOs: 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 79, 80, 83, or 84; (h) an amino acid sequence that is at least 83% identical to SEQ ID NO:60; (i) an amino acid sequence that is at least 93% identical to SEQ ID NO:70; (j) an amino acid sequence that is at least 85% identical to SEQ ID NO:76; (k) an amino acid sequence that is at least 85% identical to SEQ ID NO:76; (l) an amino acid sequence that is at least 88% identical to SEQ ID NO:79; (m) an amino acid sequence that is at least 84% identical to SEQ ID NO:80; (n) an amino acid sequence that is at least 90% identical to SEQ ID NO:83; or (o) an amino acid sequence that is at least 91% identical to SEQ ID NO:84.

For example, an anti-5T4 antibody can comprise (a) a heavy chain variable region comprising an amino acid sequence of residues 20-138 of SEQ ID NO:2, and a light chain variable region comprising an amino acid sequence of residues 21-127 of SEQ ID NO:4; (b) a heavy chain variable region comprising an amino acid sequence derived from residues 19-135 of SEQ ID NO:6, and a light chain variable region comprising an amino acid sequence derived from residues 23-130 of SEQ ID NO:8; or (c) a heavy chain variable region comprising an amino acid sequence derived from residues 20-141 of SEQ ID NO:10, and a light chain variable region comprises an amino acid sequence derived from residues 21-127 of SEQ ID NO:12.

Chimeric and humanized anti-5T4 antibodies of the invention may comprise constant regions derived from human constant regions, such as a human light chain constant region derived from human kappa light chain constant region and a human heavy chain constant region derived from a human IgG1 or human IgG4 heavy chain constant region.

Representative humanized anti-5T4 antibodies of the invention include antibodies comprising (a) framework regions comprising residues of a human antibody framework region; and (b) one or more CDRs of the light chain variable region of SEQ ID NO:4, 8, or 12, or one or more CDRs of the heavy chain variable region of SEQ ID NO:2, 6, or 10. For example, residues of a human antibody framework region can comprise (a) a human antibody light chain framework region of a DPK24 subgroup IV germ line clone, a VkIII subgroup (DPK23, DPK22, DPK20, DPK21), or a Vkl subgroup germ line clone (DPK9, DPK1, O2, DPK7); (b) a human antibody heavy chain framework region selected from the group consisting of DP-21 (VH7), DP-54 (VH3-07), DP-47 (VH3-23), DP-53 (VH-74), DP-49 (VH3-30), DP-48 (VH3-13), DP-75, DP-8(VH1-2), DP-25, VI-2b and VI-3 (VH1-03), DP-15 and V1-8 (VH1-08), DP-14 and V1-18 (VH1-18), DP-5 and V1-24P (VH1-24), DP-4 (VH1-45), DP-7 (VH1-46), DP-10, DA-6 and YAC-7 (VH1-69), DP-88 (VH1-e), DP-3 and DA-8 (VH1-f); (c) a consensus sequence of a heavy chain framework region of (b); or (d) a framework region that is at least 63% identical to a framework region of (a)-(c).

Representative humanized anti-5T4 antibodies of the invention can also include two or more CDRs of SEQ ID NOs: SEQ ID NOs:2, 4, 6, 8, 10, or 12, such as two or all three CDRs of the light chain variable region of SEQ ID NO:4, 8, or 12, or two or all three CDRs of the heavy chain variable region of SEQ ID NO:2, 6, or 10,

or one or more CDRs or the light chain variable region of SEQ ID NO:4, 8, or 12 and one or more CDRs of the heavy chain variable region of SEQ ID NO:2, 6, or 12, or all of the CDRs or SEQ ID NOs: 2, 4, 6, 8, 10, or 12.

Representative chimeric and humanized anti-5T4 antibodies include antibodies comprising a heavy chain variable region sequence comprising (a) an amino acid sequence of residues 20-138 of SEQ ID NO:2; (b) an amino acid sequence that is at least 85% identical to residues 20-138 of SEQ ID NO:2; (c) an amino acid sequence of residues 19-135 of SEQ ID NO:6; (d) an amino acid sequence that is at least 86% identical to residues 19-135 of SEQ ID NO:6; (e) an amino acid sequence of residues 20-141 of SEQ ID NO:10; (f) an amino acid sequence that is at least 91% identical to residues 20-141 of SEQ ID NO:10; (g) an amino acid sequence of residues 1-119 of SEQ ID NO:49; (h) an amino acid sequence that is at least 90% identical to residues 1-119 of SEQ ID NO:49; or (i) an amino acid sequence of a humanized heavy chain variable depicted in Figures 9A-9C.

Additional chimeric and humanized anti-5T4 antibodies of the invention include antibodies comprising a heavy chain variable region encoded by a nucleic acid comprising (a) a nucleotide sequence of nucleotides 58-414 of SEQ ID NO:1; (b) a nucleotide sequence of nucleotides 55-405 of SEQ ID NO:5; (c) a nucleotide sequence of nucleotides 58-423 of SEQ ID NO:9; (d) a nucleotide sequence of nucleotides 1-358 of SEQ ID NO:48; (e) a nucleotide sequence encoding a humanized A1, A2, or A3 variable region depicted in Figures 9A-9C; (f) a nucleotide sequence that is at least 90% identical to the nucleotide sequence of any one of (a)-(e); or (g) a nucleic acid that specifically hybridizes to the complement of any one of (a)-(e) under stringent hybridization conditions.

Representative chimeric and humanized anti-5T4 antibodies include antibodies comprising a light chain variable region sequence comprising (a) an amino acid sequence of residues 21-127 of SEQ ID NO:4; (b) an amino acid sequence that is at least 94% identical to residues 21-127 of SEQ ID NO:4; (c) an amino acid sequence of residues 23-130 of SEQ ID NO:8; (d) an amino acid sequence that is at least 96% identical to residues 23-130 of SEQ ID NO:8; (e) an amino acid sequence of residues 21-127 of SEQ ID NO:12; (f) an amino acid sequence that is at least 98% identical to residues 21-127 of SEQ ID NO:12; or (g)

an amino acid sequence of a humanized A1, A2, or A3 light chain variable region depicted in Figures 9A-9C.

Also provided are antibody/drug conjugates for drug delivery comprising (a) a chimeric or humanized anti-5T4 antibody or antibody fragment of the invention; and (b) a drug, which is directly or indirectly bound to the antibody. Representative drugs include therapeutic agents, such as cytotoxins, radioisotopes, immunomodulatory agents, anti-angiogenic agents, anti-proliferative agents, pro-apoptotic agents, chemotherapeutic agents, and therapeutic nucleic acids. A cytotoxin may be, for example, an antibiotic, an inhibitor of tubulin polymerization, an alkylating agent, a protein synthesis inhibitor, a protein kinase inhibitor, a phosphatase inhibitor, a topoisomerase inhibitor, or an enzyme. Antibiotic cytotoxins, such as calicheamicin, **N**-acetyl- γ -calicheamicin,

or derivatives thereof such as acetyl- γ -calicheamicin

dimethyl hydrazide, are particularly useful for anti-cancer therapies.

The disclosed anti-5T4 antibody/drug conjugates may include a linker for binding the antibody to the drug. Representative linkers include 4-(4'-acetylphenoxy)butanoic acid (AcBut), 3-acetylphenyl acidic acid (AcPac), and 4-mercapto-4-methyl-pentanoic acid (Amide). The antibody/drug conjugates may also include polyethylene glycol or other agents to enhance drug incorporation.

For delivery of a drug to 5T4-expressing cells, the present invention provides methods whereby cells are contacted with an antibody/drug conjugate comprising (i) a chimeric or humanized anti-5T4 antibody, and (ii) a drug which is bound to the humanized anti-5T4 antibody directly or indirectly. According to the disclosed methods, the drug is internalized within the target cell. Therapeutic methods are also disclosed herein, which comprise administering to the subject having a 5T4-positive cancer a therapeutically effective amount of an anti-5T4 antibody/drug conjugate comprising (i) a chimeric or humanized anti-5T4 antibody or antibody fragment, and (ii) a therapeutic agent which is bound to the humanized anti-5T4 antibody or antibody fragment directly or indirectly. Anti-5T4 therapies of the invention may be combined with any other known therapy for improved effect. A second therapeutic agent may be administered in combination with an anti-5T4 antibody/drug conjugate simultaneously or consecutively in any order.

Also provided are isolated nucleic acids encoding humanized anti-5T4 variable regions, which are useful for production of the disclosed humanized anti-5T4 antibodies. Representative nucleic acids encoding a humanized anti-5T4 heavy

chain variable region include (a) a nucleotide sequence of nucleotides 58-414 of SEQ ID NO:1; (b) a nucleotide sequence of nucleotides 55-405 of SEQ ID NO:5; (c) a nucleotide sequence of nucleotides 58-423 of SEQ ID NO:9; (d) a nucleotide sequence encoding any one of SEQ ID NOs:48, 50, 53, or 55; (e) a nucleotide sequence that is 89% identical to SEQ ID NO:50 when the query coverage is 100%; (f) a nucleotide sequence that is 82% identical to SEQ ID NO:53 when the query coverage is 100%; or (g) a nucleic acid that specifically hybridizes to the complement of any one of (a)-(d) under stringent hybridization conditions. Representative nucleic acids encoding a humanized anti-5T4 light chain variable region include (a) a nucleotide sequence of nucleotides 61-381 of SEQ ID NO:3; (b) a nucleotide sequence of nucleotides 67-390 of SEQ ID NO:7; (c) a nucleotide sequence of nucleotides 61-381 of SEQ ID NO:11; (d) a nucleotide sequence encoding a humanized A1, A2, or A3 light chain variable region of any one of SEQ ID NOs: 57, 59, 61, 63, 65, 67, 69, 71, 73, or 75; (e) a nucleotide sequence that is 84% identical to SEQ ID NO:59 when the query coverage is 100%; (f) a nucleotide sequence that is 86% identical to SEQ ID NO:69 when the query coverage is 100%; (g) a nucleotide sequence that is 85% identical to SEQ ID NO:75 when the query coverage is 100%; or (h) a nucleic acid that specifically hybridizes to the complement of any one of (a)-(d) under stringent hybridization conditions.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A-1C show the nucleotide and amino acid sequences of the heavy chain and light chain variable regions of murine anti-5T4 antibodies A1, A2, and A3. The amino acid sequences are annotated to identify complementarity determining regions (CDRs) by underlining and the leader sequence by double-underlining.

Figure 2 is a Western blot prepared using CT26/5T4 cell lysates and probed with the indicated antibodies.

Figures 3A-3B are line graphs that show response curves and binding kinetics for two independent preparations of H8 and A1 antibodies. The preparations were substantially equivalent.

Figures 4A-4C are line graphs that show modulation of H8, A1, A2, and A3 antibodies by MDAMB435/5T4 cells. Levels of antibody at the cell surface decline over time (Figures 4A, 4C (solid)), while the levels of antibody in the supernatant

remain constant (Figures 4B, 4C (open)). MCF, mean cellular fluorescence; supt, supernatant.

Figure 5 is a schematic diagram of the human ectodomain 5T4 Fc construct, the mouse ectodomain 5T4 Fc construct, and the human/mouse 5T4 chimera constructs. These constructs were used for epitope mapping as described in Example 4

Figures 6A-6B show graphical results of competitive binding of humanized H8 and each of the indicated antibodies to human 5T4 ectodomain Fc fusion protein. HuH8, humanized H8 antibody; ChiA1, chimeric A1 antibody; ChiA1+C67F, chimeric A1 antibody bearing C67F mutation; ChiA2, chimeric A2 antibody; muA2, murine A2 antibody; ChiA3, chimeric A3 antibody; ChiA3+C91Y, chimeric A3 antibody bearing C91Y mutation, muA3, murine A3 antibody; No Ab, no antibody (control).

Figure 7 is a linear diagram showing the human 5T4 epitopes bound by H8, A1, A2, and A3. The indicated residues are residues of the 5T4 antigen described by Myers et al. (1994) *J. Biol. Chem.* 269(12):9319-9324, also available as GenBank Accession No. Z29083 (SEQ ID NO:87). LRR, Leucine-rich repeat.

Figure 8 shows the results of spheroid assays performed as described in Example 6. Anti-5T4/calicheamicin conjugates prepared using the A1 and A3 antibodies significantly inhibited growth of 5T4-expressing cells (MDAMB435/5T4) as compared to control cells (MDAMB435/neo). CMA-676, anti-CD33/calicheamicin conjugate; huH8-AcBut-CalichDMH, humanized H8 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut); ; CalichDMH, unconjugated calicheamicin; A1-AcBut-CalichDMH, A1 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut); A3-AcBut-CalichDMH, A3 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut).

Figures 9A-9H show nucleotide and amino acid sequences of the humanized A1 heavy chain variable region version 1 (SEQ ID NOs:48-49); amino acid sequences of humanized A1 heavy chain variable region (huA1 VH) versions 1.2 and 2.0; amino acid sequences of humanized A1 light chain variable region (huA1 VL) versions 1.0, 2.0, and 3.0; amino acid sequences of humanized A2 heavy chain variable region versions 1.0 and 2.0 (huA2 VH); amino acid sequences of humanized A2 light chain variable region versions 1.0 and 2.0 (huA2 VL); amino acid sequences of humanized A3 heavy chain variable region versions 1.0 and 2.0 (huA3 VH); and

amino acid sequences of humanized A3 light chain variable region versions 1.0 and 2.0 (huA32 VL). CDRs are underlined.

Figures 10A-10B show representative human heavy chain variable region framework sequences that may be used to prepare humanized anti-5T4 antibodies. Figure 10A is an alignment of human heavy chain variable region sequences of subgroup I (SEQ ID NOs:14-24) and the consensus framework sequences derived there from (SEQ ID NOs:25-27). Figure 10B shows the sequences of human germline genes of the VH 7 and VH 3 subgroups (SEQ ID NOs:88-93).

Figure 11 is an alignment of human light chain variable region sequences of subgroup VkIII (SEQ ID NOs:29-34). Boxed sequences, CDRs.

Figure 12 is an alignment of human light chain variable region sequences of subgroup Vkl (SEQ ID NOs:35-44). Boxed sequences, CDRs.

Figure 13 shows additional human germline sequences of Vk 1 and Vk IV subgroups, which have framework regions that may be used to prepare humanized anti-5T4 antibodies (SEQ ID NOs:94-99).

Figure 14 shows the amino acid sequences of representative human constant regions that may be used to prepare chimeric and humanized anti-5T4 antibodies (SEQ ID NOs:45-47).

Figure 15 shows the amino acid sequences of a full-length cynomolgus monkey 5T4 antigen and a partial black-tailed marmoset 5T4 antigen. Underlined sequences, leader sequences. For each sequence, the 5T4 ectodomain includes amino acids 30-356.

DETAILED DESCRIPTION OF THE INVENTION

I. Anti-5T4 Antibodies

The present invention provides novel murine antibodies that bind human 5T4 antigen and that are useful for developing targeted immunotherapies. The human 5T4 antigen is a 72 kDa non-glycosylated phosphoprotein found on the surface of trophoblast cells and numerous cancer cell types *See Hole et al. (1988) Br. J. Cancer 57: 239-46, Hole et al. (1990) Int. J. Cancer 45: 179-184; PCT International Publication No. WO89/07947; U.S. Patent No. 5,869,053.*

The murine anti-5T4 antibodies of the invention are designated A1, A2, and A3, and were prepared as described in Example 1. Also provided are anti-5T4

antibodies derived from A1, A2, and A3, and which specifically bind to human 5T4 antigen. For example, anti-5T4 antibodies of the invention include antibodies comprising antigen binding residues from the A1, A2, and A3 antibodies; antibodies that compete for binding to 5T4 antigen with A1, A2, or A3 antibodies; and antibodies that bind to the same 5T4 epitope as A1, A2, or A3 antibodies.

In particular, the disclosed A1, A2, and A3 antibodies each comprise an antigen binding site that recognizes a unique epitope on the human 5T4 antigen. Each of these antibodies also binds to an epitope distinct from that bound by H8, and each of A1, A2, and A3 fails to compete with the H8 antibody for binding to human 5T4. See Examples 4-5 and Figures 6-7. Accordingly, the present invention provides antibodies that specifically bind to residues 30-163 of human 5T4 (e.g., A3), antibodies that specifically bind to residues 224-276 of human 5T4 (e.g., A1), and antibodies that specifically bind to residues 224-355 of human 5T4 (e.g., A2). Also provided are human 5T4 antigens comprising epitopes bound by an A1, A2, or A3 antibody. For example, the invention provides 5T4 antigenic fragments comprising residues 30-163, 224-276, and 224-355 of a native or full-length 5T4 antigen.

Specific binding of the disclosed anti-5T4 antibodies refers to a preferential binding of an antibody to human 5T4 antigen in a heterogeneous sample comprising multiple different antigens. Typically, specific binding occurs if the binding affinity is at least about 10^{-7} M or higher, such as at least about 10^{-8} M or higher, including at least about 10^{-9} M or higher, at least about 10^{-11} M or higher, or at least about 10^{-12} M or higher. For example, specific binding of an antibody of the invention to a human 5T4 antigen includes binding in the range of at least about 1×10^{-7} M to about 1×10^{-12} M, such as within the range of about 1×10^{-8} M to about 1×10^{-12} M, or within the range of about 1×10^{-8} M to about 1×10^{-11} M, or within the range of about 1×10^{-8} M to about 1×10^{-10} M, or within the range of about 1×10^{-9} M to about 1×10^{-10} M. Specific binding also refers to selective targeting of an anti-5T4 antibody to 5T4-expressing cells following administration of the antibody to a subject.

The anti-5T4 antibodies of the invention may have a tetrameric structure (e.g., similar to naturally occurring antibodies), or they may comprise any other structure having at least one immunoglobulin light chain variable region or at least one immunoglobulin heavy chain region, or 5T4-binding fragments thereof (e.g., Fab, modified Fab, $F(ab')_2$ or Fv fragments. Also included are single domain antibodies, in which one or more complementarity determining regions (CDRs), but less than all

six CDRs, constitute an antigen binding region. The invention also encompasses chimeric antibodies, humanized antibodies, superhumanized antibodies, diabodies, single chain antibodies, tetravalent antibodies, and/or multispecific antibodies (e.g., bispecific antibodies). These antibody descriptors are not mutually exclusive.

Naturally occurring antibodies are tetrameric (H_2L_2) glycoproteins of about 150,000 daltons, composed of two identical light (L) chains and two identical heavy (H) chains. The two heavy chains are linked to each other by disulfide bonds and each heavy chain is linked to a light chain by a disulfide bond. Each of the light and heavy chains is further characterized by an amino-terminal variable region and a constant region. The variable regions include sequences that differ extensively among antibodies and substantially determine the binding affinity and specificity of a particular antibody for its particular antigen. The variable regions of each of the light and heavy chains align to form the antigen-binding domain.

Chimeric antibodies comprise sequences from at least two different species. As one example, recombinant cloning techniques may be used to include variable regions, which contain the antigen-binding sites, from a non-human antibody (*i.e.*, an antibody prepared in a non-human species immunized with the antigen) and constant regions derived from a human immunoglobulin.

Chimeric anti-5T4 antibodies of the invention include antibodies comprising heavy chain and light chain variable regions of the A1, A2, and A3 antibodies, *i.e.*, (a) a heavy chain variable region having an amino acid sequence of residues 20-138 of SEQ ID NO:2 and a light chain variable region having an amino acid sequence of residues 21-127 of SEQ ID NO:4; (b) a heavy chain amino acid sequence of residues 19-135 of SEQ ID NO:6 and a light chain amino acid sequence of residues 23-130 of SEQ ID NO:8; and (c) a heavy chain amino acid sequence of residues 20-141 of SEQ ID NO:10 and a light chain amino acid sequence of residues 21-127 of SEQ ID NO:12. Representative humanized anti-5T4 antibodies may include a heavy chain variable region set for as amino acids 1-119 of SEQ ID NO:49, or any one of the humanized heavy chain variable region depicted in Figures 9A-9C, and a humanized light chain variable region, also depicted in Figures 9A-9C. Preparation of representative chimeric and humanized anti-5T4 antibodies of the invention is described in Example 7.

Anti-5T4 antibodies of the invention may also comprise a heavy chain and/or light chain variable region comprising an amino acid sequence that is derived from or

substantially similar to the A1, A2, or A3 variable regions, or substantially similar to the humanized A1, A2, and A3 variable regions. With respect to substantially identical heavy chain and light chain variable regions, the substantially identical sequences are at least about 90% identical to the variable region sequences of any one of SEQ ID NOs:1-12 or to the humanized A1, A2, and A3 variable regions depicted in Figures 9A-9C, such as at least 91% identical, or at least 92% identical, or at least 93% identical, or at least 94% identical, or at least 95% identical, or at least 96% identical, or at least 97% identical, or at least 98% identical, or at least 99% identical.

Representative chimeric anti-5T4 antibodies of the invention, *i.e.*, antibodies that specifically bind to 5T4 antigen, also include those antibodies having (a) a heavy chain variable region amino acid sequence set forth as residues 20-138 of SEQ ID NO:2, residues 19-135 of SEQ ID NO:6, residues 20-141 of SEQ ID NO:10, or any one of the humanized A1, A2, or A3 heavy chain variable regions depicted in Figures 9A-9C; (b) a heavy chain variable region amino acid sequence that is at least 85% identical to residues 20-138 of SEQ ID NO:2; (c) a heavy chain variable region amino acid sequence that is at least 86% identical to residues 19-135 of SEQ ID NO:6; (d) a heavy chain variable region amino acid sequence that is at least 91% identical to residues 20-141 of SEQ ID NO:10; (e) a heavy chain variable region amino acid sequence that is at least 90% identical to residues 1-119 of SEQ ID NO:49; or (f) a heavy chain variable region amino acid sequence derived from any one of the humanized A1, A2, or A3 variable regions depicted in Figures 9A-9C.

A heavy chain variable region of a chimeric or humanized anti-5T4 antibody, which specifically binds to 5T4 antigen, may be encoded by (a) a nucleic acid comprising a nucleotide sequence of nucleotides 58-414 of SEQ ID NO:1, nucleotides 55-405 of SEQ ID NO:5, nucleotides 58-423 of SEQ ID NO:9, nucleotides 1-358 of SEQ ID NO:48; or a nucleic acid encoding a humanized A1, A2, or A3 heavy chain variable region depicted in Figures 9A-9C; (b) a nucleic acid comprising a nucleotide sequence that is at least 90% identical to a nucleic acid comprising a nucleotide sequence of nucleotides 58-414 of SEQ ID NO:1, nucleotides 55-405 of SEQ ID NO:5, or nucleotides 58-423 of SEQ ID NO:9. For example, a heavy chain variable region of a chimeric anti-5T4 antibody may be encoded by a nucleic acid that is at least 98% identical to nucleotides 58-414 of SEQ ID NO:1, a nucleic acid comprising a nucleotide sequence that is at least 98%

identical to nucleotides 55-405 of SEQ ID NO:5, or a nucleic acid comprising a nucleotide sequence that is at least 89% identical to nucleotides 1-358 of SEQ ID NO:48. A heavy chain variable region of a chimeric anti-5T4 antibody may also be encoded by a nucleic acid that specifically hybridizes to the complement of a nucleic acid comprising a nucleotide sequence of nucleotides 58-414 of SEQ ID NO:1, nucleotides 55-405 of SEQ ID NO:5, nucleotides 58-423 of SEQ ID NO:9, or nucleotides 1-358 of SEQ ID NO:48, under stringent hybridization conditions, for example final wash conditions of 0.1X SSC at 65°C.

Representative chimeric anti-5T4 antibodies of the invention further include those antibodies having (a) a light chain variable region amino acid sequence set forth as residues 21-127 of SEQ ID NO:4, residues 23-130 of SEQ ID NO:8, residues 21-127 of SEQ ID NO:12, or residues of a humanized A1, A2, or A3 light chain variable region depicted in Figures 9A-9C; or (b) a light chain variable region amino acid sequence that is at least 90% identical to residues 21-127 of SEQ ID NO:4, residues 23-130 of SEQ ID NO:8, or residues 21-127 of SEQ ID NO:12. For example, a light chain variable region amino acid sequence may comprise (a) a light chain variable region amino acid sequence that is at least 94% identical to residues 21-127 of SEQ ID NO:4; (b) a light chain variable region amino acid sequence that is at least 96% identical to residues 23-130 of SEQ ID NO:8; (c) a light chain variable region amino acid sequence that is at least 98% identical to residues 21-127 of SEQ ID NO:12; (d) or a light chain variable region amino acid sequence derived from any one of the humanized A1, A2, or A3 light chain variable regions depicted in Figures 9A-9C.

A light chain variable region of a chimeric anti-5T4 antibody, which specifically binds to 5T4 antigen, may be encoded by (a) a nucleic acid comprising a nucleotide sequence of nucleotides 61-381 of SEQ ID NO:3, nucleotides 67-390 of SEQ ID NO:7, nucleotides 61-381 of SEQ ID NO:11, or nucleotides encoding any one of the humanized A1, A2, or A3 light chain variable regions depicted in Figures 9A-9C; or (b) a nucleic acid comprising a nucleotide sequence that is at least 90% identical to nucleotides 61-381 of SEQ ID NO:3, nucleotides 67-390 of SEQ ID NO:7, or nucleotides 61-381 of SEQ ID NO:11. For example, a light chain variable region of a chimeric anti-5T4 antibody may be encoded by a nucleic acid comprising (a) a nucleotide sequence that is at least 97% identical to nucleotides 61-381 of SEQ ID NO:3; (b) a nucleotide sequence that is at least 98% identical to nucleotides 67-390

of SEQ ID NO:7; or (c) a nucleotide sequence that is at least 99% identical to nucleotides 61-381 of SEQ ID NO:11. A light chain variable region of a chimeric anti-5T4 antibody, which specifically binds to 5T4 antigen, may also be encoded by a nucleic acid that specifically hybridizes to the complement of a nucleic acid comprising a nucleotide sequence of nucleotides 61-381 of SEQ ID NO:3, nucleotides 67-390 of SEQ ID NO:7, or nucleotides 61-381 of SEQ ID NO:11, under stringent hybridization conditions, for example final wash conditions of 0.1X SSC at 65°C.

Humanized antibodies are a type of chimeric antibody wherein variable region residues responsible for antigen binding (*i.e.*, residues of a complementarity determining region, abbreviated complementarity determining region, or any other residues that participate in antigen binding) are derived from a non-human species, while the remaining variable region residues (*i.e.*, residues of the framework regions) and constant regions are derived, at least in part, from human antibody sequences. A subset of framework region residues and constant region residues of a humanized antibody may be derived from non-human sources. Variable regions of a humanized antibody are also described as humanized (*i.e.*, a humanized light or heavy chain variable region). The non-human species is typically that used for immunization with antigen, such as mouse, rat, rabbit, non-human primate, or other non-human mammalian species. Humanized antibodies are typically less immunogenic than traditional chimeric antibodies and show improved stability following administration to humans. See *e.g.*, Benincosa et al. (2000) *J. Pharmacol. Exp. Ther.* 292:810-6; Kalofonos et al. (1994) *Eur. J. Cancer* 30A:1842-50; Subramanian et al. (1998) *Pediatr. Infect. Dis. J.* 17:110-5.

Complementarity determining regions (CDRs) are residues of antibody variable regions that participate in antigen binding. Several numbering systems for identifying CDRs are in common use. The Kabat definition is based on sequence variability, and the Chothia definition is based on the location of the structural loop regions. The AbM definition is a compromise between the Kabat and Chothia approaches. The CDRs of the light chain variable region are bounded by the residues at positions 24 and 34 (CDR1-L), 50 and 56 (CDR2-L), and 89 and 97 (CDR3-L) according to the Kabat, Chothia, or AbM algorithm. According to the Kabat definition, the CDRs of the heavy chain variable region are bounded by the residues at positions 31 and 35B (CDR1-H), 50 and 65 (CDR2-H), and 95 and 102

(CDR3-H) (numbering according to Kabat). According to the Chothia definition, the CDRs of the heavy chain variable region are bounded by the residues at positions 26 and 32 (CDR1-H), 52 and 56 (CDR2-H), and 95 and 102 (CDR3-H) (numbering according to Chothia). According to the AbM definition, the CDRs of the heavy chain variable region are bounded by the residues at positions 26 and 35B (CDR1-H), 50 and 58 (CDR2-H), and 95 and 102 (CDR3-H) (numbering according to Kabat). See Martin et al. (1989) *Proc. Natl. Acad. Sci. USA* 86: 9268–9272; Martin et al. (1991) *Methods Enzymol.* 203: 121–153; Pedersen et al. (1992) *Immunomethods* 1: 126; and Rees et al. (1996) In Sternberg M.J.E. (ed.), Protein Structure Prediction, Oxford University Press, Oxford, pp. 141–172.

Specificity determining regions (SDRs) are residues within CDRs that directly interact with antigen. The SDRs correspond to hypervariable residues. See (Padlan et al. (1995) *FASEB J.* 9: 133-139).

Framework residues are those residues of antibody variable regions other than hypervariable or CDR residues. Framework residues may be derived from a naturally occurring human antibody, such as a human framework that is substantially similar to a framework region of the A1, A2, or A3 antibodies. Artificial framework sequences that represent a consensus among individual sequences may also be used. When selecting a framework region for humanization, sequences that are widely represented in humans may be preferred over less populous sequences. Additional mutations of the human framework acceptor sequences may be made to restore murine residues believed to be involved in antigen contacts and/or residues involved in the structural integrity of the antigen-binding site, or to improve antibody expression. A peptide structure prediction may be used to analyze the humanized variable heavy and light region sequences to identify and avoid post-translational protein modification sites introduced by the humanization design.

Humanized antibodies may be prepared using any one of a variety of methods including veneering, grafting of complementarity determining regions (CDRs), grafting of abbreviated CDRs, grafting of specificity determining regions (SDRs), and *Frankenstein* assembly, as described below. Humanized antibodies also include superhumanized antibodies, in which one or more changes have been introduced in the CDRs. For example, human residues may be substituted for non-human residues in the CDRs. These general approaches may be combined with

standard mutagenesis and synthesis techniques to produce an anti-5T4 antibody of any desired sequence.

Veneering is based on the concept of reducing potentially immunogenic amino acid sequences in a rodent or other non-human antibody by resurfacing the solvent accessible exterior of the antibody with human amino acid sequences. Thus, veneered antibodies appear less foreign to human cells than the unmodified non-human antibody. See Padlan (1991) *Mol. Immunol.* 28:489-98. A non-human antibody is veneered by identifying exposed exterior framework region residues in the non-human antibody, which are different from those at the same positions in framework regions of a human antibody, and replacement of the identified residues with amino acids that typically occupy these same positions in human antibodies.

Grafting of CDRs is performed by replacing one or more CDRs of an acceptor antibody (e.g., a human antibody or other antibody comprising desired framework residues) with CDRs of a donor antibody (e.g., a non-human antibody). Acceptor antibodies may be selected based on similarity of framework residues between a candidate acceptor antibody and a donor antibody. For example, according to the Frankenstein approach, human framework regions are identified as having substantial sequence homology to each framework region of the relevant non-human antibody, and CDRs of the non-human antibody are grafted onto the composite of the different human framework regions. A related method also useful for preparation of antibodies of the invention is described in U.S. Patent Application Publication No. 2003/0040606.

Grafting of abbreviated CDRs is a related approach. Abbreviated CDRs include the specificity-determining residues and adjacent amino acids, including those at positions 27d-34, 50-55 and 89-96 in the light chain, and at positions 31-35b, 50-58, and 95-101 in the heavy chain (numbering convention of (Kabat et al. (1987))). See (Padlan et al. (1995) *FASEB J.* 9: 133-9). Grafting of specificity-determining residues (SDRs) is premised on the understanding that the binding specificity and affinity of an antibody combining site is determined by the most highly variable residues within each of the complementarity determining regions (CDRs). Analysis of the three-dimensional structures of antibody-antigen complexes, combined with analysis of the available amino acid sequence data may be used to model sequence variability based on structural dissimilarity of amino acid residues that occur at each position within the CDR. SDRs are identified as minimally

immunogenic polypeptide sequences consisting of contact residues. See Padlan et al. (1995) *FASEB J.* 9: 133-139.

In general, human acceptor frameworks are selected on the basis that they are substantially similar to the framework regions of the donor antibodies, or which are most similar to the consensus sequence of the variable region subfamily. Following grafting, additional changes may be made in the donor and/or acceptor sequences to optimize antibody binding, functionality, codon usage, expression levels, etc, including introduction of non-human residues into the framework regions. See e.g., PCT International Publication No. WO 91/09967.

For grafting of CDRs onto a heavy chain variable framework region, useful framework sequences may be derived from a DP-21 (VH7), DP-54 (VH3-07), DP-47 (VH3-23), DP-53 (VH-74), DP-49 (VH3-30), DP-48 (VH3-13), DP-75, DP-8(VH1-2), DP-25, VI-2b and VI-3 (VH1-03), DP-15 and V1-8 (VH1-08), DP-14 and V1-18 (VH1-18), DP-5 and V1-24P (VH1-24), DP-4 (VH1-45), DP-7 (VH1-46), DP-10, DA-6 and YAC-7 (VH1-69), DP-88 (VH1-e), DP-3 and DA-8 (VH1-f). Representative heavy chain variable regions containing framework residues for humanization are set forth as SEQ ID NOs:13-24 and 88-93. Representative frameworks that represent a consensus of VH1 framework residues are set forth as SEQ ID NOs:25-27. See also Figures 10A-10B.

For grafting of CDRs onto a light chain variable framework region, useful framework sequences may be derived from a DPK24 subgroup IV germ line clone, a V κ III subgroup (DPK23, DPK22, DPK20, DPK21), or a V κ I subgroup germ line clone (DPK9, DPK1, O2, DPK7). Representative light chain variable regions containing framework residues for humanization are set forth as SEQ ID NOs:28-34, 35-44, and 94-99. See Figures 11-14.

Representative humanized anti-5T4 antibodies of the invention include antibodies having one or more CDRs of a non-human anti-5T4 antibody selected from CDRs of a heavy chain variable region of any one of SEQ ID NOs:2, 6, or 10, or a light chain variable region of any one of SEQ ID NOs:4, 8, or 12. For example, humanized anti-5T4 antibodies may comprise two or more CDRs selected from CDRs of a heavy chain variable region of any one of SEQ ID NOs:2, 6, or 10, or a light chain variable region of any one of SEQ ID NOs:4, 8, or 12. Humanized anti-5T4 antibodies may also comprise a heavy chain comprising a variable region

having two or three CDRs of any one of SEQ ID NOs:2, 6, or 10, and a light chain comprising a variable region having two or three CDRs of any one of SEQ ID NOs:4, 8, or 12.

Humanized anti-5T4 antibodies of the invention may be constructed wherein the variable region of a first chain (*i.e.*, the light chain variable region or the heavy chain variable region) is humanized, and wherein the variable region of the second chain is not humanized (*i.e.*, a variable region of an antibody produced in a non-human species). These antibodies are a type of humanized antibody referred to as semi-humanized antibodies. Non-human anti-5T4 antibodies that may be used to prepare semi-humanized antibodies include the A1, A2, and A3 antibodies, as disclosed herein, as well as the H8 antibody described in PCT International Publication No. WO 98/55607 and in Forsberg et al. (1997) *J. Biol. Chem.* 272(19):124430-12436, or the rat monoclonal antibody described in Woods et al. (2002) *Biochem. J.* 366: 353-65). For example, a semi-humanized anti-5T4 antibody can comprise a heavy chain variable region set for as amino acids 1-119 of SEQ ID NO:49 or amino acids of a humanized A1, A2, or A3 heavy chain variable region depicted in Figures 9A-9C, and a light chain variable region of any one of SEQ ID NOs:4, 8, or 12.

The constant regions of chimeric and humanized anti-5T4 antibodies may be derived from constant regions of any one of IgA, IgD, IgE, IgG, IgM, any isotypes thereof (*e.g.*, IgG1, IgG2, IgG3, or IgG4 isotypes of IgG), as well as mutated versions thereof. The choice of a human isotype and modification of particular amino acids in the isotype may enhance or eliminate activation of host defense mechanisms and alter antibody biodistribution. See (Reff et al. (2002) *Cancer Control* 9: 152-66). Representative constant regions useful for preparing chimeric and humanized antibodies of the invention are set forth as SEQ ID NOs: 45-47. Human lamda light chain constant regions, included variant or mutant versions, may also be used. For cloning of sequences encoding immunoglobulin constant regions, intronic sequences may be deleted.

Chimeric and humanized anti-5T4 antibodies may be constructed using standard techniques known in the art. For example, variable regions may be prepared by annealing together overlapping oligonucleotides encoding the variable regions and ligating them into an expression vector containing a human antibody constant region. See *e.g.*, Harlow & Lane (1988) Antibodies: A Laboratory Manual,

Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York and U.S. Patent Nos. 4,196,265; 4,946,778; 5,091,513; 5,132,405; 5,260,203; 5,677,427; 5,892,019; 5,985,279; 6,054,561. Tetravalent antibodies (H_4L_4) comprising two intact tetrameric antibodies, including homodimers and heterodimers, may be prepared, for example, as described in PCT International Publication No. WO 02/096948. Antibody dimers may also be prepared via introduction of cysteine residue(s) in the antibody constant region, which promote interchain disulfide bond formation, by use of heterobifunctional cross-linkers (Wolff et al. (1993) *Cancer Res.* 53: 2560-5), or by recombinant production to include a dual constant region (Stevenson et al. (1989) *Anticancer Drug Des.* 3: 219-30). Antigen-binding fragments of antibodies of the invention may be prepared, for example, by expression of truncated antibody sequences, or by post-translation digestion of full-length antibodies.

Variants of anti-5T4 antibodies of the invention, i.e., the A1, A2, and A3 antibodies as well as chimeric and humanized versions thereof, may be readily prepared to include various changes, substitutions, insertions, and deletions. For example, antibody sequences may be optimized for codon usage in the cell type used for antibody expression. To increase the serum half life of the antibody, a salvage receptor binding epitope may be incorporated, if not present already, into the antibody heavy chain sequence. See U.S. Patent No. 5,739,277. Additional modifications to enhance antibody stability include modification of IgG4 to replace the serine at residue 241 with proline. See Angal et al. (1993) *Mol. Immunol.* 30: 105-108. Other useful changes include substitutions as required to optimize efficiency in conjugating the antibody with a drug. For example, an antibody may be modified at its carboxyl terminus to include amino acids for drug attachment, for example one or more cysteine residues may be added. The constant regions may be modified to introduce sites for binding of carbohydrates or other moieties.

Variants of anti-5T4 antibodies of the invention may be produced using standard recombinant techniques, including site-directed mutagenesis, or recombination cloning. A diversified repertoire of anti-5T4 antibodies may be prepared via gene arrangement and gene conversion methods in transgenic non-human animals (U.S. Patent Publication No. 2003/0017534), which are then tested for relevant activities using functional assays. In particular embodiments of the invention, anti-5T4 variants are obtained using an affinity maturation protocol for mutating CDRs (Yang et al. (1995) *J. Mol. Biol.* 254: 392-403), chain shuffling (Marks

et al. (1992) *Biotechnology (NY)* 10: 779-783), use of mutator strains of *E. coli* (Low et al. (1996) *J. Mol. Biol.* 260: 359-368), DNA shuffling (Patten et al. (1997) *Curr. Opin. Biotechnol.* 8: 724-733), phage display (Thompson et al. (1996) *J. Mol. Biol.* 256: 77-88), and sexual PCR (Crameri et al. (1998) *Nature* 391: 288-291). For immunotherapy applications, relevant functional assays include specific binding to human 5T4 antigen, antibody internalization, and targeting to a tumor site(s) when administered to a tumor-bearing animal, as described herein below.

The present invention further provides cells and cell lines expressing anti-5T4 antibodies of the invention. Representative host cells include mammalian and human cells, such as CHO cells, HEK-293 cells, HeLa cells, CV-1 cells, and COS cells. Methods for generating a stable cell line following transformation of a heterologous construct into a host cell are known in the art. Representative non-mammalian host cells include insect cells (Potter et al. (1993) *Int. Rev. Immunol.* 10(2-3):103-112). Antibodies may also be produced in transgenic animals (Houdebine (2002) *Curr. Opin. Biotechnol.* 13(6):625-629) and transgenic plants (Schillberg et al. (2003) *Cell Mol. Life Sci.* 60(3):433-45).

II. Anti-5T4 Nucleic Acids and Polypeptides

The present invention further provides isolated nucleic acids encoding anti-5T4 heavy chain and light chain variable regions, and isolated polypeptides encoded by the disclosed nucleic acids. Nucleic acids and polypeptides of the invention include the nucleotide and amino acid sequences of the A1, A2, and A3 variable regions, humanized A1, A2, and A3 variable regions, and variants thereof. The isolated nucleic acids and polypeptides may be used to prepare chimeric and humanized anti-5T4 antibodies.

II.A. Anti-5T4 Nucleic Acids

Nucleic acids are deoxyribonucleotides or ribonucleotides and polymers thereof in single-stranded, double-stranded, or triplexed form. Unless specifically limited, nucleic acids may contain known analogues of natural nucleotides that have similar properties as the reference natural nucleic acid. Nucleic acids include genes, cDNAs, mRNAs, and cRNAs. Nucleic acids may be synthesized, or may be derived from any biological source, including any organism. Representative

methods for cloning nucleic acids that encode anti-5T4 antibodies are described in Examples 1 and 7.

Representative nucleic acids of the invention comprise the nucleotide sequence of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, and 48. In particular, nucleic acids encoding the A1, A2, and A3 heavy chain variable regions comprise nucleotides 58-41 of SEQ ID NO:1, nucleotides 55-405 of SEQ ID NO:5, and nucleotides 58-423 of SEQ ID NO:9, respectively, which encode heavy chain variable regions having the amino acid sequences set forth as residues 20-138 of SEQ ID NO:2, residues 19-135 of SEQ ID NO:6, and residues 20-141 of SEQ ID NO:10, respectively. A nucleic acid encoding a humanized A1 heavy chain variable region comprises nucleotides 1-358 of SEQ ID NO:48. Nucleic acids encoding the A1, A2, and A3 light chain variable regions comprise nucleotides 61-381 of SEQ ID NO:3, nucleotides 67-390 of SEQ ID NO:7, and nucleotides 61-381 of SEQ ID NO:11, respectively, which encode heavy chain variable regions having the amino acid sequences set forth as residues 21-127 of SEQ ID NO:4, residues 23-130 of SEQ ID NO:8, and residues 21-127 of SEQ ID NO:12, respectively. Additional nucleic acids of the invention comprise nucleotides encoding the humanized A1, A2, and A3 variable regions depicted in Figures 9A-9C.

Nucleic acids of the invention may also comprise a nucleotide sequence that is substantially identical to any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, and 48, including nucleotide sequences that are at least 90% identical to the variable region encoding sequences of any one of SEQ ID NOs:1, 3, 5, 7, 9, and 11, such as at least about 91% identical or least 92% identical, such as at least 93% identical, or at least 94% identical, or at least 95% identical, or at least 96% identical, or at least 97% identical, or at least 98% identical, or at least 99% identical. For example, nucleic acids of the invention may comprise (a) a nucleotide sequence that is least 98% identical to the variable region encoding sequence of SEQ ID NO:1; (b) a nucleotide sequence that is at least 97% identical to the variable region encoding sequence of SEQ ID NO:3; (c) a nucleotide sequence that is at least 98% identical to the variable region encoding sequence of SEQ ID NO:5; (d) a nucleotide sequence that is at least 98% identical to the variable region encoding sequence of SEQ ID NO:7; (e) a nucleotide sequence that is at least 99% identical to the variable region encoding sequence of SEQ ID NO:11; or (f) a nucleotide sequence that is at least 89% identical to the variable region encoding sequence of SEQ ID NO:48. Sequences are compared for

maximum correspondence using a sequence comparison algorithm using the full-length variable region encoding sequence of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, 48, or nucleotide sequences encoding humanized A1, A2, and A3 variable region sequences depicted in Figures 9A-9H as the query sequence, as described herein below, or by visual inspection. See also Example 1 and Table 1, and Example 7 and Table 11.

Substantially identical sequences may be polymorphic sequences, *i.e.*, alternative sequences or alleles in a population. An allelic difference may be as small as one base pair. Substantially identical sequences may also comprise mutagenized sequences, including sequences comprising silent mutations. A mutation may comprise one or more residue changes, a deletion of one or more residues, or an insertion of one or more additional residues.

Substantially identical nucleic acids are further identified as nucleic acids that hybridize specifically to or hybridize substantially to the full length of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, or 48; the full length of a variable region encoding sequence of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, or 48; or nucleotide sequences encoding humanized A1, A2, and A3 variable region sequences depicted in Figures 9A-9H, under stringent conditions. In the context of nucleic acid hybridization, two nucleic acid sequences being compared may be designated a probe and a target. A probe is a reference nucleic acid molecule, and a target is a test nucleic acid molecule, often found within a heterogeneous population of nucleic acid molecules. A target sequence is synonymous with a test sequence.

For hybridization studies, useful probes are complementary to or mimic at least an about 14 to 40 nucleotide sequence of a nucleic acid molecule of the present invention. Preferably, probes comprise 14 to 20 nucleotides, or even longer where desired, such as 30, 40, 50, 60, 100, 200, 300, or 500 nucleotides or up to the full length of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, or 48; the full length of a variable region encoding sequence of any one of SEQ ID NOs:1, 3, 5, 7, 9, 11, or 48; or nucleotide sequences encoding humanized A1, A2, and A3 variable region sequences depicted in Figures 9A-9C. Such fragments may be readily prepared, for example, by chemical synthesis of the fragment, by application of nucleic acid amplification technology, or by introducing selected sequences into recombinant vectors for recombinant production.

Specific hybridization refers to the binding, duplexing, or hybridizing of a molecule only to a particular nucleotide sequence under stringent conditions when that sequence is present in a complex nucleic acid mixture (e.g., total cellular DNA or RNA). Specific hybridization may accommodate mismatches between the probe and the target sequence depending on the stringency of the hybridization conditions.

Stringent hybridization conditions and stringent hybridization wash conditions in the context of nucleic acid hybridization experiments such as Southern and Northern blot analysis are both sequence- and environment-dependent. Longer sequences hybridize specifically at higher temperatures. An extensive guide to the hybridization of nucleic acids is found in Tijssen (1993) Laboratory Techniques in Biochemistry and Molecular Biology-Hybridization with Nucleic Acid Probes, part I chapter 2, Elsevier, New York, New York. Generally, highly stringent hybridization and wash conditions are selected to be about 5°C lower than the thermal melting point (T_m) for the specific sequence at a defined ionic strength and pH. Typically, under stringent conditions a probe will hybridize specifically to its target subsequence, but to no other sequences.

The T_m is the temperature (under defined ionic strength and pH) at which 50% of the target sequence hybridizes to a perfectly matched probe. Very stringent conditions are selected to be equal to the T_m for a particular probe. An example of stringent hybridization conditions for Southern or Northern Blot analysis of complementary nucleic acids having more than about 100 complementary residues is overnight hybridization in 50% formamide with 1 mg of heparin at 42°C. An example of highly stringent wash conditions is 15 minutes in 0.1X SSC at 65°C. An example of stringent wash conditions is 15 minutes in 0.2X SSC buffer at 65°C. See Sambrook et al., eds (1989) Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, for a description of SSC buffer. Often, a high stringency wash is preceded by a low stringency wash to remove background probe signal. An example of medium stringency wash conditions for a duplex of more than about 100 nucleotides, is 15 minutes in 1X SSC at 45°C. An example of low stringency wash for a duplex of more than about 100 nucleotides, is 15 minutes in 4X to 6X SSC at 40°C. For short probes (e.g., about 10 to 50 nucleotides), stringent conditions typically involve salt concentrations of less than about 1M Na^+ ion, typically about 0.01 to 1M Na^+ ion concentration (or other salts) at pH 7.0-8.3, and the temperature is typically at least about 30°C. Stringent

conditions may also be achieved with the addition of destabilizing agents such as formamide. In general, a signal to noise ratio of 2-fold (or higher) than that observed for an unrelated probe in the particular hybridization assay indicates detection of a specific hybridization.

The following are examples of hybridization and wash conditions that may be used to identify nucleotide sequences that are substantially identical to reference nucleotide sequences of the present invention: a probe nucleotide sequence preferably hybridizes to a target nucleotide sequence in 7% sodium dodecyl sulphate (SDS), 0.5M NaPO₄, 1mM EDTA at 50°C followed by washing in 2X SSC, 0.1% SDS at 50°C; more preferably, a probe and target sequence hybridize in 7% sodium dodecyl sulphate (SDS), 0.5M NaPO₄, 1mM EDTA at 50°C followed by washing in 1X SSC, 0.1% SDS at 50°C; more preferably, a probe and target sequence hybridize in 7% sodium dodecyl sulphate (SDS), 0.5M NaPO₄, 1mM EDTA at 50°C followed by washing in 0.5X SSC, 0.1% SDS at 50°C; more preferably, a probe and target sequence hybridize in 7% sodium dodecyl sulphate (SDS), 0.5M NaPO₄, 1mM EDTA at 50°C followed by washing in 0.1X SSC, 0.1% SDS at 50°C; more preferably, a probe and target sequence hybridize in 7% sodium dodecyl sulphate (SDS), 0.5M NaPO₄, 1mM EDTA at 50°C followed by washing in 0.1X SSC, 0.1% SDS at 65°C.

A further indication that two nucleic acid sequences are substantially identical is that proteins encoded by the nucleic acids are substantially identical, share an overall three-dimensional structure, or are biologically functional equivalents. These terms are defined further herein below. Nucleic acid molecules that do not hybridize to each other under stringent conditions are still substantially identical if the corresponding proteins are substantially identical. This may occur, for example, when two nucleotide sequences comprise conservatively substituted variants as permitted by the genetic code.

Conservatively substituted variants are nucleic acid sequences having degenerate codon substitutions wherein the third position of one or more selected (or all) codons is substituted with mixed-base and/or deoxyinosine residues. See Batzer et al. (1991) *Nucleic Acids Res.* 19:5081; Ohtsuka et al. (1985) *J. Biol. Chem.* 260:2605-2608; and Rossolini et al. (1994) *Mol. Cell Probes* 8:91-98.

Nucleic acids of the invention also comprise nucleic acids complementary to any one of SEQ ID NOs: 1, 3, 5, 7, 9, 11, 48, or nucleotide sequences encoding

humanized A1, A2, and A3 variable region sequences depicted in Figures 9A-9C, and subsequences and elongated sequences of SEQ ID NOs: 1, 3, 5, 7, 9, 11, 48, or nucleotide sequences encoding humanized A1, A2, and A3 variable region sequences depicted in Figures 9A-9C, and complementary sequences thereof. Complementary sequences are two nucleotide sequences that comprise antiparallel nucleotide sequences capable of pairing with one another upon formation of hydrogen bonds between base pairs. As used herein, the term complementary sequences means nucleotide sequences which are substantially complementary, as may be assessed by the same nucleotide comparison methods set forth below, or is defined as being capable of hybridizing to the nucleic acid segment in question under relatively stringent conditions such as those described herein. A particular example of a complementary nucleic acid segment is an antisense oligonucleotide.

A subsequence is a sequence of nucleic acids that comprises a part of a longer nucleic acid sequence. An exemplary subsequence is a probe, described herein above, or a primer. The term primer as used herein refers to a contiguous sequence comprising about 8 or more deoxyribonucleotides or ribonucleotides, preferably 10-20 nucleotides, and more preferably 20-30 nucleotides of a selected nucleic acid molecule. The primers of the invention encompass oligonucleotides of sufficient length and appropriate sequence so as to provide initiation of polymerization on a nucleic acid molecule of the present invention.

An elongated sequence comprises additional nucleotides (or other analogous molecules) incorporated into the nucleic acid. For example, a polymerase (e.g., a DNA polymerase) may add sequences at the 3' terminus of the nucleic acid molecule. In addition, the nucleotide sequence may be combined with other DNA sequences, such as promoters, promoter regions, enhancers, polyadenylation signals, intronic sequences, additional restriction enzyme sites, multiple cloning sites, and other coding segments. Thus, the invention also provides vectors comprising the disclosed nucleic acids, including vectors for recombinant expression, wherein a nucleic acid of the invention is operatively linked to a functional promoter. When operatively linked to a nucleic acid, a promoter is in functional combination with the nucleic acid such that the transcription of the nucleic acid is controlled and regulated by the promoter region. Vectors refer to nucleic acids capable of replication in a host cell, such as plasmids, cosmids, and viral vectors.

Nucleic acids of the present invention may be cloned, synthesized, altered, mutagenized, or combinations thereof. Standard recombinant DNA and molecular cloning techniques used to isolate nucleic acids are known in the art. Site-specific mutagenesis to create base pair changes, deletions, or small insertions is also known in the art. See e.g., Sambrook et al. (eds.) (1989) Molecular Cloning: A Laboratory Manual. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; Silhavy et al. (1984) Experiments with Gene Fusions. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York; Glover & Hames (1995) DNA Cloning: A Practical Approach, 2nd ed. IRL Press at Oxford University Press, Oxford/New York; Ausubel (ed.) (1995) Short Protocols in Molecular Biology, 3rd ed. Wiley, New York.

II.B. Anti-5T4 Polypeptides

The present invention also provides isolated anti-5T4 polypeptides. Polypeptides and proteins each refer to a compound made up of a single chain of amino acids joined by peptide bonds. Representative heavy chain variable region polypeptides are set forth as residues 20-138 of SEQ ID NO:2, residues 19-135 of SEQ ID NO:6, residues 20-141 of SEQ ID NO:10, and residues 1-119 of SEQ ID NO:49. Representative light chain variable region polypeptides are set forth as residues 21-127 of SEQ ID NO:4, residues 23-130 of SEQ ID NO:8, and residues 21-127 of SEQ ID NO:12. Additional polypeptides of the invention comprise amino acids of the humanized A1, A2, and A3 variable regions depicted in Figures 9A-9C.

Additional polypeptides of the invention include heavy chain and light chain variable region polypeptides that are substantially similar to the disclosed anti-5T4 polypeptides, such as at least about 90% identical to the variable regions of SEQ ID NOs:2, 4, 6, 8, 10, 12, and 49, for example, at least about 91% identical, least 92% identical, at least 93% identical, at least 94% identical, at least 95% identical, at least 96% identical, at least 97% identical, at least 98% identical, or at least 99% identical. Sequences are compared for maximum correspondence using a sequence comparison algorithm using the full-length sequence of any one of SEQ ID NOs:2, 4, 6, 8, 10, 12, 49, or any one of the humanized A1, A2, or A3 variable regions depicted in Figures 9A-9C as the query sequence, or the variable region sequence thereof, or by visual inspection. The invention further encompasses polypeptides encoded by any one of the nucleic acids disclosed herein.

For example, representative polypeptides of the invention include (a) polypeptides having an amino acid sequence that is at least 85% similar to residues 20-138 of SEQ ID NO:2; (b) polypeptides having an amino acid sequence that is at least 94% similar to residues 21-127 of SEQ ID NO:4; (c) polypeptides having an amino acid sequence that is at least 86% similar to residues 19-135 of SEQ ID NO:6; (d) polypeptides having an amino acid sequence that is at least 96% similar to residues 23-130 of SEQ ID NO:8; (e) polypeptides having an amino acid sequence that is at least 91% similar to residues 20-141 of SEQ ID NO:10; (f) polypeptides having an amino acid sequence that is at least 98% similar to residues 21-127 of SEQ ID NO:12; and (g) polypeptides having an amino acid sequence that is at least 90% similar to residues 1-119 of SEQ ID NO:49. See Example 1 and Table 2, and Example 7 and Table 11.

Polypeptides of the invention may comprise naturally occurring amino acids, synthetic amino acids, genetically encoded amino acids, non-genetically encoded amino acids, and combinations thereof. Polypeptides may include both L-form and D-form amino acids.

Representative non-genetically encoded amino acids include but are not limited to 2-aminoadipic acid; 3-aminoadipic acid; β -aminopropionic acid; 2-aminobutyric acid; 4-aminobutyric acid (piperidinic acid); 6-aminocaproic acid; 2-aminoheptanoic acid; 2-aminoisobutyric acid; 3-aminoisobutyric acid; 2-aminopimelic acid; 2,4-diaminobutyric acid; desmosine; 2,2'-diaminopimelic acid; 2,3-diaminopropionic acid; N-ethylglycine; N-ethylasparagine; hydroxylysine; allo-hydroxylysine; 3-hydroxyproline; 4-hydroxyproline; isodesmosine; allo-isoleucine; N-methylglycine (sarcosine); N-methylisoleucine; N-methylvaline; norvaline; norleucine; and ornithine.

Representative derivatized amino acids include, for example, those molecules in which free amino groups have been derivatized to form amine hydrochlorides, p-toluene sulfonyl groups, carbobenzoxy groups, t-butyloxycarbonyl groups, chloroacetyl groups or formyl groups. Free carboxyl groups may be derivatized to form salts, methyl and ethyl esters or other types of esters or hydrazides. Free hydroxyl groups may be derivatized to form O-acyl or O-alkyl derivatives. The imidazole nitrogen of histidine may be derivatized to form N-im-benzylhistidine.

The present invention also provides fragments of an anti-5T4 polypeptide of the invention, for example, fragments constituting a 5T4 antigen binding site. Polypeptide sequences that are longer than the disclosed sequences are also provided. For example, one or more amino acids may be added to the N-terminus or C-terminus of an antibody polypeptide. Such additional amino acids may be employed in a variety of applications, including but not limited to purification applications. Methods of preparing elongated proteins are known in the art.

Anti-5T4 polypeptides of the invention include proteins comprising amino acids that are conservatively substituted variants of any one of SEQ ID NOs:2, 4, 6, 8, 10, 12, or 49. A conservatively substituted variant refers to a polypeptide comprising an amino acid in which one or more residues have been conservatively substituted with a functionally similar residue.

Examples of conservative substitutions include the substitution of one non-polar (hydrophobic) residue such as isoleucine, valine, leucine or methionine for another; the substitution of one polar (hydrophilic) residue for another such as between arginine and lysine, between glutamine and asparagine, between glycine and serine; the substitution of one basic residue such as lysine, arginine or histidine for another; or the substitution of one acidic residue, such as aspartic acid or glutamic acid for another.

Isolated polypeptides of the invention may be purified and characterized using a variety of standard techniques that are known to the skilled artisan. See e.g., Schröder & Lübke (1965) The Peptides. Academic Press, New York; Bodanszky (1993) Principles of Peptide Synthesis, 2nd rev. ed. Springer-Verlag, Berlin/ New York; Ausubel (ed.) (1995) Short Protocols in Molecular Biology, 3rd ed. Wiley, New York.

II.C. Nucleotide and Amino Acid Sequence Comparisons

The terms identical or percent identity in the context of two or more nucleotide or protein sequences, refer to two or more sequences or subsequences that are the same or have a specified percentage of amino acid residues or nucleotides that are the same, when compared and aligned for maximum correspondence, as measured using one of the sequence comparison algorithms disclosed herein or by visual inspection.

The term substantially identical in regards to a nucleotide or protein sequence means that a particular sequence varies from the sequence of a naturally occurring sequence by one or more deletions, substitutions, or additions, the net effect of which is to retain biological function of an anti-5T4 nucleic acid or polypeptide.

For comparison of two or more sequences, typically one sequence acts as a reference sequence to which one or more test sequences are compared. When using a sequence comparison algorithm, test and reference sequences are entered into a computer program, subsequence coordinates are designated if necessary, and sequence algorithm program parameters are selected. The sequence comparison algorithm then calculates the percent sequence identity for the designated test sequence(s) relative to the reference sequence, based on the selected program parameters.

Optimal alignment of sequences for comparison may be conducted, for example, by the local homology algorithm of Smith & Waterman (1981) *Adv. Appl. Math* 2:482-489, by the homology alignment algorithm of Needleman & Wunsch (1970) *J. Mol. Biol.* 48:443-453, by the search for similarity method of Pearson & Lipman (1988) *Proc. Natl. Acad. Sci. USA* 85:2444-2448, by computerized implementations of these algorithms (GAP, BESTFIT, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group, Madison, Wisconsin), or by visual inspection. See generally, Ausubel (ed.) (1995) Short Protocols in Molecular Biology, 3rd ed. Wiley, New York.

A preferred algorithm for determining percent sequence identity and sequence similarity is the BLAST algorithm, which is described in Altschul et al. (1990) *J. Mol. Biol.* 215:403-410. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information (<http://www.ncbi.nlm.nih.gov/>). The BLAST algorithm parameters determine the sensitivity and speed of the alignment. For comparison of two nucleotide sequences, the BLASTn default parameters are set at W=11 (wordlength) and E=10 (expectation), and also include use of a low-complexity filter to mask residues of the query sequence having low compositional complexity. For comparison of two amino acid sequences, the BLASTp program default parameters are set at W=3 (wordlength), E=10 (expectation), use of the BLOSUM62 scoring matrix, gap costs of existence=11 and extension=1, and use of a low-complexity filter to mask residues of the query sequence having low compositional complexity. See Example 1.

III. Anti-5T4 Antibody/Drug Conjugates

The present invention further provides antibody/drug conjugates comprising an anti-5T4 antibody of the invention. Also provided are methods for preparing the antibody/drug conjugates, such that the drug is bound to the antibody either directly or indirectly. Antibody/drug conjugates of the invention have the general formula $5T4Ab(-X-W)_m$

wherein:

5T4Ab is an anti-5T4 antibody or antibody fragment as described herein;

X is a linker that comprises a product of any reactive group that may react with an anti-5T4 antibody or antibody fragment;

W is a drug;

m is the average loading for a purified conjugation product (e.g., m such that the drug constitutes about 3 - 10% of the conjugate by weight); and

$(-X-W)_m$ is a drug derivative.

Also provided are methods for preparing antibody/drug conjugates of the invention. As one example, an antibody/drug conjugate of the formula $5T4Ab(-X-W)_m$ may be prepared by (a) adding the drug derivative to the anti-5T4 antibody wherein the drug is 3-10% by weight of the anti-5T4 antibody; (b) incubating the drug derivative and the anti-5T4 antibody in a non-nucleophilic, protein-compatible, buffered solution having a pH in a range from about 7 to 9 to produce an antibody/drug conjugate, wherein the solution further comprises (i) a suitable organic cosolvent, and (ii) one or more additives comprising at least one bile acid or its salt, and wherein the incubation is conducted at a temperature ranging from about 30°C to about 35°C for a period of time ranging from about 15 minutes to about 24 hours; and (c) subjecting the conjugate produced in step (b) to a chromatographic separation process to separate antibody/drug conjugates with a loading in the range of 3-10% by weight drug and with low conjugated fraction (LCF) from unconjugated anti-5T4 antibody, drug derivative, and aggregated conjugates.

III.A. Drugs

A drug is any substance having biological or detectable activity, for example, therapeutic agents, detectable labels, binding agents, *etc.*, and prodrugs, which are metabolized to an active agent *in vivo*. A drug may also be a drug derivative,

wherein a drug has been functionalized to enable conjugation with an antibody of the invention. Generally, these types of conjugates are referred to as immunoconjugates.

Therapeutic agents are compositions that may be used to treat or prevent a condition in a subject in need thereof. Therapeutic agents useful in the invention include anti-cancer agents, *i.e.*, agents having anti-cancer activity in 5T4-expressing cells such as cancer cells from squamous/adenomatous lung carcinoma (non-small-cell lung carcinoma), invasive breast carcinoma, colorectal carcinoma, gastric carcinoma, squamous cervical carcinoma, invasive endometrial adenocarcinoma, invasive pancreas carcinoma, ovarian carcinoma, squamous vesical carcinoma, and choriocarcinoma.

Representative therapeutic drugs include cytotoxins, radioisotopes, chemotherapeutic agents, immunomodulatory agents, anti-angiogenic agents, anti-proliferative agents, pro-apoptotic agents, and cytostatic and cytolytic enzymes (*e.g.*, RNAses). A drug may also include a therapeutic nucleic acid, such as a gene encoding an immunomodulatory agent, an anti-angiogenic agent, an anti-proliferative agent, or a pro-apoptotic agent. These drug descriptors are not mutually exclusive, and thus a therapeutic agent may be described using one or more of the above-noted terms. For example, selected radioisotopes are also cytotoxins. Therapeutic agents may be prepared as pharmaceutically acceptable salts, acids or derivatives of any of the above. Generally, conjugates having a radioisotope as the drug are referred to as radioimmunoconjugates and those having a chemotherapeutic agent as the drug are referred to as chemoimmunoconjugates.

Examples of suitable drugs for use in immunoconjugates include the taxanes, maytansines, CC-1065 and the duocarmycins, the calicheamicins and other enediynes, and the auristatins. Other examples include the anti-folates, vinca alkaloids, and the anthracyclines. Plant toxins, other bioactive proteins, enzymes (*i.e.*, ADEPT), radioisotopes, photosensitizers (*i.e.*, for photodynamic therapy) can also be used in immunoconjugates. In addition, conjugates can be made using secondary carriers as the cytotoxic agent, such as liposomes or polymers, for example.

The term cytotoxin generally refers to an agent that inhibits or prevents the function of cells and/or results in destruction of cells. Representative cytotoxins include antibiotics, inhibitors of tubulin polymerization, alkylating agents that bind to

and disrupt DNA, and agents that disrupt protein synthesis or the function of essential cellular proteins such as protein kinases, phosphatases, topoisomerases, enzymes, and cyclins. Representative cytotoxins include, but are not limited to, doxorubicin, daunorubicin, idarubicin, aclarubicin, zorubicin, mitoxantrone, epirubicin, carubicin, nogalamycin, menogaril, pitarubicin, valrubicin, cytarabine, gemcitabine, trifluridine, ancitabine, enocitabine, azacitidine, doxifluridine, pentostatin, broxuridine, capecitabine, cladribine, decitabine, floxuridine, fludarabine, gougerotin, puromycin, tegafur, tiazofurin, adriamycin, cisplatin, carboplatin, cyclophosphamide, dacarbazine, vinblastine, vincristine, mitoxantrone, bleomycin, mechlorethamine, prednisone, procarbazine, methotrexate, flurouracils, etoposide, taxol, taxol analogs, platins such as cis-platin and carbo-platin, mitomycin, thiotepa, taxanes, vincristine, daunorubicin, epirubicin, actinomycin, anthramycin, azaserines, bleomycins, tamoxifen, idarubicin, dolastatins/auristatins, hemiasterlins, esperamicins and maytansinoids.

In particular embodiments of the invention, a cytotoxin is an antibiotic such as a calicheamicin, also called the LL-E33288 complex, for example, gamma-calicheamicin (γ_1) or N-acetyl gamma-calicheamicin. See U.S. Patent No. 4,970,198. Additional examples of calicheamicins suitable for use in preparing antibody/drug conjugates of the invention are disclosed in U.S. Patent Nos. 4,671,958; 5,053,394; 5,037,651; 5,079,233; and 5,108,912, which are incorporated herein in their entirety. These compounds contain a methyltrisulfide that may be reacted with appropriate thiols to form disulfides, at the same time introducing a functional group such as a hydrazide or other functional group that is useful for conjugating calicheamicin to an anti-5T4 antibody. Disulfide analogs of calicheamicin can also be used, for example, analogs described in U.S. Patent Nos. 5,606,040 and 5,770,710, which are incorporated herein in their entirety.

For radiotherapy applications, an anti-5T4 antibody of the invention may comprise a high energy radioisotope. The isotope may be directly bound to the antibody, for example, at a cysteine residue present in the antibody, or a chelator may be used to mediate the binding of the antibody and the radioisotope. Radioisotopes suitable for radiotherapy include but are not limited to α -emitters, β -emitters, and auger electrons. For diagnostic applications, useful radioisotopes include positron emitters and γ -emitters. An anti-5T4 antibody of the invention may

further be iodinated, for example, on a tyrosine residue of the antibody, to facilitate detection or therapeutic effect of the antibody.

Representative radioisotopes that may be conjugated to an anti-5T4 antibody include ¹⁸fluorine, ⁶⁴copper, ⁶⁵copper, ⁶⁷gallium, ⁶⁸gallium, ⁷⁷bromine, ^{80m}bromine, ⁹⁵ruthenium, ⁹⁷ruthenium, ¹⁰³ruthenium, ¹⁰⁵ruthenium, ^{99m}technetium, ¹⁰⁷mercury, ²⁰³mercury, ¹²³iodine, ¹²⁴iodine, ¹²⁵iodine, ¹²⁶iodine, ¹³¹iodine, ¹³³iodine, ¹¹¹indium, ¹¹³indium, ^{99m}rhenium, ¹⁰⁵rhenium, ¹⁰¹rhenium, ¹⁸⁶rhenium, ¹⁸⁸rhenium, ¹²¹mtellurium, ⁹⁹technetium, ^{122m}tellurium, ^{125m}tellurium, ¹⁶⁵thulium, ¹⁶⁷thulium, ¹⁶⁸thulium, ⁹⁰yttrium, and nitride or oxide forms derived there from. Other suitable radioisotopes include alpha emitters, such as ²¹³bismuth, ²¹³lead, and ²²⁵actinium.

Antibody/drug conjugates of the invention may include immunomodulators, *i.e.*, agents that elicit an immune response, including humoral immune responses (*e.g.* production of antigen-specific antibodies) and cell-mediated immune responses (*e.g.* lymphocyte proliferation). Representative immunomodulatory agents include cytokines, xanthines, interleukins, interferons, and growth factors (*e.g.*, TNF, CSF, GM-CSF and G-CSF), and hormones such as estrogens (diethylstilbestrol, estradiol), androgens (testosterone, HALOTESTIN® (fluoxyimesterone)), progestins (MEGACE® (megestrol acetate), PROVERA® (medroxyprogesterone acetate)), and corticosteroids (prednisone, dexamethasone, hydrocortisone).

Immunomodulatory agents useful in the invention also include anti-hormones that block hormone action on tumors and immunosuppressive agents that suppress cytokine production, down-regulate self-antigen expression, or mask MHC antigens. Representative anti-hormones include anti-estrogens including, for example, tamoxifen, raloxifene, aromatase inhibiting 4(5)-imidazoles, 4-hydroxytamoxifen, trioxifene, keoxifene, LY 117018, onapnstone, and toremifene; and anti-androgens such as flutamide, nilutamide, bicalutamide, leuprolide, and goserelin; and anti-adrenal agents. Representative immunosuppressive agents include 2-amino-6-aryl-5-substituted pyrimidines, azathioprine, cyclophosphamide, bromocryptine, danazol, dapsone, glutaraldehyde, anti-idiotypic antibodies for MHC antigens and MHC fragments, cyclosporin A, steroids such as glucocorticosteroids, cytokine or cytokine receptor antagonists (*e.g.*, anti-interferon antibodies, anti-IL10 antibodies, anti-TNF α antibodies, anti-IL2 antibodies), streptokinase, TGF β , rapamycin, T-cell receptor, T-cell receptor fragments, and T cell receptor antibodies.

Additional drugs useful in the invention include anti-angiogenic agents that inhibit blood vessel formation, for example, farnesyltransferase inhibitors, COX-2 inhibitors, VEGF inhibitors, bFGF inhibitors, steroid sulphatase inhibitors (e.g., 2-methoxyoestradiol bis-sulphamate (2-MeOE2bisMATE)), interleukin-24, thrombospondin, metallospodin proteins, class I interferons, interleukin 12, protamine, angiostatin, laminin, endostatin, and prolactin fragments.

Anti-proliferative agents and pro-apoptotic agents include activators of PPAR-gamma (e.g., cyclopentenone prostaglandins (cyPGs)), retinoids, triterpinoids (e.g., cycloartane, lupane, ursane, oleanane, friedelane, dammarane, cucurbitacin, and limonoid triterpenoids), inhibitors of EGF receptor (e.g., HER4), rampamycin, CALCITRIOL® (1,25-dihydroxycholecalciferol (vitamin D)), aromatase inhibitors (FEMARA® (letrozole)), telomerase inhibitors, iron chelators (e.g., 3-aminopyridine-2-carboxaldehyde thiosemicarbazone (Triapine)), apoptin (viral protein 3 - VP3 from chicken anemia virus), inhibitors of Bcl-2 and Bcl-X(L), TNF-alpha, FAS ligand, TNF-related apoptosis-inducing ligand (TRAIL/Apo2L), activators of TNF-alpha/FAS ligand/TNF-related apoptosis-inducing ligand (TRAIL/Apo2L) signaling, and inhibitors of PI3K-Akt survival pathway signaling (e.g., UCN-01 and geldanamycin).

Representative chemotherapeutic agents include alkylating agents such as thiotepa and cyclophosphamide; alkyl sulfonates such as busulfan, improsulfan and piposulfan; azidines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, triethylenephosphoramidate, triethylenethiophosphoramidate and trimethylolomelamine; nitrogen mustards such as chlorambucil, chlornaphazine, cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfarnide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, ranimustine; antibiotics such as aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, calicheamicin, carabycin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin, epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins, mycophenolic acid, nogalamycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate,

pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine, 5-EU; androgens such as calusterone, dromostanolone propionate, epitio stanol, mepitio stanane, testolactone; anti-adrenal such as arninoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophospharnide glycoside; aminolevulinic acid; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elfornithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2, 2', 2' -trichlorotriethylamine; urethan; vindesine; dacarbazine; mannomustine; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside (Ara-C); cyclophosphamide; thiotepa; taxoids, e.g. paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology of Princeton, New Jersey) and doxetaxel (TAXOTERE®, Rhone-Poulenc Rorer of Antony, France); chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin and carboplatin; vinblastine; platinum; etoposide (VP-16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aininopterin; xeloda; ibandronate; CPT-11; topoisomerase inhibitor RFS 2000; difluoromethylornithine (DMFO); retinoic acid; esperamicins; and capecitabine.

Additional therapeutic agents that may be conjugated to anti-5T4 antibodies and used in accordance with the therapeutic methods of the present invention include photosensitizing agents (U.S. Patent Publication No. 2002/0197262 and U.S. Patent No. 5,952,329) for photodynamic therapy; magnetic particles for thermotherapy (U.S. Patent Publication No. 2003/0032995); binding agents, such as peptides, ligands, cell adhesion ligands, etc., and prodrugs such as phosphate-containing prodrugs, thiophosphate-containing prodrugs, sulfate containing prodrugs, peptide containing prodrugs, β -lactam-containing prodrugs, substituted phenoxyacetamide-containing prodrugs or substituted phenylacetamide-containing prodrugs, 5-fluorocytosine and other 5-fluorouridine prodrugs that may be converted to the more active cytotoxic free drug.

For diagnostic methods using anti-5T4 antibodies, a drug may comprise a detectable label used to detect the presence of 5T4-expressing cells *in vitro* or *in vivo*. Radioisotopes that are detectable *in vivo*, such as those labels that are detectable using scintigraphy, magnetic resonance imaging, or ultrasound, may be used in clinical diagnostic applications. Useful scintigraphic labels include positron emitters and γ -emitters. Representative contrast agents for magnetic source imaging are paramagnetic or superparamagnetic ions (e.g., iron, copper, manganese, chromium, erbium, europium, dysprosium, holmium and gadolinium), iron oxide particles, and water soluble contrast agents. For ultrasonic detection, gases or liquids may be entrapped in porous inorganic particles that are released as microbubble contrast agents. For *in vitro* detection, useful detectable labels include fluorophores, detectable epitopes or binding agents, and radioactive labels.

III.B. Linker Molecules

Drugs are conjugated to chimeric and humanized anti-5T4 antibodies of the invention either directly or indirectly via a linker molecule. The linker molecule may be stable or hydrolyzable, whereby it is released following cellular entry. The major mechanisms by which the drug is cleaved from the antibody include hydrolysis in the acidic pH of the lysosomes (hydrazones, acetals, and cis-aconitate-like amides), peptide cleavage by lysosomal enzymes (the cathepsins and other lysosomal enzymes), and reduction of disulfides. As a result of these varying mechanisms for cleavage, mechanisms of linking the drug to the antibody also vary widely and any suitable linker can be used. Preferably, the conjugation method produces a sample with minimal low conjugate fraction (LCF, the fraction of mostly unconjugated antibody), *i.e.*, less than about 10%.

One example of a suitable conjugation procedure relies on the conjugation of hydrazides and other nucleophiles to the aldehydes generated by oxidation of the carbohydrates that naturally occur on antibodies. Hydrazone-containing conjugates can be made with introduced carbonyl groups that provide the desired drug-release properties. Conjugates can also be made with a linker that has a disulfide at one end, an alkyl chain in the middle, and a hydrazine derivative at the other end. The anthracyclines are one example of cytotoxins that can be conjugated to antibodies using this technology.

Linkers containing functional groups other than hydrazones have the potential to be cleaved in the acidic milieu of the lysosomes. For example, conjugates can be made from thiol-reactive linkers that contain a site other than a hydrazone that is cleavable intracellularly, such as esters, amides, and acetals/ketals. Camptothecin is one cytotoxic agent that can be conjugated using these linkers. Ketals made from a 5 to 7-member ring ketone and that has one of the oxygens attached to the cytotoxic agent and the other to a linker for antibody attachment also can be used. The anthracyclines are also an example of a suitable cytotoxin for use with these linkers.

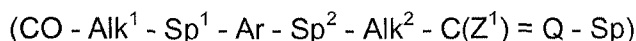
Another example of a class of pH sensitive linkers are the cis-aconitates, which have a carboxylic acid juxtaposed to an amide bond. The carboxylic acid accelerates amide hydrolysis in the acidic lysosomes. Linkers that achieve a similar type of hydrolysis rate acceleration with several other types of structures can also be used. The maytansinoids are an example of a cytotoxin that can be conjugated with linkers attached at C-9.

Another potential release method for drug conjugates is the enzymatic hydrolysis of peptides by the lysosomal enzymes. In one example, a peptide is attached via an amide bond to para-aminobenzyl alcohol and then a carbamate or carbonate is made between the benzyl alcohol and the cytotoxic agent. Cleavage of the peptide leads to the collapse, or self-immolation, of the aminobenzyl carbamate or carbonate. The cytotoxic agents exemplified with this strategy include anthracyclines, taxanes, mitomycin C, and the auristatins. In one example, a phenol can also be released by collapse of the linker instead of the carbamate. In another variation, disulfide reduction is used to initiate the collapse of a para-mercaptobenzyl carbamate or carbonate.

Many of the cytotoxic agents conjugated to antibodies have little, if any, solubility in water and that can limit drug loading on the conjugate due to aggregation of the conjugate. One approach to overcoming this is to add solubilizing groups to the linker. Conjugates made with a linker consisting of PEG and a dipeptide can be used, including those having a PEG di-acid, thiol-acid, or maleimide-acid attached to the antibody, a dipeptide spacer, and an amide bond to the amine of an anthracycline or a duocarmycin analogue. Another example is a conjugate prepared with a PEG-containing linker disulfide bonded to a cytotoxic agent and amide bonded

to an antibody. Approaches that incorporate PEG groups may be beneficial in overcoming aggregation and limits in drug loading.

Representative linkers preferred for preparation of antibody/drug conjugates of the invention include linkers of the formula:



wherein

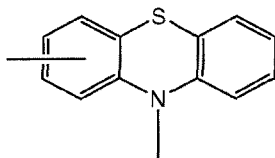
Alk^1 and Alk^2 are independently a bond or branched or unbranched ($\text{C}_1\text{-C}_{10}$) alkylene chain;

Sp^1 is a bond, -S-, -O-, -CONH-, -NHCO-, -NR', -N(CH₂CH₂)₂N-, or -X-Ar'-Y-(CH₂)_n-Z wherein X, Y, and Z are independently a bond, -NR', -S-, or -O-, with the proviso that when $n = 0$, then at least one of Y and Z must be a bond and Ar' is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups of ($\text{C}_1\text{-C}_5$) alkyl, ($\text{C}_1\text{-C}_4$) alkoxy, ($\text{C}_1\text{-C}_4$) thioalkoxy, halogen, nitro, -COOR', -CONHR', -(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR', with the proviso that when Alk^1 is a bond, Sp^1 is a bond;

n is an integer from 0 to 5;

R' is a branched or unbranched ($\text{C}_1\text{-C}_5$) chain optionally substituted by one or two groups of -OH, ($\text{C}_1\text{-C}_4$) alkoxy, ($\text{C}_1\text{-C}_4$) thioalkoxy, halogen, nitro, ($\text{C}_1\text{-C}_3$) dialkylamino, or ($\text{C}_1\text{-C}_3$) trialkylammonium -A⁻ where A⁻ is a pharmaceutically acceptable anion completing a salt;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups of ($\text{C}_1\text{-C}_6$) alkyl, ($\text{C}_1\text{-C}_5$) alkoxy, ($\text{C}_1\text{-C}_4$) thioalkoxy, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR' wherein n and R' are as hereinbefore defined or a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7-naphthylidene or



with each naphthylidene or phenothiazine optionally substituted with one, two, three, or four groups of ($\text{C}_1\text{-C}_6$) alkyl, ($\text{C}_1\text{-C}_5$) alkoxy, ($\text{C}_1\text{-C}_4$) thioalkoxy, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', or -S(CH₂)_nCONHR' wherein n and R' are as defined above, with the proviso that when Ar is phenothiazine, Sp^1 is a bond only connected to nitrogen;

Sp² is a bond, -S-, or -O-, with the proviso that when Alk² is a bond, Sp² is a bond;

Z¹ is H, (C₁-C₅) alkyl, or phenyl optionally substituted with one, two, or three groups of (C₁-C₅) alkyl, (C₁-C₅) alkoxy, (C₁-C₄) thioalkoxy, halogen, nitro, -COOR', -ONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR' wherein n and R' are as defined above;

Sp is a straight or branched-chain divalent or trivalent (C₁-C₁₈) radical, divalent or trivalent aryl or heteroaryl radical, divalent or trivalent (C₃-C₁₈) cycloalkyl or heterocycloalkyl radical, divalent or trivalent aryl- or heteroaryl-aryl (C₁-C₁₈) radical, divalent or trivalent cycloalkyl- or heterocycloalkyl-alkyl (C₁-C₁₈) radical or divalent or trivalent (C₂-C₁₈) unsaturated alkyl radical, wherein heteroaryl is preferably furyl, thienyl, N-methylpyrrolyl, pyridinyl, N-methylimidazolyl, oxazolyl, pyrimidinyl, quinolyl, isoquinolyl, N-methylcarbazoyl, aminocourmarinyl, or phenazinyl and wherein if Sp is a trivalent radical, Sp may be additionally substituted by lower (C₁-C₅) dialkylamino, lower (C₁-C₅) alkoxy, hydroxy, or lower (C₁-C₅) alkylthio groups; and

Q is =NHNCO-, =NHNCS-, =NHNCONH-, =NHNCSNH-, or =NHO-.

Preferably, Alk¹ is a branched or unbranched (C₁-C₁₀) alkylene chain; Sp' is a bond, -S-, -O-, -CONH-, -NHCO-, or -NR' wherein R' is as hereinbefore defined, with the proviso that when Alk¹ is a bond, Sp¹ is a bond;

Ar is 1,2-, 1,3-, or 1,4-phenylene optionally substituted with one, two, or three groups of (C₁-C₆) alkyl, (C₁-C₅) alkoxy, (C₁-C₄) thioalkoxy, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR' wherein n and R' are as hereinbefore defined, or Ar is a 1,2-, 1,3-, 1,4-, 1,5-, 1,6-, 1,7-, 1,8-, 2,3-, 2,6-, or 2,7- naphthylidene each optionally substituted with one, two, three, or four groups of (C₁-C₆) alkyl, (C₁-C₅) alkoxy, (C₁-C₄) thioalkoxy, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR'.

Z¹ is (C₁-C₅) alkyl, or phenyl optionally substituted with one, two, or three groups of (C₁-C₅) alkyl, (C₁-C₄) alkoxy, (C₁-C₄) thioalkoxy, halogen, nitro, -COOR', -CONHR', -O(CH₂)_nCOOR', -S(CH₂)_nCOOR', -O(CH₂)_nCONHR', or -S(CH₂)_nCONHR'; Alk² and Sp² are together a bond; and Sp and Q are as immediately defined above.

U.S. Patent No. 5,773,001, incorporated herein in its entirety, discloses linkers that may be used with nucleophilic drugs, particularly hydrazides and related

nucleophiles, prepared from the calicheamicins. These linkers are especially useful in those cases where better activity is obtained when the linkage formed between the drug and the linker is hydrolyzable. These linkers contain two functional groups, including (1) a group for reaction with an antibody (e.g., carboxylic acid), and (2) a carbonyl group (e.g., an aldehyde or a ketone) for reaction with a drug. The carbonyl groups may react with a hydrazide group on the drug to form a hydrazone linkage. This linkage is hydrolyzable, allowing for release of the therapeutic agent from the conjugate after binding to the target cells.

As one example, an anti-5T4 antibody may be conjugated to a cytotoxic drug by (1) adding the cytotoxic drug derivative to the anti-5T4 antibody wherein the cytotoxic drug is 4.5%-11% by weight of the proteinaceous carrier; (2) incubating the cytotoxic drug derivative and anti-5T4 antibody in a non-nucleophilic, protein-compatible, buffered solution having a pH in the range from about 7 to 9 to produce a monomeric cytotoxic drug/antibody conjugate, wherein the solution further comprises (a) a suitable organic cosolvent, and (b) an additive comprising at least one C₆-C₁₈ carboxylic acid or its salt, and wherein the incubation is conducted at a temperature ranging from about 30°C to about 35°C for a period of time ranging from about 15 minutes to 24 hours; and (3) subjecting the conjugate produced in step (2) to a chromatographic separation process to separate monomeric conjugates with a loading in the range of 3% to 10 % by weight cytotoxic drug and with low conjugated fraction (LCF) below 10 percent from unconjugated antibody, cytotoxic drug derivative, and aggregated conjugates.

The chromatographic separation of step (3) can include processes such as size exclusion chromatography (SEC), ultrafiltration/diafiltration, HPLC, FPLC, or Sephacryl S-200 chromatography. The chromatographic separation may also be accomplished by hydrophobic interaction chromatography (HIC) using Phenyl Sepharose 6 Fast Flow chromatographic medium, Butyl Sepharose 4 Fast Flow chromatographic medium, Octyl Sepharose 4 Fast Flow chromatographic medium, Toyopearl Ether-650M chromatographic medium, Macro-Prep methyl HIC medium or Macro-Prep t-Butyl HIC medium.

Representative methods for preparing anti-5T4 antibody/drug conjugates include those described for preparation of CMC-544 in co-pending published U.S. Patent Application Publication No. 2004-082764A1 and U.S. Patent Application No. 10/699,874, which are incorporated herein in their entirety. Conjugation may be

performed using the following conditions: 10 mg/ml antibody, 8.5% (w/w) calicheamicin derivative, 37.5 mM sodium decanoate, 9% (v/v) ethanol, 50 mM HEPES (N-(2-Hydroxyethyl)piperazine-N'-(4-butanedisulfonic acid)), pH 8.5, 32°C, 1 hour. Hydrophobic interaction chromatography (HIC) may be performed using a butyl sepharose FF resin, 0.65 M potassium phosphate loading buffer, 0.49 M potassium phosphate wash buffer, and 4 mM potassium phosphate elution buffer. Buffer exchange may be accomplished by size exclusion chromatography, ultrafiltration/diafiltration, or other suitable means. The antibody/drug conjugate may be formulated in 1.5% Dextran-40, 0.9% sucrose, 0.01% TWEEN®-80, 20 mM Tris/50 mM NaCl, pH 8.0. An alternative formulation solution containing 5% sucrose, 0.01% TWEEN®-80, 20 mM Tris/10 mM NaCl, pH 8.0 may also be used. Lyophilization cycles are adjusted based on the formulation. The concentration of the formulated bulk may be 0.5 mg conjugate/ml. Each may vial contain 1 mg of conjugate, i.e., 2 ml fill. Other fill volumes may be prepared as desired, e.g., 5 ml fill.

Other representative methods include those described for CMD-193, also described in U.S. Patent Application Publication No. 20060002942. Conjugation may be performed using the following conditions: 10 mg/ml antibody, 7% (w/w) calicheamicin derivative, 10 mM deoxycholate, 50 mM HEPBS (N-(2-Hydroxyethyl)piperazine-N'-(4-butanedisulfonic acid)), 9% (v/v) ethanol, pH 8.2, 32°C, 1 hour. The reaction may be diluted 10-fold with 0.66 M potassium phosphate pH 8.56, and HIC may be performed using a butyl sepharose FF resin, 0.60 M potassium phosphate loading buffer and wash buffer, and 20 mM Tris/25 mM NaCl elution buffer. Buffer exchange may be accomplished using ultrafiltration/diafiltration with a regenerated cellulose membrane. The conjugate may be diafiltered against 20 mM Tris/10 mM NaCl pH 8.0 (10 diavolumes). The antibody/drug conjugate may be formulated in 5% sucrose, 0.01% TWEEN®-80, 20 mM Tris/10 mM NaCl, pH 8.0. The concentration of the bulk conjugate after formulation may be 1 mg/ml, and the vial fill may be 5 mg/vial, i.e., 5 ml fill, or other fill volumes may be prepared as desired.

In a particular embodiment of the invention, the linker employed is 4-(4-acetylphenoxy) butanoic acid (AcBut). Antibody/drug conjugates are prepared by reacting β -calicheamicin, γ -calicheamicin or N-acetyl γ -calicheamicin, or derivatives thereof, with 3-mercapto-3-methyl butanoyl hydrazide, the AcBut linker, and an anti-5T4 antibody of the invention. See e.g., U.S. Patent No. 5,773,001. This linker

produces conjugates that are substantially stable in circulation, releasing an estimated 2% of the NAc-gamma DMH per day, and which release the NAc-gamma DMH readily in the acidic lysosomes. In other embodiments of the invention, antibody/drug conjugates are prepared using 3-acetylphenyl acidic acid (AcPac) or 4-mercapto-4-methyl-pentanoic acid (Amide) as the linker molecule.

Representative linkers useful for conjugation of radioisotopes include diethylenetriamine pentaacetate (DTPA)-isothiocyanate, succinimidyl 6-hydrazinium nicotinate hydrochloride (SHNH), and hexamethylpropylene amine oxime (HMPAO) (Bakker et al. (1990) *J. Nucl. Med.* 31: 1501-1509, Chattopadhyay et al. (2001) *Nucl. Med. Biol.* 28: 741-744, Dewanjee et al. (1994) *J. Nucl. Med.* 35: 1054-63, Krenning et al. (1989) *Lancet* 1: 242-244, Sagiuchi et al. (2001) *Ann. Nucl. Med.* 15: 267-270); U.S. Patent No. 6,024,938). Alternatively, a targeting molecule may be derivatized so that a radioisotope may be bound directly to it (Yoo et al. (1997) *J. Nucl. Med.* 38: 294-300). Iodination methods are also known in the art, and representative protocols may be found, for example, in Krenning et al. (1989) *Lancet* 1:242-4 and in Bakker et al. (1990) *J. Nucl. Med.* 31:1501-9.

To further increase the number of drug molecules per antibody/drug conjugate, the drug may be conjugated to polyethylene glycol (PEG), including straight or branched polyethylene glycol polymers and monomers. A PEG monomer is of the formula: $-(CH_2CH_2O)-$. Drugs and/or peptide analogs may be bound to PEG directly or indirectly, *i.e.* through appropriate spacer groups such as sugars. A PEG/antibody/drug composition may also include additional lipophilic and/or hydrophilic moieties to facilitate drug stability and delivery to a target site *in vivo*. Representative methods for preparing PEG-containing compositions may be found in U.S. Patent Nos. 6,461,603; 6,309,633; and 5,648,095, among other places.

For example, to increase the amount of calicheamicin in antibody-calicheamicin conjugates, the antibody is conjugated to PEG prior to conjugation with calicheamicin, for example, using PEG-SPA, PEG-SBA, or PEG-bis-maleimide. Antibody/drug conjugates prepared using PEG may show reduced binding affinity for the target antigen, but are still effective as a result of increased drug load. Additives such as deoxycholate and decanoate may be used to produce an antibody/calicheamicin conjugates with low levels of unconjugated antibody and low levels of aggregate.

The hydrophobic nature of many drugs, including calicheamicins, may result in aggregation of antibody/drug conjugates. To produce monomeric antibody/drug conjugates with higher drug loading/yield and decreased aggregation, the conjugation reaction may be performed in a non-nucleophilic, protein-compatible, buffered solution containing (i) propylene glycol as a cosolvent and (ii) an additive comprising at least one C₆-C₁₈ carboxylic acid. Useful acids include C₇ to C₁₂ acids, such as octanoic acid or caprylic acid, or its salts. Other protein-compatible organic cosolvents other than propylene glycol, such as ethylene glycol, ethanol, DMF, DMSO, *etc.*, may also be used. Some or all of the organic cosolvent is used to transfer the drug into the conjugation mixture. Useful buffers for the preparation of antibody/drug conjugates using N-hydroxysuccinimide (OSu) esters or other comparably activated esters include phosphate-buffered saline (PBS) and N-2-hydroxyethyl piperazine-N'-2-ethanesulfonic acid (HEPES buffer). The buffered solution used in conjugation reactions should substantially lack free amines and nucleophiles. As another approach, the conjugation reactions may be performed in a non-nucleophilic, protein-compatible, buffered solution containing t-butanol without the additional additives. *See e.g.*, U.S. Patent Nos. 5,712,374 and 5,714,586. Additional methods for conjugation and calicheamicin-containing conjugates are described in U.S. Patent Nos. 5,739,116 and 5,877,296.

Optimal reaction conditions for formation of a monomeric conjugate may be empirically determined by variation of reaction variables such as temperature, pH, calicheamicin derivative input, and additive concentration. Representative amounts of propylene glycol range from 10% to 60%, for example, 10% to 40%, or about 30% by volume of the total solution. Representative amounts of an additive comprising at least one C₆-C₁₈ carboxylic acid or its salt range from 20 mM to 100 mM, such as from 40 mM to 90 mM, or about 60 mM to 90 mM. The concentration of the C₆-C₁₈ carboxylic acid or its salt may be increased to 150-300 mM and the cosolvent dropped to 1% to 10%. In representative embodiments of the invention, the carboxylic acid is octanoic acid, decanoic acid, or the corresponding salts. For example, 200 mM caprylic acid may be used with 5% propylene glycol or ethanol. The conjugation reaction may be performed at slightly elevated temperature (30-35°C) and pH (8.2-8.7). The concentration of antibody may range from 1 to 15 mg/ml and the concentration of a calicheamicin derivative, *e.g.*, N-Acetyl gamma-calicheamicin DMH AcBut OSu ester may range from about 4.5% to 11% by weight

of the antibody. Conditions suitable for conjugation of other drugs may be determined by those skilled in the art without undue experimentation.

III.C. Purification of Antibody/Drug Conjugates

Following conjugation, the monomeric conjugates may be separated from unconjugated reactants and/or aggregated forms of the conjugates by conventional methods, for example, size exclusion chromatography (SEC), hydrophobic interaction chromatography (HIC), ion exchange chromatography (IEC), or chromatofocusing (CF). The purified conjugates are monomeric, and usually contain from 3% to 10% drug by weight. Antibody/drug conjugates may also be purified using hydrophobic interaction chromatography (HIC), which offers some advantages over SEC including (1) a capability to efficiently reduce the LCF content as well as aggregate; (2) accommodation of large reaction volumes; and (3) minimal dilution of the product. High-capacity HIC media suitable for production scale use include Phenyl Sepharose 6 Fast Flow chromatographic medium, Butyl Sepharose 4 Fast Flow chromatographic medium, Octyl Sepharose 4 Fast Flow chromatographic medium, Toyopearl Ether-650M chromatographic medium, Macro-Prep methyl HIC medium or Macro-Prep t-Butyl HIC medium. Ultrafiltration/diafiltration may also be used for buffer exchange.

In a representative purification process, multiple steps are performed, including a centrifuge cell removal step, a Protein A affinity capture step followed by one or two orthogonal chromatographic polishing steps, a virus filtration step, and a tangential flow filtration step for concentration and formulation. The purification process preferably yields product with less than 5% aggregate, less than 20ppm Protein A, less than 50ppm host cell protein, and overall recovery of greater than 50%.

A typical anti-5T4/calicheamicin preparation contains predominantly (~95%) conjugated antibody containing 5-7 moles calicheamicin per mole antibody. The conjugate has been reproducibly prepared at the laboratory scale (10-200 mg). Drug loading, which is expressed as μg calicheamicin/mg monoclonal antibody, is determined by dividing the calicheamicin concentration ($\mu\text{g/mL}$) by the antibody concentration (mg/mL). These values are determined by measuring the UV absorbance of the conjugate solution at 280nm and 310nm. It is important to note that this is an average loading and that the actual loading is a quasi-gaussian

distribution centered on the average loading value, *i.e.*, some of the antibody is loaded higher than average and some of the antibody is loaded lower than the average. Unconjugated antibody (low conjugated fraction), which can be measured using analytical HIC-HPLC (hydrophobic interaction high-performance liquid chromatography), is the population of antibody that has little or no conjugated calicheamicin. This value is a measure of calicheamicin distribution on the antibody and does not generally affect the amount of calicheamicin dosed. Unconjugated calicheamicin, which can be measured using ELISA, refers to the amount of calicheamicin that is not conjugated to the antibody and is expressed in terms of percent of total calicheamicin. Drug-loading assays do not differentiate between unconjugated and conjugated calicheamicin. The amount of unconjugated calicheamicin is undetectable or negligible when using drug-loading assays, and therefore these assays effectively measure the amount of conjugated calicheamicin.

Analytical methods can be used to assay for release and stability testing of humanized anti-5T4 calicheamicin conjugates. The conjugates can be evaluated for identity (IEF), strength (total protein and total calicheamicin loading), purity (unconjugated calicheamicin, low conjugated antibody, aggregate content and SDS-PAGE Reduced), and immunoaffinity (antigen binding ELISA). Additional assays known to those of skill in the art can be used. Using these assays, batch-to-batch consistency can be maintained in commercial manufacture.

III.D. Pharmacokinetics of Antibody/Drug Conjugates

The pharmacokinetics of 5T4-targeted immunoconjugates can be evaluated and compared to the pharmacokinetics of unconjugated calicheamicin in various animals. For example, this can be done following a single intravenous bolus administration in female nude mice, male Sprague-Dawley rats, and female cynomolgus monkeys. Pharmacokinetics of an anti-5T4 antibody are generally characterized by low clearance, low volume of distribution, and long apparent terminal half-life in various species. The serum concentrations of unconjugated calicheamicin derivatives are expected to be below the quantification limit. The toxicity profile for these conjugates in single-dose toxicity ranging studies is expected to be similar to that obtained for other antibody/calicheamicin conjugates at comparable doses.

IV. Functional Assays for Characterization of Anti-5T4 Antibodies and Antibody/Drug Conjugates

The present invention further discloses *in vitro* and *in vivo* assays to characterize activities of an anti-5T4 antibody, including 5T4 binding activity, cellular internalization following binding to 5T4 antigen presented on a cell surface, and targeting to 5T4-expressing cells in a subject. When conjugated to a cytotoxin, the disclosed antibodies of the invention may elicit anti-cancer activity, including inhibition of growth of 5T4-expressing cancer cells and/or induction of cell death in 5T4-expressing cells. Anti-5T4 antibodies of the invention may comprise one or more of the foregoing activities.

Techniques for detecting binding of anti-5T4 antibodies to 5T4 antigen are known in the art, including for example, BIACORE® assays as described in Example 2. Additional representative techniques include centrifugation, affinity chromatography and other immunochemical methods. See e.g., Manson (1992) Immunochemical Protocols, Humana Press, Totowa, New Jersey, United States of America; Ishikawa (1999) Ultrasensitive and Rapid Enzyme Immunoassay, Elsevier, Amsterdam/New York. Antigen binding assays may be performed using isolated 5T4 antigen or 5T4-expressing cells. See Example 2.

The binding specificity of anti-5T4 antibodies may be further described by definition of a binding epitope, *i.e.*, identification of residues, including nonadjacent residues that participate in antigen binding, and/or definition of residues that influence antigen binding. See Examples 4-5.

Internalization of anti-5T4 antibodies and antibody/drug conjugates by 5T4-expressing cells may be assayed by observing the amount of antibodies or conjugates bound to the surface of the 5T4-expressing cells over time. Representative techniques for assessing membrane localization of antibodies and antibody/drug conjugates are described in Example 3.

Functional assays also include methods for assessing anti-cancer activity of antibody/drug conjugates, for example, an ability to destroy existing cancer cells, or to delay or prevent growth of cancer cells. Cancers targeted by antibody/drug conjugates of the invention include both primary and metastasized tumors and carcinomas of any tissue in a subject, including carcinomas and hematopoietic malignancies such as leukemias and lymphomas.

Anti-5T4 antibodies having growth inhibitory activity can eliminate 5T4-expressing cells or to prevent or reduce proliferation of 5T4-expressing cells. Representative methods for rapid *in vitro* assessment of cell growth inhibition are described in Jones et al. (2001) *J. Immunol. Methods* 254:85-98.

Anti-5T4 antibodies may also comprise an ability to induce cell death, for example, programmed cell death characterized by nuclear DNA degradation, nuclear degeneration and condensation, loss of membrane integrity, and phagocytosis. Representative assays to assess cell are described in Hoves et al. (2003) *Methods* 31:127-34; Peng et al. (2002) *Chin. Med. Sci. J.* 17:17-21; Yasuhara et al. (2003) *J. Histochem. Cytochem.* 51:873-885.

For example, to assess the cytotoxicity of anti-5T4 antibody/calicheamicin conjugates *in vitro*, MDAMB435/5T4 cells (human breast carcinoma cells overexpressing human 5T4 antigen) and MDAMB435/neo cells (control cells) are cultured in the presence of antibody-calicheamicin conjugates or free calicheamicin, essentially as described by Boghaert et al. (2004), *Clin. Cancer Res.*, 10: 4538-4549. The cytotoxicity of each agent is reported as ED50 (ng/ml), which is the amount of calicheamicin given as conjugate or as free drug that causes 50% reduction of a cell culture relative to an untreated control. The number of cells in culture is determined using a vital dye (MTS) following drug exposure. See also Example 6.

The cytotoxicity of antibody/calicheamicin conjugates may also be assessed using MDAMB435/5T4 and MDAMB435/neo cells cultured in a manner suitable for spheroid growth. Cells are cultured in the presence of antibody/calicheamicin conjugates or free calicheamicin, and following drug exposure, the dimensions of each spheroid was determined. The efficiency of each of agent in inhibiting spheroid growth is reported as ED50 (ng/ml), *i.e.*, the amount of calicheamicin given as conjugate or as free drug that causes 50% inhibition of spheroid growth relative to an untreated control. See Example 6.

To assess the cytotoxicity of anti-5T4 antibody/calicheamicin conjugates *in vivo*, tumors are prepared in nude mice by subcutaneous injection of MDAMB435/5T4 cells (human breast carcinoma cells overexpressing human 5T4 antigen), NCI-H157 cells (human non-small cell lung cancer cells), PC14PE6 cells (human non-small cell lung cancer cells), or N87 cells (human gastric carcinoma cells). Antibody/calicheamicin conjugates and control compounds are administered to tumor-bearing mice, for example, by intraperitoneal injection in a total of 3 doses

given at 4-day intervals, e.g., on days 1, 5, and 9. Measurable therapeutic outcomes include inhibition of tumor cell growth.

To further assess the targeting ability of anti-5T4 antibody/calicheamicin conjugates, an orthotopic model for non-small cell and small cell cancer may be used, essentially as described by Onn et al. (2003) *Clin. Cancer Res.* 9(15):5532-5539. In brief, human lung adenocarcinoma (PC14PE6) cells are injected into tail veins of nude mice, which then migrate to form tumors in lung. Tumors may appear as solid nodules in the lung parenchyma and cause hemorrhagic pleural effusions containing suspended tumor cells. Control compounds and antibody/calicheamicin conjugates are administered to tumor-bearing mice, for example, by intraperitoneal injection beginning at 6 days after injection of tumor cells for a total of 3 doses given at 4-day intervals, e.g., on days 6, 10, and 14. Measurable therapeutic outcomes include reduced pleural effusions and increased survival.

V. Uses of Anti-5T4 Antibodies and Antibody/Drug Conjugates

The anti-5T4 antibodies and antibody/drug conjugates of the invention are useful both *in vitro* and *in vivo* for applications related to 5T4-expressing cells. Cancers expressing 5T4 include squamous/adenomatous lung carcinoma (non-small-cell lung carcinoma), invasive breast carcinoma, colorectal carcinoma, gastric carcinoma, squamous cervical carcinoma, invasive endometrial adenocarcinoma, invasive pancreas carcinoma, ovarian carcinoma, squamous vesical carcinoma, and choriocarcinoma. 5T4 is detected at high levels on carcinomas of bronchi, breast, colon, rectum, stomach, cervix, endometrium, pancreas, ovaria, chorium, and seminal vesicles.

V.A. *In Vitro* Applications

The present invention provides *in vitro* methods using anti-5T4 antibodies. For example, the disclosed antibodies may be used, either alone or in combination with cytotoxic agents or other drugs to specifically bind 5T4-positive cancer cells to deplete such cells from a cell sample. Methods are also provided for inducing apoptosis and/or inhibition of cell proliferation via contacting 5T4-expressing cells with an antibody/drug conjugate comprising an anti-5T4 antibody conjugated to a cytotoxin. Representative *in vitro* methods are described herein above under the

heading of "Functional Assays for Characterization of Anti-5T4 Antibodies and Antibody/Drug Conjugates."

Anti-5T4 antibodies of the invention also have utility in the detection of 5T4-positive cells *in vitro* based on their ability to specifically bind 5T4 antigen. A method for detecting 5T4-expressing cells may comprise: (a) preparing a biological sample comprising cells; (b) contacting an anti-5T4 antibody with the biological sample *in vitro*; and (c) detecting binding of anti-5T4 antibody. To facilitate detection, the antibody may be conjugated to a label.

V.B. *In Vivo* Detection and Diagnosis

Anti-5T4 antibodies of the invention may also be used for *in vivo* detection methods, for example, as useful for diagnosis, to provide intraoperative assistance, or for dose determination. Following administration of a labeled anti-5T4 antibody to a subject, and after a time sufficient for binding, the biodistribution of 5T4-expressing cells bound by the antibody may be visualized. The disclosed diagnostic methods may be used in combination with treatment methods. In addition, anti-5T4 antibodies of the invention may be administered for the dual purpose of detection and therapy.

Representative non-invasive detection methods include scintigraphy (e.g., SPECT (Single Photon Emission Computed Tomography), PET (Positron Emission Tomography), gamma camera imaging, and rectilinear scanning), magnetic resonance imaging (e.g., convention magnetic resonance imaging, magnetization transfer imaging (MTI), proton magnetic resonance spectroscopy (MRS), diffusion-weighted imaging (DWI) and functional MR imaging (fMRI)), and ultrasound.

V.C. Therapeutic Applications

The present invention further relates to methods and compositions useful for inducing cytotoxicity of 5T4-expressing cancer cells in a subject. The anti-5T4 antibody/drug conjugates of the invention are useful for inhibiting growth of cancerous cells and cells of a non-neoplastic proliferative disorder, such as hyperplasia, metaplasia, or most particularly, dysplasia (for review of such abnormal growth conditions, see DeVita, Jr. et al. (2001), Cancer: Principles and Practice, 6th edition, Lippincott Williams & Wilkins.

Cancers suitable for targeting using anti-5T4 antibody/drug conjugates include 5T4-expressing primary and metastatic tumors in breast, colon, rectum, lung, oropharynx, hypopharynx, esophagus, stomach, pancreas, liver, gallbladder, bile ducts, small intestine, urinary tract including kidney, bladder and urothelium, female genital tract, cervix, uterus, ovaries, male genital tract, prostate, seminal vesicles, testes, an endocrine gland, thyroid gland, adrenal gland, pituitary gland, skin, bone, soft tissues, blood vessels, brain, nerves, eyes, meninges. Other relevant cancers are 5T4-expressing leukemias and lymphomas (e.g., Hodgkin's lymphoma and non-Hodgkin's lymphoma), including indolent, aggressive, low-grade, intermediate-grade, or high-grade leukemia or lymphoma.

In particular, 5T4 is known to be expressed on cells of squamous/adenomatous lung carcinoma (non-small-cell lung carcinoma), invasive breast carcinoma, colorectal carcinoma, gastric carcinoma, squamous cervical carcinoma, *invasive endometrial adenocarcinoma*, *invasive pancreas carcinoma*, ovarian carcinoma, squamous vesical carcinoma, and choriocarcinoma. 5T4 is detected at high levels on carcinomas of bronchi, breast, colon, rectum, stomach, cervix, endometrium, pancreas, ovaria, chorion and seminal vesicles. The cell surface distribution of the 5T4 antigen may be homogeneous or heterogeneous. In colorectal carcinoma, gastric carcinoma, and ovarian carcinoma, expression of 5T4 is directly related to progression of the disease. In breast carcinoma, increased intensity of 5T4 staining on metastatic nodules is observed, however, 5T4 expression is not correlated with disease stage. The cancers may also express the Lewis Y carbohydrate antigen, including breast, colon, gastric, esophageal, pancreatic, duodenal, lung, bladder and renal carcinomas and gastric and islet cell neuroendocrine tumors. See U.S. Patent No. 6,310,185.

Thus, patients to be treated with the anti-5T4/drug conjugates of the invention may be selected based on biomarker expression, including but not limited to elevated expression of 5T4 antigen, resulting in a patient population selected for enriched target expression rather than tumor origin or histology. Target expression can be measured as a function of the number of cells staining combined with the intensity of the cells staining. For example, classification of high expression of 5T4 includes those patients with greater than 30% (*i.e.*, 40%, 50% or 60%) of the cells tested by immunohistochemical staining positive for 5T4 at a level of 3+ (on a scale

of 1 to 4), while moderate expression of the 5T4 can include those patients with greater than 20% of the cell cells staining at 1+ to 2+.

Biomarkers other than expression of 5T4 antigen can be also used for patient selection, including characterization of the tumor based on multi-drug resistance (MDR), for example. Nearly 50 per cent of human cancers are either completely resistant to chemotherapy or respond only transiently, after which they are no longer affected by commonly used anticancer drugs. This phenomenon is referred to as MDR and is inherently expressed by some tumor types; while others acquire MDR after exposure to chemotherapy treatment. The drug efflux pump P-glycoprotein mediates a majority of the MDR associated with cytotoxic chemotherapeutics. Phenotypic and functional analysis of MDR mechanisms present in cancer patient tumor specimens can be conducted in order to relate specific MDR mechanism(s) with resistance to chemotherapy in specific tumor types.

Cancer growth or abnormal proliferation refers to any one of a number of indices that suggest change within cells to a more developed cancer form or disease state. Inhibition of growth of cancer cells or cells of a non-neoplastic proliferative disorder may be assayed by methods known in the art, such as delayed tumor growth and inhibition of metastasis. Other indices for measuring inhibition of cancer growth include a decrease in cancer cell survival, a decrease in tumor volume or morphology (for example, as determined using computed tomographic (CT), sonography, or other imaging method), destruction of tumor vasculature, improved performance in delayed hypersensitivity skin test, an increase in the activity of cytolytic T-lymphocytes, and a decrease in levels of tumor-specific antigens.

While not intending to be bound by any single mode of operation, both antigen-guided targeting as well as passive targeting of anti-5T4 antibody/drug conjugates may contribute to anti-tumor efficacy. Antigen-guided targeting refers to the preferential movement and/or accumulation of a peptide or peptide analog in a target tissue (*i.e.*, a tissue comprising 5T4-expressing cells and intended site for accumulation of an anti-5T4/drug conjugate) as compared with a control tissue (*i.e.*, a tissue suspected to substantially lack 5T4-expressing cells and binding and/or accumulation of an administered anti-5T4/drug conjugate). Preferential localization of an antibody/drug conjugate is generally such that an amount of antibody/drug conjugate in a target tissue is about 2-fold greater than an amount of antibody/drug

conjugate in a control tissue, such as an amount that is about 5-fold or greater, or about 10-fold or greater.

Passive targeting generally refers to sequestering of antibodies or antibody/drug conjugates at a tumor site due to local changes in vasculature. For example, anti-5T4/drug conjugates may leave the vasculature at the tumor site, which is fenestrated due to increased VEGF production, bind to 5T4-expressing cells and trigger internalization of the anti-5T4/drug conjugate. Poor venous and lymphatic drainage of the tumor also result in sequestration of unbound anti-5T4/drug conjugates. Antibodies conjugated to drugs with acid labile linkers can release the drug, which then diffuses into tumor cells. The anti-tumor effects of passive targeting are not permanent or as potent as those induced by antigen-guided targeting, but may contribute to total efficacy.

V.D. Formulations

Anti-5T4 antibodies and anti-5T4/drug conjugates of the invention are readily prepared and formulated for safe and efficacious clinical use. Suitable formulations for administration to a subject include aqueous and non-aqueous sterile injection solutions which may contain anti-oxidants, buffers, bacteriostats, antibacterial and antifungal agents (e.g., parabens, chlorobutanol, phenol, ascorbic acid, and thimerosal), solutes that render the formulation isotonic with the bodily fluids of the intended recipient (e.g., sugars, salts, and polyalcohols), suspending agents and thickening agents. Suitable solvents include water, ethanol, polyol (e.g., glycerol, propylene glycol, and liquid polyethylene glycol), and mixtures thereof. The formulations may be presented in unit-dose or multi-dose containers, for example, sealed ampoules and vials, and may be stored in a frozen or freeze-dried (lyophilized) condition requiring only the addition of sterile liquid carrier immediately prior to use for administration to a subject or for subsequent radiolabeling with an isotope appropriate for the intended application. Anti-5T4 antibodies and antibody/drug conjugates of the invention are preferably formulated as an effective dose, described below.

As one example, a representative anti-5T4 antibody or anti-5T4/drug conjugate formulation comprises a multi-dose formulation of 40 mg/ml antibody or antibody/drug conjugate, 25 mM acetate, 150 mM trehalose, 0.9% benzyl alcohol, 0.02% polysorbate 20 at pH 5.0, and which has a minimum shelf life of two years

storage at 2-8°C. As another example, an anti-5T4 antibody or anti-5T4/drug conjugate formulation may comprise 10 mg/ml antibody or antibody/drug conjugate in 9.0 mg/ml sodium chloride, 7.35 mg/ml sodium citrate dihydrate, 0.7 mg/ml polysorbate 80, and sterile water, pH 6.5. Representative formulations of an anti-5T4/calicheamicin conjugate for administration to experimental mouse models include 2 µg or 4 µg calicheamicin (see Examples 3, 4, and 7), which may be scaled accordingly for administration to humans.

A stable lyophilized formulation of an anti-5T4 antibody or antibody/drug conjugate may be prepared by (a) dissolving an antibody/drug conjugate to a final concentration of 0.5 to 2 mg/ml in a solution comprising a cryoprotectant at a concentration of 1.5%-5% by weight, a polymeric bulking agent at a concentration of 0.5-1.5% by weight, electrolytes at a concentration 0.01 M to 0.1 M, a solubility facilitating agent at a concentration of 0.005% to 0.05% by weight, buffering agent at a concentration of 5-50 mM such that the final pH of the solution is 7.8-8.2, and water; (b) dispensing the above solution into vials at a temperature of +5°C to +10°C; (c) freezing the solution at a freezing temperature of -35°C to -50°C; (d) subjecting the frozen solution to an initial freeze drying step at a primary drying pressure of 20 to 80 microns at a shelf temperature at -10°C to -40°C for 24 to 78 hours; and (e) subjecting the freeze-dried product of step (d) to a secondary drying step at a drying pressure of 20 to 80 microns at a shelf temperature of +10°C to +35°C for 15 to 30 hours.

Representative cryoprotectants useful for lyophilization of the cryoprotectant include alditol, mannitol, sorbitol, inositol, polyethylene glycol, aldonic acid, uronic acid, aldaric acid, aldoses, ketoses, amino sugars, alditols, inositols, glyceraldehydes, arabinose, lyxose, pentose, ribose, xylose, galactose, glucose, hexose, idose, mannose, talose, heptose, glucose, fructose, gluconic acid, sorbitol, lactose, mannitol, methyl α -glucopyranoside, maltose, isoascorbic acid, ascorbic acid, lactone, sorbose, glucaric acid, erythrose, threose, arabinose, allose, altrose, gulose, idose, talose, erythrulose, ribulose, xylulose, psicose, tagatose, glucuronic acid, gluconic acid, glucaric acid, galacturonic acid, mannuronic acid, glucosamine, galactosamine, sucrose, trehalose, neuraminic acid, arabinans, fructans, fucans, galactans, galacturonans, glucans, mannans, xylans, levan, fucoidan, carrageenan, galactocarolose, pectins, pectic acids, amylose, pullulan, glycogen, amylopectin,

cellulose, dextran, pustulan, chitin, agarose, keratin, chondroitin, dermatan, hyaluronic acid, alginic acid, xanthan gum, starch, sucrose, glucose, lactose, trehalose, ethylene glycol, polyethylene glycol, polypropylene glycol, glycerol and pentaerythritol.

For example, the cryoprotectant sucrose may be used at a concentration of 1.5% by weight, the polymeric bulking agent Dextran 40 or hydroxyethyl starch 40 may be used at a concentration of 0.9% by weight, the electrolyte used in the lyophilization solution is sodium chloride, which is present at a concentration of 0.05 M, and the buffering agent tromethamine may be used at a concentration of 0.02 M. A solubility facilitating agent (e.g., a surfactant such as Polysorbate 80) may also be used during the lyophilization process. Usually this solubility facilitating agent is a surfactant. Representative steps for preparation of a lyophilized formulation include freezing the vials at a temperature of -45 °C; the frozen solution is subjected to an initial freeze drying step at a primary drying pressure of 60 microns and at a shelf temperature of -30°C for 60 hours; and subjecting the freeze-dried product to a secondary drying step at a drying pressure of 60 microns at a shelf temperature of +25°C for 24 hours.

Anti-5T4 antibodies and antibody/drug conjugates are formulated in a pharmaceutically acceptable carrier, for example, large slowly metabolized macromolecules such as proteins, polypeptides, liposomes, polysaccharides, polylactic acids, polyglycolic acids, polymeric amino acids, amino acid copolymers and inactive virus particles. Pharmaceutically acceptable salts may also be used, for example, mineral acid salts, such as hydrochlorides, hydrobromides, phosphates and sulfates, or salts of organic acids, such as acetates, propionates, malonates and benzoates. Formulations may additionally contain liquids such as water, saline, glycerol, and ethanol, and/or auxiliary substances, such as wetting or emulsifying agents or pH buffering substances, may be present in such compositions. Such carriers enable the compositions to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries and suspensions, for ingestion by the patient.

V.E. Dose and Administration

Anti-5T4 antibodies and anti-5T4/drug conjugates of the invention may be administered parenterally, for example, via intravascular, subcutaneous, intraperitoneal, or intramuscular administration. For delivery of compositions to

pulmonary pathways, compositions may be administered as an aerosol or coarse spray, *i.e.* transnasal administration. Intrathecal, intra medullary, or intraventricular administration may be used for treatment of central nervous system (CNS) cancers and CNS-related cancers. Anti-5T4 antibodies and anti-5T4/drug conjugates may also be administered transdermally, transcutaneously, topically, enterally, intravaginally, sublingually or rectally. Intravenous administration may be routinely used in the clinic. A delivery method is selected based on considerations such as the condition and site to be treated, the type of antibody formulation, and the therapeutic efficacy of the composition.

The present invention provides that an effective amount of an anti-5T4 antibody and anti-5T4/drug conjugate is administered to a subject, *i.e.*, an amount of an anti-5T4 antibody or anti-5T4/drug conjugate sufficient to elicit a desired biological response. For example, when administered to a cancer-bearing subject, an effective amount comprises an amount sufficient to elicit anti-cancer activity, including cancer cell cytotoxicity, inhibition of cancer cell proliferation, induction of cancer cell apoptosis, reduction of cancer cell antigens, delayed tumor growth, and/or inhibition of metastasis. Tumor shrinkage is well accepted as a clinical surrogate marker for efficacy. Another well accepted marker for efficacy is progression-free survival. Anti-5T4/calicheamicin conjugates generally demonstrate at least a 25% improvement in key efficacy parameters, such as improvement in median survival, time to tumor progression, and overall response rate.

Generally, an effective dose will be in the range from about 0.01 mg/m² to about 50 mg/m², such as from about 0.1 mg/m² to about 20 mg/m², or about 15 mg/m², which dose is calculated based on the amount of anti-5T4 antibody. An effective dose of an anti-5T4/drug conjugate may also be calculated based upon an amount of the conjugated drug. For example, representative doses of an anti-5T4/calicheamicin conjugate for administration to experimental mouse models include 2 µg or 4 µg calicheamicin, which may be scaled accordingly for administration to humans. For example, anti-5T4/calicheamicin conjugates of the invention may be administered to human patients once every 3 weeks for up to 6 cycles. For a radiolabeled anti-5T4 antibody, an effective dose is typically in the range from about 1 mCi to about 300 mCi, normally about 5 mCi to 100 mCi, depending on the radioisotope and the binding affinity of the antibody.

For detection of 5T4-positive cells using the disclosed anti-5T4 antibodies, a detectable amount of a composition of the invention is administered to a subject, *i.e.*, a dose of an anti-5T4 antibody such that the presence of the antibody may be determined *in vitro* or *in vivo*. For scintigraphic imaging using radioisotopes, typical doses of a radioisotope may include an activity of about 10 μ Ci to 50 mCi, or about 100 μ Ci to 25 mCi, or about 500 μ Ci to 20 mCi, or about 1 mCi to 10 mCi, or about 10 mCi.

Actual dosage levels of active ingredients in a composition of the invention may be varied so as to administer an amount of the composition that is effective to achieve the desired diagnostic or therapeutic outcome. Administration regimens may also be varied. A single injection or multiple injections may be used. The selected dosage level and regimen will depend upon a variety of factors including the activity and stability (*i.e.*, half life) of the therapeutic composition, formulation, the route of administration, combination with other drugs or treatments, the disease or disorder to be detected and/or treated, and the physical condition and prior medical history of the subject being treated.

For anti-5T4 antibodies and anti-5T4/drug conjugates of the invention, the therapeutically effective dose may be estimated initially either in cell culture assays or in animal models, such as rodents, rabbits, dogs, pigs, and/or primates. The animal model may also be used to determine the appropriate concentration range and route of administration. Such information may then be used to determine useful doses and routes for administration in humans. Typically, a minimal dose is administered, and the dose is escalated in the absence of dose-limiting cytotoxicity. Determination and adjustment of an effective amount or dose, as well as evaluation of when and how to make such adjustments, are known to those of ordinary skill in the art of medicine.

For combination therapies, anti-5T4 antibodies, anti-5T4/drug conjugates, and/or additional therapeutic or diagnostic agents are administered within any time frame suitable for performance of the intended therapy or diagnosis. Thus, the single agents may be administered substantially simultaneously (*i.e.*, as a single formulation or within minutes or hours) or consecutively in any order. For example, single agent treatments may be administered within about 1 year of each other, such as within about 10, 8, 6, 4, or 2 months, or within 4, 3, 2 or 1 week(s), or within about 5, 4, 3, 2 or 1 day(s).

For additional guidance regarding formulation, dose, administration regimen, and measurable therapeutic outcomes, see Berkow et al. (2000) The Merck Manual of Medical Information, Merck & Co., Inc., Whitehouse Station, New Jersey; Ebadi (1998) CRC Desk Reference of Clinical Pharmacology, CRC Press, Boca Raton, Florida; Gennaro (2000) Remington: The Science and Practice of Pharmacy, Lippincott, Williams & Wilkins, Philadelphia, Pennsylvania; Katzung (2001) Basic & Clinical Pharmacology, Lange Medical Books / McGraw-Hill Medical Pub. Div., New York; Hardman et al. (2001) Goodman & Gilman's the Pharmacological Basis of Therapeutics, The McGraw-Hill Companies, Columbus, Ohio; Speight & Holford (1997) Avery's Drug Treatment: A Guide to the Properties, Choices, Therapeutic Use and Economic Value of Drugs in Disease Management, Lippincott, Williams, & Wilkins, Philadelphia, Pennsylvania.

V.F. Combination Therapies

The disclosed anti-5T4 antibodies and anti-5T4/drug conjugates may be administered as an initial treatment, or for treatment of conditions that are unresponsive to conventional therapies. In addition, the anti-5T4 antibodies and anti-5T4/drug conjugates may be used in combination with other therapies (e.g., surgical excision, radiation, additional anti-cancer drugs etc.) to thereby elicit additive or potentiated therapeutic effects and/or reduce hepatocytotoxicity of some anti-cancer agents. Anti-5T4 antibodies and anti-5T4/drug conjugates of the invention may be co-administered or co-formulated with additional agents, or formulated for consecutive administration with additional agents in any order.

Representative agents useful for combination therapy include any of the drugs described herein above as useful for preparation of anti-5T4/drug conjugates. Anti-5T4 antibodies and anti-5T4/drug conjugates of the invention may also be used in combination with other therapeutic antibodies and antibody/drug conjugates, including anti-5T4 antibodies other than the disclosed anti-5T4 antibodies, as well as antibodies and conjugates targeting a different antigen. Representative antibodies, which may be used alone or as an antibody/drug conjugate, include anti-CD19 antibodies, anti-CD20 antibodies (e.g., RITUXAN®, ZEVALIN®, BEXXAR®), anti-CD22 antibodies, anti-CD33 antibodies (e.g., MYLOTARG®), anti-CD33 antibody/drug conjugates, anti-Lewis Y antibodies (e.g., Hu3S193, Mthu3S193, AGmthu3S193), anti-HER-2 antibodies (e.g., HERCEPTIN® (trastuzumab), MDX-

210, OMNITARG® (pertuzumab, rhuMAb 2C4)), anti-CD52 antibodies (e.g., CAMPATH®), anti-EGFR antibodies (e.g., ERBITUX® (cetuximab), ABX-EGF (panitumumab)), anti-VEGF antibodies (e.g., AVASTIN® (bevacizumab)), anti-DNA/histone complex antibodies (e.g., ch-TNT-1/b), anti-CEA antibodies (e.g., CEA-Cide, YMB-1003) hLM609, anti-CD47 antibodies (e.g., 6H9), anti-VEGFR2 (or kinase insert domain-containing receptor, KDR) antibodies (e.g., IMC-1C11), anti-Ep-CAM antibodies (e.g., ING-1), anti-FAP antibodies (e.g., sibrotuzumab), anti-DR4 antibodies (e.g., TRAIL-R), anti-progesterone receptor antibodies (e.g., 2C5), anti-CA19.9 antibodies (e.g., GIVAREX®) and anti-fibrin antibodies (e.g., MH-1).

Anti-5T4 antibody/drug conjugates may also be administered together with one or more combinations of cytotoxic agents as part of a treatment regimen. Useful cytotoxic preparations for this purpose include CHOPP (cyclophosphamide, doxorubicin, vincristine, prednisone and procarbazine); CHOP (cyclophosphamide, doxorubicin, vincristine, and prednisone); COP (cyclophosphamide, vincristine, prednisone); CAP-BOP (cyclophosphamide, doxorubicin, procarbazine, bleomycin, vincristine and prednisone); m-BACOD (methotrexate, bleomycin, doxorubicin, cyclophosphamide, vincristine, dexamethasone, and leucovorin; ProMACE-MOPP (prednisone, methotrexate, doxorubicin, cyclophosphamide, etoposide, leukovorin, mechloethamine, vincristine, prednisone and procarbazine); ProMACE-CytaBOM (prednisone, methotrexate, doxorubicin, cyclophosphamide, etoposide, leukovorin, cytarabine, bleomycin and vincristine); MACOP-B (methotrexate, doxorubicin, cyclophosphamide, vincristine, prednisone, bleomycin and leukovorin); MOPP (mechloethamine, vincristine, prednisone and procarbazine); ABVD (adriamycin/doxorubicin, bleomycin, vinblastine and dacarbazine); MOPP (mechloethamine, vincristine, prednisone and procarbazine) alternating with ABV (adriamycin/doxorubicin, bleomycin, vinblastine); MOPP (mechloethamine, vincristine, prednisone and procarbazine) alternating with ABVD(adriamycin/doxorubicin, bleomycin, vinblastine and dacarbazine); ChIVPP (chlorambucil, vinblastine, procarbazine, prednisone); IMVP-16 (ifosfamide, methotrexate, etoposide); MIME (methyl-gag, ifosfamide, methotrexate, etoposide); DHAP (dexamethasone, high-dose cytarabine and cisplatin); ESHAP (etoposide, methylprednisolone, HD cytarabine, and cisplatin); CEPP(B) (cyclophosphamide, etoposide, procarbazine, prednisone and bleomycin); CAMP (lomustine, mitoxantrone, cytarabine and prednisone); and CVP-1 (cyclophosphamide,

vincristine and prednisone); DHAP (cisplatin, high-dose cytarabine and dexamethasone); CAP (cyclophosphamide, doxorubicin, cisplatin); PV (cisplatin, vinblastine or vindesine); CE (carboplatin, etoposide); EP (etoposide, cisplatin); MVP (mitomycin, vinblastine or vindesine, cisplatin); PFL (cisplatin, 5-fluorouracil, leucovorin); IM (ifosfamide, mitomycin); IE (ifosfamide, etoposide); IP (ifosfamide, cisplatin); MIP (mitomycin, ifosfamide, cisplatin); ICE (ifosfamide, carboplatin, etoposide); PIE (cisplatin, ifosfamide, etoposide); Viorelbine and cisplatin; Carboplatin and paclitaxel; CAV (cyclophosphamide, doxorubicin, vincristine); CAE (cyclophosphamide, doxorubicin, etoposide); CAVE (cyclophosphamide, doxorubicin, vincristine, etoposide); EP (etoposide, cisplatin); and CMCCV (cyclophosphamide, methotrexate, lomustine, vincristine).

Anti-5T4 antibodies and anti-5T4/calicheamicin conjugates may be used in combination with systemic anti-cancer drugs, such as epithilones (BMS-247550, Epo-906), reformulations of taxanes (Abraxane, Xyotax), microtubulin inhibitors (MST-997, TTI-237), or with targeted cytotoxins such as CMD-193 and SGN-15. Additional useful anti-cancer agents include TAXOTERE®, TARCEVA®, GEMZAR® (gemcitabine), 5-FU, AVASTIN®, ERBITUX®, TROVAX®, anatumomab mafenatox, letrozole, docetaxel, and anthracyclines.

For combination therapies, an anti-5T4 antibody, anti-5T4/drug conjugate, and/or one or more additional therapeutic or diagnostic agents are administered within any time frame suitable for performance of the intended therapy or diagnosis. Thus, the single agents may be administered substantially simultaneously (*i.e.*, as a single formulation or within minutes or hours) or consecutively in any order. For example, single agent treatments may be administered within about 1 year of each other, such as within about 10, 8, 6, 4, or 2 months, or within 4, 3, 2 or 1 week(s), or within about 5, 4, 3, 2 or 1 day(s). The administration of an anti-5T4 antibody or anti-5T4/calicheamicin conjugate in combination with a second therapeutic agent preferably elicits a greater effect than administration of either alone.

EXAMPLES

The following examples have been included to illustrate modes of the invention. Certain aspects of the following examples are described in terms of techniques and procedures found or contemplated by the present co-inventors to work well in the practice of the invention. These examples illustrate standard

laboratory practices of the co-inventors. In light of the present disclosure and the general level of skill in the art, those of skill will appreciate that the following examples are intended to be exemplary only and that numerous changes, modifications, and alterations may be employed without departing from the scope of the invention.

EXAMPLE 1

Murine Anti-5T4 Antibodies

Anti-5T4 antibodies were prepared in mice using human 5T4 antigen and standard methods for immunization. Hybridoma cell lines producing the A1, A2, and A3 antibodies were produced by fusion of individual B cells with myeloma cells.

The A1, A2, and A3 anti-5T4 antibody heavy chain and light chain variable regions were cloned using the SMART® cDNA synthesis system (Clontech Laboratories Inc. of Mountain View, California) followed by PCR amplification. The cDNA was synthesized from 1 µg total RNA isolated from A1, A2, or A3 hybridoma cells, using oligo(dT) and the SMART® IIA oligo (Clontech Laboratories Inc.) with POWERSCRIPT™ reverse transcriptase (Clontech Laboratories Inc.). The cDNA was then amplified by PCR using a primer which anneals to the SMART® IIA oligo sequence and mouse constant region specific primer (mouse Kappa for the light chain, mouse IgG2a for the A1 heavy chain, mouse IgG2b for the A2 heavy chain, and mouse IgG1 for the A3 heavy chain) with VENT® polymerase (New England Biolabs Inc. of Ipswich, Massachusetts). Heavy chain and light chain variable region PCR products were subcloned into the pED6 expression vector and the nucleic acid sequence was determined. This method is advantageous in that no prior knowledge of the DNA sequence is required. In addition, the resultant DNA sequence is not altered by use of degenerate PCR primers.

The nucleotide sequences of the A1, A2, and A3 heavy chain variable regions are set forth as nucleotides 58-414 of SEQ ID NO:1, nucleotides 55-405 of SEQ ID NO:5, and nucleotides 58-423 of SEQ ID NO:9, respectively. The amino acid sequences of the A1, A2, and A3 heavy chain variable regions are set forth as residues 20-138 of SEQ ID NO:2, residues 19-135 of SEQ ID NO:6, and residues 20-141 of SEQ ID NO:10, respectively. The nucleotide sequences of the A1, A2, and A3 light chain variable regions are set forth as nucleotides 61-381 of SEQ ID

NO:3, nucleotides 67-390 of SEQ ID NO:7, and nucleotides 61-381 of SEQ ID NO:11, respectively. The amino acid sequences of the A1, A2, and A3 light chain variable regions are set forth as residues 21-127 of SEQ ID NO:4, residues 23-130 of SEQ ID NO:8, and residues 21-127 of SEQ ID NO:12, respectively. See also Figures 1A-1C.

To assess the novelty of the A1, A2, and A3 anti-5T4 variable region sequences, BLASTp searches (for protein query sequences) were conducted using default parameters of Expect=10, Word Size=3, a low complexity filter, and the BLOSUM62 matrix, permitting gap costs of existence=11, and extension=1. BLASTn searches (for nucleotide query sequences) were conducted using default parameters of Expect=10, Word Size=11, and a low complexity filter. BLAST search results are reported as a list of sequences related to the query sequence, ranked in order of E value, which is an indicator of the statistical significance of matches identified in the database. Sequences most closely related to the variable region sequences used for BLAST analysis are identified in Table 1 (BLASTn) and Table 2 (BLASTp).

Table 1
BLASTn Analysis

Query Sequence	Identity (%) of Closest Subject Sequence	Description of Closest Subject Sequence
A1 VH (SEQ ID NO:1)	97%	gi 31322165 gb AY169686.1 Mus musculus clone VGBC1.13 immunoglobulin heavy chain variable region precursor, gene, partial cds
A1 VL (SEQ ID NO:3)	96%	gi 804922 dbj D50385.1 MUSIKCVRJ Mus musculus mRNA for immunoglobulin kappa chain variable region, partial sequence, cell_line:K3F10
A2 VH (SEQ ID NO:5)	97%	gi 11612012 gb AF303853.1 AF303853 Mus musculus clone J558.22 immunoglobulin heavy chain variable region mRNA, partial cds
A2 VL (SEQ ID NO:7)	97%	gi 1556423 emb X79906.1 MMMABMST2 M.musculus mRNA for monoclonal antibody MST2 light chain
A3 VH (SEQ ID NO:9)	99%	gi 3420272 gb AF064445.1 AF064445 Mus musculus immunoglobulin heavy chain variable region (Vh10.2) gene, Vh10.2a allele, partial cds
A3 VL (SEQ ID NO:11)	98%	gi 2906107 gb AF045512.1 AF045512 Mus musculus 9E10 monoclonal antibody kappa light chain variable region, (IgK) mRNA, partial cds

Table 2
BLASTp Analysis

Query Sequence	Identity (%) of Closest Subject Sequence	Description of Closest Subject Sequence
A1 VH (SEQ ID NO:2)	84%	gi 15865327 emb CAC82228.1 immunoglobulin heavy chain [Mus musculus]
A1 VL (SEQ ID NO:4)	93%	gi 644862 gb AAA62143.1 anti-alpha 4 integrin immunoglobulin kappa chain V region
A2 VH (SEQ ID NO:6)	85%	gi 15149453 gb AAK85298.1 single chain antibody HFN7.1 [synthetic construct]
A2 VL (SEQ ID NO:8)	95%	gi 297678 emb CAA80086.1 immunoglobulin variable region [Mus musculus domesticus]
A3 VH (SEQ ID NO:10)	90%	gi 2906050 gb AAC04511.1 anti-poly(dC) monoclonal antibody heavy chain [Mus musculus]
A3 VL (SEQ ID NO:12)	97%	gi 2906108 gb AAC04540.1 monoclonal antibody kappa light chain [Mus musculus]

EXAMPLE 2

Binding Specificity and Affinity of Murine Anti-5T4 Antibodies

To assess the binding specificity and affinity of the A1, A2, and A3 antibodies, BIACORE® analysis was performed using human 5T4 antigen immobilized on a CM5 chip. BIACORE® technology utilizes changes in the refractive index at the surface layer upon binding of the antibody to the 5T4 antigen immobilized on the layer. Binding is detected by surface plasmon resonance (SPR) of laser light refracting from the surface. Analysis of the signal kinetics on rate and off rate allows discrimination between non-specific and specific interactions. The H8 anti-5T4 antibody was used as a control. H8 is a hybridoma-generated monoclonal mouse IgG1 antibody described in PCT International Publication No. WO 98/55607 and in Forsberg et al. (1997) *J. Biol. Chem.* 272(19):124430-12436.

Table 3
Results of BIACORE® Assay

Antibody	KD (M)	KA (1/M)	kd (1/s)	ka (1/Ms)
H8	4.1×10^{-10}	2.5×10^9	5.1×10^{-5}	1.3×10^5
A1	6.4×10^{-10}	1.6×10^9	1.3×10^{-4}	2.0×10^5
A2	1.5×10^{-8}	6.5×10^7	8.7×10^{-4}	5.6×10^4
A3	2.2×10^{-9}	4.6×10^8	5.2×10^{-5}	2.4×10^4

The BIACORE® results show that H8 and A1 antibodies have higher affinity for 5T4 when compared to the A2 and A3 antibodies. A2 is a relatively low affinity antibody. Unusual cysteines are present at residue 67 of the A1 heavy chain variable region and residue 91 of the A3 heavy chain variable region. Replacement of these residues with phenylalanine (A1) or tyrosine (A3) did not alter antibody binding properties or expression levels.

The binding affinity of the H8, A1, A2, and A3 antibodies was also assayed by Western blotting using CT26/5T4 cell lysates, which identified strong binding by H8, A1, and A3. See Figure 2.

The ability of the H8, A1, A2, and A3 antibodies to bind cells expressing 5T4 antigen was assayed using fluorescence activated cell sorting (FACS) of PC14PE6 cells. All antibodies showed specific binding to 5T4-expressing PC14PE6 cells, however, the level of A2 binding was significantly lower than that observed for H8, A1, and A3. See Table 4.

Table 4
Results of FACS Analysis

Antibody	Mean Cellular Flouresence
Control (secondary Ab)	4
Control (murine IgG)	4
H8	24
A1	18
A2	7
A3	27

To assess potential variability in antibody production, two independent preparations of A1 and H8 were tested. The binding and kinetic properties of each antibody, when compared from each preparation, were not significantly different. See Figures 3A-3B.

EXAMPLE 3

Internalization of Murine Anti-5T4 Antibodies by 5T4-Expressing Cells

To assess internalization of antibodies upon binding to 5T4 antigen, the amount of H8 and A1 antibodies detected at the cell surface versus in the supernatant was determined as a function of time. Non-enzymatically dissociated MDAMB435/5T4 cells (human breast cancer cells) were exposed to anti-5T4 antibodies for 1 hour at 4°C. Cells were washed and incubated in media at 37°C for 4 hours or 24 hours. The amount of antibody bound to cellular membranes versus unbound antibody (*i.e.*, presence in the supernatant) was determined using FACS. The disappearance of 5T4 antibodies from the surface of MDAMB435/5T4 cells demonstrates modulation of the 5T4 antigen/antibody complex at the cell surface, which may indicate internalization and/or dissociation. See Figures 4A-4C.

EXAMPLE 4

Epitope Mapping Using 5T4 Chimeras

To identify the epitopes to which each of the A1, A2, A3, and H8 antibodies bind, ELISA assays were performed using (1) 5T4 ectodomain Fc constructs with deleted or mutated sequences, and (2) 5T4 chimera constructs transiently expressed in COS-1 cells. The ectodomain includes the amino-terminal region, two leucine-rich repeats, and the intervening hydrophilic region. Fusion proteins containing a 5T4 ectodomain and a Fc constant regions from human IgG1 were prepared using mouse 5T4 (amino acids 1-361), rat 5T4 (amino acids 1-361), cynomolgus monkey 5T4 (amino acids 1-355), chimpanzee 5T4 (amino acids 1-355), and black-tailed marmoset (amino acids 1-355). The 5T4 chimera constructs are depicted in Figure 5. The binding results are summarized in Table 5, which indicates specific binding, partial binding, or lack of binding, by each of the H8, A1, A2, and A3 antibodies. Humanized H8 and chimeric A1, A2, and A3 antibodies showed binding properties similar to murine H8, A1, A2, and A3 respectively.

Based upon these results, it was determined that humanized H8 antibody binds to human 5T4 between residues 173 and 252. Humanized H8 binds to 5T4 with or without N-linked glycosylation at residue 344, which confirms that binding of humanized H8 to human 5T4 is not membrane proximal. The A1 antibody has a first contact with human 5T4 between residues 173 and 252 and a second contact with human 5T4 between residues 282 and 361. The A2 antibody binds human 5T4 between residues 282 and 361. The A3 antibody binds the first leucine-rich repeat region of human 5T4 between residues 83 through 163. The epitopes bound by each antibody are depicted in Figure 7.

Table 5
Results of Epitope Mapping Using 5T4 Ectodomain Fc Fusions
and Human/Mouse 5T4 Chimeras

5T4 antigen construct	Antibody			
	H8	A1	A2	A3
human 5T4 ectodomain Fc	+	+	+	+
mouse 5T4 ectodomain Fc	-	-	-	-
rat 5T4 ectodomain Fc	-	+/-	-	-
cynomolgus monkey 5T4 ectodomain Fc	-	+	+	+
chimpanzee 5T4 ectodomain Fc	+	+	+	+
black-tailed marmoset 5T4 ectodomain Fc	+/-	+	+	-
human/mouse 83-163	+	+	+	-
human/mouse 173-361	-	-	-	+
human/mouse 173-258	-	+/-	+	+
human/mouse 282-361 (with or without N-link at position 344)	+	+/-	-	+

(+) binding; (-) no binding; (+/-) partial binding

Based upon the different binding observed to 5T4 ectodomains from human and cynomolgus monkey, targeted mutations were made to distinguish residues that participate in antibody binding. Binding of humanized H8 antibody was assayed to each of the mutated 5T4 ectodomains noted in Table 6 below, i.e., human 5T4 ectodomains that include a residue from cynomolgus monkey at the indicated position. These results showed that residues 213 and 214 of human 5T4 antigen are required for the epitope bound by humanized H8.

Table 6
Results of Epitope Mapping Using Human 5T4 Ectodomain / Fc Fusion
With Targeted Mutations

mutation	humanized H8 binding
E189K	+
V200K	+
L204V	+
R213H	+/-
R213H and R214L	-

(+) binding; (-) no binding; (+/-) partial binding

In addition to direct binding assays, competitive binding assays were performed using biotinylated humanized H8 antibody and each of the A1, A2, or A3 antibodies. Inhibition of binding to human 5T4 was not observed, supporting that each of A1, A2, and A3 binds to a 5T4 epitope that is distinct from that bound by the H8 antibody. See Figures 6A-6.

EXAMPLE 5

Epitope Mapping Using BIACORE®

Epitope mapping of the H8, A1, A2, and A3 antibodies was also performed using BIACORE® using a CM5 chip with bound human 5T4 antigen. The chip was saturated with H8, A1, A2, or A3 antibody, and a first response was measured. The chip was then saturated with a second antibody from among the H8, A1, A2, and A3 antibodies, and a second response was measured. For multiple experiments, the chip was regenerated by dissociation of the bound antibodies in 10 mM glycine, pH 1.5, followed by a buffer wash. The results are summarized in Table 7 below. The percentages shown are the response units measured upon binding by a second antibody directly to the CM5 chip divided by the response units measured upon binding of the second antibody to a CM5 chip saturated with a first antibody. These results show that H8, A1, A2, and A3 each bind a distinct epitope on human 5T4.

The epitopes bound by the H8 and A3 antibodies are sterically close to each other such that the rate of association with antigen is decreased when binding of H8 is assayed in the presence of A3, and vice versa. Similar results were obtained using the chimeric and humanized H8, A1, A2, and A3 antibodies, which were prepared as described in Example 7 herein below. See Table 8.

Table 7
Results of Competition Assays Using BIACORE® --
Percentage Response of Second Antibody Following Saturation With First Antibody

2nd antibody	1 st antibody			
	H8	A1	A2	A3
H8	-----	114%	102%	85%
A1	109%	-----	109%	98%
A2	99%	98%	-----	94%
A3	73%	104%	106%	-----

Table 8
Results of Competition Assays Using BIACORE® --
Percentage of Second Antibody Bound Following Saturation With First Antibody

second antibody / first antibody bound	time after injection of second antibody (seconds)					
	19	37.5	75	150	300	600
humanized H8 / chimeric A3	44.9%	57.0%	69.1%	79.4%	86.6%	91.3%
chimeric A3 / humanized H8	46.2%	51.2%	58.4%	67.5%	76.2%	83.6%
chimeric A2 / chimeric A1	102.9%	93.5%	90.1%	89.0%	88.9%	89.1%
chimeric A1 / chimeric A2	92.5%	90.6%	91.4%	92.7%	93.9%	95.5%
chimeric A3 / chimeric A1	82.1%	82.0%	84.5%	87.8%	90.8%	92.8%
chimeric A1 / chimeric A3	98.8%	96.5%	97.0%	98.0%	98.8%	99.6%
chimeric A3 / chimeric A2	92.2%	88.6%	89.5%	91.5%	93.4%	94.6%
chimeric A2 / chimeric A3	89.2%	88.4%	89.8%	91.5%	92.9%	94.3%
humanized H8 / chimeric A1	93.2%	92.7%	94.2%	95.9%	96.9%	97.3%
chimeric A1 / humanized H8	92.7%	92.4%	93.8%	95.8%	97.3%	98.7%
humanized H8 / chimeric A2	93.8%	94.0%	96.0%	98.1%	99.8%	101.3%
chimeric A2 / humanized H8	86.9%	84.7%	86.9%	90.5%	93.7%	96.7%

The combined results of epitope mapping studies as determined using chimeric constructs (see Example 4) and BIACORE® are presented in Figure 7.

EXAMPLE 6

Efficacy of Anti-5T4/Calicheamicin Conjugates

A vital dye (MTS) staining was used to determine the number of surviving cells following exposure to various treatments. MTS (non-radioactive cell proliferation assay kit) was purchased from Promega (Madison, Wisconsin) and used according to the manufacturer's specifications. For each cell line a calibration curve (cell number versus optical density after 2 hours) was established to estimate an appropriate initial seeding density. Cells were then seeded in 96-multiwell dishes at a density of 750 to 5,000 cells per well. Immediately after seeding, the cells were exposed to various concentrations (0, 0.01, 0.05, 0.1, 1, 10, 100 and 500 ng calicheamicin equivalents/ml) of calicheamicin, CMA-676 and calicheamicin conjugates of anti-5T4 antibodies. Following determination of the number of cells surviving 96 hours of drug-exposure, the ED₅₀ was calculated based on the logistic regression parameters derived from the dose-response curves. The ED₅₀ was defined as the concentration of drug (CalichDMH) that caused a 50% reduction of the cell number after 96 hours exposure to the drug. A calicheamicin equivalent (cal. eq.) is the concentration of calicheamicin given either as a pure substance or as a conjugate. Depending on the amount of calicheamicin bound to the antibody (antibody drug loading), calicheamicin equivalents which are different may indicate different protein concentrations.

The results of MTS assays are shown in Table 9. Antibody/calicheamicin conjugates prepared using the A1 and A3 anti-5T4 assays substantially reduced viability of MDAMB435/5T4 cells. Selectivity values were calculated by comparing the specific activity of the conjugate to the non-specific activity. That is, fold CalichDMH for the 5T4 expressing cells were divided by the fold CalichDMN values for cells not expressing 5T4. When a non-specific antibody is used, for example hp67.6 (CMA-676), the fold CalichDMH values are approximately the same such that the selectivity is 1.

Table 9
Results of MTS Assays

Treatment	cell line	
	MDAMB435/neo ED50 (ng/ml)	MDAMB435/5T4 ED50 (ng/ml)
CalichDMH	3.3 - 5.0	5.0 - 8.0
huH8-ActBut-CalichDMH	0.4 - 0.8	0.08 - 0.1
CMA-676	34 - 60	50 - 100
A1-ActBut-CalichDMH	22 - 34	0.4 - 0.6
A2-ActBut-CalichDMH	60	40
A3-ActBut-CalichDMH	20 - 20	0.3 - 20

treatment	cell line	
	MDAMB435/neo Fold CalichDMH	MDAMB435/5T4 Fold CalichDMH
CalichDMH	1.0 - 1.0	1.0 - 1.0
huH8-ActBut-CalichDMH	4.0 - 12.5	50 - 100
CMA-676	0.08 - 0.1	0.08 - 0.1
A1-ActBut-CalichDMH	0.14 - 0.15	13 - 13
A2-ActBut-CalichDMH	0.06	0.13
A3-ActBut-CalichDMH	0.17 - 0.25	0.4 - 17

Selectivity: H8=8; hP67.6=1; A1=93; A3=1.6

CalichDMH, unconjugated calicheamicin

huH8-AcBut-CalichDMH, humanized H8 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut)

CMA-676, anti-CD33/calicheamicin conjugate

A1-AcBut-CalichDMH, A1 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut)

A2-AcBut-CalichDMH, A2 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut)

A3-AcBut-CalichDMH, A3 antibody conjugated to calicheamicin using 4-(4'-acetylphenoxy)butanoic acid (AcBut)

The cytotoxicity of anti-5T4/calicheamicin conjugates was also assayed using a three-dimensional spheroid cell culture that more closely approximates an *in vivo* cellular environment. Spheroids were made essentially according to Yuhas et al.

(1977) *Cancer Res.* 37:3639-3643. Briefly, 10^5 cells in 5 ml of culture medium were seeded on 60 mm polystyrene cell culture dishes previously coated with 5 ml 0.65 % tissue culture grade agar in culture medium (Sigma of St. Louis, Missouri). The dishes were incubated for 5-6 days at 37 °C and in 5% CO₂ in air. Spheroids with a diameter of 0.2 mm were selected and placed in a 24-well multiwell dish. Each well contained 0.5 ml agar underlay, 1 spheroid, and 1 ml culture medium overlay. The spheroids were then exposed to various concentrations (0, 0.091, 0.365, 1.46, 5.86, 23.44, 93.75 and 375 ng calicheamicin equivalents/ml) of calicheamicin, CMA-676 and anti-5T4/calicheamicin conjugates prepared using the A1 and A3 anti-5T4 antibodies and an AcBut linker. Both anti-5T4/calicheamicin conjugates significantly inhibited growth of MDAMB435/5T4 cells. See Figure 8.

EXAMPLE 7

Preparation and Binding Properties

of Chimeric and Humanized Anti-5T4 Antibodies

Chimeric H8, A1, A2, and A3 antibodies were constructed having murine H8 heavy chain and light chain variable regions sequences and human IgG4 heavy chain constant regions and human kappa light chain constant regions. The cysteine present at position 67 of the A1 heavy chain variable region was optionally changed to phenylalanine, and the cysteine present at position 91 of the A3 heavy chain variable region was optionally changed to tyrosine. These variants are set for in SEQ ID NO:2 (A1 VH) and SEQ ID NO:10 (A3 VH). The presence or absence of intronic sequences and the replacement of cysteine residues did not affect antibody expression. For cloning of sequences encoding IgG constant regions, intronic sequences were optionally deleted.

Humanized H8 was prepared as described in PCT International Publication No. WO 2006/031653. Humanized A1 antibodies were prepared by CDR grafting as described further herein below. The CDRs of the murine A1, A2, and A3 antibodies were identified using the AbM definition, which is based on sequence variability as well as the location of the structural loop regions. In general, human acceptor frameworks were selected on the basis that they are substantially similar to the framework regions of the murine antibodies, or which were most similar to the

consensus sequence of the variable region subfamily. Consideration was also given to representation of the framework loci in humans, such that widely represented sequences were generally preferred over less populous sequences. Additional mutations of the human framework acceptor sequences were made to restore murine residues believed to be involved in antigen contacts and/or residues involved in the structural integrity of the antigen-binding site. The amino acid sequence may also be optimized for codon preference of CHO cells and to remove restriction enzyme sites. A peptide structure prediction program may be used to analyze the humanized variable heavy and light region sequences to identify and avoid post-translational protein modification sites introduced by the humanization design.

A humanized A1 heavy chain variable region (A1 VH version 1.0) was constructed to include the CDRs of murine A1 grafted onto a human DP-21 framework region (VH7 subgroup, Accession No.CAA43346, SEQ ID NO:88), which contains a framework mutation (S82A) and one backmutation (E46K). Variants were prepared by removing the backmutation (A1 VH versions 1.1 and 1.2). A second humanized A1 heavy chain variable region was prepared by grafting A1 CDRs onto a human DP-54 germline framework region (A1 VH version 2.0). Six (6) backmutations were made to produce A1 VH version 2.1. As described further below, both A1 heavy chain variable regions retained 5T4 binding properties. The DP-21 and DP-54 framework regions show 63% amino acid sequence identity over their length, indicating that numerous amino acid changes may be made to while preserving the binding specificity of the antibody, including the ability to bind to a particular epitope. The similarity of humanized A1 heavy chain variable regions is shown in Table 10. Representative nucleotide sequences encoding humanized A1 heavy chain variable regions are set forth as SEQ ID NOs:48, 50, 53, and 55. Representative amino acid sequences of humanized A1 heavy chain variable regions are set forth as SEQ ID NOs:49, 51, 52, 54, and 56. See *also* Figures 9A-9B.

A humanized A1 light chain variable region was constructed to include the CDRs of murine A1 grafted onto human DPK24 (VKIV subgroup), DPK9 (VKI subgroup) , and DPK23 (VKIII subgroup) germline framework regions. After incorporation of a S67Y backmutation into humanized A1 light chain variable region frameworks prepared with each of these frameworks demonstrated 5T4 binding. See *below*, including Table 13. The DPK24 framework region shows 74% and 73%

amino acid sequence identity over its length to DPK9 and DPK23, respectively. The DPK9 framework region shows 74% amino acid sequence identity over its length to DPK23. The similarity of humanized A1 light chain variable regions is shown in Table 10. The multiple versions of humanized light chain variable framework regions demonstrate that numerous amino acid changes may be made to while preserving the binding specificity of the antibody, including the ability to bind to a particular epitope. Representative nucleotide sequences encoding humanized A1 light chain variable regions are set forth as SEQ ID NOs:57, 59, 61, 63, 65, 67, 69, 71, 73, and 75. Representative amino acid sequences of humanized A1 light chain variable regions are set forth as SEQ ID NOs:58, 60, 62, 64, 66, 68, 70, 72, 74, and 76. See *also* Figures 9C-9F.

Table 10
Relatedness of Humanized A1 Antibodies

1 st Variable Region / 2 nd Variable Region	Percentage Identity
HuA1 VL v1.1 (SEQ ID NO:60) / HuA1 VL v2.4 protein (SEQ ID NO:70)	86%
HuA1 VL v1.1 (SEQ ID NO:60) / HuA1 VL v3.1 protein (SEQ ID NO:75)	86%
HuA1 VL v2.4 protein (SEQ ID NO:70) / HuA1 VL v3.1 protein (SEQ ID NO:75)	85%
HuA1 VH v1.1 protein (SEQ ID NO:52) / HuA1 VH v2.0 protein (SEQ ID NO:54)	78%

Humanized A2 and A3 antibodies were designed using a similar strategy. Representative amino acid sequences of humanized A2 heavy chain variable regions and humanized A2 light chain variable regions are set forth as SEQ ID NOs:77-78 and SEQ ID NOs:79-80, respectively. See *also* Figure 9G. Representative amino acid sequences of humanized A3 heavy chain variable regions and humanized A3 light chain variable regions are set forth as SEQ ID NOs:81-82 and SEQ ID NOs:83-84, respectively. See *also* Figure 9H.

To assess the novelty of humanized A1, A2, and A3 heavy chain and light chain variable regions, BLASTn and BLASTp analysis was performed as described in Example 1. The results are presented in Table 11.

Table 11
BLASTn and BLASTp Analysis

Query Sequence	Identity (%) of Closest Subject Sequence	Description of Closest Subject Sequence
Humanized A1 VL version 1.1 DNA (SEQ ID NO:59)	83%*	DEFINITION Homo sapiens partial mRNA for immunoglobulin kappa chain variable region (IGKV2 gene). ACCESSION AM040532
Humanized A1 VL version 1.1 protein (SEQ ID NO:60)	82%	DEFINITION Ig kappa chain V-IV region B17 precursor. ACCESSION P06314
Humanized A1 VL version 2.4 DNA (SEQ ID NO:69)	85%*	DEFINITION Homo sapiens clone SC4064 anti-rabies virus immunoglobulin light chain variable region mRNA, complete cds. ACCESSION AY942044
Humanized A1 VL version 2.4 protein (SEQ ID NO:70)	92%	DEFINITION anti-alpha 4 integrin humanized immunoglobulin kappa chain V region. ACCESSION AAA62146
Humanized A1 VL version 3.1 DNA (SEQ ID NO:75)	84%*	DEFINITION Homo sapiens clone 136e06 anti-tetanus toxoid immunoglobulin light chain variable region (IGL@) mRNA, partial cds. ACCESSION AY867377
Humanized A1 VL version 3.1 protein (SEQ ID NO:76)	84%	DEFINITION anti-Burkholderia mallei scFv antibody [synthetic construct]. ACCESSION ABI97018
Humanized A1 VH version 1.1 DNA (SEQ ID NO:50)	88%*	DEFINITION Homo sapiens ID:CLL097 IgA heavy chain variable region mRNA, partial cds. ACCESSION AF021940
Humanized A1 VH version 1.1 protein (SEQ ID NO:51)	90%	DEFINITION IgA heavy chain variable region [Homo sapiens]. ACCESSION AAC09074
Humanized A1 VH version 2.0 DNA (SEQ ID NO:53)	81%*	DEFINITION Homo sapiens clone 23u-45 immunoglobulin heavy chain variable region (IGH) mRNA, partial cds. ACCESSION AF062241

Table 11 Continued
BLASTn and BLASTp Analysis

Humanized A1 VH version 2.0 protein (SEQ ID NO:54)	77%	DEFINITION Chain D, Insights Into Erbb Signaling From The Structure Of The Erbb2-Pertuzumab Complex. ACCESSION 1S78_D
Humanized A2 VL version 1.0 protein (SEQ ID NO:79)	87%	DEFINITION Chain A, Crystal Structure Of The Fab Fragment Of A Human Monoclonal Igm Cold Agglutinin. ACCESSION 1QLR_A
Humanized A2 VL version 2.0 protein (SEQ ID NO:80)	83%	DEFINITION kappa 1 immunoglobulin light chain [Homo sapiens]. ACCESSION AAD29608
Humanized A2 VH version 1.0 protein (SEQ ID NO:77)	88%	DEFINITION Chain A, The Crystal Structure Of A Humanized Antibody Fv 528. ACCESSION 1WT5_A
Humanized A2 VH version 2.0 protein (SEQ ID NO:78)	78%	DEFINITION Chain D, Insights Into Erbb Signaling From The Structure Of The Erbb2-Pertuzumab Complex. ACCESSION 1S78_D
Humanized A3 VL version 1.0 protein (SEQ ID NO:83)	85%	DEFINITION immunoglobulin kappa light chain VLJ region [Homo sapiens]. ACCESSION BAC01708
Humanized A3 VL version 2.0 protein (SEQ ID NO:84)	90%	DEFINITION HerMel [synthetic construct]. ACCESSION CAL47329
Humanized A3 VH version 1.0 protein (SEQ ID NO:81)	79%	DEFINITION Igh-1a protein [Mus musculus]. ACCESSION AAH80671
Humanized A3 VH version 2.0 protein (SEQ ID NO:82)	77%	DEFINITION Igh-1a protein [Mus musculus]. ACCESSION AAH80671

* When Query Coverage = 100%

Figures 10A-10B show additional heavy chain variable region sequences that may be used as frameworks for preparation of humanized A1, A2, and A3 anti-5T4 antibodies. Figures 11-13 show additional light chain variable region sequences that may be used as a framework for preparation of humanized A1, A2, and A3 anti-5T4 antibodies. Figure 14 shows representative constant regions that may be used for the preparation of chimeric and humanized A1, A2, and A3 anti-5T4 antibodies.

To assess the binding specificity and affinity of the chimeric and humanized H8, A1, A2, and A3 antibodies, BIACORE® analysis was performed using human 5T4 antigen immobilized on a CM5 chip. See Example 2. The results for chimeric A1, A2, and A3 antibodies are shown in Table 12 below.

Table 12
Results of BIACORE® Assay

Antibody	KD (M)	KA (1/M)	kd (1/s)	ka (1/Ms)
Humanized H8	1.5×10^{-10}	6.5×10^9	4.0×10^{-5}	2.6×10^5
Chimeric A1	4.4×10^{-10}	2.3×10^9	6.7×10^{-5}	1.5×10^5
Chimeric A2	1.8×10^{-9}	5.7×10^8	2.5×10^{-4}	1.4×10^5
Chimeric A3	$\sim 1.8 \times 10^{-10}$	$\sim 5.4 \times 10^9$	$\sim 1.0 \times 10^{-5}$	$\sim 5.4 \times 10^4$
Chimeric A1 + C67F	3.8×10^{-10}	2.6×10^9	6.3×10^{-5}	1.7×10^5
Chimeric A3 + C91Y	5.9×10^{-9}	1.7×10^9	1.6×10^{-5}	2.7×10^4

In general, chimerization/humanization increased the affinity of H8, A1, A2, and A3 to human 5T4. Compare Table 3. The increase in binding affinities appears to result primarily from a slower dissociation of the antibody and antigen rather than a faster association. The chimeric A2 and A3 antibodies showed the most improved binding properties following chimerization.

All humanized A1 heavy chain variable regions retained 5T4 binding properties. In addition, removal of the K46 backmutation from humanized A1 heavy chain variable region did not affect 5T4 binding properties. Humanized A1 light chain variable regions showed compromised 5T4 binding properties. Humanized A1 light chain variable regions constructed using DPK9 and DPK23 frameworks bound 5T4 with higher affinity than a humanized A1 light chain variable regions constructed

using DPK24 frameworks. Backmutations were incorporated to restore and/or optimize 5T4 binding. Replacement of the serine residue at position 67 with a tyrosine residue, as seen in the murine A1 framework region, completely restored 5T4 antigen binding properties. See Table 13.

Table 13

Inhibition of Biotinylated Chimeric A1 Antibody Binding to Human 5T4 by ELISA

Version A1 Antibody	IC ₅₀
Chimeric A1	16-20 nM
huA1 V _H v2.0 + huA1 V _L v1.1	>1 μ M
huA1 V _H v2.0 + huA1 V _L v1.1	28 nM
huA1 V _H v2.0 + huA1 V _L v2.0	>1 μ M
huA1 V _H v2.0 + huA1 V _L v2.4	16 nM
huA1 V _H v2.0 + huA1 V _L v3.0	>1 μ M
huA1 V _H v2.0 + huA1 V _L v3.1	27 nM

huA1, humanized A1
v, version

EXAMPLE 8

Species Cross-Reactivity of Anti-5T4 Antibodies

The cross-species reactivity of anti-5T4 antibodies disclosed herein was assayed to determine relevant species for *in vivo* efficacy studies and toxicology analysis. Correlation of binding activity and relatedness of the different 5T4 ectodomains was also used to further describe the epitope bound by each antibody. Binding assays were performed using 5T4 ectodomains from various species fused to human IgG1 Fc. The percentage identity of each ectodomain region to human 5T4 is shown in Table 14.

Table 14
Relatedness of 5T4 From Different Species

Species	Percentage Identity to Human 5T4	Amino Acids of Ectodomain
Human	100	1-355
Mouse	84.0	1-361 ^a
Rat	83.1	1-361 ^a
Chimpanzee (partial sequence – 396/420 amino acids)	~ 99.5	1-355
Cynomolgus Monkey	96.7	1-355
Black-Tailed Marmoset (partial sequence – 367/420 amino acids)	~94.6	1-355
Dog	87.9	1-355
Cow	86.9	1-355

^a Contains 6 amino acid direct repeat within hydrophilic domain

The full-length or partial sequences of 5T4 from human, mouse, rat, dog, and cow have been disclosed previously as GenBank Accession Nos. Z29083 (human, SEQ ID NO:87), AJ012160 (mouse), BC087011 (rat), XM539020 (dog), and XM593502 (cow). A virtual partial sequence of chimpanzee 5T4 was generated using an alignment of mRNA and genomic sequences. Nucleic acids encoding 5T4 proteins were isolated from **cynomolgus** monkey and black-tailed marmoset. The amino acid sequences of these additional 5T4 antigens are shown in Figure 15 and are also set forth as SEQ ID NO:86 (**cynomolgus** monkey) and SEQ ID NO:85 (black-tailed marmoset).

To assess the novelty of **cynomolgus** monkey and black-tailed marmoset sequences, BLAST analyses were performed as described in Example 2. When

using the full-length black-tailed marmoset 5T4 amino acid sequence as a query sequence, the closest subject sequence was identified as human 5T4 (GenBank Accession No. NP_006661.1), with 94% identity (302/320 amino acids). The sequences also differed at the carboxyl terminus, with amino acids 1-19 of SEQ ID NO:85 not aligning with the closest subject sequence. When using the full-length cynomolgus monkey 5T4 amino acid sequence as a query sequence, the closest non-virtual subject sequence was identified as a trophoblast glycoprotein precursor also from cynomolgus monkey (GenBank Accession No. BAE00432.1), with 99% identity (364/366 amino acids). The sequences also differed at the carboxyl terminus, with amino acids 1-25 of SEQ ID NO:86 not aligning with the closest non-virtual subject sequence.

To assay binding of anti-5T4 antibodies, 5T4 ectodomain/Fc fusion proteins were transiently transfected into COS-1 cells, and ELISA assays were performed. Non-relevant human IgG4 and IgG1 antibodies were used as controls. The cross-species reactivity of anti-5T4 antibodies is summarized in Table 15.

Table 15
Cross-Reactivity of Anti-5T4 Antibodies (ED50 in nM)

	huH8 γ 4	huH8 γ 1	ChiA1 γ 4	ChiA2 γ 4	ChiA3 γ 4
human	0.19	0.20	0.28	0.21	0.20
chimpanzee	0.19	0.22	0.27	0.22	0.20
black-tailed marmoset	+/-	+/-	0.24	0.22	-
cynomolgus monkey	-	-	0.18	0.18	0.23
rat	-	-	+/-	-	-
mouse	-	-	-	-	-

huH8 γ 4, humanized H8 antibody having IgG4 constant regions

huH8 γ 1, humanized H8 antibody having IgG1 constant regions

ChiA1 γ 4, chimeric A1 antibody having IgG4 constant regions

ChiA2 γ 4, chimeric A2 antibody having IgG4 constant regions

ChiA3 γ 4, chimeric A3 antibody having IgG4 constant regions

(+/-), partial binding

(-), no binding

Claims:

1. An isolated antibody, or fragment thereof, that specifically binds human 5T4 antigen, wherein the antibody or antibody fragment comprises an antigen binding domain of, competes for 5T4 binding with, or binds a 5T4 epitope bound by, an antibody comprising a heavy chain variable region having an amino acid sequence set forth as SEQ ID NO:2 and a light chain variable region having an amino acid sequence set forth as SEQ ID NO:4.
2. The antibody of claim 1, which is a chimeric antibody, a humanized antibody, a single chain antibody, a Fab fragment, a F(ab)₂ fragment, a Fv fragment, a tetrameric antibody, a tetravalent antibody, a multispecific antibody, or a fusion protein.
3. The antibody of claim 1, which is a murine monoclonal antibody.
4. The antibody of claim 1, which has a binding affinity for human 5T4 antigen of at least about 1×10^{-7} to about 1×10^{-12} M.
5. The antibody of claim 1, which specifically targets 5T4-expressing cells in vivo.
6. The antibody of claim 3, wherein the murine monoclonal antibody comprises a heavy chain variable region comprising an amino acid sequence of residues 20-138 of SEQ ID NO:2.
7. The antibody of claim 3, wherein the murine monoclonal antibody comprises a light chain variable region comprising an amino acid sequence of residues 21-127 of SEQ ID NO:4.
8. The antibody of claim 3, wherein the murine monoclonal antibody comprises a heavy chain variable region comprising an amino acid sequence of residues 20-138 of SEQ ID NO:2, and wherein the light chain variable region of the murine monoclonal antibody comprises an amino acid sequence of residues 21-127 of SEQ ID NO:4.
9. The antibody of claim 2, which is a chimeric or humanized anti-5T4 antibody.
10. The chimeric or humanized antibody of claim 9, which comprises human constant regions.

11. The chimeric or humanized antibody of claim 10, which comprises a human kappa light chain constant region.
12. The chimeric or humanized antibody of claim 10, which comprises a human IgG1, IgG2, IgG3, or IgG4 heavy chain constant region.
13. The chimeric or humanized antibody of claim 12, wherein the human IgG4 heavy chain constant region comprises proline at position 241.
14. The humanized antibody of claim 9, which comprises at least one light chain variable region and at least one heavy chain variable region comprising,

framework regions comprising human residues of a human antibody framework region; and wherein the at least one light chain variable region comprises three CDRs of SEQ ID NO:4.
15. The humanized antibody of claim 14, wherein the human residues are human framework residues selected from the group consisting of:
 - (a) a human antibody heavy chain framework region of any one of SEQ ID NOs:14-23, 77, and 88-93;
 - (b) a human antibody light chain framework region of any one of SEQ ID NOs:28-34, 35-44, and 94-99;
 - (c) a consensus sequence of a heavy chain framework region of (a); and
 - (d) a framework region that is at least 63% identical to a framework region of (a)-(c).
16. The humanized antibody of claim 14, wherein the at least one heavy chain of the humanized antibody comprises a variable region comprising three CDRs of SEQ ID NO:2.
17. The chimeric or humanized antibody of claim 9, which comprises a heavy chain variable region sequence comprising:
 - (a) an amino acid sequence of residues 20-138 of SEQ ID NO:2; or
 - (b) an amino acid sequence of any one of SEQ ID NOs: 49, 51, 52, 54, or 56.
18. The chimeric or humanized antibody of claim 9, which comprises a light chain variable region sequence comprising:

- (a) an amino acid sequence of residues 21-127 of SEQ ID NO:4; or
 - (b) an amino acid sequence of any one of SEQ ID NOs: 58, 60, 62, 64, 66, 68, 70, 72, 74, or 76.
19. An antibody/drug conjugate for drug delivery comprising:
- (a) an antibody according to claim 1; and
 - (b) a drug, which is directly or indirectly bound to the antibody.
20. The antibody/drug conjugate of claim 19, wherein the drug is a therapeutic agent selected from the group consisting of a cytotoxin, a radioisotope, an immunomodulatory agent, an anti-angiogenic agent, an anti-proliferative agent, a pro-apoptotic agent, a chemotherapeutic agent, and a therapeutic nucleic acid.
21. The antibody/drug conjugate of claim 20, wherein the therapeutic agent is a cytotoxin.
22. The antibody/drug conjugate of claim 20, wherein the cytotoxin is an antibiotic, an inhibitor of tubulin polymerization, an alkylating agent, a protein synthesis inhibitor, a protein kinase inhibitor, a phosphatase inhibitor, a topoisomerase inhibitor, or an enzyme.
23. The antibody/drug conjugate of claim 20, wherein the cytotoxin is an antibiotic.
24. The antibody/drug conjugate of claim 23, wherein the antibiotic is calicheamicin.
25. The antibody/drug conjugate of claim 24, wherein the calicheamicin is an N-acetyl derivative or disulfide analog of calicheamicin.
26. The antibody/drug conjugate of claim 25, wherein the calicheamicin is N-acetyl- α -calicheamicin.
27. The antibody/drug conjugate of claim 19, wherein the drug is bound to the antibody via a linker.
28. The antibody/drug conjugate of claim 27, wherein the linker is selected from the group consisting of 4-(4'-acetylphenoxy)butanoic acid (AcBut), 3-acetylphenyl acidic acid (AcPac), 4-mercapto-4-methyl-pentanoic acid (Amide), and derivatives thereof.
29. An isolated antibody that specifically binds to a human 5T4 epitope comprising residues 173-252 and 276-355 of SEQ ID NO:87.

30. The chimeric or humanized antibody of claim 9, which comprises:
- (a) a light chain variable region comprising an amino acid sequence selected from the group consisting of an amino acid sequence of residues 21-127 of SEQ ID NO:4 and any one of SEQ ID NOs: 58, 60, 62, 64, 66, 68, 70, 72, 74, or 76; and
 - (b) a heavy chain variable region comprising an amino acid sequence selected from the group consisting of residues 20-138 of SEQ ID NO:2 and any one of SEQ ID NOs: 49, 51, 52, 54, or 56.
31. The chimeric or humanized antibody of claim 9, which comprises:
- (a) a light chain variable region comprising an amino acid sequence of SEQ ID NO: 70; and
 - (b) a heavy chain variable region comprising an amino acid sequence of SEQ ID NO: 54.