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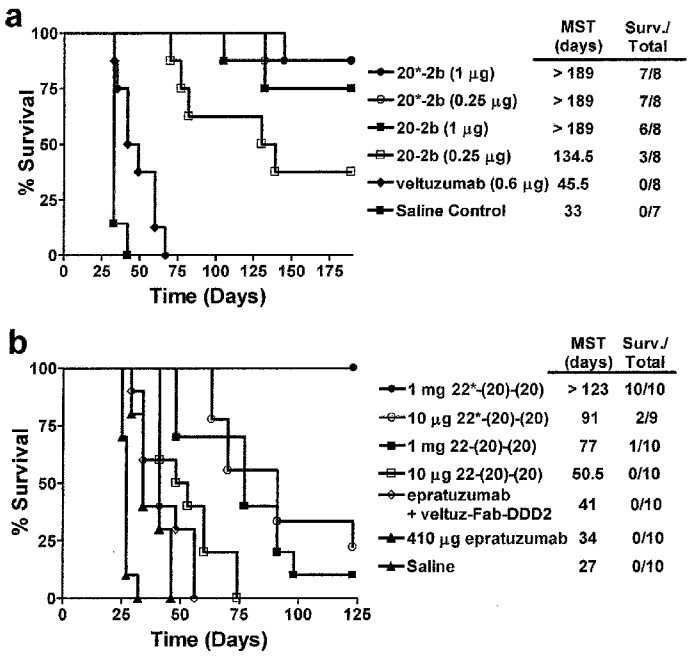

(57) **Abstract**: The present invention concerns multimeric complexes based on antibody fusion proteins comprising an AD moiety attached to the C-terminal end of each antibody light chain. The complexes further comprise effector moities attached to DDD moieties. Two copies of the DDD moiety form a dimer that binds to the AD moiety. The complexes may be trimers, pentamers, hexamers or other multimers. The effector moieties may be selected from a second antibody or antigen-binding fragment thereof, a cytokine, an interferon, a toxin, an antigen, a xenoantigen, a hapten, a protamine, a hormone, an enzyme, a ligand-binding protein, a pro-apoptotic agent and an anti-angiogenic agent. Surprisingly, attachment of the AD moiety to the C-terminal end of the antibody light chain results in improved pharmacokinetics and *in vivo* stability and efficacy, compared to homologous complexes wherein the AD moiety is attached to the antibody heavy chain.

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MULTIMERIC COMPLEXES WITH IMPROVED *IN VIVO* STABILITY, PHARMACOKINETICS AND EFFICACY

CROSS REFERENCE TO RELATED APPLICATIONS

[01] This application claims the benefit under 35 U.S.C. 119(e) of provisional U.S. Patent Applications 61/654,310, filed 6/1/2012, 61/662,086, filed 6/20/2012, 61/673,553, filed 7/19/2012, 61/682,531, filed 8/13/2012, 61/693,042, filed 8/24/2012 and 61/694,072, filed 8/28/2012, each priority application incorporated herein by reference in its entirety.

SEQUENCE LISTING

[01.1] The instant application contains a Sequence Listing which has been submitted in ASCII format via EFS-Web and is hereby incorporated by reference in its entirety. Said ASCII copy, created on May 3, 2013, is named IBC137WO1_SL.txt and is 59,652 bytes in size.

FIELD

[02] The present invention relates to compositions and methods of use of multimeric complexes comprising multiple effector moieties. Preferably the effector moieties are fusion proteins, each comprising an anchoring domain (AD) moiety from an A-kinase anchoring protein (AKAP) or a dimerization and docking domain (DDD) moiety from a protein kinase A (PKA) regulatory subunit RIα, RIβ, RIIα or RIIβ. Two copies of the DDD moiety dimerize and bind to an AD moiety to form the multimeric complex, which may be trimeric, tetrameric, pentameric, hexameric or multimeric. The person of ordinary skill will realize that in alternative embodiments the AD and/or DDD moieties may be attached to an effector by chemical cross-linking or other known means. The effectors may be selected from antibodies, antigen-binding antibody fragments, antigens, cytokines, chemokines, interleukins, interferons, growth factors, pro-apoptotic agents, anti-angiogenic agents, toxins, ligand-binding proteins, enzymes, therapeutic agents or polymers such as polyethylene glycol (PEG). Preferably, at least one effector is an antibody or antigen-binding antibody fragment, with an AD moiety attached to the C-terminal end of each light chain of the antibody or antibody fragment. More preferably, at least one effector is an IgG antibody. In certain embodiments, all of the effectors may be antibodies or antibody fragments, providing bispecific or multispecific antigen-binding complexes. The subject multimeric complexes are of use for treating a wide variety of diseases and medical conditions, such as cancer,

autoimmune disease, immune system dysfunction, graft-versus-host disease, organ transplant rejection, neurologic disease, metabolic disease, infectious disease or cardiovascular disease.

BACKGROUND

[03] A significant aspect of recent biomedical research is the development of increasingly sophisticated antibody-based biologics, such as bispecific antibodies, immunocytokines, antibody-toxin conjugates and antibody-drug conjugates. Development of more complex, and less natural, fusion proteins faces problems with yield, stability, immunogenicity and pharmacokinetics (Pk). In particular, immunoconjugates based on antibody fragments, including single-chain Fv (scFv), Fab, or other Fc-lacking formats (Kontermann, 2010, Curr Opin Mol Ther 12:176-83), are often difficult to produce with homogeneity and sufficient yield, lack Fc-effector functions, and inherently suffer from short circulating serum half-lives ($T_{1/2}$). By comparison, immunoconjugates of IgG can be produced in high yields, with longer $T_{1/2}$ and *in-vivo* stability. Further, intact monoclonal antibodies (mAbs) offer high-avidity bivalent binding with Fc-effector functions, including antibody-dependent cell-mediated cytotoxicity (ADCC) and complement-dependent cytotoxicity (CDC). The enhanced Pk of IgG is attributed to two major factors. Its larger molecular size (~150 kDa) precludes renal clearance, which is responsible for the rapid elimination of smaller constructs (<60 kDa), such as scFv, and its dynamic binding to the neonatal Fc receptor (FcRn) (Kue & Aveson, 2011, MAbs 3:422-30) extends $T_{1/2}$.

[04] Multispecific or bispecific antibodies are useful in a number of biomedical applications. For instance, a bispecific antibody with binding sites for a tumor cell surface antigen and for a T-cell surface receptor can direct the lysis of specific tumor cells by T cells. Bispecific antibodies recognizing gliomas and the CD3 epitope on T cells have been successfully used in treating brain tumors in human patients (Nitta, et al. Lancet. 1990; 355:368-371). Numerous methods to produce bispecific antibodies are known (see, e.g. U.S. Patent No. 7,405,320). Bispecific antibodies can be produced by the quadroma method, which involves the fusion of two different hybridomas, each producing a monoclonal antibody recognizing a different antigenic site (Milstein and Cuello. Nature. 1983; 305:537-540). The fused hybridomas are capable of synthesizing two different heavy chains and two different light chains, which can associate randomly to give a heterogeneous population of 10 different antibody structures of which only one of them, amounting to 1/8 of the total antibody molecules, will be bispecific, and therefore must be further purified from the other

forms. Fused hybridomas are often less stable cytogenetically than the parent hybridomas, making the generation of a production cell line more problematic.

[05] Another method for producing bispecific antibodies uses heterobifunctional cross-linkers to chemically tether two different monoclonal antibodies, so that the resulting hybrid conjugate will bind to two different targets (Staerz, et al. Nature. 1985; 314:628-631; Perez, et al. Nature. 1985; 316:354-356). Bispecific antibodies generated by this approach are essentially heteroconjugates of two IgG molecules, which diffuse slowly into tissues and are rapidly removed from the circulation. Bispecific antibodies can also be produced by reduction of each of two parental monoclonal antibodies to the respective half molecules, which are then mixed and allowed to reoxidize to obtain the hybrid structure (Staerz and Bevan. Proc Natl Acad Sci USA. 1986; 83:1453-1457). An alternative approach involves chemically cross-linking two or three separately purified Fab' fragments using appropriate linkers. All these chemical methods are undesirable for commercial development due to high manufacturing cost, laborious production process, extensive purification steps, low yields (<20%), and heterogeneous products.

[06] Other methods include improving the efficiency of generating hybrid hybridomas by gene transfer of distinct selectable markers via retrovirus-derived shuttle vectors into respective parental hybridomas, which are fused subsequently (DeMonte, et al. Proc Natl Acad Sci USA. 1990, 87:2941-2945); or transfection of a hybridoma cell line with expression plasmids containing the heavy and light chain genes of a different antibody. These methods also face the inevitable purification problems discussed above.

[07] Discrete V_H and V_L domains of antibodies produced by recombinant DNA technology may pair with each other to form a dimer (recombinant Fv fragment) with binding capability (U.S. Pat. No. 4,642,334). However, such non-covalently associated molecules are not sufficiently stable under physiological conditions to have any practical use. Cognate V_H and V_L domains can be joined with a peptide linker of appropriate composition and length (usually consisting of more than 12 amino acid residues) to form a single-chain Fv (scFv) with binding activity. Methods of manufacturing scFv-based agents of multivalency and multispecificity by varying the linker length were disclosed in U.S. Pat. No. 5,844,094, U.S. Pat. No. 5,837,242 and WO 98/44001. Common problems that have been frequently associated with generating scFv-based agents of multivalency and multispecificity are low expression levels, heterogeneous products, instability in solution leading to aggregates, instability in serum, and impaired affinity.

[08] Dock-and-Lock™ (DNL™) technology has been used to produce a variety of

immunoconjugates in assorted formats (Rossi et al., 2012, Bioconjug Chem 23:309-23). Bispecific hexavalent antibodies (bsHexAbs) based on veltuzumab (anti-CD20) and epratuzumab (anti-CD22) were constructed by combining a stabilized $(Fab)_2$ fused to a dimerization and docking domain (DDD) with an IgG containing an anchor domain (AD) appended at the C-terminus of each heavy chain (C_H3-AD2-IgG) (Rossi et al., 2009, Blood 113, 6161-71). Compared to mixtures of their parental mAbs, these Fc-based bsHexAbs, referred to henceforth as "Fc-bsHexAbs", induced unique signaling events (Gupta et al., 2010, Blood 116:3258-67), and exhibited potent cytotoxicity *in vitro*. However, the Fc-bsHexAbs were cleared from circulation of mice approximately twice as fast as the parental mAbs (Rossi et al., 2009, Blood 113, 6161-71). Although the Fc-bsHexAbs are highly stable *ex vivo*, it is possible that some dissociation occurs *in vivo*, for example by intracellular processing. Further, the Fc-bsHexAbs lack CDC activity.

[09] Fc-based immunocytokines have also been assembled as DNL™ complexes, comprising two or four molecules of interferon-alpha 2b (IFNα2b) fused to the C-terminal end of the C_H3-AD2-IgG Fc (Rossi et al., 2009, Blood 114:3864-71; Rossi et al., 2010, Cancer Res 70:7600-09; Rossi et al., 2011, Blood 118:1877-84). The Fc-IgG-IFNα maintained high specific activity, approaching that of recombinant IFNα, and were remarkably potent *in vitro* and *in vivo* against non-Hodgkin lymphoma (NHL) xenografts. The $T_{1/2}$ of the Fc-IgG-IFNα in mice was longer than PEGylated IFNα, but half as long as the parental mAbs. Similar to the Fc-bsHexAbs, the Fc-IgG-IFNα dissociated *in vivo* over time and exhibited diminished CDC, but ADCC was enhanced.

[010] A need exists for methods and compositions to generate improved multimeric complexes with longer $T_{1/2}$, better pharmacokinetic properties, increased *in vivo* stability and improved *in vivo* efficacy.

SUMMARY

[011] The present invention concerns compositions and methods for producing improved DNL™ complexes with longer $T_{1/2}$, better pharmacokinetic properties and increased *in vivo* stability. In preferred embodiments, the improved DNL™ complexes comprise IgG components in which AD moieties are fused to the C-terminal end of the antibody light chains. Surprisingly, the relocation of the AD attachment site from the heavy chain to the light chain results in substantially improved pharmacokinetics, *in vivo* stability and Fc effector function, along with increased *in vivo* efficacy, compared to the already potent Fc-based counterparts.

[012] In various embodiments, the subject complexes may be administered to a subject with

a condition, for therapeutic and/or diagnostic purposes. The skilled artisan will realize that any condition that may be diagnosed and/or treated with a multifunctional, bivalent, trivalent, multispecific or bispecific complex may be treated with the subject compositions. Exemplary conditions include, but are not limited to, cancer, hyperplasia, neurodegenerative disease, Alzheimer's disease, cardiovascular disease, metabolic disease, vasculitis, viral infection, fungal infection, bacterial infection, diabetic retinopathy, macular degeneration, autoimmune disease, edema, pulmonary hypertension, sepsis, myocardial angiogenesis, plaque neovascularization, restenosis, neointima formation after vascular trauma, telangiectasia, hemophiliac joints, angiofibroma, fibrosis associated with chronic inflammation, lung fibrosis, deep venous thrombosis or wound granulation.

[013] In particular embodiments, the disclosed methods and compositions may be of use to treat autoimmune disease, such as acute idiopathic thrombocytopenic purpura, chronic idiopathic thrombocytopenic purpura, dermatomyositis, Sydenham's chorea, myasthenia gravis, systemic lupus erythematosus, lupus nephritis, rheumatic fever, polyglandular syndromes, bullous pemphigoid, type 1 diabetes, type 2 diabetes, Henoch-Schonlein purpura, post-streptococcalnephritis, erythema nodosurn, Takayasu's arteritis, Addison's disease, rheumatoid arthritis, multiple sclerosis, sarcoidosis, ulcerative colitis, erythema multiforme, IgA nephropathy, polyarteritis nodosa, ankylosing spondylitis, Goodpasture's syndrome, thromboangitisubiterans, Sjogren's syndrome, primary biliary cirrhosis, Hashimoto's thyroiditis, thyrotoxicosis, scleroderma, chronic active hepatitis, polymyositis/dermatomyositis, polychondritis, pemphigus vulgaris, Wegener's granulomatosis, membranous nephropathy, amyotrophic lateral sclerosis, tabes dorsalis, giant cell arteritis/polymyalgia, pernicious anemia, rapidly progressive glomerulonephritis, psoriasis or fibrosing alveolitis.

[014] In certain embodiments, the complexes may be of use for therapeutic treatment of cancer. It is anticipated that any type of tumor and any type of tumor antigen may be targeted. Exemplary types of cancers that may be targeted include acute lymphoblastic leukemia, acute myelogenous leukemia, biliary cancer, breast cancer, cervical cancer, chronic lymphocytic leukemia, chronic myelogenous leukemia, colorectal cancer, endometrial cancer, esophageal, gastric, head and neck cancer, Hodgkin's lymphoma, lung cancer, medullary thyroid cancer, non-Hodgkin's lymphoma, multiple myeloma, renal cancer, ovarian cancer, pancreatic cancer, glioma, melanoma, liver cancer, prostate cancer, and urinary bladder cancer.

[015] Tumor-associated antigens that may be targeted include, but are not limited to, carbonic anhydrase IX, CCCL19, CCCL21, CSAp, CD1, CD1a, CD2, CD3, CD4, CD5,

CD8, CD11A, CD14, CD15, CD16, CD18, CD19, IGF-1R, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD95, CD126, CD133, CD138, CD147, CD154, AFP, PSMA, CEACAM5, CEACAM-6, CSAp, B7, ED-B of fibronectin, Factor H, FHL-1, Flt-3, folate receptor, GROB, HMGB-1, hypoxia inducible factor (HIF), HM1.24, insulin-like growth factor-1 (ILGF-1), IFN-γ, IFN-α, IFN-β, IL-2, IL-4R, IL-6R, IL-13R, IL-15R, IL-17R, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, IP-10, MAGE, mCRP, MCP-1, MIP-1A, MIP-1B, MIF, MUC1, MUC2, MUC3, MUC4, MUC5ac, macrophage inhibition factor (MIF), antigen bound by the PAM4 antibody, NCA-95, NCA-90, Ia, HM1.24, EGP-1, EGP-2, HLA-DR, tenascin, Le(y), RANTES, T101, TAC, Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, TNF-α, TRAIL receptor (R1 and R2), VEGFR, EGFR, PlGF, PSA, PSMA, complement factors C3, C3a, C3b, C5a, C5, and an oncogene product

[016] Exemplary antibodies that may be utilized include, but are not limited to, hR1 (anti-IGF-1R, U.S. Patent Application Serial No. 12/722,645, filed 3/12/10), hPAM4 (anti-mucin, U.S. Patent No. 7,282,567), hA20 (anti-CD20, U.S. Patent No. 7,251,164), hA19 (anti-CD19, U.S. Patent No. 7,109,304), hIMMU31 (anti-AFP, U.S. Patent No. 7,300,655), hLL1 (anti-CD74, U.S. Patent No. 7,312,318), hLL2 (anti-CD22, U.S. Patent No. 7,074,403), hMu-9 (anti-CSAp, U.S. Patent No. 7,387,773), hL243 (anti-HLA-DR, U.S. Patent No. 7,612,180), hMN-14 (anti-CEACAM5, U.S. Patent No. 6,676,924), hMN-15 (anti-CEACAM6, U.S. Patent No. 7,541,440), hRS7 (anti-EGP-1, U.S. Patent No. 7,238,785) and hMN-3 (anti-CEACAM6, U.S. Patent Application Serial No. 7,541,440) the Examples section of each cited patent or application incorporated herein by reference. The skilled artisan will realize that this list is not limiting and that any known antibody may be used, as discussed in more detail below.

[017] In other embodiments, the subject complexes may be of use to treat subjects infected with pathogenic organisms, such as bacteria, viruses or fungi. Exemplary fungi that may be treated include *Microsporum, Trichophyton, Epidermophyton, Sporothrix schenckii, Cryptococcus neoformans, Coccidioides immitis, Histoplasma capsulatum, Blastomyces dermatitidis* or *Candida albican.* Exemplary viruses include human immunodeficiency virus (HIV), herpes virus, cytomegalovirus, rabies virus, influenza virus, human papilloma virus, hepatitis B virus, hepatitis C virus, Sendai virus, feline leukemia virus, Reo virus, polio virus, human serum parvo-like virus, simian virus 40, respiratory syncytial virus, mouse mammary tumor virus, Varicella-Zoster virus, Dengue virus, rubella virus, measles virus, adenovirus,

human T-cell leukemia viruses, Epstein-Barr virus, murine leukemia virus, mumps virus, vesicular stomatitis virus, Sindbis virus, lymphocytic choriomeningitis virus or blue tongue virus. Exemplary bacteria include *Bacillus anthracis, Streptococcus agalactiae, Legionella pneumophilia, Streptococcus pyogenes, Escherichia coli, Neisseria gonorrhoeae, Neisseria meningitidis, Pneumococcus spp., Hemophilis influenzae B, Treponema pallidum,* Lyme disease spirochetes, *Pseudomonas aeruginosa, Mycobacterium leprae, Brucella abortus, Mycobacterium tuberculosis* or a *Mycoplasma.*

[018] Complexes of use for infection may comprise, for example, binding sites for one or more antigenic determinant on a pathogen, and may be conjugated or attached to a therapeutic agent for the pathogen, for example an anti-viral, antibiotic or anti-fungal agent. Alternatively, a stably tethered conjugate may comprise a first binding site for a pathogen antigen and a second binding site for a hapten or carrier that is attached to one or more therapeutic agents. Therapeutic agents of use against infectious organisms that may be conjugated to, incorporated into or targeted to bind to the subject complexes include, but are not limited to, acyclovir, albendazole, amantadine, amikacin, amoxicillin, amphotericin B, ampicillin, aztreonam, azithromycin, bacitracin, bactrim, BATRAFEN®, bifonazole, carbenicillin, caspofungin, cefaclor, cefazolin, cephalosporins, cefepime, ceftriaxone, cefotaxime, chloramphenicol, cidofovir, CIPRO®, clarithromycin, clavulanic acid, clotrimazole, cloxacillin, doxycycline, econazole, erythrocycline, erythromycin, flagyl, fluconazole, flucytosine, foscamet, furazolidone, ganciclovir, gentamycin, imipenem, isoniazid, itraconazole, kanamycin, ketoconazole, lincomycin, linezolid, meropenem, miconazole, minocycline, naftifine, nalidixic acid, neomycin, netilmicin, nitrofurantoin, nystatin, oseltamivir, oxacillin, paromomycin, penicillin, pentamidine, piperacillin-tazobactam, rifabutin, rifampin, rimantadine, streptomycin, sulfamethoxazole, sulfasalazine, tetracycline, tioconazole, tobramycin, tolciclate, tolnaftate, trimethoprim sulfamethoxazole, valacyclovir, vancomycin, zanamir, and zithromycin.

[019] In various embodiments, the complexes may comprise one or more toxins, such as a bacterial toxin, a plant toxin, ricin, abrin, a ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, *Pseudomonas* exotoxin, *Pseudomonas* endotoxin, onconase, ranpirnase (Rap), Rap (N69Q) or PE38. In a preferred embodiment, the complex may comprise an IgG antibody attached to two AD moieties and four copies of a toxin, such as ranpirnase, attached to DDD moieties. Such complexes have been demonstrated to be highly efficacious, with improved toxocity and phamacokinetic properties (see, e.g., U.S. Patent Application Serial No. 12/871,345, the Examples section of

which is incorporated herein by reference).

[020] The subject complexes may also comprise an immunomodulator selected from the group consisting of a cytokine, a chemokine, a stem cell growth factor, a lymphotoxin, an hematopoietic factor, a colony stimulating factor (CSF), an interferon, erythropoietin, thrombopoietin, tumor necrosis factor-α (TNF), TNF-β, granulocyte-colony stimulating factor (G-CSF), granulocyte macrophage-colony stimulating factor (GM-CSF), interferon-α, interferon-β, interferon-γ, interferon-λ, stem cell growth factor designated "S1 factor", human growth hormone, N-methionyl human growth hormone, bovine growth hormone, parathyroid hormone, thyroxine, insulin, proinsulin, relaxin, prorelaxin, follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), luteinizing hormone (LH), hepatic growth factor, prostaglandin, fibroblast growth factor, prolactin, placental lactogen, OB protein, mullerian-inhibiting substance, mouse gonadotropin-associated peptide, inhibin, activin, vascular endothelial growth factor, integrin, NGF-β, platelet-growth factor, TGF-α, TGF-β, insulin-like growth factor-I, insulin-like growth factor-II, macrophage-CSF (M-CSF), IL-1, IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, IL-25, LIF, FLT-3, angiostatin, thrombospondin, endostatin and lymphotoxin. In certain preferred embodiments, the complex may comprise an antibody or antibody fragment attached to two AD moieties and four copies of an immunomodulator, such as a cytokine, each attached to a DDD moiety. Cytokine complexes are disclosed, for example, in U.S. Patent Nos. 7,906,118 and 8,034,3522, the Examples section of each incorporated herein by reference.

[021] Chemokines of use that may be incorporated in a subject complex include, but are not limited to, RANTES, MCAF, MIP1-alpha, MIP1-beta and IT-10.

[022] Anti-angiogenic agents of use that may be incorporated in a subject complex include, but are not limited to, angiostatin, baculostatin, canstatin, maspin, anti-VEGF antibodies or peptides, anti-placental growth factor antibodies or peptides, anti-Flk-1 antibodies, anti-Flt-1 antibodies or peptides, laminin peptides, fibronectin peptides, plasminogen activator inhibitors, tissue metalloproteinase inhibitors, interferons, interleukin 12, IP-10, Gro-β, thrombospondin, 2-methoxyoestradiol, proliferin-related protein, carboxiamidotriazole, CM101, Marimastat, pentosan polysulphate, angiopoietin 2, interferon-alpha, herbimycin A, PNU145156E, 16K prolactin fragment, Linomide, thalidomide, pentoxifylline, genistein, TNP-470, endostatin, paclitaxel, accutin, angiostatin, cidofovir, vincristine, bleomycin, AGM-1470, platelet factor 4 or minocycline.

[023] In still other embodiments, one or more therapeutic agents, such as aplidin, azaribine,

anastrozole, azacytidine, bleomycin, bortezomib, bryostatin-1, busulfan, calicheamycin, camptothecin, 10-hydroxycamptothecin, carmustine, celebrex, chlorambucil, cisplatin, irinotecan (CPT-11), SN-38, carboplatin, cladribine, cyclophosphamide, cytarabine, dacarbazine, docetaxel, dactinomycin, daunomycin glucuronide, daunorubicin, dexamethasone, diethylstilbestrol, doxorubicin, 2-pyrrolinodoxorubicine (2P-DOX), cyano-morpholino doxorubicin, doxorubicin glucuronide, epirubicin glucuronide, ethinyl estradiol, estramustine, etoposide, etoposide glucuronide, etoposide phosphate, floxuridine (FUdR), 3',5'-O-dioleoyl-FudR (FUdR-dO), fludarabine, flutamide, fluorouracil, fluoxymesterone, gemcitabine, hydroxyprogesterone caproate, hydroxyurea, idarubicin, ifosfamide, L-asparaginase, leucovorin, lomustine, mechlorethamine, medroprogesterone acetate, megestrol acetate, melphalan, mercaptopurine, 6-mercaptopurine, methotrexate, nitoxantrone, mithramycin, mitomycin, mitotane, phenyl butyrate, prednisone, procarbazine, paclitaxel, pentostatin, PSI-341, semustine streptozocin, tamoxifen, taxanes, taxol, testosterone propionate, thalidomide, thioguanine, thiotepa, teniposide, topotecan, uracil mustard, velcade, vinblastine, vinorelbine, vincristine, an antisense oligonucleotide, an interference RNA, or a combination thereof, may be conjugated to or incorporated into a complex.

[024] In embodiments involving pretargeting, the complex may comprise a first antibody or fragment thereof that binds to an antigen associated with a diseased cell, tissue or pathogen, while a second antibody or fragment thereof may bind to a hapten on a targetable construct. Following administration of the complex and localization to a disease-associated cell, tissue, or pathogen, a targetable construct may be added to bind to the localized complex. Optionally, a clearing agent may be administered to clear non-localized complexes from circulation before administration of the targetable construct. These methods are known in the art and described in U.S. Pat. No. 4,624,846, WO 92/19273, and Sharkey et al., Int. J. Cancer 51: 266 (1992). An exemplary targetable construct may have a structure of X-Phe-Lys(HSG)-D-Tyr-Lys(HSG)-Lys(Y)-NH_2, where the compound includes a hard acid cation chelator at X or Y, and a soft acid cation chelator at remaining X or Y; and wherein the compound further comprises at least one diagnostic or therapeutic cation, and/or one or more chelated or chemically bound therapeutic agent, diagnostic agent, or enzyme.

[025] Various embodiments may concern complexes that are of use to induce apoptosis of diseased cells. Further details may be found in U.S. Patent Application Publication No. 20050079184, the entire text of which is incorporated herein by reference. Such structures may comprise a first and/or second precursor with binding affinity for an antigen selected from the group consisting of CD2, CD3, CD8, CD10, CD21, CD23, CD24, CD25, CD30,

CD33, CD37, CD38, CD40, CD48, CD52, CD55, CD59, CD70, CD74, CD80, CD86, CD138, CD147, HLA-DR, CEA, CSAp, CA-125, TAG-72, EFGR, HER2, HER3, HER4, IGF-1R, c-Met, PDGFR, MUC1, MUC2, MUC3, MUC4, TNFR1, TNFR2, NGFR, Fas (CD95), DR3, DR4, DR5, DR6, VEGF, PIGF, ED-B fibronectin, tenascin, PSMA, PSA, carbonic anhydrase IX, and IL-6. In more particular embodiments, a complex of use to induce apoptosis may comprise monoclonal antibodies, Fab fragments, chimeric, humanized or human antibodies or fragments. In preferred embodiments, the complex may comprise combinations of anti-CD74 X anti-CD20, anti-CD74 X anti-CD22, anti-CD22 X anti-CD20, anti-CD20 X anti-HLA-DR, anti-CD19 X anti-CD20, anti-CD20 X anti-CD80, anti-CD2 X anti-CD25, anti-CD8 X anti-CD25, and anti-CD2 X anti-CD147. In more preferred embodiments, the chimeric, humanized or human antibodies or antibody fragments may be derived from the variable domains of LL2 (anti-CD22), LL1 (anti-CD74) or A20 (anti-CD20).

[026] Various embodiments may concern complexes and methods of use for treating inflammatory and immune-dysregulatory diseases, infectious diseases, pathologic angiogenesis or cancer. In this application the complexes bind to two different targets selected from the group consisting of (A) proinflammatory effectors of the innate immune system, (B) coagulation factors, (C) complement factors and complement regulatory proteins, and (D) targets specifically associated with an inflammatory or immune-dysregulatory disorder or with a pathologic angiogenesis or cancer, wherein the latter target is not (A), (B), or (C). At least one of the targets is (A), (B) or (C). Suitable combinations of targets are described in U.S. Provisional Application No. 60/634,076, filed Dec. 8, 2004, entitled "Methods and Compositions for Immunotherapy and Detection of Inflammatory and Immune-Dysregulatory Disease, Infectious Disease, Pathologic Angiogenesis and Cancer," the contents of which are incorporated herein in their entirety.

[027] The proinflammatory effector of the innate immune system to which the binding molecules may bind may be a proinflammatory effector cytokine, a proinflammatory effector chemokine or a proinflammatory effector receptor. Suitable proinflammatory effector cytokines include MIF, HMGB-1 (high mobility group box protein 1), TNF-a, IL-1, IL-4, IL-5, IL-6, IL-8, IL-12, IL-15, and IL-18. Examples of proinflammatory effector chemokines include CCL19, CCL21, IL-8, MCP-1, RANTES, MIP-1A, MIP-1B, ENA-78, MCP-1, IP-10, GROB, and Eotaxin. Proinflammatory effector receptors include IL-4R (interleukin-4 receptor), IL-6R (interleukin-6 receptor), IL-13R (interleukin-13 receptor), IL-15R (interleukin-15 receptor) and IL-18R (interleukin-18 receptor).

[028] The complex also may react with at least one coagulation factor, particularly tissue factor (TF) or thrombin. In other embodiments, the complex reacts with at least one complement factor or complement regulatory protein. In preferred embodiments, the complement factor is selected from the group consisting of C3, C5, C3a, C3b, and C5a. When the binding molecule reacts specifically with a complement regulatory protein, the complement regulatory protein preferably is selected from the group consisting of CD46, CD55, CD59 and mCRP.

[029] In certain embodiments, any therapeutic protein or peptide known in the art may be attached to an AD or DDD sequence and used as an effector in the claimed methods and compositions. A large number of such therapeutic proteins or peptides are known, and are described for example, in U.S. Patent Application Publication No. 20060084794, "Albumin fusion proteins," filed Nov. 2, 2005, incorporated herein by reference in its entirety. Table 1 of 20060084794, which lists various known exemplary therapeutic proteins or peptides of use, including exemplary identifiers, patent reference numbers and preferred indications, is specifically incorporated herein by reference in its entirety. Additional therapeutic proteins or peptides of use are disclosed, for example, in U.S. Pat. No. 6,309,633, incorporated herein by reference in its entirety, and may include but are not limited to adrenocorticotropic hormone, ebiratide, angiotensin, angiotensin II, asparaginase, atrial natriuretic peptides, atrial sodium diuretic peptides, bacitracin, beta-endorphins, blood coagulation factors VII, VIII and IX, blood thymic factor, bone morphogenic factor, bone morphogenic protein, bradykinin, caerulein, calcitonin gene related polypeptide, calcitonins, CCK-8, cell growth factors, EGF, TGF-alpha, TGF-beta, acidic FGF, basic FGF, chemokines, cholecystokinin, cholecystokinin-8, cholecystokinin-pancreozymin, colistin, colony-stimulating factors, GMCSF, MCSF, corticotropin-releasing factor, cytokines, desmopressin, dipeptide, dismutase, dynorphin, eledoisin, endorphins, endothelin, endothelin-antagonistic peptides, endotherins, enkephalins, epidermal growth factor, erythropoietin, follicle-stimulating hormone, gallanin, gastric inhibitory polypeptide, gastrin-releasing polypeptide, gastrins, G-CSF, glucagon, glutathione peroxidase, glutathio-peroxidase, gonadotropin, gramicidin, gramicidines, growth factor, growth hormone-releasing factor, growth hormones, h-ANP, hormone releasing hormone, human chorionic gonadotrophin, human chorionic gonadotrophin β-chain, human placental lactogen, insulin, insulin-like growth factors, IGF-I, IGF-II, interferons, interleukins, intestinal polypeptide, kallikrein, kyotorphin, luliberin, luteinizing hormone, luteinizing hormone-releasing hormone, lysozyme chloride, melanocyte-stimulating hormone, melanophore stimulating hormone, mellitin, motilin,

muramyl, muramyldipeptide, nerve growth factor, nerve nutrition factors, NT-3, NT-4, CNTF, GDNF, BDNF, neuropeptide Y, neurotensin, oxytocin, pancreastatin, pancreatic polypeptide, pancreozymin, parathyroid hormone, pentagastrin, polypeptide YY, pituitary adenyl cyclase-activating polypeptides, platelet derived growth factor, polymixin B, prolactin, protein synthesis stimulating polypeptide, PTH-related protein, relaxin, renin, secretin, serum thymic factor, somatomedins, somatostatins, substance P, superoxide, superoxide dismutase, taftsin, tetragastrin, thrombopoietin, thymic humoral factor, thymopoietin, thymosin, thymostimulin, thyroid hormone releasing hormone, thyroid-stimulating hormone, thyrotropin releasing hormone TRH, trypsin, tuftsin, tumor growth factor, tumor necrosis factor, tyrocidin, urogastrone, urokinase, vasoactive intestinal polypeptide, vasopressins, and functional equivalents.

[030] In other preferred embodiments, the complexes may comprise an antibody or fragment thereof that binds to an antigen on an antigen-presenting cell (APC), such as a dendritic cell (DC) antigen, attached to a xenoantigen or a mutagenized or chemically modified antigen (see, e.g., U.S. Patent No. 7,901,680, USSN 12/754,740; the Examples section of each incorporated herein by reference). Such complexes are of use to induce an immune response against the selected target antigen, for example a tumor-associated antigen. Exemplary DC antigens that may be targeted include, but are not limited to, CD209 (DC-SIGN), CD34, CD74, CD205, TLR 2 (toll-like receptor 2), TLR 4, TLR 7, TLR 9, BDCA-2, BDCA-3, BDCA-4, and HLA-DR. In other embodiments, the DC targeting antibody or fragment thereof may be attached to a pathogen-associated antigen to induce an immune response against pathogens responsible for infectious disease. An exemplary embodiment is disclosed for pox-virus associated antigens in U.S. Patent Application Serial No. 12/915,515, the Examples section of which is incorporated herein by reference.

[031] In alternative embodiments, the DNL™ complex may comprise an antibody or antigen-binding antibody fragment attached to an oligonucleotide carrier moiety, such as a protamine, dendrimer or other polymer, of use to deliver interference RNA species such as siRNA. Exemplary complexes of use for such purposes are disclosed in U.S. Patent Application Serial No. 12/964,021, filed 12/9/10, the Examples section of which is incorporated herein by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[032] The following drawings form part of the present specification and are included to further demonstrate certain embodiments of the present invention. The embodiments may be better understood by reference to one or more of these drawings in combination with the

detailed description of specific embodiments presented herein.

[033] FIG. 1. DNL™ modules and conjugates. (**a**) C_k-AD2-IgG (C_k-AD2-IgG-epratuzumab or C_k-AD2-IgG-veltuzumab), an IgG-AD2 module with an AD2 fused to the carboxyl-terminal end of each kappa light chain. (**b**) Dimeric C_H1-DDD2-Fab-veltuzumab, a Fab-DDD module with DDD2 fused to the carboxyl-terminal end of the F_d chain. (**c**) 22*-(20)-(20), a bsHexAb comprising C_k-AD2-IgG-epratuzumab and two dimeric C_H1-DDD2-Fab-veltuzumab modules. (**d**) 22-(20)-(20), a bsHexAb comprising C_H3-AD2-IgG-epratuzumab and two dimeric C_H1-DDD2-Fab-veltuzumab modules. (**e**) A dimeric IFNα2b-DDD2 module with DDD2 fused to the carboxyl-terminal end of IFNα2b via a flexible peptide linker. (**f**) 20*-2b, an immunocytokine with tetrameric IFNα2b constructed with C_k-AD2-IgG-veltuzumab fused with two dimeric IFNα2b-DDD2 modules. (**g**) 20-2b, an IgG-IFNα with tetrameric IFNα2b constructed with C_H3-AD2-IgG fused with two dimeric IFNα2b-DDD2 modules. Variable (V) and constant (C) domains of IgG heavy (H) and light (L) chains are represented as ovals. The DDD2 and AD2 peptides are shown as dark and light helices, respectively, with the locations indicated for the reactive sulfhydryl groups (SH) and the "locking" disulfide bridges indicated as lines joining the helices.

[034] FIG. 2. Pharmacokinetics of 22*-(20)-(20) and 22-(20)-(20) in mice and rabbits. In this and other Figures, use of an asterisk (*) indicates a DNL™ complex comprising light-chain conjugated AD moieties, while the absence of an asterisk indicates a DNL™ complex comprising heavy-chain conjugated AD moieties. At the indicated intervals, the concentration of the intact molecules in serum samples was measured using a bispecific ELISA. Animals were administered 22*-(20)-(20) (circles), 22-(20)-(20) (squares) or epratuzumab (triangles) subcutaneously. Mice were terminally bled, while rabbits were serially bled. (**a**) Groups of 3 mice (mean ± SD) were dosed with 1.0 mg of bsHexAb or an equal molar amount of epratuzumab (0.41 mg). (**b**) Groups of 4 mice were dosed with 0.5 mg of bsAb. Individual data points are plotted with non-linear regression analysis using a one-phase exponential decay model with Prism software. (**c,d**) Rabbits were administered 18 mg (6 mg/kg) of bsAb. The Pk curves are shown for the individual animals (**c**) and the mean ±SD of each group (**d**).

[035] FIG. 3. Pharmacokinetics and *in vivo* stability of 20*-2b and 20-2b in mice. Groups of 3 mice were administered 1.0 mg of 20*-2b (circles) or 20-2b (squares) by subcutaneous (**a**) or intravenous (**b,c,d**) injection. (**c**) For each data point, obtained from individual animals, the serum concentration of the intact IgG-IFNα and total IgG (veltuzumab) was measured

using bispecific (solid line) or veltuzumab-specific (dashed line) ELISA formats. **(d)** For each data point the % intact IgG-IFNα was calculated by dividing the serum concentration measured with the bispecific ELISA by that determined with the veltuzumab-specific assay, and multiplying the quotient by 100. The % intact IgG-IFNα was plotted vs. hours post injection, and the dissociation rate was determined by linear regression analysis (± SD).

[036] FIG. 4. Effector functions. *In vitro* CDC was compared among **(a)** 20*-2b, 20-2b and veltuzumab, and **(b)** 22*-(20)-(20), 22-(20)-(20), veltuzumab and epratuzumab. **(c)** *In vitro* ADCC was compared among 22*-(20)-(20), 22-(20)-(20), veltuzumab and epratuzumab. mAb hMN-14 was used as a non-binding isotype control for each experiment.

[037] FIG. 5. *In vivo* efficacy with disseminated Daudi Burkitt lymphoma xenografts. **(a)** Groups of 8 SCID mice were inoculated with Daudi by IV injection. On day 7, mice were administered a single dose of 1.0 or 0.25 μg of 20*-2b or 20-2b by SC injection. Control groups were administered 0.6 μg of veltuzumab or saline. **(b)** Groups of 10 SCID mice were inoculated by IV injection on day 0. On days 1 and 5, mice were administered high (1 mg) or low (10 μg) doses of 22*-(20)-(20) or 22-(20)-(20) by SC injection. Control groups were administered a high dose of epratuzumab, high dose epratuzumab plus C_H1-DDD2-veltuzumab or saline. Statistical significance was determined by log-rank analysis of Kaplan-Myer survival plots.

[038] FIG. 6. CD20 binding. Daudi cells were incubated with increasing concentrations of PE-labeled 20*-2b or veltuzumab and binding was evaluated by flow cytometry. MFI, mean fluorescence intensity.

[039] FIG. 7. *In vitro* cytotoxicity. Daudi cells were incubated with increasing concentrations of 20*-2b (circles) or 20-2b (squares) for three days before quantification of the relative viable cell density.

[040] FIG. 8. *In vivo* dissociation of 22*-(20)-(20) and 22-(20)-(20) in mice. For each data point, obtained from individual animals, the serum concentration of the intact bsHexAb and total IgG (epratuzumab) was measured using bispecific or epratuzumab-specific ELISA. The % intact bsHexAb was calculated by dividing the serum concentration measured with the bispecific ELISA by that determined with the epratuzumab-specific assay, and multiplying the quotient by 100. The % intact IgG-IFNα was plotted vs. hours post injection, and the dissociation rate was determined by linear regression analysis. Error bars, standard deviation.

[041] FIG. 9. *In vivo* dissociation of 22*-(20)-(20) and 22-(20)-(20) in rabbits. For each data point, the serum concentration of the intact bsHexAb and total IgG was measured using bispecific or epratuzumab-specific ELISA. The % intact bsHexAb was calculated by dividing

the serum concentration measured with the bispecific ELISA by that determined with the epratuzumab-specific assay, and multiplying the quotient by 100. No dissociation was observed in rabbits. Error bars, standard deviation.

[042] FIG. 10. Ex vivo depletion of Raji and normal B cells from whole blood. Heparinized whole blood was incubated with 5 nM of the indicated mAb for two days at 37°C before FACS analysis.

[043] FIG. 11. Schematic representation of a C_k-AD2-IgG-pdHL2 expression vector.

[044] FIG. 12. Schematic representation of a C_k-AD2-IgG-pGSHL expression vector.

DETAILED DESCRIPTION

Definitions

[045] Unless otherwise specified, "a" or "an" means "one or more".

[046] As used herein, the terms “and” and “or” may be used to mean either the conjunctive or disjunctive. That is, both terms should be understood as equivalent to “and/or” unless otherwise stated.

[047] A "therapeutic agent" is an atom, molecule, or compound that is useful in the treatment of a disease. Examples of therapeutic agents include antibodies, antibody fragments, peptides, drugs, toxins, enzymes, nucleases, hormones, immunomodulators, antisense oligonucleotides, small interfering RNA (siRNA), chelators, boron compounds, photoactive agents, dyes, and radioisotopes.

[048] A "diagnostic agent" is an atom, molecule, or compound that is useful in diagnosing a disease. Useful diagnostic agents include, but are not limited to, radioisotopes, dyes (such as with the biotin-streptavidin complex), contrast agents, fluorescent compounds or molecules, and enhancing agents (e.g., paramagnetic ions) for magnetic resonance imaging (MRI).

[049] An "antibody" as used herein refers to a full-length (i.e., naturally occurring or formed by normal immunoglobulin gene fragment recombinatorial processes) immunoglobulin molecule *(e.g.,* an IgG antibody) or an immunologically active (i.e., specifically binding) portion of an immunoglobulin molecule, like an antibody fragment. An "antibody" includes monoclonal, polyclonal, bispecific, multispecific, murine, chimeric, humanized and human antibodies.

[050] A "naked antibody" is an antibody or antigen binding fragment thereof that is not attached to a therapeutic or diagnostic agent. The Fc portion of an intact naked antibody can provide effector functions, such as complement fixation and ADCC (see, *e.g.,* Markrides,

Pharmacol Rev 50:59-87, 1998). Other mechanisms by which naked antibodies induce cell death may include apoptosis. (Vaswani and Hamilton, *Ann Allergy Asthma Immunol* 81: 105-119, 1998.)

[051] An "antibody fragment" is a portion of an intact antibody such as $F(ab')_2$, $F(ab)_2$, Fab', Fab, Fv, sFv, scFv, dAb and the like. Regardless of structure, an antibody fragment binds with the same antigen that is recognized by the full-length antibody. For example, antibody fragments include isolated fragments consisting of the variable regions, such as the "Fv" fragments consisting of the variable regions of the heavy and light chains or recombinant single chain polypeptide molecules in which light and heavy variable regions are connected by a peptide linker ("scFv proteins"). "Single-chain antibodies", often abbreviated as "scFv" consist of a polypeptide chain that comprises both a V_H and a V_L domain which interact to form an antigen- binding site. The V_H and V_L domains are usually linked by a peptide of 1 to 25 amino acid residues. Antibody fragments also include diabodies, triabodies and single domain antibodies (dAb).

[052] A "chimeric antibody" is a recombinant protein that contains the variable domains including the complementarity determining regions (CDRs) of an antibody derived from one species, preferably a rodent antibody, while the constant domains of the antibody molecule are derived from those of a human antibody. For veterinary applications, the constant domains of the chimeric antibody may be derived from that of other species, such as a cat or dog.

[053] A "humanized antibody" is a recombinant protein in which the CDRs from an antibody from one species; e.g., a rodent antibody, are transferred from the heavy and light variable chains of the rodent antibody into human heavy and light variable domains, including human framework region (FR) sequences. The constant domains of the antibody molecule are derived from those of a human antibody.

[054] A "human antibody" is an antibody obtained from transgenic mice that have been genetically engineered to produce specific human antibodies in response to antigenic challenge. In this technique, elements of the human heavy and light chain locus are introduced into strains of mice derived from embryonic stem cell lines that contain targeted disruptions of the endogenous heavy chain and light chain loci. The transgenic mice can synthesize human antibodies specific for human antigens, and the mice can be used to produce human antibody-secreting hybridomas. Methods for obtaining human antibodies from transgenic mice are described by Green et al., Nature Genet. 7:13 (1994), Lonberg et al., Nature 368:856 (1994), and Taylor et al., Int. Immun. 6:579 (1994). A fully human antibody

also can be constructed by genetic or chromosomal transfection methods, as well as phage display technology, all of which are known in the art. (See, e.g., McCafferty et al., Nature 348:552-553 (1990) for the production of human antibodies and fragments thereof in vitro, from immunoglobulin variable domain gene repertoires from unimmunized donors). In this technique, antibody variable domain genes are cloned in-frame into either a major or minor coat protein gene of a filamentous bacteriophage, and displayed as functional antibody fragments on the surface of the phage particle. Because the filamentous particle contains a single-stranded DNA copy of the phage genome, selections based on the functional properties of the antibody also result in selection of the gene encoding the antibody exhibiting those properties. In this way, the phage mimics some of the properties of the B cell. Phage display can be performed in a variety of formats, for their review, see, e.g. Johnson and Chiswell, Current Opinion in Structural Biology 3:5564-571 (1993). Human antibodies may also be generated by *in vitro* activated B cells. (See, U.S. Pat. Nos. 5,567,610 and 5,229,275).

[055] As used herein, the term "antibody fusion protein" is a recombinantly produced antigen-binding molecule in which an antibody or antibody fragment is linked to another protein or peptide, such as the same or different antibody or antibody fragment or a DDD or AD peptide. The fusion protein may comprise a single antibody component, a multivalent or multispecific combination of different antibody components or multiple copies of the same antibody component. The fusion protein may additionally comprise an antibody or an antibody fragment and a therapeutic agent. Examples of therapeutic agents suitable for such fusion proteins include immunomodulators and toxins. One preferred toxin comprises a ribonuclease (RNase), preferably a recombinant RNase.

[056] A "multispecific antibody" is an antibody that can bind simultaneously to at least two targets that are of different structure, e.g., two different antigens, two different epitopes on the same antigen, or a hapten and/or an antigen or epitope. A "multivalent antibody" is an antibody that can bind simultaneously to at least two targets that are of the same or different structure. Valency indicates how many binding arms or sites the antibody has to a single antigen or epitope; i.e., monovalent, bivalent, trivalent or multivalent. The multivalency of the antibody means that it can take advantage of multiple interactions in binding to an antigen, thus increasing the avidity of binding to the antigen. Specificity indicates how many antigens or epitopes an antibody is able to bind; i.e., monospecific, bispecific, trispecific, multispecific. Using these definitions, a natural antibody, e.g., an IgG, is bivalent because it has two binding arms but is monospecific because it binds to one epitope. Multispecific,

multivalent antibodies are constructs that have more than one binding site of different specificity.

[057] A "bispecific antibody" is an antibody that can bind simultaneously to two targets which are of different structure. Bispecific antibodies (bsAb) and bispecific antibody fragments (bsFab) may have at least one arm that specifically binds to, for example, a B cell, T cell, myeloid-, plasma-, and mast-cell antigen or epitope and at least one other arm that specifically binds to a targetable conjugate that bears a therapeutic or diagnostic agent. A variety of bispecific antibodies can be produced using molecular engineering.

[058] A "xenoantigen" is an antigen that is found in more than one species. When used herein in a vaccine to induce an immune response in a subject, the xenoantigen is from a species that is different from the subject. For example, a xenoantigen that is of use in a human vaccine may be from a mouse, a rat, a rabbit or another non-human species.

[059] An antibody or immunotoxin preparation, or a composition described herein, is said to be administered in a "therapeutically effective amount" if the amount administered is physiologically significant. An agent is physiologically significant if its presence results in a detectable change in the physiology of a recipient subject. In particular embodiments, an antibody preparation is physiologically significant if its presence invokes an antitumor response or mitigates the signs and symptoms of an autoimmune disease state. A physiologically significant effect could also be the evocation of a humoral and/or cellular immune response in the recipient subject leading to growth inhibition or death of target cells.

Antibodies

[060] Techniques for preparing monoclonal antibodies against virtually any target antigen are well known in the art. *See*, for example, Kohler and Milstein, *Nature 256*: 495 (1975), and Coligan *et al.* (eds.), CURRENT PROTOCOLS IN IMMUNOLOGY, VOL. 1, pages 2.5.1-2.6.7 (John Wiley & Sons 1991). Briefly, monoclonal antibodies can be obtained by injecting mice with a composition comprising an antigen, removing the spleen to obtain B-lymphocytes, fusing the B-lymphocytes with myeloma cells to produce hybridomas, cloning the hybridomas, selecting positive clones which produce antibodies to the antigen, culturing the clones that produce antibodies to the antigen, and isolating the antibodies from the hybridoma cultures.

[061] MAbs can be isolated and purified from hybridoma cultures by a variety of well-established techniques. Such isolation techniques include affinity chromatography with Protein-A Sepharose, size-exclusion chromatography, and ion-exchange chromatography.

See, for example, Coligan at pages 2.7.1-2.7.12 and pages 2.9.1-2.9.3. Also, see Baines *et al.*, "Purification of Immunoglobulin G (IgG)," in METHODS IN MOLECULAR BIOLOGY, VOL. 10, pages 79-104 (The Humana Press, Inc. 1992).

[062] After the initial raising of antibodies to the immunogen, the antibodies can be sequenced and subsequently prepared by recombinant techniques. Humanization and chimerization of murine antibodies and antibody fragments are well known to those skilled in the art. The use of antibody components derived from humanized, chimeric or human antibodies obviates potential problems associated with the immunogenicity of murine constant regions.

Chimeric Antibodies

[063] A chimeric antibody is a recombinant protein in which the variable regions of a human antibody have been replaced by the variable regions of, for example, a mouse antibody, including the complementarity-determining regions (CDRs) of the mouse antibody. Chimeric antibodies exhibit decreased immunogenicity and increased stability when administered to a subject. General techniques for cloning murine immunoglobulin variable domains are disclosed, for example, in Orlandi *et al., Proc. Nat'l Acad. Sci. USA 86*: 3833 (1989). Techniques for constructing chimeric antibodies are well known to those of skill in the art. As an example, Leung *et al., Hybridoma 13:*469 (1994), produced an LL2 chimera by combining DNA sequences encoding the V_κ and V_H domains of murine LL2, an anti-CD22 monoclonal antibody, with respective human κ and IgG_1 constant region domains.

Humanized Antibodies

[064] Techniques for producing humanized MAbs are well known in the art (see, e.g., Jones *et al., Nature 321*: 522 (1986), Riechmann *et al., Nature 332*: 323 (1988), Verhoeyen *et al., Science 239*: 1534 (1988), Carter *et al., Proc. Nat'l Acad. Sci. USA 89*: 4285 (1992), Sandhu, *Crit. Rev. Biotech. 12*: 437 (1992), and Singer *et al., J. Immun. 150*: 2844 (1993)). A chimeric or murine monoclonal antibody may be humanized by transferring the mouse CDRs from the heavy and light variable chains of the mouse immunoglobulin into the corresponding variable domains of a human antibody. The mouse framework regions (FR) in the chimeric monoclonal antibody are also replaced with human FR sequences. As simply transferring mouse CDRs into human FRs often results in a reduction or even loss of antibody affinity, additional modification might be required in order to restore the original affinity of the murine antibody. This can be accomplished by the replacement of one or more human residues in the FR regions with their murine counterparts to obtain an antibody that possesses good

binding affinity to its epitope. See, for example, Tempest *et al.*, *Biotechnology* 9:266 (1991) and Verhoeyen *et al.*, *Science* 239: 1534 (1988). Generally, those human FR amino acid residues that differ from their murine counterparts and are located close to or touching one or more CDR amino acid residues would be candidates for substitution.

Human Antibodies

[065] Methods for producing fully human antibodies using either combinatorial approaches or transgenic animals transformed with human immunoglobulin loci are known in the art (*e.g.*, Mancini et al., 2004, *New Microbiol.* 27:315-28; Conrad and Scheller, 2005, *Comb. Chem. High Throughput Screen.* 8:117-26; Brekke and Loset, 2003, *Curr. Opin. Phamacol.* 3:544-50). A fully human antibody also can be constructed by genetic or chromosomal transfection methods, as well as phage display technology, all of which are known in the art. See for example, McCafferty *et al., Nature* 348:552-553 (1990). Such fully human antibodies are expected to exhibit even fewer side effects than chimeric or humanized antibodies and to function *in vivo* as essentially endogenous human antibodies. In certain embodiments, the claimed methods and procedures may utilize human antibodies produced by such techniques.

[066] In one alternative, the phage display technique may be used to generate human antibodies (*e.g.*, Dantas-Barbosa et al., 2005, *Genet. Mol. Res.* 4:126-40). Human antibodies may be generated from normal humans or from humans that exhibit a particular disease state, such as cancer (Dantas-Barbosa et al., 2005). The advantage to constructing human antibodies from a diseased individual is that the circulating antibody repertoire may be biased towards antibodies against disease-associated antigens.

[067] In one non-limiting example of this methodology, Dantas-Barbosa et al. (2005) constructed a phage display library of human Fab antibody fragments from osteosarcoma patients. Generally, total RNA was obtained from circulating blood lymphocytes (*Id.*). Recombinant Fab were cloned from the μ, γ and κ chain antibody repertoires and inserted into a phage display library (*Id.*). RNAs were converted to cDNAs and used to make Fab cDNA libraries using specific primers against the heavy and light chain immunoglobulin sequences (Marks et al., 1991, *J. Mol. Biol.* 222:581-97). Library construction was performed according to Andris-Widhopf et al. (2000, In: *Phage Display Laboratory Manual*, Barbas et al. (eds), 1st edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY pp. 9.1 to 9.22). The final Fab fragments were digested with restriction endonucleases and inserted into the bacteriophage genome to make the phage display library. Such libraries may

be screened by standard phage display methods, as known in the art (see, e.g., Pasqualini and Ruoslahti, 1996, Nature 380:364-366; Pasqualini, 1999, The Quart. J. Nucl. Med. 43:159-162).

[068] Phage display can be performed in a variety of formats, for their review, see e.g. Johnson and Chiswell, *Current Opinion in Structural Biology* 3:5564-571 (1993). Human antibodies may also be generated by *in vitro* activated B cells. See U.S. Patent Nos. 5,567,610 and 5,229,275, incorporated herein by reference in their entirety. The skilled artisan will realize that these techniques are exemplary and any known method for making and screening human antibodies or antibody fragments may be utilized.

[069] In another alternative, transgenic animals that have been genetically engineered to produce human antibodies may be used to generate antibodies against essentially any immunogenic target, using standard immunization protocols. Methods for obtaining human antibodies from transgenic mice are disclosed by Green *et al., Nature Genet. 7*:13 (1994), Lonberg *et al., Nature 368*:856 (1994), and Taylor *et al., Int. Immun. 6*:579 (1994). A non-limiting example of such a system is the XenoMouse® (*e.g.*, Green et al., 1999, *J. Immunol. Methods* 231:11-23) from Abgenix (Fremont, CA). In the XenoMouse® and similar animals, the mouse antibody genes have been inactivated and replaced by functional human antibody genes, while the remainder of the mouse immune system remains intact.

[070] The XenoMouse® was transformed with germline-configured YACs (yeast artificial chromosomes) that contained portions of the human IgH and Igkappa loci, including the majority of the variable region sequences, along accessory genes and regulatory sequences. The human variable region repertoire may be used to generate antibody producing B cells, which may be processed into hybridomas by known techniques. A XenoMouse® immunized with a target antigen will produce human antibodies by the normal immune response, which may be harvested and/or produced by standard techniques discussed above. A variety of strains of XenoMouse® are available, each of which is capable of producing a different class of antibody. Transgenically produced human antibodies have been shown to have therapeutic potential, while retaining the pharmacokinetic properties of normal human antibodies (Green et al., 1999). The skilled artisan will realize that the claimed compositions and methods are not limited to use of the XenoMouse® system but may utilize any transgenic animal that has been genetically engineered to produce human antibodies.

Antibody Cloning and Production

[071] Various techniques, such as production of chimeric or humanized antibodies, may involve procedures of antibody cloning and construction. The antigen-binding Vκ (variable light chain)

and V_H (variable heavy chain) sequences for an antibody of interest may be obtained by a variety of molecular cloning procedures, such as RT-PCR, 5'-RACE, and cDNA library screening. The V genes of an antibody from a cell that expresses a murine antibody can be cloned by PCR amplification and sequenced. To confirm their authenticity, the cloned V_L and V_H genes can be expressed in cell culture as a chimeric Ab as described by Orlandi *et al.*, (*Proc. Natl. Acad. Sci.*, USA, 86: 3833 (1989)). Based on the V gene sequences, a humanized antibody can then be designed and constructed as described by Leung et al. (*Mol. Immunol.*, 32: 1413 (1995)).

[072] cDNA can be prepared from any known hybridoma line or transfected cell line producing a murine antibody by general molecular cloning techniques (Sambrook et al., Molecular Cloning, A laboratory manual, 2nd Ed (1989)). The Vκ sequence for the antibody may be amplified using the primers VK1BACK and VK1FOR (Orlandi *et al.*, 1989) or the extended primer set described by Leung et al. (*BioTechniques*, 15: 286 (1993)). The V_H sequences can be amplified using the primer pair VH1BACK/VH1FOR (Orlandi *et al.*, 1989) or the primers annealing to the constant region of murine IgG described by Leung et al. (Hybridoma, 13:469 (1994)). Humanized V genes can be constructed by a combination of long oligonucleotide template syntheses and PCR amplification as described by Leung et al. (*Mol. Immunol.*, 32: 1413 (1995)).

[073] PCR products for Vκ can be subcloned into a staging vector, such as a pBR327-based staging vector, VKpBR, that contains an Ig promoter, a signal peptide sequence and convenient restriction sites. PCR products for V_H can be subcloned into a similar staging vector, such as the pBluescript-based VHpBS. Expression cassettes containing the Vκ and V_H sequences together with the promoter and signal peptide sequences can be excised from VKpBR and VHpBS and ligated into appropriate expression vectors, such as pKh and pG1g, respectively (Leung et al., Hybridoma, 13:469 (1994)). The expression vectors can be co-transfected into an appropriate cell and supernatant fluids monitored for production of a chimeric, humanized or human antibody. Alternatively, the Vκ and V_H expression cassettes can be excised and subcloned into a single expression vector, such as pdHL2, as described by Gillies *et al.* (*J. Immunol. Methods* 125:191 (1989) and also shown in Losman et al., *Cancer*, 80:2660 (1997)).

[074] In an alternative embodiment, expression vectors may be transfected into host cells that have been pre-adapted for transfection, growth and expression in serum-free medium. Exemplary cell lines that may be used include the Sp/EEE, Sp/ESF and Sp/ESF-X cell lines (see, e.g., U.S. Patent Nos. 7,531,327; 7,537,930 and 7,608,425; the Examples section of each of which is incorporated herein by reference). These exemplary cell lines are based on the

Sp2/0 myeloma cell line, transfected with a mutant Bcl-EEE gene, exposed to methotrexate to amplify transfected gene sequences and pre-adapted to serum-free cell line for protein expression.

Antibody Fragments

[075] Antibody fragments which recognize specific epitopes can be generated by known techniques. Antibody fragments are antigen binding portions of an antibody, such as $F(ab')_2$, Fab', $F(ab)_2$, Fab, Fv, sFv and the like. $F(ab')_2$ fragments can be produced by pepsin digestion of the antibody molecule and Fab′ fragments can be generated by reducing disulfide bridges of the $F(ab')_2$ fragments. Alternatively, Fab′ expression libraries can be constructed (Huse *et al.*, 1989, *Science*, 246:1274-1281) to allow rapid and easy identification of monoclonal Fab′ fragments with the desired specificity. $F(ab)_2$ fragments may be generated by papain digestion of an antibody.

[076] A single chain Fv molecule (scFv) comprises a VL domain and a VH domain. The VL and VH domains associate to form a target binding site. These two domains are further covalently linked by a peptide linker (L). Methods for making scFv molecules and designing suitable peptide linkers are described in US Patent No. 4,704,692, US Patent No. 4,946,778, R. Raag and M. Whitlow, "*Single Chain Fvs.*" FASEB Vol 9:73-80 (1995) and R.E. Bird and B.W. Walker, "*Single Chain Antibody Variable Regions*," TIBTECH, Vol 9: 132-137 (1991).

[077] Techniques for producing single domain antibodies (DABs) are also known in the art, as disclosed for example in Cossins et al. (2006, Prot Express Purif 51:253-259), incorporated herein by reference.

[078] Techniques for producing single domain antibodies are also known in the art, as disclosed for example in Cossins et al. (2006, Prot Express Purif 51:253-259), incorporated herein by reference. Single domain antibodies (VHH) may be obtained, for example, from camels, alpacas or llamas by standard immunization techniques. (See, e.g., Muyldermans et al., TIBS 26:230-235, 2001; Yau et al., J Immunol Methods 281:161-75, 2003; Maass et al., J Immunol Methods 324:13-25, 2007). The VHH may have potent antigen-binding capacity and can interact with novel epitopes that are inacessible to conventional VH-VL pairs. (Muyldermans et al., 2001). Alpaca serum IgG contains about 50% camelid heavy chain only IgG antibodies (HCAbs) (Maass et al., 2007). Alpacas may be immunized with known antigens, such as TNF-α, and VHHs can be isolated that bind to and neutralize the target antigen (Maass et al., 2007). PCR primers that amplify virtually all alpaca VHH coding sequences have been identified and may be used to construct alpaca VHH phage display libraries, which can be used for antibody fragment isolation by standard biopanning

techniques well known in the art (Maass et al., 2007). In certain embodiments, anti-pancreatic cancer VHH antibody fragments may be utilized in the claimed compositions and methods.

[079] An antibody fragment can be prepared by proteolytic hydrolysis of the full length antibody or by expression in *E. coli* or another host of the DNA coding for the fragment. An antibody fragment can be obtained by pepsin or papain digestion of full length antibodies by conventional methods. These methods are described, for example, by Goldenberg, U.S. Patent Nos. 4,036,945 and 4,331,647 and references contained therein. Also, see Nisonoff *et al., Arch Biochem. Biophys. 89*: 230 (1960); Porter, *Biochem. J. 73*: 119 (1959), Edelman *et al.,* in METHODS IN ENZYMOLOGY VOL. 1, page 422 (Academic Press 1967), and Coligan at pages 2.8.1-2.8.10 and 2.10.-2.10.4.

Antibody Allotypes

[080] Immunogenicity of therapeutic antibodies is associated with increased risk of infusion reactions and decreased duration of therapeutic response (Baert et al., 2003, N Engl J Med 348:602-08). The extent to which therapeutic antibodies induce an immune response in the host may be determined in part by the allotype of the antibody (Stickler et al., 2011, Genes and Immunity 12:213-21). Antibody allotype is related to amino acid sequence variations at specific locations in the constant region sequences of the antibody. The allotypes of IgG antibodies containing a heavy chain γ-type constant region are designated as Gm allotypes (1976, J Immunol 117:1056-59).

[081] For the common IgG1 human antibodies, the most prevalent allotype is G1m1 (Stickler et al., 2011, Genes and Immunity 12:213-21). However, the G1m3 allotype also occurs frequently in Caucasians (Stickler et al., 2011). It has been reported that G1m1 antibodies contain allotypic sequences that tend to induce an immune response when administered to non-G1m1 (nG1m1) recipients, such as G1m3 patients (Stickler et al., 2011). Non-G1m1 allotype antibodies are not as immunogenic when administered to G1m1 patients (Stickler et al., 2011).

[082] The human G1m1 allotype comprises the amino acids aspartic acid at Kabat position 356 and leucine at Kabat position 358 in the CH3 sequence of the heavy chain IgG1. The nG1m1 allotype comprises the amino acids glutamic acid at Kabat position 356 and methionine at Kabat position 358. Both G1m1 and nG1m1 allotypes comprise a glutamic acid residue at Kabat position 357 and the allotypes are sometimes referred to as DEL and EEM allotypes. A non-limiting example of the heavy chain constant region sequences for G1m1 and nG1m1 allotype antibodies is shown for the exemplary antibodies rituximab (SEQ ID NO:85) and veltuzumab (SEQ ID NO:86).

Rituximab heavy chain variable region sequence (SEQ ID NO:85)

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVL
QSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKKAEPKSCDKTHTCPPCPAP
ELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKT
KPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREP
QVYTLPPSRDELTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGS
FFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

Veltuzumab heavy chain variable region (SEQ ID NO:86)

ASTKGPSVFPLAPSSKSTSGGTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVL
QSSGLYSLSSVVTVPSSSLGTQTYICNVNHKPSNTKVDKRVEPKSCDKTHTCPPCPAP
ELLGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVKFNWYVDGVEVHNAKT
KPREEQYNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKALPAPIEKTISKAKGQPREP
QVYTLPPSREEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGS
FFLYSKLTVDKSRWQQGNVFSCSVMHEALHNHYTQKSLSLSPGK

[083] Jefferis and Lefranc (2009, mAbs 1:1-7) reviewed sequence variations characteristic of IgG allotypes and their effect on immunogenicity. They reported that the G1m3 allotype is characterized by an arginine residue at Kabat position 214, compared to a lysine residue at Kabat 214 in the G1m17 allotype. The nG1m1,2 allotype was characterized by glutamic acid at Kabat position 356, methionine at Kabat position 358 and alanine at Kabat position 431. The G1m1,2 allotype was characterized by aspartic acid at Kabat position 356, leucine at Kabat position 358 and glycine at Kabat position 431. In addition to heavy chain constant region sequence variants, Jefferis and Lefranc (2009) reported allotypic variants in the kappa light chain constant region, with the Km1 allotype characterized by valine at Kabat position 153 and leucine at Kabat position 191, the Km1,2 allotype by alanine at Kabat position 153 and leucine at Kabat position 191, and the Km3 allotype characterized by alanine at Kabat position 153 and valine at Kabat position 191.

[084] With regard to therapeutic antibodies, veltuzumab and rituximab are, respectively, humanized and chimeric IgG1 antibodies against CD20, of use for therapy of a wide variety of hematological malignancies and/or autoimmune diseases. **Table 1** compares the allotype sequences of rituximab vs. veltuzumab. As shown in **Table 1**, rituximab (G1m17,1) is a DEL allotype IgG1, with an additional sequence variation at Kabat position 214 (heavy chain CH1) of lysine in rituximab vs. arginine in veltuzumab. It has been reported that veltuzumab is less immunogenic in subjects than rituximab (*see, e.g.,* Morchhauser et al., 2009, J Clin Oncol 27:3346-53; Goldenberg et al., 2009, Blood 113:1062-70; Robak & Robak, 2011, BioDrugs

25:13-25), an effect that has been attributed to the difference between humanized and chimeric antibodies. However, the difference in allotypes between the EEM and DEL allotypes likely also accounts for the lower immunogenicity of veltuzumab.

Table 1. Allotypes of Rituximab vs. Veltuzumab

		Heavy chain position and associated allotypes					
	Complete allotype	*214 (allotype)*		*356/358 (allotype)*		*431 (allotype)*	
Rituximab	*G1m17,1*	*K*	*17*	*D/L*	*1*	*A*	-
Veltuzumab	*G1m3*	*R*	*3*	*E/M*	-	*A*	-

[085] In order to reduce the immunogenicity of therapeutic antibodies in individuals of nG1m1 genotype, it is desirable to select the allotype of the antibody to correspond to the G1m3 allotype, characterized by arginine at Kabat 214, and the nG1m1,2 null-allotype, characterized by glutamic acid at Kabat position 356, methionine at Kabat position 358 and alanine at Kabat position 431. Surprisingly, it was found that repeated subcutaneous administration of G1m3 antibodies over a long period of time did not result in a significant immune response. In alternative embodiments, the human IgG4 heavy chain in common with the G1m3 allotype has arginine at Kabat 214, glutamic acid at Kabat 356, methionine at Kabat 359 and alanine at Kabat 431. Since immunogenicity appears to relate at least in part to the residues at those locations, use of the human IgG4 heavy chain constant region sequence for therapeutic antibodies is also a preferred embodiment. Combinations of G1m3 IgG1 antibodies with IgG4 antibodies may also be of use for therapeutic administration.

Known Antibodies

[086] In various embodiments, the claimed methods and compositions may utilize any of a variety of antibodies known in the art. Antibodies of use may be commercially obtained from a number of known sources. For example, a variety of antibody secreting hybridoma lines are available from the American Type Culture Collection (ATCC, Manassas, VA). A large number of antibodies against various disease targets, including but not limited to tumor-associated antigens, have been deposited at the ATCC and/or have published variable region sequences and are available for use in the claimed methods and compositions. See, e.g., U.S. Patent Nos. 7,312,318; 7,282,567; 7,151,164; 7,074,403; 7,060,802; 7,056,509; 7,049,060; 7,045,132; 7,041,803; 7,041,802; 7,041,293; 7,038,018; 7,037,498; 7,012,133; 7,001,598; 6,998,468; 6,994,976; 6,994,852; 6,989,241; 6,974,863; 6,965,018; 6,964,854; 6,962,981; 6,962,813; 6,956,107; 6,951,924; 6,949,244; 6,946,129; 6,943,020; 6,939,547; 6,921,645; 6,921,645; 6,921,533; 6,919,433; 6,919,078; 6,916,475; 6,905,681; 6,899,879; 6,893,625; 6,887,468; 6,887,466; 6,884,594; 6,881,405; 6,878,812; 6,875,580; 6,872,568; 6,867,006;

6,864,062; 6,861,511; 6,861,227; 6,861,226; 6,838,282; 6,835,549; 6,835,370; 6,824,780; 6,824,778; 6,812,206; 6,793,924; 6,783,758; 6,770,450; 6,767,711; 6,764,688; 6,764,681; 6,764,679; 6,743,898; 6,733,981; 6,730,307; 6,720,155; 6,716,966; 6,709,653; 6,693,176; 6,692,908; 6,689,607; 6,689,362; 6,689,355; 6,682,737; 6,682,736; 6,682,734; 6,673,344; 6,653,104; 6,652,852; 6,635,482; 6,630,144; 6,610,833; 6,610,294; 6,605,441; 6,605,279; 6,596,852; 6,592,868; 6,576,745; 6,572;856; 6,566,076; 6,562,618; 6,545,130; 6,544,749; 6,534,058; 6,528,625; 6,528,269; 6,521,227; 6,518,404; 6,511,665; 6,491,915; 6,488,930; 6,482,598; 6,482,408; 6,479,247; 6,468,531; 6,468,529; 6,465,173; 6,461,823; 6,458,356; 6,455,044; 6,455,040, 6,451,310; 6,444,206; 6,441,143; 6,432,404; 6,432,402; 6,419,928; 6,413,726; 6,406,694; 6,403,770; 6,403,091; 6,395,276; 6,395,274; 6,387,350; 6,383,759; 6,383,484; 6,376,654; 6,372,215; 6,359,126; 6,355,481; 6,355,444; 6,355,245; 6,355,244; 6,346,246; 6,344,198; 6,340,571; 6,340,459; 6,331,175; 6,306,393; 6,254,868; 6,187,287; 6,183,744; 6,129,914; 6,120,767; 6,096,289; 6,077,499; 5,922,302; 5,874,540; 5,814,440; 5,798,229; 5,789,554; 5,776,456; 5,736,119; 5,716,595; 5,677,136; 5,587,459; 5,443,953, 5,525,338, the Examples section of each of which is incorporated herein by reference. These are exemplary only and a wide variety of other antibodies and their hybridomas are known in the art. The skilled artisan will realize that antibody sequences or antibody-secreting hybridomas against almost any disease-associated antigen may be obtained by a simple search of the ATCC, NCBI and/or USPTO databases for antibodies against a selected disease-associated target of interest. The antigen binding domains of the cloned antibodies may be amplified, excised, ligated into an expression vector, transfected into an adapted host cell and used for protein production, using standard techniques well known in the art (see, e.g., U.S. Patent Nos. 7,531,327; 7,537,930; 7,608,425 and 7,785,880, the Examples section of each of which is incorporated herein by reference).

[087] Particular antibodies that may be of use for therapy of cancer within the scope of the claimed methods and compositions include, but are not limited to, LL1 (anti-CD74), LL2 and RFB4 (anti-CD22), RS7 (anti-epithelial glycoprotein-1 (EGP-1)), PAM4 and KC4 (both anti-mucin), MN-14 (anti-carcinoembryonic antigen (CEA, also known as CD66e), Mu-9 (anti-colon-specific antigen-p), Immu 31 (an anti-alpha-fetoprotein), TAG-72 (e.g., CC49), Tn, J591 or HuJ591 (anti-PSMA (prostate-specific membrane antigen)), AB-PG1-XG1-026 (anti-PSMA dimer), D2/B (anti-PSMA), G250 (anti-carbonic anhydrase IX), hL243 (anti-HLA-DR), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20); panitumumab (anti-EGFR); rituximab (anti-CD20); tositumomab (anti-CD20); GA101 (anti-CD20); and trastuzumab

(anti-ErbB2). Such antibodies are known in the art (e.g., U.S. Patent Nos. 5,686,072; 5,874,540; 6,107,090; 6,183,744; 6,306,393; 6,653,104; 6,730.300; 6,899,864; 6,926,893; 6,962,702; 7,074,403; 7,230,084; 7,238,785; 7,238,786; 7,256,004; 7,282,567; 7,300,655; 7,312,318; 7,585,491; 7,612,180; 7,642,239; and U.S. Patent Application Publ. No. 20040202666 (now abandoned); 20050271671; and 20060193865; the Examples section of each incorporated herein by reference.) Specific known antibodies of use include hPAM4 (U.S. Patent No. 7,282,567), hA20 (U.S. Patent No. 7,251,164), hA19 (U.S. Patent No. 7,109,304), hIMMU31 (U.S. Patent No. 7,300,655), hLL1 (U.S. Patent No. 7,312,318,), hLL2 (U.S. Patent No. 7,074,403), hMu-9 (U.S. Patent No. 7,387,773), hL243 (U.S. Patent No. 7,612,180), hMN-14 (U.S. Patent No. 6,676,924), hMN-15 (U.S. Patent No. 7,541,440), hR1 (U.S. Patent Application 12/772,645), hRS7 (U.S. Patent No. 7,238,785), hMN-3 (U.S. Patent No. 7,541,440), AB-PG1-XG1-026 (U.S. Patent Application 11/983,372, deposited as ATCC PTA-4405 and PTA-4406) and D2/B (WO 2009/130575) the text of each recited patent or application is incorporated herein by reference with respect to the Figures and Examples sections.

[088] Anti-TNF-α antibodies are known in the art and may be of use to treat immune diseases, such as autoimmune disease, immune dysfunction (e.g., graft-versus-host disease, organ transplant rejection) or diabetes. Known antibodies against TNF-α include the human antibody CDP571 (Ofei et al., 2011, Diabetes 45:881-85); murine antibodies MTNFAI, M2TNFAI, M3TNFAI, M3TNFABI, M302B and M303 (Thermo Scientific, Rockford, IL); infliximab (Centocor, Malvern, PA); certolizumab pegol (UCB, Brussels, Belgium); and adalimumab (Abbott, Abbott Park, IL). These and many other known anti-TNF-α antibodies may be used in the claimed methods and compositions. Other antibodies of use for therapy of immune dysregulatory or autoimmune disease include, but are not limited to, anti-B-cell antibodies such as veltuzumab, epratuzumab, milatuzumab or hL243; tocilizumab (anti-IL-6 receptor); basiliximab (anti-CD25); daclizumab (anti-CD25); efalizumab (anti-CD11a); muromonab-CD3 (anti-CD3 receptor); anti-CD40L (UCB, Brussels, Belgium); natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

[089] Type-1 and Type-2 diabetes may be treated using known antibodies against B-cell antigens, such as CD22 (epratuzumab), CD74 (milatuzumab), CD19 (hA19), CD20 (veltuzumab) or HLA-DR (hL243) (*see, e.g.*, Winer et al., 2011, Nature Med 17:610-18). Anti-CD3 antibodies also have been proposed for therapy of type 1 diabetes (Cernea et al., 2010, Diabetes Metab Rev 26:602-05).

[090] Macrophage migration inhibitory factor (MIF) is an important regulator of innate and adaptive immunity and apoptosis. It has been reported that CD74 is the endogenous receptor for MIF (Leng et al., 2003, J Exp Med 197:1467-76). The therapeutic effect of antagonistic anti-CD74 antibodies on MIF-mediated intracellular pathways may be of use for treatment of a broad range of disease states, such as cancers of the bladder, prostate, breast, lung, colon and chronic lymphocytic leukemia (e.g., Meyer-Siegler et al., 2004, BMC Cancer 12:34; Shachar & Haran, 2011, Leuk Lymphoma 52:1446-54); autoimmune diseases such as rheumatoid arthritis and systemic lupus erythematosus (Morand & Leech, 2005, Front Biosci 10:12-22; Shachar & Haran, 2011, Leuk Lymphoma 52:1446-54); kidney diseases such as renal allograft rejection (Lan, 2008, Nephron Exp Nephrol. 109:e79-83); and numerous inflammatory diseases (Meyer-Siegler et al., 2009, Mediators Inflamm epub March 22, 2009; Takahashi et al., 2009, Respir Res 10:33; Milatuzumab (hLL1) is an exemplary anti-CD74 antibody of therapeutic use for treatment of MIF-mediated diseases.

[091] The complement system is a complex cascade involving proteolytic cleavage of serum glycoproteins often activated by cell receptors. The "complement cascade" is constitutive and non-specific but it must be activated in order to function. Complement activation results in a unidirectional sequence of enzymatic and biochemical reactions. In this cascade, a specific complement protein, C5, forms two highly active, inflammatory byproducts, C5a and C5b, which jointly activate white blood cells. This in turn evokes a number of other inflammatory byproducts, including injurious cytokines, inflammatory enzymes, and cell adhesion molecules. Together, these byproducts can lead to the destruction of tissue seen in many inflammatory diseases. This cascade ultimately results in induction of the inflammatory response, phagocyte chemotaxis and opsonization, and cell lysis.

[092] The complement system can be activated via two distinct pathways, the classical pathway and the alternate pathway. Most of the complement components are numbered (*e.g.*, C1, C2, C3, etc.) but some are referred to as "Factors." Some of the components must be enzymatically cleaved to activate their function; others simply combine to form complexes that are active. Active components of the classical pathway include C1q, C1r, C1s, C2a, C2b, C3a, C3b, C4a, and C4b. Active components of the alternate pathway include C3a, C3b, Factor B, Factor Ba, Factor Bb, Factor D, and Properdin. The last stage of each pathway is the same, and involves component assembly into a membrane attack complex. Active components of the membrane attack complex include C5a, C5b, C6, C7, C8, and C9n.

[093] While any of these components of the complement system can be targeted by an antibody complex, certain of the complement components are preferred. C3a, C4a and C5a

cause mast cells to release chemotactic factors such as histamine and serotonin, which attract phagocytes, antibodies and complement, etc. These form one group of preferred targets. Another group of preferred targets includes C3b, C4b and C5b, which enhance phagocytosis of foreign cells. Another preferred group of targets are the predecessor components for these two groups, *i.e.*, C3, C4 and C5. C5b, C6, C7, C8 and C9 induce lysis of foreign cells (membrane attack complex) and form yet another preferred group of targets.

[094] Complement C5a, like C3a, is an anaphylatoxin. It mediates inflammation and is a chemotactic attractant for induction of neutrophilic release of antimicrobial proteases and oxygen radicals. Therefore, C5a and its predecessor C5 are particularly preferred targets. By targeting C5, not only is C5a affected, but also C5b, which initiates assembly of the membrane-attack complex. Thus, C5 is another preferred target. C3b, and its predecessor C3, also are preferred targets, as both the classical and alternate complement pathways depend upon C3b. Three proteins affect the levels of this factor, C1 inhibitor, protein H and Factor I, and these are also preferred targets according to the invention. Complement regulatory proteins, such as CD46, CD55, and CD59, may be targets to which the antibody complexes bind.

[095] Coagulation factors also are preferred targets, particularly tissue factor and thrombin. Tissue factor is also known also as tissue thromboplastin, CD142, coagulation factor III, or factor III. Tissue factor is an integral membrane receptor glycoprotein and a member of the cytokine receptor superfamily. The ligand binding extracellular domain of tissue factor consists of two structural modules with features that are consistent with the classification of tissue factor as a member of type-2 cytokine receptors. Tissue factor is involved in the blood coagulation protease cascade and initiates both the extrinsic and intrinsic blood coagulation cascades by forming high affinity complexes between the extracellular domain of tissue factor and the circulating blood coagulation factors, serine proteases factor VII or factor VIIa. These enzymatically active complexes then activate factor IX and factor X, leading to thrombin generation and clot formation.

[096] Tissue factor is expressed by various cell types, including monocytes, macrophages and vascular endothelial cells, and is induced by IL-1, TNF-α or bacterial lipopolysaccharides. Protein kinase C is involved in cytokine activation of endothelial cell tissue factor expression. Induction of tissue factor by endotoxin and cytokines is an important mechanism for initiation of disseminated intravascular coagulation seen in patients with Gram-negative sepsis. Tissue factor also appears to be involved in a variety of non-hemostatic functions including inflammation, cancer, brain function, immune response, and

tumor-associated angiogenesis. Thus, antibody complexes that target tissue factor are useful not only in the treatment of coagulopathies, but also in the treatment of sepsis, cancer, pathologic angiogenesis, and other immune and inflammatory dysregulatory diseases according to the invention. A complex interaction between the coagulation pathway and the cytokine network is suggested by the ability of several cytokines to influence tissue factor expression in a variety of cells and by the effects of ligand binding to the receptor. Ligand binding (factor VIIa) has been reported to give an intracellular calcium signal, thus indicating that tissue factor is a true receptor.

[097] Thrombin is the activated form of coagulation factor II (prothrombin); it converts fibrinogen to fibrin. Thrombin is a potent chemotaxin for macrophages, and can alter their production of cytokines and arachidonic acid metabolites. It is of particular importance in the coagulopathies that accompany sepsis. Numerous studies have documented the activation of the coagulation system either in septic patients or following LPS administration in animal models. Despite more than thirty years of research, the mechanisms of LPS-induced liver toxicity remain poorly understood. It is now clear that they involve a complex and sequential series of interactions between cellular and humoral mediators. In the same period of time, gram-negative systemic sepsis and its sequalae have become a major health concern, attempts to use monoclonal antibodies directed against LPS or various inflammatory mediators have yielded only therapeutic failures. antibody complexes that target both thrombin and at least one other target address the clinical failures in sepsis treatment.

[098] In other embodiments, the antibody complexes bind to a MHC class I, MHC class II or accessory molecule, such as CD40, CD54, CD80 or CD86. The antibody complex also may bind to a T-cell activation cytokine, or to a cytokine mediator, such as NF-κB.

[099] In certain embodiments, one of the two different targets may be a cancer cell receptor or cancer-associated antigen, particularly one that is selected from the group consisting of B-cell lineage antigens (CD19, CD20, CD21, CD22, CD23, etc.), VEGF, VEGFR, EGFR, carcinoembryonic antigen (CEA), placental growth factor (PlGF), tenascin, HER-2/*neu*, EGP-1, EGP-2, CD25, CD30, CD33, CD38, CD40, CD45, CD52, CD74, CD80, CD138, NCA66, CEACAM1, CEACAM6 (carcinoembryonic antigen-related cellular adhesion molecule 6), MUC1, MUC2, MUC3, MUC4, MUC16, IL-6, α-fetoprotein (AFP), A3, CA125, colon-specific antigen-p (CSAp), folate receptor, HLA-DR, human chorionic gonadotropin (HCG), Ia, EL-2, insulin-like growth factor (IGF) and IGF receptor, KS-1, Le(y), MAGE, necrosis antigens, PAM-4, prostatic acid phosphatase (PAP), Pr1, prostate

specific antigen (PSA), prostate specific membrane antigen (PSMA), S100, T101, TAC, TAG72, TRAIL receptors, and carbonic anhydrase IX.

[0100] Targets associated with sepsis and immune dysregulation and other immune disorders include MIF, IL-1, IL-6, IL-8, CD74, CD83, and C5aR. Antibodies and inhibitors against C5aR have been found to improve survival in rodents with sepsis (Huber-Lang *et al.*, *FASEB J* 2002; 16:1567-1574; Riedemann *et al.*, *J Clin Invest* 2002; 110:101-108) and septic shock and adult respiratory distress syndrome in monkeys (Hangen *et al.*, *J Surg Res* 1989; 46:195-199; Stevens *et al.*, *J Clin Invest* 1986; 77:1812-1816). Thus, for sepsis, one of the two different targets preferably is a target that is associated with infection, such as LPS/C5a. Other preferred targets include HMGB-1, tissue factor, CD14, VEGF, and IL-6, each of which is associated with septicemia or septic shock. Preferred antibody complexes are those that target two or more targets from HMGB-1, tissue factor and MIF, such as MIF/tissue factor, and HMGB-1/tissue factor.

[0101] In still other embodiments, one of the different targets may be a target that is associated with graft versus host disease or transplant rejection, such as MIF (Lo *et al.*, *Bone Marrow Transplant*, 30(6):375-80 (2002)). One of the different targets also may be one that associated with acute respiratory distress syndrome, such as IL-8 (Bouros *et al.*, *PMC Pulm Med*, 4(1):6 (2004), atherosclerosis or restenosis, such as MIF (Chen *et al.*, *Arterioscler Thromb Vasc Biol*, 24(4):709-14 (2004), asthma, such as IL-18 (Hata *et al.*, *Int Immunol*, Oct. 11, 2004 Epub ahead of print), a granulomatous disease, such as TNF-α (Ulbricht *et al.*, *Arthritis Rheum*, 50(8):2717-8 (2004), a neuropathy, such as carbamylated EPO (erythropoietin) (Leist *et al.*, *Science* 305(5681):164-5 (2004), or cachexia, such as IL-6 and TNF-α.

[0102] Other targets include C5a, LPS, IFN-gamma, B7; CD2, CD4, CD14, CD18, CD11a, CD11b, CD11c, CD14, CD18, CD27, CD29, CD38, CD40L, CD52, CD64, CD83, CD147, CD154. Activation of mononuclear cells by certain microbial antigens, including LPS, can be inhibited to some extent by antibodies to CD18, CD11b, or CD11c, which thus implicate β_2-integrins (Cuzzola *et al.*, *J Immunol* 2000; 164:5871-5876; Medvedev *et al.*, *J Immunol* 1998; 160: 4535-4542). CD83 has been found to play a role in giant cell arteritis (GCA), which is a systemic vasculitis that affects medium- and large-size arteries, predominately the extracranial branches of the aortic arch and of the aorta itself, resulting in vascular stenosis and subsequent tissue ischemia, and the severe complications of blindness, stroke and aortic arch syndrome (Weyand and Goronzy, *N Engl J Med* 2003; 349:160-169; Hunder and Valente, *In:* Inflammatory Diseases of Blood Vessels. G.S. Hoffman and C.M. Weyand, eds,

Marcel Dekker, New York, 2002; 255-265). Antibodies to CD83 were found to abrogate vasculitis in a SCID mouse model of human GCA (Ma-Krupa *et al.*, *J Exp Med* 2004; 199:173-183), suggesting to these investigators that dendritic cells, which express CD83 when activated, are critical antigen-processing cells in GCA. In these studies, they used a mouse anti-CD83 MAb (IgG1 clone HB15e from Research Diagnostics). CD154, a member of the TNF family, is expressed on the surface of CD4-positive T-lymphocytes, and it has been reported that a humanized monoclonal antibody to CD154 produced significant clinical benefit in patients with active systemic lupus erythematosus (SLE) (Grammar *et al.*, *J Clin Invest* 2003; 112:1506-1520). It also suggests that this antibody might be useful in other autoimmune diseases (Kelsoe, *J Clin Invest* 2003; 112:1480-1482). Indeed, this antibody was also reported as effective in patients with refractory immune thrombocytopenic purpura (Kuwana *et al.*, *Blood* 2004; 103:1229-1236).

[0103] In rheumatoid arthritis, a recombinant interleukin-1 receptor antagonist, IL-1Ra or anakinra, has shown activity (Cohen *et al.*, *Ann Rheum Dis* 2004; 63:1062-8; Cohen, *Rheum Dis Clin North Am* 2004; 30:365-80). An improvement in treatment of these patients, which hitherto required concomitant treatment with methotrexate, is to combine anakinra with one or more of the anti-proinflammatory effector cytokines or anti-proinflammatory effector chemokines (as listed above). Indeed, in a review of antibody therapy for rheumatoid arthritis, Taylor (*Curr Opin Pharmacol* 2003; 3:323-328) suggests that in addition to TNF, other antibodies to such cytokines as IL-1, IL-6, IL-8, IL-15, IL-17 and IL-18, are useful.

[0104] The pharmaceutical composition of the present invention may be used to treat a subject having a metabolic disease, such amyloidosis, or a neurodegenerative disease, such as Alzheimer's disease. Bapineuzumab is in clinical trials for Alzheimer's disease therapy. Other antibodies proposed for therapy of Alzheimer's disease include Alz 50 (Ksiezak-Reding et al., 1987, J Biol Chem 263:7943-47), gantenerumab, and solanezumab. Infliximab, an anti-TNF-α antibody, has been reported to reduce amyloid plaques and improve cognition.

[0105] In a preferred embodiment, diseases that may be treated using the claimed compositions and methods include cardiovascular diseases, such as fibrin clots, atherosclerosis, myocardial ischemia and infarction. Antibodies to fibrin (e.g., scFv(59D8); T2G1s; MH1) are known and in clinical trials as imaging agents for disclosing said clots and pulmonary emboli, while anti-granulocyte antibodies, such as MN-3, MN-15, anti-NCA95, and anti-CD15 antibodies, can target myocardial infarcts and myocardial ischemia. (See, e.g., U.S. Patent Nos. 5,487,892; 5,632,968; 6,294,173; 7,541,440, the Examples section of

each incorporated herein by reference) Anti-macrophage, anti-low-density lipoprotein (LDL), anti-MIF, and anti-CD74 (e.g., hLL1) antibodies can be used to target atherosclerotic plaques. Abciximab (anti-glycoprotein IIb/IIIa) has been approved for adjuvant use for prevention of restenosis in percutaneous coronary interventions and the treatment of unstable angina (Waldmann et al., 2000, Hematol 1:394-408). Anti-CD3 antibodies have been reported to reduce development and progression of atherosclerosis (Steffens et al., 2006, Circulation 114:1977-84). Antibodies against oxidized LDL induced a regression of established atherosclerosis in a mouse model (Ginsberg, 2007, J Am Coll Cardiol 52:2319-21). Anti-ICAM-1 antibody was shown to reduce ischemic cell damage after cerebral artery occlusion in rats (Zhang et al., 1994, Neurology 44:1747-51). Commercially available monoclonal antibodies to leukocyte antigens are represented by: OKT anti-T-cell monoclonal antibodies (available from Ortho Pharmaceutical Company) which bind to normal T-lymphocytes; the monoclonal antibodies produced by the hybridomas having the ATCC accession numbers HB44, HB55, HB12, HB78 and HB2; G7Ell, W8E7, NKP15 and GO22 (Becton Dickinson); NEN9.4 (New England Nuclear); and FMCll (Sera Labs). A description of antibodies against fibrin and platelet antigens is contained in Knight, Semin. Nucl. Med., 20:52-67 (1990).

[0106] Other antibodies that may be used include antibodies against infectious disease agents, such as bacteria, viruses, mycoplasms or other pathogens. Many antibodies against such infectious agents are known in the art and any such known antibody may be used in the claimed methods and compositions. For example, antibodies against the gp120 glycoprotein antigen of human immunodeficiency virus I (HIV-1) are known, and certain of such antibodies can have an immunoprotective role in humans. See, e.g., Rossi et al., Proc. Natl. Acad. Sci. USA. 86:8055-8058, 1990. Known anti-HIV antibodies include the anti-envelope antibody described by Johansson et al. (AIDS. 2006 Oct 3;20(15):1911-5), as well as the anti-HIV antibodies described and sold by Polymun (Vienna, Austria), also described in U.S. Patent 5,831,034, U.S. patent 5,911,989, and Vcelar et al., AIDS 2007; 21(16):2161-2170 and Joos et al., Antimicrob. Agents Chemother. 2006; 50(5):1773-9, all incorporated herein by reference.

[0107] Antibodies against malaria parasites can be directed against the sporozoite, merozoite, schizont and gametocyte stages. Monoclonal antibodies have been generated against sporozoites (cirumsporozoite antigen), and have been shown to neutralize sporozoites in vitro and in rodents (N. Yoshida et al., Science 207:71-73, 1980). Several groups have developed antibodies to T. gondii, the protozoan parasite involved in toxoplasmosis (Kasper et al., J.

Immunol. 129:1694-1699, 1982; Id., 30:2407-2412, 1983). Antibodies have been developed against schistosomular surface antigens and have been found to act against schistosomulae in vivo or in vitro (Simpson et al., Parasitology, 83:163-177, 1981; Smith et al., Parasitology, 84:83-91, 1982: Gryzch et al., J. Immunol., 129:2739-2743, 1982; Zodda et al., J. Immunol. 129:2326-2328, 1982; Dissous et al., J. immunol., 129:2232-2234, 1982)

[0108] Trypanosoma cruzi is the causative agent of Chagas' disease, and is transmitted by blood-sucking reduviid insects. An antibody has been generated that specifically inhibits the differentiation of one form of the parasite to another (epimastigote to trypomastigote stage) in vitro, and which reacts with a cell-surface glycoprotein; however, this antigen is absent from the mammalian (bloodstream) forms of the parasite (Sher et al., Nature, 300:639-640, 1982).

[0109] Anti-fungal antibodies are known in the art, such as anti-Sclerotinia antibody (U.S. Patent 7,910,702); antiglucuronoxylomannan antibody (Zhong and Priofski, 1998, Clin Diag Lab Immunol 5:58-64); anti-Candida antibodies (Matthews and Burnie, 2001, 2:472-76); and anti-glycosphingolipid antibodies (Toledo et al., 2010, BMC Microbiol 10:47).

[0110] Suitable antibodies have been developed against most of the microorganism (bacteria, viruses, protozoa, fungi, other parasites) responsible for the majority of infections in humans, and many have been used previously for in vitro diagnostic purposes. These antibodies, and newer antibodies that can be generated by conventional methods, are appropriate for use in the present invention.

Immunoconjugates

[0111] In certain embodiments, the antibodies or fragments thereof may be conjugated to one or more therapeutic or diagnostic agents. The therapeutic agents do not need to be the same but can be different, e.g. a drug and a radioisotope. For example, ^{131}I can be incorporated into a tyrosine of an antibody or fusion protein and a drug attached to an epsilon amino group of a lysine residue. Therapeutic and diagnostic agents also can be attached, for example to reduced SH groups and/or to carbohydrate side chains. Many methods for making covalent or non-covalent conjugates of therapeutic or diagnostic agents with antibodies or fusion proteins are known in the art and any such known method may be utilized.

[0112] A therapeutic or diagnostic agent can be attached at the hinge region of a reduced antibody component via disulfide bond formation. Alternatively, such agents can be attached using a heterobifunctional cross-linker, such as *N*-succinyl 3-(2-pyridyldithio)propionate (SPDP). Yu *et al., Int. J. Cancer 56*: 244 (1994). General techniques for such conjugation are well-known in the art. See, for example, Wong, CHEMISTRY OF PROTEIN

CONJUGATION AND CROSS-LINKING (CRC Press 1991); Upeslacis *et al.*, "Modification of Antibodies by Chemical Methods," in MONOCLONAL ANTIBODIES: PRINCIPLES AND APPLICATIONS, Birch *et al.* (eds.), pages 187-230 (Wiley-Liss, Inc. 1995); Price, "Production and Characterization of Synthetic Peptide-Derived Antibodies," in MONOCLONAL ANTIBODIES: PRODUCTION, ENGINEERING AND CLINICAL APPLICATION, Ritter *et al.* (eds.), pages 60-84 (Cambridge University Press 1995). Alternatively, the therapeutic or diagnostic agent can be conjugated via a carbohydrate moiety in the Fc region of the antibody. The carbohydrate group can be used to increase the loading of the same agent that is bound to a thiol group, or the carbohydrate moiety can be used to bind a different therapeutic or diagnostic agent.

[0113] Methods for conjugating peptides to antibody components via an antibody carbohydrate moiety are well-known to those of skill in the art. See, for example, Shih *et al.*, *Int. J. Cancer 41*: 832 (1988); Shih *et al., Int. J. Cancer 46*: 1101 (1990); and Shih *et al.*, U.S. Patent No. 5,057,313, incorporated herein in their entirety by reference. The general method involves reacting an antibody component having an oxidized carbohydrate portion with a carrier polymer that has at least one free amine function. This reaction results in an initial Schiff base (imine) linkage, which can be stabilized by reduction to a secondary amine to form the final conjugate.

[0114] The Fc region may be absent if the antibody used as the antibody component of the immunoconjugate is an antibody fragment. However, it is possible to introduce a carbohydrate moiety into the light chain variable region of a full length antibody or antibody fragment. See, for example, Leung *et al., J. Immunol. 154*: 5919 (1995); Hansen *et al.*, U.S. Patent No. 5,443,953 (1995), Leung *et al.*, U.S. patent No. 6,254,868, incorporated herein by reference in their entirety. The engineered carbohydrate moiety is used to attach the therapeutic or diagnostic agent.

[0115] In some embodiments, a chelating agent may be attached to an antibody, antibody fragment or fusion protein and used to chelate a therapeutic or diagnostic agent, such as a radionuclide. Exemplary chelators include but are not limited to DTPA (such as Mx-DTPA), DOTA, TETA, NETA or NOTA. Methods of conjugation and use of chelating agents to attach metals or other ligands to proteins are well known in the art (see, e.g., U.S. Patent No. 7,563,433, the Examples section of which is incorporated herein by reference).

[0116] In certain embodiments, radioactive metals or paramagnetic ions may be attached to proteins or peptides by reaction with a reagent having a long tail, to which may be attached a multiplicity of chelating groups for binding ions. Such a tail can be a polymer such as a

polylysine, polysaccharide, or other derivatized or derivatizable chains having pendant groups to which can be bound chelating groups such as, *e.g.*, ethylenediaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), porphyrins, polyamines, crown ethers, bis-thiosemicarbazones, polyoximes, and like groups known to be useful for this purpose.

[0117] Chelates may be directly linked to antibodies or peptides, for example as disclosed in U.S. Patent 4,824,659, incorporated herein in its entirety by reference. Particularly useful metal-chelate combinations include 2-benzyl-DTPA and its monomethyl and cyclohexyl analogs, used with diagnostic isotopes in the general energy range of 60 to 4,000 keV, such as ^{125}I, ^{131}I, ^{123}I, ^{124}I, ^{62}Cu, ^{64}Cu, ^{18}F, ^{111}In, ^{67}Ga, ^{68}Ga, ^{99m}Tc, ^{94m}Tc, ^{11}C, ^{13}N, ^{15}O, ^{76}Br, for radioimaging. The same chelates, when complexed with non-radioactive metals, such as manganese, iron and gadolinium are useful for MRI. Macrocyclic chelates such as NOTA, DOTA, and TETA are of use with a variety of metals and radiometals, most particularly with radionuclides of gallium, yttrium and copper, respectively. Such metal-chelate complexes can be made very stable by tailoring the ring size to the metal of interest. Other ring-type chelates such as macrocyclic polyethers, which are of interest for stably binding nuclides, such as ^{223}Ra for RAIT are encompassed.

[0118] More recently, methods of ^{18}F-labeling of use in PET scanning techniques have been disclosed, for example by reaction of F-18 with a metal or other atom, such as aluminum. The ^{18}F-Al conjugate may be complexed with chelating groups, such as DOTA, NOTA or NETA that are attached directly to antibodies or used to label targetable constructs in pre-targeting methods. Such F-18 labeling techniques are disclosed in U.S. Patent No. 7,563,433, the Examples section of which is incorporated herein by reference.

Pre-Targeting

[0119] In certain embodiments, therapeutic agents may be administered by a pretargeting method, utilizing bispecific or multispecific antibody complexes. In pretargeting, the bispecific or multispecific antibody comprises at least one binding arm that binds to an antigen exhibited by a targeted cell or tissue, while at least one other binding arm binds to a hapten on a targetable construct. The targetable construct comprises one or more haptens and one or more therapeutic and/or diagnostic agents.

[0120] Pre-targeting is a multistep process originally developed to resolve the slow blood clearance of directly targeting antibodies, which contributes to undesirable toxicity to normal tissues such as bone marrow. With pre-targeting, a radionuclide or other diagnostic or therapeutic agent is attached to a small delivery molecule (targetable construct) that is cleared

within minutes from the blood. A pre-targeting bispecific or multispecific antibody, which has binding sites for the targetable construct as well as a target antigen, is administered first, free antibody is allowed to clear from circulation and then the targetable construct is administered.

[0121] Pre-targeting methods are disclosed, for example, in Goodwin et al., U.S. Pat. No. 4,863,713; Goodwin et al., J. Nucl. Med. 29:226, 1988; Hnatowich et al., J. Nucl. Med. 28:1294, 1987; Oehr et al., J. Nucl. Med. 29:728, 1988; Klibanov et al., J. Nucl. Med. 29:1951, 1988; Sinitsyn et al., J. Nucl. Med. 30:66, 1989; Kalofonos et al., J. Nucl. Med. 31:1791, 1990; Schechter et al., Int. J. Cancer 48:167, 1991; Paganelli et al., Cancer Res. 51:5960, 1991; Paganelli et al., Nucl. Med. Commun. 12:211, 1991; U.S. Pat. No. 5,256,395; Stickney et al., Cancer Res. 51:6650, 1991; Yuan et al., Cancer Res. 51:3119, 1991; U.S. Pat. Nos. 6,077,499; 7,011,812; 7,300,644; 7,074,405; 6,962,702; 7,387,772; 7,052,872; 7,138,103; 6,090,381; 6,472,511; 6,962,702; and 6,962,702, each incorporated herein by reference.

[0122] A pre-targeting method of treating or diagnosing a disease or disorder in a subject may be provided by: (1) administering to the subject an antibody complex comprising a bispecific antibody or antibody fragment; (2) optionally administering to the subject a clearing composition, and allowing the composition to clear the antibody from circulation; and (3) administering to the subject the targetable construct, containing one or more chelated or chemically bound therapeutic or diagnostic agents.

DOCK-AND-LOCK™ (DNL™)

[0123] In preferred embodiments, a bivalent or multivalent antibody or an antibody complexed to one or more effectors, such as cytokines, toxins, xenoantigens or siRNA carriers, is formed as a DOCK-AND-LOCK™ (DNL™) complex (see, e.g., U.S. Patent Nos. 7,521,056; 7,527,787; 7,534,866; 7,550,143; 7,666,400; 7,901,680; 7,906,118; 7,981,398; 8,003,111, the Examples section of each of which is incorporated herein by reference.) Generally, the technique takes advantage of the specific and high-affinity binding interactions that occur between a dimerization and docking domain (DDD) sequence of the regulatory (R) subunits of cAMP-dependent protein kinase (PKA) and an anchor domain (AD) sequence derived from any of a variety of AKAP proteins (Baillie *et al.*, FEBS Letters. 2005; 579: 3264. Wong and Scott, Nat. Rev. Mol. Cell Biol. 2004; 5: 959). The DDD and AD peptides may be attached to any protein, peptide or other molecule. Because the DDD sequences

spontaneously dimerize and bind to the AD sequence, the technique allows the formation of complexes between any selected molecules that may be attached to DDD or AD sequences.

[0124] Although the standard DNL™ complex comprises a trimer with two DDD-linked molecules attached to one AD-linked molecule, variations in complex structure allow the formation of dimers, trimers, tetramers, pentamers, hexamers and other multimers. In some embodiments, the DNL™ complex may comprise two or more antibodies, antibody fragments or fusion proteins which bind to the same antigenic determinant or to two or more different antigens. The DNL™ complex may also comprise one or more other effectors, such as proteins, peptides, immunomodulators, cytokines, interleukins, interferons, binding proteins, peptide ligands, carrier proteins, toxins, ribonucleases such as onconase, inhibitory oligonucleotides such as siRNA, antigens or xenoantigens, polymers such as PEG, enzymes, therapeutic agents, hormones, cytotoxic agents, anti-angiogenic agents, pro-apoptotic agents or any other molecule or aggregate.

[0125] PKA, which plays a central role in one of the best studied signal transduction pathways triggered by the binding of the second messenger cAMP to the R subunits, was first isolated from rabbit skeletal muscle in 1968 (Walsh *et al.*, J. Biol. Chem. 1968;243:3763). The structure of the holoenzyme consists of two catalytic subunits held in an inactive form by the R subunits (Taylor, J. Biol. Chem. 1989;264:8443). Isozymes of PKA are found with two types of R subunits (RI and RII), and each type has α and β isoforms (Scott, Pharmacol. Ther. 1991;50:123). Thus, the four isoforms of PKA regulatory subunits are RIα, RIβ, RIIα and RIIβ. The R subunits have been isolated only as stable dimers and the dimerization domain has been shown to consist of the first 44 amino-terminal residues of RIIα (Newlon *et al.*, Nat. Struct. Biol. 1999; 6:222). As discussed below, similar portions of the amino acid sequences of other regulatory subunits are involved in dimerization and docking, each located near the N-terminal end of the regulatory subunit. Binding of cAMP to the R subunits leads to the release of active catalytic subunits for a broad spectrum of serine/threonine kinase activities, which are oriented toward selected substrates through the compartmentalization of PKA via its docking with AKAPs (Scott *et al.*, J. Biol. Chem. 1990;265;21561)

[0126] Since the first AKAP, microtubule-associated protein-2, was characterized in 1984 (Lohmann *et al.*, Proc. Natl. Acad. Sci USA. 1984; 81:6723), more than 50 AKAPs that localize to various sub-cellular sites, including plasma membrane, actin cytoskeleton, nucleus, mitochondria, and endoplasmic reticulum, have been identified with diverse structures in species ranging from yeast to humans (Wong and Scott, Nat. Rev. Mol. Cell

Biol. 2004;5:959). The AD of AKAPs for PKA is an amphipathic helix of 14-18 residues (Carr *et al.*, J. Biol. Chem. 1991;266:14188). The amino acid sequences of the AD are quite varied among individual AKAPs, with the binding affinities reported for RII dimers ranging from 2 to 90 nM (Alto *et al.*, Proc. Natl. Acad. Sci. USA. 2003;100:4445). AKAPs will only bind to dimeric R subunits. For human RIIα, the AD binds to a hydrophobic surface formed by the 23 amino-terminal residues (Colledge and Scott, Trends Cell Biol. 1999; 6:216). Thus, the dimerization domain and AKAP binding domain of human RIIα are both located within the same N-terminal 44 amino acid sequence (Newlon *et al.*, Nat. Struct. Biol. 1999;6:222; Newlon *et al.*, EMBO J. 2001;20:1651), which is termed the DDD herein.

[0127] We have developed a platform technology to utilize the DDD of human PKA regulatory subunits and the AD of AKAP as an excellent pair of linker modules for docking any two entities, referred to hereafter as **A** and **B**, into a noncovalent complex, which could be further locked into a DNL™ complex through the introduction of cysteine residues into both the DDD and AD at strategic positions to facilitate the formation of disulfide bonds. The general methodology of the approach is as follows. Entity **A** is constructed by linking a DDD sequence to a precursor of **A,** resulting in a first component hereafter referred to as **a**. Because the DDD sequence would effect the spontaneous formation of a dimer, **A** would thus be composed of $\mathbf{a}_2$. Entity **B** is constructed by linking an AD sequence to a precursor of **B,** resulting in a second component hereafter referred to as **b**. The dimeric motif of DDD contained in $\mathbf{a}_2$ will create a docking site for binding to the AD sequence contained in **b,** thus facilitating a ready association of $\mathbf{a}_2$ and **b** to form a binary, trimeric complex composed of $\mathbf{a}_2\mathbf{b}$. This binding event is stabilized with a subsequent reaction to covalently secure the two entities via disulfide bridges, which occurs very efficiently based on the principle of effective local concentration because the initial binding interactions should bring the reactive thiol groups placed onto both the DDD and AD into proximity (Chmura *et al.*, Proc. Natl. Acad. Sci. USA. 2001;98:8480) to ligate site-specifically. Using various combinations of linkers, adaptor modules and precursors, a wide variety of DNL™ constructs of different stoichiometry may be produced and used (see, e.g., U.S. Nos. 7,550,143; 7,521,056; 7,534,866; 7,527,787 and 7,666,400.)

[0128] By attaching the DDD and AD away from the functional groups of the two precursors, such site-specific ligations are also expected to preserve the original activities of the two precursors. This approach is modular in nature and potentially can be applied to link, site-specifically and covalently, a wide range of substances, including peptides, proteins,

antibodies, antibody fragments, and other effector moieties with a wide range of activities. Utilizing the fusion protein method of constructing AD and DDD conjugated effectors described in the Examples below, virtually any protein or peptide may be incorporated into a DNL™ construct. However, the technique is not limiting and other methods of conjugation may be utilized.

[0129] A variety of methods are known for making fusion proteins, including nucleic acid synthesis, hybridization and/or amplification to produce a synthetic double-stranded nucleic acid encoding a fusion protein of interest. Such double-stranded nucleic acids may be inserted into expression vectors for fusion protein production by standard molecular biology techniques (see, e.g. Sambrook et al., Molecular Cloning, A laboratory manual, 2nd Ed, 1989). In such preferred embodiments, the AD and/or DDD moiety may be attached to either the N-terminal or C-terminal end of an effector protein or peptide. However, the skilled artisan will realize that the site of attachment of an AD or DDD moiety to an effector moiety may vary, depending on the chemical nature of the effector moiety and the part(s) of the effector moiety involved in its physiological activity. Site-specific attachment of a variety of effector moieties may be performed using techniques known in the art, such as the use of bivalent cross-linking reagents and/or other chemical conjugation techniques.

Structure-Function Relationships in AD and DDD Moieties

[0130] For different types of DNL™ constructs, different AD or DDD sequences may be utilized. Exemplary DDD and AD sequences are provided below.

DDD1

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:1)

DDD2

CGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:2)

AD1

QIEYLAKQIVDNAIQQA (SEQ ID NO:3)

AD2

CGQIEYLAKQIVDNAIQQAGC (SEQ ID NO:4)

[0131] The skilled artisan will realize that DDD1 and DDD2 are based on the DDD sequence of the human RIIα isoform of protein kinase A. However, in alternative embodiments, the

DDD and AD moieties may be based on the DDD sequence of the human RIα form of protein kinase A and a corresponding AKAP sequence, as exemplified in DDD3, DDD3C and AD3 below.

DDD3

SLRECELYVQKHNIQALLKDSIVQLCTARPERPMAFLREYFERLEKEEAK (SEQ ID NO:5)

DDD3C

MSCGGSLRECELYVQKHNIQALLKDSIVQLCTARPERPMAFLREYFERLEKEEAK (SEQ ID NO:6)

AD3

CGFEELAWKIAKMIWSDVFQQGC (SEQ ID NO:7)

[0132] In other alternative embodiments, other sequence variants of AD and/or DDD moieties may be utilized in construction of the DNL™ complexes. For example, there are only four variants of human PKA DDD sequences, corresponding to the DDD moieties of PKA RIα, RIIα, RIβ and RIIβ. The RIIα DDD sequence is the basis of DDD1 and DDD2 disclosed above. The four human PKA DDD sequences are shown below. The DDD sequence represents residues 1-44 of RIIα, 1-44 of RIIβ, 12-61 of RIα and 13-66 of RIβ. (Note that the sequence of DDD1 is modified slightly from the human PKA RIIα DDD moiety.)

PKA RIα

SLRECELYVQKHNIQALLKDVSIVQLCTARPERPMAFLREYFEKLEKEEAK (SEQ ID NO:8)

PKA RIβ

SLKGCELYVQLHGIQQVLKDCIVHLCISKPERPMKFLREHFEKLEKEENRQILA (SEQ ID NO:9)

PKA RIIα

SHIQIPPGLTELLQGYTVEVGQQPPDLVDFAVEYFTRLREARRQ (SEQ ID NO:10)

PKA RIIβ

SIEIPAGLTELLQGFTVEVLRHQPADLLEFALQHFTRLQQENER (SEQ ID NO:11)

[0133] The structure-function relationships of the AD and DDD domains have been the subject of investigation. (See, e.g., Burns-Hamuro et al., 2005, Protein Sci 14:2982-92; Carr et al., 2001, J Biol Chem 276:17332-38; Alto et al., 2003, Proc Natl Acad Sci USA 100:4445-50; Hundsrucker et al., 2006, Biochem J 396:297-306; Stokka et al., 2006, Biochem J 400:493-99; Gold et al., 2006, Mol Cell 24:383-95; Kinderman et al., 2006, Mol Cell 24:397-408, the entire text of each of which is incorporated herein by reference.)

[0134] For example, Kinderman et al. (2006, Mol Cell 24:397-408) examined the crystal structure of the AD-DDD binding interaction and concluded that the human DDD sequence contained a number of conserved amino acid residues that were important in either dimer formation or AKAP binding, underlined in SEQ ID NO:1 below. (See Figure 1 of Kinderman et al., 2006, incorporated herein by reference.) The skilled artisan will realize that in designing sequence variants of the DDD sequence, one would desirably avoid changing any of the underlined residues, while conservative amino acid substitutions might be made for residues that are less critical for dimerization and AKAP binding.

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:1)

[0135] As discussed in more detail below, conservative amino acid substitutions have been characterized for each of the twenty common L-amino acids. Thus, based on the data of Kinderman (2006) and conservative amino acid substitutions, potential alternative DDD sequences based on SEQ ID NO:1 are shown in **Table 2**. In devising **Table 2**, only highly conservative amino acid substitutions were considered. For example, charged residues were only substituted for residues of the same charge, residues with small side chains were substituted with residues of similar size, hydroxyl side chains were only substituted with other hydroxyls, etc. Because of the unique effect of proline on amino acid secondary structure, no other residues were substituted for proline. A limited number of such potential alternative DDD moiety sequences are shown in SEQ ID NO:12 to SEQ ID NO:31 below. The skilled artisan will realize that an almost unlimited number of alternative species within the genus of DDD moieties can be constructed by standard techniques, for example using a commercial peptide synthesizer or well known site-directed mutagenesis techniques. The effect of the amino acid substitutions on AD moiety binding may also be readily determined by standard binding assays, for example as disclosed in Alto et al. (2003, Proc Natl Acad Sci USA 100:4445-50).

Table 2. Conservative Amino Acid Substitutions in DDD1 (SEQ ID NO:1). Consensus sequence disclosed as SEQ ID NO:87.

S	H	I	Q	I	P	P	G	L	T	E	L	L	Q	G	Y	T	V	E	V	L	R
T	K R		N				A		S	D			N	A		S		D			K

Q	Q	P	P	D	L	V	E	F	A	V	E	Y	F	T	R	L	R	E	A	R	A
N	N			E			D		L I V		D			S	K		K	D	L I V	K	L I V

THIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:12)

SKIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:13)

SRIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:14)

SHINIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:15)

SHIQIPPALTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:16)

SHIQIPPGLSELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:17)

SHIQIPPGLTDLLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:18)

SHIQIPPGLTELLNGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:19)

SHIQIPPGLTELLQAYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:20)

SHIQIPPGLTELLQGYSVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:21)

SHIQIPPGLTELLQGYTVDVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:22)

SHIQIPPGLTELLQGYTVEVLKQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:23)

SHIQIPPGLTELLQGYTVEVLRNQPPDLVEFAVEYFTRLREARA (SEQ ID NO:24)

SHIQIPPGLTELLQGYTVEVLRQNPPDLVEFAVEYFTRLREARA (SEQ ID NO:25)

SHIQIPPGLTELLQGYTVEVLRQQPPELVEFAVEYFTRLREARA (SEQ ID NO:26)

SHIQIPPGLTELLQGYTVEVLRQQPPDLVDFAVEYFTRLREARA (SEQ ID NO:27)

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFLVEYFTRLREARA (SEQ ID NO:28)

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFIVEYFTRLREARA (SEQ ID NO:29)

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFVVEYFTRLREARA (SEQ ID NO:30)

SHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVDYFTRLREARA (SEQ ID NO:31)

[0136] Alto et al. (2003, Proc Natl Acad Sci USA 100:4445-50) performed a bioinformatic analysis of the AD sequence of various AKAP proteins to design an RII selective AD sequence called AKAP-IS (SEQ ID NO:3), with a binding constant for DDD of 0.4 nM. The AKAP-IS sequence was designed as a peptide antagonist of AKAP binding to PKA. Residues in the AKAP-IS sequence where substitutions tended to decrease binding to DDD are underlined in SEQ ID NO:3 below. The skilled artisan will realize that in designing sequence variants of the AD sequence, one would desirably avoid changing any of the underlined residues, while conservative amino acid substitutions might be made for residues that are less critical for DDD binding. **Table 3** shows potential conservative amino acid substitutions in the sequence of AKAP-IS (AD1, SEQ ID NO:3), similar to that shown for DDD1 (SEQ ID NO:1) in **Table 2** above.

[0137] A limited number of such potential alternative AD moiety sequences are shown in SEQ ID NO:32 to SEQ ID NO:49 below. Again, a very large number of species within the genus of possible AD moiety sequences could be made, tested and used by the skilled artisan, based on the data of Alto et al. (2003). It is noted that Figure 2 of Alto (2003) shows an even large number of potential amino acid substitutions that may be made, while retaining binding activity to DDD moieties, based on actual binding experiments.

AKAP-IS

QIEYLAKQIVDNAIQQA (SEQ ID NO:3)

Table 3. Conservative Amino Acid Substitutions in AD1 (SEQ ID NO:3). Consensus sequence disclosed as SEQ ID NO:88.

Q	**I**	**E**	**Y**	**L**	**A**	**K**	**Q**	**I**	**V**	**D**	**N**	**A**	**I**	**Q**	**Q**	**A**
N	L V	D	F T S	I V		R	N			E	Q			N	N	L I V

NIEYLAKQIVDNAIQQA (SEQ ID NO:32)
QLEYLAKQIVDNAIQQA (SEQ ID NO:33)
QVEYLAKQIVDNAIQQA (SEQ ID NO:34)
QIDYLAKQIVDNAIQQA (SEQ ID NO:35)
QIEFLAKQIVDNAIQQA (SEQ ID NO:36)
QIETLAKQIVDNAIQQA (SEQ ID NO:37)

QIESLAKQIVDNAIQQA (SEQ ID NO:38)

QIEYIAKQIVDNAIQQA (SEQ ID NO:39)

QIEYVAKQIVDNAIQQA (SEQ ID NO:40)

QIEYLARQIVDNAIQQA (SEQ ID NO:41)

QIEYLAKNIVDNAIQQA (SEQ ID NO:42)

QIEYLAKQIVENAIQQA (SEQ ID NO:43)

QIEYLAKQIVDQAIQQA (SEQ ID NO:44)

QIEYLAKQIVDNAINQA (SEQ ID NO:45)

QIEYLAKQIVDNAIQNA (SEQ ID NO:46)

QIEYLAKQIVDNAIQQL (SEQ ID NO:47)

QIEYLAKQIVDNAIQQI (SEQ ID NO:48)

QIEYLAKQIVDNAIQQV (SEQ ID NO:49)

[0138] Gold et al. (2006, Mol Cell 24:383-95) utilized crystallography and peptide screening to develop a SuperAKAP-IS sequence (SEQ ID NO:50), exhibiting a five order of magnitude higher selectivity for the RII isoform of PKA compared with the RI isoform. Underlined residues indicate the positions of amino acid substitutions, relative to the AKAP-IS sequence, which increased binding to the DDD moiety of RIIα. In this sequence, the N-terminal Q residue is numbered as residue number 4 and the C-terminal A residue is residue number 20. Residues where substitutions could be made to affect the affinity for RIIα were residues 8, 11, 15, 16, 18, 19 and 20 (Gold et al., 2006). It is contemplated that in certain alternative embodiments, the SuperAKAP-IS sequence may be substituted for the AKAP-IS AD moiety sequence to prepare DNL™ constructs. Other alternative sequences that might be substituted for the AKAP-IS AD sequence are shown in SEQ ID NO:51-53. Substitutions relative to the AKAP-IS sequence are underlined. It is anticipated that, as with the AD2 sequence shown in SEQ ID NO:4, the AD moiety may also include the additional N-terminal residues cysteine and glycine and C-terminal residues glycine and cysteine.

SuperAKAP-IS

QIEYVAKQIVDYAIHQA (SEQ ID NO:50)

Alternative AKAP sequences

QIEYKAKQIVDHAIHQA (SEQ ID NO:51)

QIEYHAKQIVDHAIHQA (SEQ ID NO:52)

QIEYVAKQIVDHAIHQA (SEQ ID NO:53)

[0139] Figure 2 of Gold et al. disclosed additional DDD-binding sequences from a variety of AKAP proteins, shown below.

RII-Specific AKAPs

AKAP-KL

PLEYQAGLLVQNAIQQAI (SEQ ID NO:54)

AKAP79

LLIETASSLVKNAIQLSI (SEQ ID NO:55)

AKAP-Lbc

LIEEAASRIVDAVIEQVK (SEQ ID NO:56)

RI-Specific AKAPs

AKAPce

ALYQFADRFSELVISEAL (SEQ ID NO:57)

RIAD

LEQVANQLADQIIKEAT (SEQ ID NO:58)

PV38

FEELAWKIAKMIWSDVF (SEQ ID NO:59)

Dual-Specificity AKAPs

AKAP7

ELVRLSKRLVENAVLKAV (SEQ ID NO:60)

MAP2D

TAEEVSARIVQVVTAEAV (SEQ ID NO:61)

DAKAP1

QIKQAAFQLISQVILEAT (SEQ ID NO:62)

DAKAP2

LAWKIAKMIVSDVMQQ (SEQ ID NO:63)

[0140] Stokka et al. (2006, Biochem J 400:493-99) also developed peptide competitors of AKAP binding to PKA, shown in SEQ ID NO:64-66. The peptide antagonists were designated as Ht31 (SEQ ID NO:64), RIAD (SEQ ID NO:65) and PV-38 (SEQ ID NO:66). The Ht-31 peptide exhibited a greater affinity for the RII isoform of PKA, while the RIAD and PV-38 showed higher affinity for RI.

Ht31

DLIEEAASRIVDAVIEQVKAAGAY (SEQ ID NO:64)

RIAD

LEQYANQLADQIIKEATE (SEQ ID NO:65)

PV-38

FEELAWKIAKMIWSDVFQQC (SEQ ID NO:66)

[0141] Hundsrucker et al. (2006, Biochem J 396:297-306) developed still other peptide competitors for AKAP binding to PKA, with a binding constant as low as 0.4 nM to the DDD of the RII form of PKA. The sequences of various AKAP antagonistic peptides are provided in Table 1 of Hundsrucker et al., reproduced in **Table 4** below. AKAPIS represents a synthetic RII subunit-binding peptide. All other peptides are derived from the RII-binding domains of the indicated AKAPs.

Table 4. AKAP Peptide sequences

	Peptide Sequence
AKAPIS	QIEYLAKQIVDNAIQQA (SEQ ID NO:3)
AKAPIS-P	QIEYLAKQIPDNAIQQA (SEQ ID NO:67)
Ht31	KGADLIEEAASRIVDAVIEQVKAAG (SEQ ID NO:68)
Ht31-P	KGADLIEEAASRIPDAPIEQVKAAG (SEQ ID NO:69)
AKAP7δ-wt-pep	PEDAELVRLSKRLVENAVLKAVQQY (SEQ ID NO:70)
AKAP7δ-L304T-pep	PEDAELVRTSKRLVENAVLKAVQQY (SEQ ID NO:71)
AKAP7δ-L308D-pep	PEDAELVRLSKRDVENAVLKAVQQY (SEQ ID NO:72)
AKAP7δ-P-pep	PEDAELVRLSKRLPENAVLKAVQQY (SEQ ID NO:73)
AKAP7δ-PP-pep	PEDAELVRLSKRLPENAPLKAVQQY (SEQ ID NO:74)
AKAP7δ-L314E-pep	PEDAELVRLSKRLVENAVEKAVQQY (SEQ ID NO:75)
AKAP1-pep	EEGLDRNEEIKRAAFQIISQVISEA (SEQ ID NO:76)
AKAP2-pep	LVDDPLEYQAGLLVQNAIQQAIAEQ (SEQ ID NO:77)
AKAP5-pep	QYETLLIETASSLVKNAIQLSIEQL (SEQ ID NO:78)
AKAP9-pep	LEKQYQEQLEEEVAKVIVSMSIAFA (SEQ ID NO:79)
AKAP10-pep	NTDEAQEELAWKIAKMIVSDIMQQA (SEQ ID NO:80)
AKAP11-pep	VNLDKKAVLAEKIVAEAIEKAEREL (SEQ ID NO:81)
AKAP12-pep	NGILELETKSSKLVQNIIQTAVDQF (SEQ ID NO:82)
AKAP14-pep	TQDKNYEDELTQVALALVEDVINYA (SEQ ID NO:83)
Rab32-pep	ETSAKDNINIEEAARFLVEKILVNH (SEQ ID NO:84)

[0142] Residues that were highly conserved among the AD domains of different AKAP proteins are indicated below by underlining with reference to the AKAP IS sequence (SEQ ID NO:3). The residues are the same as observed by Alto et al. (2003), with the addition of the C-terminal alanine residue. (See FIG. 4 of Hundsrucker et al. (2006), incorporated herein by reference.) The sequences of peptide antagonists with particularly high affinities for the RII DDD sequence were those of AKAP-IS, AKAP7δ-wt-pep, AKAP7δ-L304T-pep and AKAP7δ-L308D-pep.

AKAP-IS

QIEYLAKQIVDNAIQQA (SEQ ID NO:3)

[0143] Carr et al. (2001, J Biol Chem 276:17332-38) examined the degree of sequence homology between different AKAP-binding DDD sequences from human and non-human proteins and identified residues in the DDD sequences that appeared to be the most highly conserved among different DDD moieties. These are indicated below by underlining with reference to the human PKA RIIα DDD sequence of SEQ ID NO:1. Residues that were particularly conserved are further indicated by italics. The residues overlap with, but are not identical to those suggested by Kinderman et al. (2006) to be important for binding to AKAP proteins. The skilled artisan will realize that in designing sequence variants of DDD, it would be most preferred to avoid changing the most conserved residues (italicized), and it would be preferred to also avoid changing the conserved residues (underlined), while conservative amino acid substitutions may be considered for residues that are neither underlined nor italicized..

SHIQ*IP*P*GL*TE*LLQGYT*V*EVLR*Q*Q*P*P*DL*VE*FA*VE*YF*TR*L*RE*A*RA (SEQ ID NO:1)

[0144] A modified set of conservative amino acid substitutions for the DDD1 (SEQ ID NO:1) sequence, based on the data of Carr et al. (2001) is shown in **Table 5**. Even with this reduced set of substituted sequences, there are over 65,000 possible alternative DDD moiety sequences that may be produced, tested and used by the skilled artisan without undue experimentation. The skilled artisan could readily derive such alternative DDD amino acid sequences as disclosed above for **Table 2** and **Table 3.**

Table 5. Conservative Amino Acid Substitutions in DDD1 (SEQ ID NO:1). Consensus sequence disclosed as SEQ ID NO:89.

S	H	I	Q	I	P	P	G	L	T	E	L	L	Q	G	Y	T	V	E	V	L	R
T			N						S								I				

																L A				

Q	*Q*	*P*	P	*D*	*L*	V	E	*F*	*A*	V	E	*Y*	*F*	T	R	*L*	R	E	A	*R*	A
N										I L A	D			S	K		K		L I V		L I V

[0145] The skilled artisan will realize that these and other amino acid substitutions in the DDD or AD amino acid sequences may be utilized to produce alternative species within the genus of AD or DDD moieties, using techniques that are standard in the field and only routine experimentation.

Amino Acid Substitutions

[0146] In alternative embodiments, the disclosed methods and compositions may involve production and use of proteins or peptides with one or more substituted amino acid residues. For example, the DDD and/or AD sequences used to make DNL™ constructs may be modified as discussed above.

[0147] The skilled artisan will be aware that, in general, amino acid substitutions typically involve the replacement of an amino acid with another amino acid of relatively similar properties (i.e., conservative amino acid substitutions). The properties of the various amino acids and effect of amino acid substitution on protein structure and function have been the subject of extensive study and knowledge in the art.

[0148] For example, the hydropathic index of amino acids may be considered (Kyte & Doolittle, 1982, J. Mol. Biol., 157:105-132). The relative hydropathic character of the amino acid contributes to the secondary structure of the resultant protein, which in turn defines the interaction of the protein with other molecules. Each amino acid has been assigned a hydropathic index on the basis of its hydrophobicity and charge characteristics (Kyte & Doolittle, 1982), these are: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6); histidine (-3.2); glutamate (-3.5); glutamine (-3.5); aspartate (-3.5); asparagine (-3.5); lysine (-3.9); and arginine (-4.5). In making conservative substitutions, the use of amino acids whose hydropathic indices are within ± 2 is preferred, within ± 1 are more preferred, and within ± 0.5 are even more preferred.

[0149] Amino acid substitution may also take into account the hydrophilicity of the amino acid residue (e.g., U.S. Pat. No. 4,554,101). Hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0); glutamate (+3.0); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); threonine (-0.4); proline (-0.5 .+-.1); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5); tryptophan (-3.4). Replacement of amino acids with others of similar hydrophilicity is preferred.

[0150] Other considerations include the size of the amino acid side chain. For example, it would generally not be preferred to replace an amino acid with a compact side chain, such as glycine or serine, with an amino acid with a bulky side chain, e.g., tryptophan or tyrosine. The effect of various amino acid residues on protein secondary structure is also a consideration. Through empirical study, the effect of different amino acid residues on the tendency of protein domains to adopt an alpha-helical, beta-sheet or reverse turn secondary structure has been determined and is known in the art (see, e.g., Chou & Fasman, 1974, Biochemistry, 13:222-245; 1978, Ann. Rev. Biochem., 47: 251-276; 1979, Biophys. J., 26:367-384).

[0151] Based on such considerations and extensive empirical study, tables of conservative amino acid substitutions have been constructed and are known in the art. For example: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine; and valine, leucine and isoleucine. Alternatively: Ala (A) leu, ile, val; Arg (R) gln, asn, lys; Asn (N) his, asp, lys, arg, gln; Asp (D) asn, glu; Cys (C) ala, ser; Gln (Q) glu, asn; Glu (E) gln, asp; Gly (G) ala; His (H) asn, gln, lys, arg; Ile (I) val, met, ala, phe, leu; Leu (L) val, met, ala, phe, ile; Lys (K) gln, asn, arg; Met (M) phe, ile, leu; Phe (F) leu, val, ile, ala, tyr; Pro (P) ala; Ser (S), thr; Thr (T) ser; Trp (W) phe, tyr; Tyr (Y) trp, phe, thr, ser; Val (V) ile, leu, met, phe, ala.

[0152] Other considerations for amino acid substitutions include whether or not the residue is located in the interior of a protein or is solvent exposed. For interior residues, conservative substitutions would include: Asp and Asn; Ser and Thr; Ser and Ala; Thr and Ala; Ala and Gly; Ile and Val; Val and Leu; Leu and Ile; Leu and Met; Phe and Tyr; Tyr and Trp. (See, e.g., PROWL website at rockefeller.edu) For solvent exposed residues, conservative substitutions would include: Asp and Asn; Asp and Glu; Glu and Gln; Glu and Ala; Gly and Asn; Ala and Pro; Ala and Gly; Ala and Ser; Ala and Lys; Ser and Thr; Lys and Arg; Val and Leu; Leu and Ile; Ile and Val; Phe and Tyr. (Id.) Various matrices have been constructed to assist in selection of amino acid substitutions, such as the PAM250 scoring matrix, Dayhoff

matrix, Grantham matrix, McLachlan matrix, Doolittle matrix, Henikoff matrix, Miyata matrix, Fitch matrix, Jones matrix, Rao matrix, Levin matrix and Risler matrix (*Idem.*)

[0153] In determining amino acid substitutions, one may also consider the existence of intermolecular or intramolecular bonds, such as formation of ionic bonds (salt bridges) between positively charged residues (e.g., His, Arg, Lys) and negatively charged residues (e.g., Asp, Glu) or disulfide bonds between nearby cysteine residues.

[0154] Methods of substituting any amino acid for any other amino acid in an encoded protein sequence are well known and a matter of routine experimentation for the skilled artisan, for example by the technique of site-directed mutagenesis or by synthesis and assembly of oligonucleotides encoding an amino acid substitution and splicing into an expression vector construct.

Therapeutic Agents

[0155] In alternative embodiments, therapeutic agents such as cytotoxic agents, anti-angiogenic agents, pro-apoptotic agents, antibiotics, hormones, hormone antagonists, chemokines, drugs, prodrugs, toxins, enzymes or other agents may be used, either conjugated to the subject immunotoxins or separately administered before, simultaneously with, or after the immunotoxin. Drugs of use may possess a pharmaceutical property selected from the group consisting of antimitotic, antikinase, alkylating, antimetabolite, antibiotic, alkaloid, anti-angiogenic, pro-apoptotic agents and combinations thereof.

[0156] Exemplary drugs of use may include 5-fluorouracil, aplidin, azaribine, anastrozole, anthracyclines, bendamustine, bleomycin, bortezomib, bryostatin-1, busulfan, calicheamycin, camptothecin, carboplatin, 10-hydroxycamptothecin, carmustine, celebrex, chlorambucil, cisplatin (CDDP), Cox-2 inhibitors, irinotecan (CPT-11), SN-38, carboplatin, cladribine, camptothecans, cyclophosphamide, cytarabine, dacarbazine, docetaxel, dactinomycin, daunorubicin, doxorubicin, 2-pyrrolinodoxorubicine (2P-DOX), cyano-morpholino doxorubicin, doxorubicin glucuronide, epirubicin glucuronide, estramustine, epipodophyllotoxin, estrogen receptor binding agents, etoposide (VP16), etoposide glucuronide, etoposide phosphate, floxuridine (FUdR), 3',5'-O-dioleoyl-FudR (FUdR-dO), fludarabine, flutamide, farnesyl-protein transferase inhibitors, gemcitabine, hydroxyurea, idarubicin, ifosfamide, L-asparaginase, lenolidamide, leucovorin, lomustine, mechlorethamine, melphalan, mercaptopurine, 6-mercaptopurine, methotrexate, mitoxantrone, mithramycin, mitomycin, mitotane, navelbine, nitrosourea, plicomycin, procarbazine, paclitaxel, pentostatin, PSI-341, raloxifene, semustine, streptozocin, tamoxifen, taxol, temazolomide (an aqueous form of DTIC), transplatinum, thalidomide,

thioguanine, thiotepa, teniposide, topotecan, uracil mustard, vinorelbine, vinblastine, vincristine and vinca alkaloids.

[0157] Toxins of use may include ricin, abrin, alpha toxin, saporin, ribonuclease (RNase), e.g., onconase, DNase I, *Staphylococcal* enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, *Pseudomonas* exotoxin, and *Pseudomonas* endotoxin.

[0158] Chemokines of use may include RANTES, MCAF, MIP1-alpha, MIP1-Beta and IP-10.

[0159] In certain embodiments, anti-angiogenic agents, such as angiostatin, baculostatin, canstatin, maspin, anti-VEGF antibodies, anti-PlGF peptides and antibodies, anti-vascular growth factor antibodies, anti-Flk-1 antibodies, anti-Flt-1 antibodies and peptides, anti-Kras antibodies, anti-cMET antibodies, anti-MIF (macrophage migration-inhibitory factor) antibodies, laminin peptides, fibronectin peptides, plasminogen activator inhibitors, tissue metalloproteinase inhibitors, interferons, interleukin-12, IP-10, Gro-ß, thrombospondin, 2-methoxyoestradiol, proliferin-related protein, carboxiamidotriazole, CM101, Marimastat, pentosan polysulphate, angiopoietin-2, interferon-alpha, herbimycin A, PNU145156E, 16K prolactin fragment, Linomide (roquinimex), thalidomide, pentoxifylline, genistein, TNP-470, endostatin, paclitaxel, accutin, angiostatin, cidofovir, vincristine, bleomycin, AGM-1470, platelet factor 4 or minocycline may be of use.

[0160] Immunomodulators of use may be selected from a cytokine, a stem cell growth factor, a lymphotoxin, a hematopoietic factor, a colony stimulating factor (CSF), an interferon (IFN), erythropoietin, thrombopoietin and a combination thereof. Specifically useful are lymphotoxins such as tumor necrosis factor (TNF), hematopoietic factors, such as interleukin (IL), colony stimulating factor, such as granulocyte-colony stimulating factor (G-CSF) or granulocyte macrophage-colony stimulating factor (GM-CSF), interferon, such as interferons-α, -β or -γ, and stem cell growth factor, such as that designated "S1 factor". Included among the cytokines are growth hormones such as human growth hormone, N-methionyl human growth hormone, and bovine growth hormone; parathyroid hormone; thyroxine; insulin; proinsulin; relaxin; prorelaxin; glycoprotein hormones such as follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), and luteinizing hormone (LH); hepatic growth factor; prostaglandin, fibroblast growth factor; prolactin; placental lactogen, OB protein; tumor necrosis factor-α and - ß; mullerian-inhibiting substance; mouse gonadotropin-associated peptide; inhibin; activin; vascular endothelial growth factor; integrin; thrombopoietin (TPO); nerve growth factors such as NGF-ß; platelet-growth factor; transforming growth factors (TGFs) such as TGF- α and TGF- ß; insulin-like growth factor-I

and -II; erythropoietin (EPO); osteoinductive factors; interferons such as interferon-α, -β, and -γ; colony stimulating factors (CSFs) such as macrophage-CSF (M-CSF); interleukins (ILs) such as IL-1, IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12; IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, IL-25, LIF, kit-ligand or FLT-3, angiostatin, thrombospondin, endostatin, tumor necrosis factor and LT.

[0161] Radionuclides of use include, but are not limited to- ^{111}In, ^{177}Lu, ^{212}Bi, ^{213}Bi, ^{211}At, ^{62}Cu, ^{67}Cu, ^{90}Y, ^{125}I, ^{131}I, ^{32}P, ^{33}P, ^{47}Sc, ^{111}Ag, ^{67}Ga, ^{142}Pr, ^{153}Sm, ^{161}Tb, ^{166}Dy, ^{166}Ho, ^{186}Re, ^{188}Re, ^{189}Re, ^{212}Pb, ^{223}Ra, ^{225}Ac, ^{59}Fe, ^{75}Se, ^{77}As, ^{89}Sr, ^{99}Mo, ^{105}Rh, ^{109}Pd, ^{143}Pr, ^{149}Pm, ^{169}Er, ^{194}Ir, ^{198}Au, ^{199}Au, and ^{211}Pb. The therapeutic radionuclide preferably has a decay-energy in the range of 20 to 6,000 keV, preferably in the ranges 60 to 200 keV for an Auger emitter, 100-2,500 keV for a beta emitter, and 4,000-6,000 keV for an alpha emitter. Maximum decay energies of useful beta-particle-emitting nuclides are preferably 20-5,000 keV, more preferably 100-4,000 keV, and most preferably 500-2,500 keV. Also preferred are radionuclides that substantially decay with Auger-emitting particles. For example, Co-58, Ga-67, Br-80m, Tc-99m, Rh-103m, Pt-109, In-111, Sb-119, 1-125, Ho-161, Os-189m and Ir-192. Decay energies of useful beta-particle-emitting nuclides are preferably <1,000 keV, more preferably <100 keV, and most preferably <70 keV. Also preferred are radionuclides that substantially decay with generation of alpha-particles. Such radionuclides include, but are not limited to: Dy-152, At-211, Bi-212, Ra-223, Rn-219, Po-215, Bi-211, Ac-225, Fr-221, At-217, Bi-213 and Fm-255. Decay energies of useful alpha-particle-emitting radionuclides are preferably 2,000-10,000 keV, more preferably 3,000-8,000 keV, and most preferably 4,000-7,000 keV. Additional potential radioisotopes of use include ^{11}C, ^{13}N, ^{15}O, ^{75}Br, ^{198}Au, ^{224}Ac, ^{126}I, ^{133}I, ^{77}Br, ^{113m}In, ^{95}Ru, ^{97}Ru, ^{103}Ru, ^{105}Ru, ^{107}Hg, ^{203}Hg, ^{121m}Te, ^{122m}Te, ^{125m}Te, ^{165}Tm, ^{167}Tm, ^{168}Tm, ^{197}Pt, ^{109}Pd, ^{105}Rh, ^{142}Pr, ^{143}Pr, ^{161}Tb, ^{166}Ho, ^{199}Au, ^{57}Co, ^{58}Co, ^{51}Cr, ^{59}Fe, ^{75}Se, ^{201}Tl, ^{225}Ac, ^{76}Br, ^{169}Yb, and the like. Some useful diagnostic nuclides may include ^{18}F, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{89}Zr, ^{94}Tc, ^{94m}Tc, ^{99m}Tc, or ^{111}In.

[0162] Therapeutic agents may include a photoactive agent or dye. Fluorescent compositions, such as fluorochrome, and other chromogens, or dyes, such as porphyrins sensitive to visible light, have been used to detect and to treat lesions by directing the suitable light to the lesion. In therapy, this has been termed photoradiation, phototherapy, or photodynamic therapy. See Jori et al. (eds.), PHOTODYNAMIC THERAPY OF TUMORS AND OTHER DISEASES (Libreria Progetto 1985); van den Bergh, Chem. Britain (1986),

22:430. Moreover, monoclonal antibodies have been coupled with photoactivated dyes for achieving phototherapy. See Mew et al., J. Immunol. (1983),130:1473; idem., Cancer Res. (1985), 45:4380; Oseroff et al., Proc. Natl. Acad. Sci. USA (1986), 83:8744; idem., Photochem. Photobiol. (1987), 46:83; Hasan et al., Prog. Clin. Biol. Res. (1989), 288:471; Tatsuta et al., Lasers Surg. Med. (1989), 9:422; Pelegrin et al., Cancer (1991), 67:2529.

[0163] Other useful therapeutic agents may comprise oligonucleotides, especially antisense oligonucleotides that preferably are directed against oncogenes and oncogene products, such as bcl-2 or p53. A preferred form of therapeutic oligonucleotide is siRNA. The skilled artisan will realize that any siRNA or interference RNA species may be attached to an antibody or fragment thereof for delivery to a targeted tissue. Many siRNA species against a wide variety of targets are known in the art, and any such known siRNA may be utilized in the claimed methods and compositions.

[0164] Known siRNA species of potential use include those specific for IKK-gamma (U.S. Patent 7,022,828); VEGF, Flt-1 and Flk-1/KDR (U.S. Patent 7,148,342); Bcl2 and EGFR (U.S. Patent 7,541,453); CDC20 (U.S. Patent 7,550,572); transducin (beta)-like 3 (U.S. Patent 7,576,196); KRAS (U.S. Patent 7,576,197); carbonic anhydrase II (U.S. Patent 7,579,457); complement component 3 (U.S. Patent 7,582,746); interleukin-1 receptor-associated kinase 4 (IRAK4) (U.S. Patent 7,592,443); survivin (U.S. Patent 7,608,7070); superoxide dismutase 1 (U.S. Patent 7,632,938); MET proto-oncogene (U.S. Patent 7,632,939); amyloid beta precursor protein (APP) (U.S. Patent 7,635,771); IGF-1R (U.S. Patent 7,638,621); ICAM1 (U.S. Patent 7,642,349); complement factor B (U.S. Patent 7,696,344); p53 (7,781,575), and apolipoprotein B (7,795,421), the Examples section of each referenced patent incorporated herein by reference.

[0165] Additional siRNA species are available from known commercial sources, such as Sigma-Aldrich (St Louis, MO), Invitrogen (Carlsbad, CA), Santa Cruz Biotechnology (Santa Cruz, CA), Ambion (Austin, TX), Dharmacon (Thermo Scientific, Lafayette, CO), Promega (Madison, WI), Mirus Bio (Madison, WI) and Qiagen (Valencia, CA), among many others. Other publicly available sources of siRNA species include the siRNAdb database at the Stockholm Bioinformatics Centre, the MIT/ICBP siRNA Database, the RNAi Consortium shRNA Library at the Broad Institute, and the Probe database at NCBI. For example, there are 30,852 siRNA species in the NCBI Probe database. The skilled artisan will realize that for any gene of interest, either a siRNA species has already been designed, or one may readily be designed using publicly available software tools. Any such siRNA species may be delivered using the subject DNL complexes.

[0166] Exemplary siRNA species known in the art are listed in **Table 6**. Although siRNA is delivered as a double-stranded molecule, for simplicity only the sense strand sequences are shown in **Table 6.**

Table 6. Exemplary siRNA Sequences

Target	**Sequence**	**SEQ ID NO**
VEGF R2	AATGCGGCGGTGGTGACAGTA	SEQ ID NO:90
VEGF R2	AAGCTCAGCACACAGAAAGAC	SEQ ID NO:91
CXCR4	UAAAAUCUUCCUGCCCACCdTdT	SEQ ID NO:92
CXCR4	GGAAGCUGUUGGCUGAAAAdTdT	SEQ ID NO:93
PPARC1	AAGACCAGCCUCUUUGCCCAG	SEQ ID NO:94
Dynamin 2	GGACCAGGCAGAAAACGAG	SEQ ID NO:95
Catenin	CUAUCAGGAUGACGCGG	SEQ ID NO:96
E1A binding protein	UGACACAGGCAGGCUUGACUU	SEQ ID NO:97
Plasminogen activator	GGTGAAGAAGGGCGTCCAA	SEQ ID NO:98
K-ras	GATCCGTTGGAGCTGTTGGCGTAGTT CAAGAGACTCGCCAACAGCTCCAACT TTTGGAAA	SEQ ID NO:99
Sortilin 1	AGGTGGTGTTAACAGCAGAG	SEQ ID NO:100
Apolipoprotein E	AAGGTGGAGCAAGCGGTGGAG	SEQ ID NO:101
Apolipoprotein E	AAGGAGTTGAAGGCCGACAAA	SEQ ID NO:102
Bcl-X	UAUGGAGCUGCAGAGGAUGdTdT	SEQ ID NO:103
Raf-1	TTTGAATATCTGTGCTGAGAACACA GTTCTCAGCACAGATATTCTTTTT	SEQ ID NO:104
Heat shock transcription factor 2	AATGAGAAAAGCAAAAGGTGCCCTGTCTC	SEQ ID NO:105
IGFBP3	AAUCAUCAUCAAGAAAGGGCA	SEQ ID NO:106
Thioredoxin	AUGACUGUCAGGAUGUUGCdTdT	SEQ ID NO:107
CD44	GAACGAAUCCUGAAGACAUCU	SEQ ID NO:108
MMP14	AAGCCTGGCTACAGCAATATGCCTGTCTC	SEQ ID NO:109
MAPKAPK2	UGACCAUCACCGAGUUUAUdTdT	SEQ ID NO:110
FGFR1	AAGTCGGACGCAACAGAGAAA	SEQ ID NO:111
ERBB2	CUACCUUUCUACGGACGUGdTdT	SEQ ID NO:112
BCL2L1	CTGCCTAAGGCGGATTTGAAT	SEQ ID NO:113
ABL1	TTAUUCCUUCUUCGGGAAGUC	SEQ ID NO:114
CEACAM1	AACCTTCTGGAACCCGCCCAC	SEQ ID NO:115

CD9	GAGCATCTTCGAGCAAGAA	SEQ ID NO:116
CD151	CATGTGGCACCGTTTGCCT	SEQ ID NO:117
Caspase 8	AACTACCAGAAAGGTATACCT	SEQ ID NO:118
BRCA1	UCACAGUGUCCUUUAUGUAdTdT	SEQ ID NO:119
p53	GCAUGAACCGGAGGCCCAUTT	SEQ ID NO:120
CEACAM6	CCGGACAGTTCCATGTATA	SEQ ID NO:121

[0167] The skilled artisan will realize that **Table 6** represents a very small sampling of the total number of siRNA species known in the art, and that any such known siRNA may be utilized in the claimed methods and compositions.

Diagnostic Agents

[0168] Diagnostic agents are preferably selected from the group consisting of a radionuclide, a radiological contrast agent, a paramagnetic ion, a metal, a fluorescent label, a chemiluminescent label, an ultrasound contrast agent and a photoactive agent. Such diagnostic agents are well known and any such known diagnostic agent may be used. Non-limiting examples of diagnostic agents may include a radionuclide such as ^{110}In, ^{111}In, ^{177}Lu, ^{18}F, ^{52}Fe, ^{62}Cu, ^{64}Cu, ^{67}Cu, ^{67}Ga, ^{68}Ga, ^{86}Y, ^{90}Y, ^{89}Zr, ^{94m}Tc, ^{94}Tc, ^{99m}Tc, ^{120}I, ^{123}I, ^{124}I, ^{125}I, ^{131}I, $^{154\text{-}158}Gd$, ^{32}P, ^{11}C, ^{13}N, ^{15}O, ^{186}Re, ^{188}Re, ^{51}Mn, ^{52m}Mn, ^{55}Co, ^{72}As, ^{75}Br, ^{76}Br, ^{82m}Rb, ^{83}Sr, or other gamma-, beta-, or positron-emitters. Paramagnetic ions of use may include chromium (III), manganese (II), iron (III), iron (II), cobalt (II), nickel (II), copper (II), neodymium (III), samarium (III), ytterbium (III), gadolinium (III), vanadium (II), terbium (III), dysprosium (III), holmium (III) or erbium (III). Metal contrast agents may include lanthanum (III), gold (III), lead (II) or bismuth (III). Ultrasound contrast agents may comprise liposomes, such as gas filled liposomes. Radiopaque diagnostic agents may be selected from compounds, barium compounds, gallium compounds, and thallium compounds. A wide variety of fluorescent labels are known in the art, including but not limited to fluorescein isothiocyanate, rhodamine, phycoerytherin, phycocyanin, allophycocyanin, o-phthaldehyde and fluorescamine. Chemiluminescent labels of use may include luminol, isoluminol, an aromatic acridinium ester, an imidazole, an acridinium salt or an oxalate ester.

Methods of Therapeutic Treatment

[0169] Various embodiments concern methods of treating a cancer in a subject, such as a mammal, including humans, domestic or companion pets, such as dogs and cats, comprising administering to the subject a therapeutically effective amount of a cytotoxic immunoconjugate.

[0170] In one embodiment, immunological diseases which may be treated with the subject immunotoxins may include, for example, joint diseases such as ankylosing spondylitis, juvenile rheumatoid arthritis, rheumatoid arthritis; neurological disease such as multiple sclerosis and myasthenia gravis; pancreatic disease such as diabetes, especially juvenile onset diabetes; gastrointestinal tract disease such as chronic active hepatitis, celiac disease, ulcerative colitis, Crohn's disease, pernicious anemia; skin diseases such as psoriasis or scleroderma; allergic diseases such as asthma and in transplantation related conditions such as graft versus host disease and allograft rejection.

[0171] The administration of the cytotoxic immunoconjugates can be supplemented by administering concurrently or sequentially a therapeutically effective amount of another antibody that binds to or is reactive with another antigen on the surface of the target cell. Preferred additional MAbs comprise at least one humanized, chimeric or human MAb selected from the group consisting of a MAb reactive with CD4, CD5, CD8, CD14, CD15, CD16, CD19, IGF-1R, CD20, CD21, CD22, CD23, CD25, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD45, CD46, CD52, CD54, CD70, CD74, CD79a, CD80, CD95, CD126, CD133, CD138, CD154, CEACAM5, CEACAM6, B7, AFP, PSMA, EGP-1, EGP-2, carbonic anhydrase IX, PAM4 antigen, MUC1, MUC2, MUC3, MUC4, MUC5, Ia, MIF, HM1.24, HLA-DR, tenascin, Flt-3, VEGFR, PlGF, ILGF, IL-6, IL-25, tenascin, TRAIL-R1, TRAIL-R2, complement factor C5, oncogene product, or a combination thereof. Various antibodies of use, such as anti-CD19, anti-CD20, and anti-CD22 antibodies, are known to those of skill in the art. See, for example, Ghetie *et al., Cancer Res. 48*:2610 (1988); Hekman *et al., Cancer Immunol. Immunother. 32*:364 (1991); Longo, *Curr. Opin. Oncol. 8*:353 (1996), U.S. Patent Nos. 5,798,554; 6,187,287; 6,306,393; 6,676,924; 7,109,304; 7,151,164; 7,230,084; 7,230,085; 7,238,785; 7,238,786; 7,282,567; 7,300,655; 7,312,318; 7,501,498; 7,612,180; 7,670,804; and U.S. Patent Application Publ. Nos. 20080131363; 20070172920; 20060193865; and 20080138333, the Examples section of each incorporated herein by reference.

[0172] The immunotoxin therapy can be further supplemented with the administration, either concurrently or sequentially, of at least one therapeutic agent. For example, "CVB" (1.5 g/m^2 cyclophosphamide, 200-400 mg/m^2 etoposide, and 150-200 mg/m^2 carmustine) is a regimen used to treat non-Hodgkin's lymphoma. Patti *et al., Eur. J. Haematol. 51*: 18 (1993). Other

suitable combination chemotherapeutic regimens are well-known to those of skill in the art. See, for example, Freedman *et al.*, "Non-Hodgkin's Lymphomas," in CANCER MEDICINE, VOLUME 2, 3rd Edition, Holland *et al.* (eds.), pages 2028-2068 (Lea & Febiger 1993). As an illustration, first generation chemotherapeutic regimens for treatment of intermediate-grade non-Hodgkin's lymphoma (NHL) include C-MOPP (cyclophosphamide, vincristine, procarbazine and prednisone) and CHOP (cyclophosphamide, doxorubicin, vincristine, and prednisone). A useful second generation chemotherapeutic regimen is m-BACOD (methotrexate, bleomycin, doxorubicin, cyclophosphamide, vincristine, dexamethasone and leucovorin), while a suitable third generation regimen is MACOP-B (methotrexate, doxorubicin, cyclophosphamide, vincristine, prednisone, bleomycin and leucovorin). Additional useful drugs include phenyl butyrate, bendamustine, and bryostatin-1.

[0173] The subject immunotoxins can be formulated according to known methods to prepare pharmaceutically useful compositions, whereby the immunotoxin is combined in a mixture with a pharmaceutically suitable excipient. Sterile phosphate-buffered saline is one example of a pharmaceutically suitable excipient. Other suitable excipients are well-known to those in the art. See, for example, Ansel *et al.*, PHARMACEUTICAL DOSAGE FORMS AND DRUG DELIVERY SYSTEMS, 5th Edition (Lea & Febiger 1990), and Gennaro (ed.), REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition (Mack Publishing Company 1990), and revised editions thereof.

[0174] The subject immunotoxins can be formulated for intravenous administration via, for example, bolus injection or continuous infusion. Preferably, the immunotoxin is infused over a period of less than about 4 hours, and more preferably, over a period of less than about 3 hours. For example, the first 25-50 mg could be infused within 30 minutes, preferably even 15 min, and the remainder infused over the next 2-3 hrs. Formulations for injection can be presented in unit dosage form, e.g., in ampoules or in multi-dose containers, with an added preservative. The compositions can take such forms as suspensions, solutions or emulsions in oily or aqueous vehicles, and can contain formulatory agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient can be in powder form for constitution with a suitable vehicle, e.g., sterile pyrogen-free water, before use.

[0175] Additional pharmaceutical methods may be employed to control the duration of action of the immunotoxins. Control release preparations can be prepared through the use of polymers to complex or adsorb the immunotoxins. For example, biocompatible polymers include matrices of poly(ethylene-co-vinyl acetate) and matrices of a polyanhydride copolymer of a stearic acid dimer and sebacic acid. Sherwood *et al.*, *Bio/Technology* 10:

1446 (1992). The rate of release from such a matrix depends upon the molecular weight of the immunotoxin, the amount of immunotoxin within the matrix, and the size of dispersed particles. Saltzman *et al.*, *Biophys. J.* 55: 163 (1989); Sherwood *et al.*, *supra.* Other solid dosage forms are described in Ansel *et al.*, PHARMACEUTICAL DOSAGE FORMS AND DRUG DELIVERY SYSTEMS, 5th Edition (Lea & Febiger 1990), and Gennaro (ed.), REMINGTON'S PHARMACEUTICAL SCIENCES, 18th Edition (Mack Publishing Company 1990), and revised editions thereof.

[0176] The immunotoxin may also be administered to a mammal subcutaneously or even by other parenteral routes. Moreover, the administration may be by continuous infusion or by single or multiple boluses. Preferably, the immunotoxin is infused over a period of less than about 4 hours, and more preferably, over a period of less than about 3 hours.

[0177] More generally, the dosage of an administered immunotoxin for humans will vary depending upon such factors as the patient's age, weight, height, sex, general medical condition and previous medical history. It may be desirable to provide the recipient with a dosage of immunotoxin that is in the range of from about 1 mg/kg to 25 mg/kg as a single intravenous infusion, although a lower or higher dosage also may be administered as circumstances dictate. A dosage of 1-20 mg/kg for a 70 kg patient, for example, is 70-1,400 mg, or 41-824 mg/m^2 for a 1.7-m patient. The dosage may be repeated as needed, for example, once per week for 4-10 weeks, once per week for 8 weeks, or once per week for 4 weeks. It may also be given less frequently, such as every other week for several months, or monthly or quarterly for many months, as needed in a maintenance therapy.

[0178] Alternatively, an immunotoxin may be administered as one dosage every 2 or 3 weeks, repeated for a total of at least 3 dosages. Or, the construct may be administered twice per week for 4-6 weeks. If the dosage is lowered to approximately 200-300 mg/m^2 (340 mg per dosage for a 1.7-m patient, or 4.9 mg/kg for a 70 kg patient), it may be administered once or even twice weekly for 4 to 10 weeks. Alternatively, the dosage schedule may be decreased, namely every 2 or 3 weeks for 2-3 months. It has been determined, however, that even higher doses, such as 20 mg/kg once weekly or once every 2-3 weeks can be administered by slow i.v. infusion, for repeated dosing cycles. The dosing schedule can optionally be repeated at other intervals and dosage may be given through various parenteral routes, with appropriate adjustment of the dose and schedule.

[0179] In preferred embodiments, the immunotoxins are of use for therapy of cancer. Examples of cancers include, but are not limited to, carcinoma, lymphoma, glioblastoma, melanoma, sarcoma, and leukemia, myeloma, or lymphoid malignancies. More particular

examples of such cancers are noted below and include: squamous cell cancer (e.g., epithelial squamous cell cancer), Ewing sarcoma, Wilms tumor, astrocytomas, lung cancer including small-cell lung cancer, non-small cell lung cancer, adenocarcinoma of the lung and squamous carcinoma of the lung, cancer of the peritoneum, hepatocellular cancer, gastric or stomach cancer including gastrointestinal cancer, pancreatic cancer, glioblastoma multiforme, cervical cancer, ovarian cancer, liver cancer, bladder cancer, hepatoma, hepatocellular carcinoma, neuroendocrine tumors, medullary thyroid cancer, differentiated thyroid carcinoma, breast cancer, ovarian cancer, colon cancer, rectal cancer, endometrial cancer or uterine carcinoma, salivary gland carcinoma, kidney or renal cancer, prostate cancer, vulvar cancer, anal carcinoma, penile carcinoma, as well as head-and-neck cancer. The term "cancer" includes primary malignant cells or tumors (e.g., those whose cells have not migrated to sites in the subject's body other than the site of the original malignancy or tumor) and secondary malignant cells or tumors (e.g., those arising from metastasis, the migration of malignant cells or tumor cells to secondary sites that are different from the site of the original tumor). Cancers conducive to treatment methods of the present invention involves cells which express, over-express, or abnormally express IGF-1R.

[0180] Other examples of cancers or malignancies include, but are not limited to: Acute Childhood Lymphoblastic Leukemia, Acute Lymphoblastic Leukemia, Acute Lymphocytic Leukemia, Acute Myeloid Leukemia, Adrenocortical Carcinoma, Adult (Primary) Hepatocellular Cancer, Adult (Primary) Liver Cancer, Adult Acute Lymphocytic Leukemia, Adult Acute Myeloid Leukemia, Adult Hodgkin's Lymphoma, Adult Lymphocytic Leukemia, Adult Non-Hodgkin's Lymphoma, Adult Primary Liver Cancer, Adult Soft Tissue Sarcoma, AIDS-Related Lymphoma, AIDS-Related Malignancies, Anal Cancer, Astrocytoma, Bile Duct Cancer, Bladder Cancer, Bone Cancer, Brain Stem Glioma, Brain Tumors, Breast Cancer, Cancer of the Renal Pelvis and Ureter, Central Nervous System (Primary) Lymphoma, Central Nervous System Lymphoma, Cerebellar Astrocytoma, Cerebral Astrocytoma, Cervical Cancer, Childhood (Primary) Hepatocellular Cancer, Childhood (Primary) Liver Cancer, Childhood Acute Lymphoblastic Leukemia, Childhood Acute Myeloid Leukemia, Childhood Brain Stem Glioma, Childhood Cerebellar Astrocytoma, Childhood Cerebral Astrocytoma, Childhood Extracranial Germ Cell Tumors, Childhood Hodgkin's Disease, Childhood Hodgkin's Lymphoma, Childhood Hypothalamic and Visual Pathway Glioma, Childhood Lymphoblastic Leukemia, Childhood Medulloblastoma, Childhood Non-Hodgkin's Lymphoma, Childhood Pineal and Supratentorial Primitive Neuroectodermal Tumors, Childhood Primary Liver Cancer, Childhood Rhabdomyosarcoma,

Childhood Soft Tissue Sarcoma, Childhood Visual Pathway and Hypothalamic Glioma, Chronic Lymphocytic Leukemia, Chronic Myelogenous Leukemia, Colon Cancer, Cutaneous T-Cell Lymphoma, Endocrine Pancreas Islet Cell Carcinoma, Endometrial Cancer, Ependymoma, Epithelial Cancer, Esophageal Cancer, Ewing's Sarcoma and Related Tumors, Exocrine Pancreatic Cancer, Extracranial Germ Cell Tumor, Extragonadal Germ Cell Tumor, Extrahepatic Bile Duct Cancer, Eye Cancer, Female Breast Cancer, Gaucher's Disease, Gallbladder Cancer, Gastric Cancer, Gastrointestinal Carcinoid Tumor, Gastrointestinal Tumors, Germ Cell Tumors, Gestational Trophoblastic Tumor, Hairy Cell Leukemia, Head and Neck Cancer, Hepatocellular Cancer, Hodgkin's Lymphoma, Hypergammaglobulinemia, Hypopharyngeal Cancer, Intestinal Cancers, Intraocular Melanoma, Islet Cell Carcinoma, Islet Cell Pancreatic Cancer, Kaposi's Sarcoma, Kidney Cancer, Laryngeal Cancer, Lip and Oral Cavity Cancer, Liver Cancer, Lung Cancer, Lymphoproliferative Disorders, Macroglobulinemia, Male Breast Cancer, Malignant Mesothelioma, Malignant Thymoma, Medulloblastoma, Melanoma, Mesothelioma, Metastatic Occult Primary Squamous Neck Cancer, Metastatic Primary Squamous Neck Cancer, Metastatic Squamous Neck Cancer, Multiple Myeloma, Multiple Myeloma/Plasma Cell Neoplasm, Myelodysplastic Syndrome, Myelogenous Leukemia, Myeloid Leukemia, Myeloproliferative Disorders, Nasal Cavity and Paranasal Sinus Cancer, Nasopharyngeal Cancer, Neuroblastoma, Non-Hodgkin's Lymphoma, Nonmelanoma Skin Cancer, Non-Small Cell Lung Cancer, Occult Primary Metastatic Squamous Neck Cancer, Oropharyngeal Cancer, Osteo-/Malignant Fibrous Sarcoma, Osteosarcoma/Malignant Fibrous Histiocytoma, Osteosarcoma/Malignant Fibrous Histiocytoma of Bone, Ovarian Epithelial Cancer, Ovarian Germ Cell Tumor, Ovarian Low Malignant Potential Tumor, Pancreatic Cancer, Paraproteinemias, Polycythemia vera, Parathyroid Cancer, Penile Cancer, Pheochromocytoma, Pituitary Tumor, Primary Central Nervous System Lymphoma, Primary Liver Cancer, Prostate Cancer, Rectal Cancer, Renal Cell Cancer, Renal Pelvis and Ureter Cancer, Retinoblastoma, Rhabdomyosarcoma, Salivary Gland Cancer, Sarcoidosis Sarcomas, Sezary Syndrome, Skin Cancer, Small Cell Lung Cancer, Small Intestine Cancer, Soft Tissue Sarcoma, Squamous Neck Cancer, Stomach Cancer, Supratentorial Primitive Neuroectodermal and Pineal Tumors, T-Cell Lymphoma, Testicular Cancer, Thymoma, Thyroid Cancer, Transitional Cell Cancer of the Renal Pelvis and Ureter, Transitional Renal Pelvis and Ureter Cancer, Trophoblastic Tumors, Ureter and Renal Pelvis Cell Cancer, Urethral Cancer, Uterine Cancer, Uterine Sarcoma, Vaginal Cancer, Visual Pathway and Hypothalamic Glioma, Vulvar Cancer, Waldenstrom's

Macroglobulinemia, Wilms' Tumor, and any other hyperproliferative disease, besides neoplasia, located in an organ system listed above.

[0181] The methods and compositions described and claimed herein may be used to treat malignant or premalignant conditions and to prevent progression to a neoplastic or malignant state, including but not limited to those disorders described above. Such uses are indicated in conditions known or suspected of preceding progression to neoplasia or cancer, in particular, where non-neoplastic cell growth consisting of hyperplasia, metaplasia, or most particularly, dysplasia has occurred (for review of such abnormal growth conditions, see Robbins and Angell, Basic Pathology, 2d Ed., W. B. Saunders Co., Philadelphia, pp. 68-79 (1976)).

[0182] Dysplasia is frequently a forerunner of cancer, and is found mainly in the epithelia. It is the most disorderly form of non-neoplastic cell growth, involving a loss in individual cell uniformity and in the architectural orientation of cells. Dysplasia characteristically occurs where there exists chronic irritation or inflammation. Dysplastic disorders which can be treated include, but are not limited to, anhidrotic ectodermal dysplasia, anterofacial dysplasia, asphyxiating thoracic dysplasia, atriodigital dysplasia, bronchopulmonary dysplasia, cerebral dysplasia, cervical dysplasia, chondroectodermal dysplasia, cleidocranial dysplasia, congenital ectodermal dysplasia, craniodiaphysial dysplasia, craniocarpotarsal dysplasia, craniometaphysial dysplasia, dentin dysplasia, diaphysial dysplasia, ectodermal dysplasia, enamel dysplasia, encephalo-ophthalmic dysplasia, dysplasia epiphysialis hemimelia, dysplasia epiphysialis multiplex, dysplasia epiphysialis punctata, epithelial dysplasia, faciodigitogenital dysplasia, familial fibrous dysplasia of jaws, familial white folded dysplasia, fibromuscular dysplasia, fibrous dysplasia of bone, florid osseous dysplasia, hereditary renal-retinal dysplasia, hidrotic ectodermal dysplasia, hypohidrotic ectodermal dysplasia, lymphopenic thymic dysplasia, mammary dysplasia, mandibulofacial dysplasia, metaphysial dysplasia, Mondini dysplasia, monostotic fibrous dysplasia, mucoepithelial dysplasia, multiple epiphysial dysplasia, oculoauriculovertebral dysplasia, oculodentodigital dysplasia, oculovertebral dysplasia, odontogenic dysplasia, opthalmomandibulomelic dysplasia, periapical cemental dysplasia, polyostotic fibrous dysplasia, pseudoachondroplastic spondyloepiphysial dysplasia, retinal dysplasia, septo-optic dysplasia, spondyloepiphysial dysplasia, and ventriculoradial dysplasia.

[0183] Additional pre-neoplastic disorders which can be treated include, but are not limited to, benign dysproliferative disorders (e.g., benign tumors, fibrocystic conditions, tissue hypertrophy, intestinal polyps or adenomas, and esophageal dysplasia), leukoplakia, keratoses, Bowen's disease, Farmer's Skin, solar cheilitis, and solar keratosis.

[0184] In preferred embodiments, the method of the invention is used to inhibit growth, progression, and/or metastasis of cancers, in particular those listed above.

[0185] Additional hyperproliferative diseases, disorders, and/or conditions include, but are not limited to, progression, and/or metastases of malignancies and related disorders such as leukemia (including acute leukemias (e.g., acute lymphocytic leukemia, acute myelocytic leukemia (including myeloblastic, promyelocytic, myelomonocytic, monocytic, and erythroleukemia)) and chronic leukemias (e.g., chronic myelocytic (granulocytic) leukemia and chronic lymphocytic leukemia)), polycythemia vera, lymphomas (e.g., Hodgkin's disease and non-Hodgkin's disease), multiple myeloma, Waldenstrom's macroglobulinemia, heavy chain disease, and solid tumors including, but not limited to, sarcomas and carcinomas such as fibrosarcoma, myxosarcoma, liposarcoma, chondrosarcoma, osteogenic sarcoma, chordoma, angiosarcoma, endotheliosarcoma, lymphangiosarcoma, lymphangioendotheliosarcoma, synovioma, mesothelioma, Ewing's tumor, leiomyosarcoma, rhabdomyosarcoma, colon carcinoma, pancreatic cancer, breast cancer, ovarian cancer, prostate cancer, squamous cell carcinoma, basal cell carcinoma, adenocarcinoma, sweat gland carcinoma, sebaceous gland carcinoma, papillary carcinoma, papillary adenocarcinomas, cystadenocarcinoma, medullary carcinoma, bronchogenic carcinoma, renal cell carcinoma, hepatoma, bile duct carcinoma, choriocarcinoma, seminoma, embryonal carcinoma, Wilm's tumor, cervical cancer, testicular tumor, lung carcinoma, small cell lung carcinoma, bladder carcinoma, epithelial carcinoma, glioma, astrocytoma, medulloblastoma, craniopharyngioma, ependymoma, pinealoma, emangioblastoma, acoustic neuroma, oligodendroglioma, meningioma, melanoma, neuroblastoma, and retinoblastoma.

Expression Vectors

[0186] Still other embodiments may concern DNA sequences comprising a nucleic acid encoding an antibody, antibody fragment, toxin or constituent fusion protein of an immunotoxin, such as a DNL™ construct. Fusion proteins may comprise an antibody or fragment or toxin attached to, for example, an AD or DDD moiety.

[0187] Various embodiments relate to expression vectors comprising the coding DNA sequences. The vectors may contain sequences encoding the light and heavy chain constant regions and the hinge region of a human immunoglobulin to which may be attached chimeric, humanized or human variable region sequences. The vectors may additionally contain promoters that express the encoded protein(s) in a selected host cell, enhancers and signal or leader sequences. Vectors that are particularly useful are pdHL2 or GS. More preferably, the light and heavy chain constant regions and hinge region may be from a human EU myeloma

immunoglobulin, where optionally at least one of the amino acid in the allotype positions is changed to that found in a different IgG1 allotype, and wherein optionally amino acid 253 of the heavy chain of EU based on the EU number system may be replaced with alanine. See Edelman *et al., Proc. Natl. Acad. Sci USA* 63: 78-85 (1969). In other embodiments, an IgG1 sequence may be converted to an IgG4 sequence.

[0188] The skilled artisan will realize that methods of genetically engineering expression constructs and insertion into host cells to express engineered proteins are well known in the art and a matter of routine experimentation. Host cells and methods of expression of cloned antibodies or fragments have been described, for example, in U.S. Patent Nos. 7,531,327 and 7,537,930, the Examples section of each incorporated herein by reference.

Kits

[0189] Various embodiments may concern kits containing components suitable for treating or diagnosing diseased tissue in a patient. Exemplary kits may contain one or more immunotoxins as described herein. If the composition containing components for administration is not formulated for delivery via the alimentary canal, such as by oral delivery, a device capable of delivering the kit components through some other route may be included. One type of device, for applications such as parenteral delivery, is a syringe that is used to inject the composition into the body of a subject. Inhalation devices may also be used. In certain embodiments, a therapeutic agent may be provided in the form of a prefilled syringe or autoinjection pen containing a sterile, liquid formulation or lyophilized preparation.

[0190] The kit components may be packaged together or separated into two or more containers. In some embodiments, the containers may be vials that contain sterile, lyophilized formulations of a composition that are suitable for reconstitution. A kit may also contain one or more buffers suitable for reconstitution and/or dilution of other reagents. Other containers that may be used include, but are not limited to, a pouch, tray, box, tube, or the like. Kit components may be packaged and maintained sterilely within the containers. Another component that can be included is instructions to a person using a kit for its use.

EXAMPLES

[0191] The following examples are provided to illustrate, but not to limit, the claims of the present invention.

Example 1. Production and Use of DNL™ Complexes Showing Improved Stability, Pharmacokinetics and Efficacy by Attaching AD Moieties to the C-

Terminal End of the Antibody Light Chain

[0192] We explored the production and use of improved Dock-and-Lock™ (DNL™) complexes, incorporating IgG molecules with an AD moiety fused to the C-terminal end of the kappa light chain (hereafter denoted as "C_k" complexes or fusion proteins), instead of the C-terminal end of the Fc (hereafter denoted as "C_H"). In the Examples below, the C_k DNL™ complexes are also indicated by an asterisk (e.g., 20*-2b). Two exemplary C_k-derived prototypes, an anti-CD22/CD20 bispecific hexavalent antibody, comprising epratuzumab (anti-CD22) and four Fabs of veltuzumab (anti-CD20), and a CD20-targeting immunocytokine, comprising veltuzumab and four molecules of interferon-α2b, displayed enhanced Fc-effector functions *in vitro*, as well as improved pharmacokinetics, stability and anti-lymphoma activity *in vivo*, compared to their Fc-derived counterparts. These unexpected superior results favor the use of DNL™ conjugates with the C_k-design for clinical development.

[0193] The C_k-IgG-IFNα, designated 20*-2b, had a similar molecular size and composition to its Fc-IgG-IFNα counterpart, 20-2b, each comprising veltuzumab and 4 copies of IFNα2b fused at the C-terminal ends of the light or heavy chains, respectively. The C_k-bsHexAb, designated 22*-(20)-(20), and its Fc-bsHexAb homologue, 22-(20)-(20), each comprised epratuzumab and 4 veltuzumab Fabs, which were fused at the C-terminal ends of the light and heavy chains, respectively. Compared to the analogous Fc-based immunoconjugates, the C_k-IgG-IFNα and C_k-bsHexAb were more stable *in vivo*, cleared more slowly from the circulation and had improved Fc-effector function, significantly enhancing efficacy *in vivo*.

Methods

[0194] Antibodies and cell culture - Immunomedics provided veltuzumab (anti-CD20 IgG1), epratuzumab (anti-CD22 IgG_1), a murine anti-IFNα mAb, hMN-14 (labetuzumab), a rat anti-idiotype mAb veltuzumab (WR2), and a rat anti-idiotype mAb to epratuzumab (WN). HRP-conjugated second antibodies were from Jackson Immunoresearch (Westgrove, PA). Heat-inactivated fetal bovine serum (FBS) was obtained from Hyclone (Logan, UT). All other cell culture media and supplements were purchased from Invitrogen Life Technologies (Carlsbad, CA). SpESFX-10 cells (Rossi et al., 2011, *Biotechnol. Prog.* **27**:766-775) and production clones were maintained in H-SFM. Daudi cell line was purchased from ATCC and grown in 10% FBS-RPMI (Manassas, VA).

[0195] DNL™ constructs - Methods for production of C_k-based DNL™ constructs are described in further detail below. For C_H3-AD2-IgG-veltuzumab, C_H3-AD2-IgG-

epratuzumab, C_H1-DDD2-Fab-veltuzumab, and IFNα2b-DDD2, generation of the mammalian expression vectors and production clones, and their use for the DNL™ conjugation of 20-2b and 22-(20)-(20), have been reported previously (Rossi et al., 2008, *Cancer Res.* **68**:8384-8392; Chang et al., 2009, *Bioconjug. Chem.* **20**:1899-1907; Rossi et al., 2009, *Blood* **114**:3864-3871; Rossi et al., 2009, *Blood* **113**:6161-6171). C_k-AD2-IgG, was generated by recombinant engineering, whereby the AD2 peptide was fused to the C-terminal end of the kappa light chain (**FIG. 1a**). Because the natural C-terminus of C_K is a cysteine residue, which forms a disulfide bridge to C_H1, a 16-amino acid residue "hinge" linker (SEQ ID NO:122) was used to space the AD2 from the C_K-V_H1 disulfide bridge. The goal of this approach was to obtain full binding and activities of all Fabs and effector groups, while maintaining a full Fc effector function. The ultimate goal was to maintain a Pk that approaches that of IgG and prevent the intracellular dissociation of the modules, which presumably occurs by proteolysis following uptake of the complex into the cell.

[0196] The first C_K-AD2-IgG module was constructed for veltuzumab (hA20), with additional C_K-AD2-IgG modules produced subsequently for milatuzumab (hLL1), epratuzumab (hLL2) and hR1 (anti-IGF-1R). These modules have been used to generate hexavalent antibodies and immunocytokines, which were compared to constructs of similar composition that were made with the corresponding C_H3-AD2-IgG modules. The mammalian expression vectors for C_k-AD2-IgG-veltuzumab and C_k-AD2-IgG-epratuzumab were constructed using the pdHL2 vector, which was used previously for expression of the homologous C_H3-AD2-IgG modules. A 2208-bp nucleotide sequence (SEQ ID NO:130) was synthesized comprising the pdHL2 vector sequence ranging from the *Bam HI* restriction site within the V_K/C_K intron to the *Xho I* restriction site 3' of the C_k intron, with the insertion of the coding sequence for the hinge linker (EFPKPSTPPGSSGGAP, SEQ ID NO:122) and AD2 in frame at the 3'end of the coding sequence for C_K. This synthetic sequence was inserted into the IgG-pdHL2 expression vectors for veltuzumab and epratuzumab via *Bam HI* and *Xho I* restriction sites. Generation of production clones with SpESFX-10 were performed as described for the C_H3-AD2-IgG modules (Rossi et al., 2008, *Cancer Res.* **68**:8384-8392; Rossi et al., 2009, *Blood* **113**:6161-6171). C_k-AD2-IgG-veltuzumab and C_k-AD2-IgG-epratuzumab were produced by stably-transfected production clones in batch roller bottle culture, and purified from the supernatant fluid in a single step using MABSELECT™ (GE Healthcare) Protein A affinity chromatography.

[0197] Following the same process described previously for 22-(20)-(20) (Rossi et al., 2009, *Blood* **113**:6161-6171), C_k-AD2-IgG-epratuzumab was conjugated with C_H1-DDD2-Fab-

veltuzumab (**FIG. 1b**), a Fab-based module derived from veltuzumab, to generate the bsHexAb 22*-(20)-(20), where the 22* indicates the C_k-AD2 module of epratuzumab and each (20) symbolizes a stabilized dimer of veltuzumab Fab (**FIG. 1c**). The properties of 22*-(20)-(20) were compared with those of 22-(20)-(20), the homologous Fc-bsHexAb comprising C_H3-AD2-IgG-epratuzumab (**FIG. 1d**), which has similar composition and molecular size, but a different architecture.

[0198] Following the same process described previously for 20-2b (Rossi et al., 2009, *Blood* **114**:3864-3871), C_k-AD2-IgG-veltuzumab (**FIG. 1a**), was conjugated with IFNα2b-DDD2, a module of IFNα2b with a DDD2 peptide fused at its C-terminal end (**FIG. 1e**), to generate 20*-2b (**FIG. 1f**), which comprises veltuzumab with a dimeric IFNα2b fused to each light chain. The properties of 20*-2b were compared with those of 20-2b (**FIG. 1g**), which is the homologous Fc-IgG-IFNα. Each of the bsHexAbs and IgG-IFNα were isolated from the reaction mixture by MABSELECT™ affinity chromatography.

[0199] Production of DNA vectors for the expression of C_K-AD2-IgG modules. - A 2208 basepair DNA sequence (SEQ ID NO:130) was synthesized, comprising the sequence of the pdHL2 expression vector from the Bam HI restriction site (within the V_K/C_K intron) to the Xho I restriction site (preceding the heavy chain expression cassette), with the insertion of the coding sequence for the hinge linker (SEQ ID NO:122) and AD2 (SEQ ID NO:4), in frame at the 3'end of the coding sequence for C_K. This synthetic sequence was inserted into the Bam HI/XhoI restriction sites in the expression vector for veltuzumab (hA20-pdHL2) in a single cloning step, to generate C_K-AD2-IgG-hA20-pdHL2 (**FIG. 11**). Similarly, the 2208 basepair fragment was inserted into the pGSHL expression vectors for epratuzumab, milatuzumab and hR1 using Bam HI/Xho I restriction sites (**FIG. 12**).

[0200] The synthetic nucleic acid sequence for conversion of IgG-pdHL2 to CK-AD2-IgG-pdHL2 vector is shown in SEQ ID NO:130. 5' Bam HI and 3' Xho I restriction sites are underlined. The coding sequence for the C_K-hinge linker-AD2 peptide is shown in bold.

GGATCCCGCAATTCTAAACTCTGAGGGGGTCGGATGACGTGGCCATTCTTTGCCT
AAAGCATTGAGTTTACTGCAAGGTCAGAAAAGCATGCAAAGCCCTCAGAATGGC
TGCAAAGAGCTCCAACAAAACAATTTAGAACTTTATTAAGGAATAGGGGGAAGC
TAGGAAGAAACTCAAAACATCAAGATTTTAAATACGCTTCTTGGTCTCCTTGCTA
TAATTATCTGGGATAAGCATGCTGTTTTCTGTCTGTCCCTAACATGCCCTGTGATT
ATCCGCAAACAACACACCCAAGGGCAGAACTTTGTTACTTAAACACCATCCTGTT
TGCTTCTTTCCTCAGGAACTGTGGCTGCACCATCTGTCTTCATCTTCCCGCCATCT
GATGAGCAGTTGAAATCTGGAACTGCCTCTGTTGTGTGCCTGCTGAATAACTTCT
ATCCCAGAGAGGCCAAAGTACAGTGGAAGGTGGATAACGCCCTCCAATCGGGTA
ACTCCCAGGAGAGTGTCACAGAGCAGGACAGCAAGGACAGCACCTACAGCCTCA
GCAGCACCCTGACGCTGAGCAAAGCAGACTACGAGAAACACAAAGTCTACGCCT

GCGAAGTCACCCATCAGGGCCTGAGCTCGCCCGTCACAAAGAGCTTCAACAGGG
GAGAGTGTGAGTTCCCTAAACCCAGCACTCCACCCGGATCTTCCGGCGGCGCTCC
CTGTGGCCAGATCGAGTACCTGGCCAAGCAGATCGTGGACAACGCCATCCAGCA
GGCCGGGTGCTAGAGGGAGAAGTGCCCCCACCTGCTCCTCAGTTCCAGCCTGACC
CCCTCCCATCCTTTGGCCTCTGACCCTTTTTCCACAGGGGACCTACCCCTATTGCG
GTCCTCCAGCTCATCTTTCACCTCACCCCCCTCCTCCTCCTTGGCTTTAATTATGCT
AATGTTGGAGGAGAATGAATAAATAAAGTGAATCTTTGCACCTGTGGTTTCTCTC
TTTCCTCATTTAATAATTATTATCTGTTGTTTTACCAACTACTCAATTTCTCTTATA
AGGGACTAAATATGTAGTCATCCTAAGGCGCATAACCATTTATAAAAATCATCCT
TCATTCTATTTTACCCTATCATCCTCTGCAAGACAGTCCTCCCTCAAACCCACAAG
CCTTCTGTCCTCACAGTCCCCTGGGCCATGGTAGGAGAGACTTGCTTCCTTGTTTT
CCCCTCCTCAGCAAGCCCTCATAGTCCTTTTTAAGGGTGACAGGTCTTACAGTCA
TATATCCTTTGATTCAATTCCCTGAGAATCAACCAAAGCAAATTTTTCAAAAGAA
GAAACCTGCTATAAAGAGAATCATTCATTGCAACATGATATAAAATAACAACAC
AATAAAAGCAATTAAATAAACAAACAATAGGGAAATGTTTAAGTTCATCATGGT
ACTTAGACTTAATGGAATGTCATGCCTTATTTACATTTTTAAACAGGTACTGAGG
GACTCCTGTCTGCCAAGGGCCGTATTGAGTACTTTCCACAACCTAATTTAATCCA
CACTATACTGTGAGATTAAAAACATTCATTAAAATGTTGCAAAGGTTCTATAAAG
CTGAGAGACAAATATATTCTATAACTCAGCAATTCCCACTTCTAGGGGTTCGACT
GGCAGGAAGCAGGTCATGTGGCAAGGCTATTTGGGGAAGGGAAAATAAAACCA
CTAGGTAAACTTGTAGCTGTGGTTTGAAGAAGTGGTTTTGAAACACTCTGTCCAG
CCCCACCAAACCGAAAGTCCAGGCTGAGCAAAACACCACCTGGGTAATTTGCAT
TTCTAAAATAAGTTGAGGATTCAGCCGAAACTGGAGAGGTCCTCTTTTAACTTAT
TGAGTTCAACCTTTTAATTTTAGCTTGAGTAGTTCTAGTTTCCCCAAACTTAAGTT
TATCGACTTCTAAAATGTATTTAGAATTTCGACCAATTCTCATGTTTGACAGCTTA
TCATCGCTGCACTCCGCCCGAAAAGTGCGCTCGGCTCTGCCAAGGACGCGGGGC
GCGTGACTATGCGTGGGCTGGAGCAACCGCCTGCTGGGTGCAAACCCTTTGCGCC
CGGACTCGTCCAACGACTATAAAGAGGGCAGGCTGTCCTCTAAGCGTCACCACG
ACTTCAACGTCCTGAGTACCTTCTCCTCACTTACTCCGTAGCTCCAGCTTCACCAG
ATCCCTCGAG (SEQ ID NO:130)

[0201] Production and purification of C_K-AD2-IgG modules - The C_K-AD2-IgG-hA20-pdHL2 vector was linearized by digestion with Sal I restriction enzyme and transfected into SpESFX-10 myeloma cells by electroporation. Following electroporation, the cells were plated in 96-well tissue culture plates and transfectant clones were selected with 0.05 μM methotrexate (MTX). Clones were screened for protein expression by sandwich ELISA using wells coated with WR2 (hA20 anti-Id) and detection with peroxidase-conjugated goat anti-human Fab.

[0202] The three C_K-AD2-IgG-pGSHL expression vectors were transfected similarly to above, but plated in glutamine-free media for selection, instead of MTX. Clones were screened for protein expression by sandwich ELISA using wells coated with antibody-specific anti-Ids and detection with peroxidase-conjugated goat anti-human Fab.

[0203] The highest producing clones were expanded and cultured in roller bottles for protein expression. The C_K-AD2-IgG modules were purified using Protein A affinity

chromatography. The productivity of the cell lines was similar to that of IgG or C_H3-AD2-IgG. Reducing SDS-PAGE resolved a protein band for the hA20 Kappa-AD2 polypeptide with a relative mobility consistent with its calculated molecular weight (26,951 Da) and larger than hA20 Kappa (23,204 Da) (not shown). Expectedly, the heavy chain polypeptides of C_k-AD2-IgG-hA20 co-migrated with those of hA20 IgG.

[0204] Bispecific hexavalent antibodies made by DNL™ with C_K-AD2-IgG - Bispecific hexavalent antibodies (bsHexAbs) were generated by combining C_k-AD2-IgG modules with C_H3-DDD2-Fab modules of a different specificity and performing DNL™ conjugation under mild redox conditions. Six bsHexAbs and one monospecific HexAb were produced and characterized, as exemplified by the construct named 20C_k-(74)-(74) (alternatively, 20*-(74)-(74)), where the first code (20C_k or 20*) indicates the Ck-AD2-IgG module and codes in parentheses indicate stabilized dimeric Fab-DDD2 modules. Thus, 20C_k-(74)-(74) (or 20*-(74)-(74))comprises veltuzumab (anti-CD20) fused with four anti-CD74 Fabs derived from milatuzumab. The component parts and valencies of the 7 HexAbs are given in Table 7.

Table 7. Bispecific hexavalent antibodies targeting B-cell malignancies.

HexAb	IgG-AD2 module (parent mAb)	Fab-DDD2 module (parent mAb)	Valency CD20	CD22	CD74
20Ck-(22)-(22)	C_k-AD2-IgG-hA20 (veltuzumab)	C_H3-DDD2-Fab-hLL2 (epratuzumab)	2	4	
20Ck-(74)-(74)	C_k-AD2-IgG-hA20 (veltuzumab)	C_H3-DDD2-Fab-hLL1 (milatuzumab)	2		4
20Ck-(20)-(20)	C_k-AD2-IgG-hA20 (veltuzumab)	C_H3-DDD2-Fab-hA20 (veltuzumab)	6		
22Ck-(20)-(20)*	C_k-AD2-IgG-hLL2 (epratuzumab)	C_H3-DDD2-Fab-hA20 (veltuzumab)	4	2	
22Ck-(74)-(74)	C_k-AD2-IgG-hLL2 (epratuzumab)	C_H3-DDD2-Fab-hLL1 (milatuzumab)		2	4
74Ck-(20)-(20)	C_k-AD2-IgG-hLL1 (milatuzumab)	C_H3-DDD2-Fab-hA20 (veltuzumab)	4		2
74Ck-(22)-(22)	C_k-AD2-IgG-hLL1 (milatuzumab)	C_H3-DDD2-Fab-hLL2 (epratuzumab)		4	2

*monospecific hexavalent

[0205] Each of the HexAbs was produced and purified in a similar fashion. A detailed description of one preparation of 22*-(20)-(20) is provided as an example. A molar excess of C_H3-DD2-Fab-hA20 (42 mg) was mixed with 25 mg of C_K-AD2-IgG-hLL2 in Tris-Citrate buffer (pH 7.5 ±0.2). Reduced glutathione and EDTA were added at 2mM and 1mM, respectively, and the reaction was held overnight at room temperature, prior to addition of 4 mM oxidized glutathione and an additional 4-hour incubation at room temperature. The reaction mixture was applied to a 5-ml MABSELECT™ (Protein A) chromatography column, which was washed with PBS prior to elution of the bsHexAb with 0.1M Citrate, pH 3.5. The 22*-(20)-(20) construct was dialyzed into 0.04M PBS, pH 7.4. A total of 56 mg of

22*-(20)-(20) was recovered, representing 96% yield. Size exclusion HPLC (SE-HPLC) resolved a single homogeneous protein peak with a retention time consistent with a protein of ~368 kDa molecular weight (not shown). The SE-HPLC peak for the C_k-AD2-based bsHexAbs resolve with a slightly longer retention time compared to the corresponding C_H3-AD2-based bsHexAbs (not shown), which have a similar composition and molecular weight, indicating that the former have a smaller Stokes radius and are more compact molecules, compared to the latter.

[0206] 20(C_k)-2b, an IgG-IFNα immunocytokine based on C_k-AD2-IgG-hA20 - An immunocytokine comprising veltuzumab fused with four IFNα2b groups was prepared using the DNL™ method by combining C_k-AD2-IgG-hA20 with IFNα2b-DDD2 (**FIG. 1f**). C_K-AD2-IgG-hA20 (54 mg) was combined with 81.1 mg of IFNα-DDD2. EDTA (1 mM) and reduced glutathione (2 mM) were added and the solution was held for 5 hours at room temperature. Oxidized glutathione (4 mM) was added to the mixture, which was held overnight at room temperature. The 20*-2b was purified to near homogeneity using two sequential affinity chromatography steps. First, the reaction mixture was applied to a 4-ml MABSELECT™ (Protein A) column. Protein was eluted with 4 column volumes (16 ml) of 0.02% Polysorbate-80, 50 mM citrate, pH 3.5 directly into 16 ml of 0.02% P-80, 80 mM imidazole, 1 M NaCl, 100 mM Na_2HPO_4 and the solution was adjusted to pH 7.3 with 50 mM Na_2HPO_4, 40mM imidazole, 500 mM NaCl. The adjusted eluent was applied to an 8-ml Ni-SEPHAROSE® 6 FF column equilibrated with 0.02% P-80, 40 mM imidazole, 0.5 M NaCl, 50 mM $NaPO_4$, pH 7.5. A total of 85 mg of 20(C_k)-2b was eluted with 5 column volumes of 500 mM imidazole, 0.02% P-80, 50 mM NaCl, 20 mM NaH_2PO_4, pH 7.5.

[0207] SE-HPLC resolved a major protein peak for 20*-2b with a retention time consistent with a protein of ~250 kDa (not shown). The 20*-2b peak resolved with a longer retention time than that of 20-2b, which comprises the same components (veltuzumab and four IFNα2b) and has a similar molecular weight, indicating that the former has a smaller Stokes radius and is more compact than the latter, similar to what was observed for the HexAbs.

[0208] Analytical methods - Size-exclusion high performance liquid chromatography (SE-HPLC) was performed using a 4 μm UHR SEC column (Waters Corp., Milford MA). SDS-PAGE was performed using 4 - 20% gradient Tris-glycine gels (Invitrogen, Gaithersburg, MD). IEF was performed at 1000 V, 20 mM and 25 watts for 1 h, using pH 6 -10.5 ISOGEL® Agarose IEF plates (Lonza, Basel, Switzerland) on a BIO-PHORESIS® horizontal electrophoresis cell (Bio-Rad, Hercules, CA). All colorimetric (ELISA and MTS) and fluorometric (CDC and ADCC) assays were quantified with an ENVISION® 2100

Multilabel Plate Reader (PerkinElmer, Waltham, MA).

[0209] Cell binding - Binding to cells was measured by flow cytometry on a GUAVA® PCA using GUAVA® Express software (Millipore Corp., Billerica, MA). Veltuzumab and 20*-2b were labeled with phycoerythrin (PE) using a ZENON® R-Phycoerythrin human IgG labeling kit following the manufacturer's protocol (Invitrogen, Molecular Probes). Daudi cells were incubated with the PE-veltuzumab and PE-20*-2b (0.1 – 15 nM) for 30 min at room temperature and washed with 1% BSA-PBS prior to analysis. Plots of concentration vs. mean fluorescence intensity (MFI) were analyzed by linear regression.

[0210] *In vitro* cytotoxicity - Daudi cells were plated at 10,000 cells/well in 96-well plates and incubated at 37°C for 3 days in the presence of increasing concentrations of 20*-2b or 20-2b. Viable cell densities were determined using the MTS-based CELLTITER 96® Cell Proliferation Assay (Promega, Madison, WI).

[0211] FcRn binding measurements - FcRn binding was evaluated by surface plasmon resonance on a BIACORE® X instrument (GE Healthcare) following the methods of Wang et al. (2011, *Drug Metab Dispos.* **39**:1469-1477). Soluble single-chain FcRn was generated following the methods of Feng et al. (2011, *Protein Expr. Purif.* **79**:66-71). The extracellular domain of the human FcRn heavy chain was fused with β2-microglobulin via a flexible peptide linker. The fusion protein was expressed using a modified pdHL2 vector in transfectant SpESFX-10 cells, and purified using Ni-Sepharose. Purified scFcRn was immobilized onto a CM5 biosensor chip using an amine coupling kit (GE Healthcare) to a density of ~600 response units (RU). The test articles were diluted with pH 6.0 running buffer [50 mM $NaPO_4$, 150 mM NaCl, and 0.05% (v/v) Surfactant 20] to 400, 200, 100, 50, and 25 nM and bound to the immobilized scFcRn for 3 min to reach equilibrium, followed by 2 min of dissociation with the flow rate at 30 μL/min. The sensorchip was regenerated with pH 7.5 running buffer between runs. To determine FcRn binding affinity (K_D) at pH 6.0, the data from all five concentrations were used simultaneously to fit a two-state reaction model (BIAevaluation software; GE Healthcare). Goodness of fit was indicated by χ^2 values.

[0212] Pk analyses - The pharmacokinetics (Pk) and *in vivo* stability were compared between 20*-2b and 20-2b following intravenous (i.v.) or subcutaneous (s.c) injection in mice. Groups of 18 Swiss-Webster mice were administered 1-mg doses of 20*-2b or 20-2b by either i.v. or s.c. injection. Using 3 mice per time point, animals were sacrificed and bled at 6, 16, 24, 48, 72 and 96 hours. Therefore, each serum sample represented an independent animal/time point. For measurement of intact and total (intact plus dissociated) IgG-IFNα, microtiter

wells were adsorbed with WR2, a rat anti-Id for veltuzumab, at 5 μg/mL in 0.5 M Na_2CO_3, pH 9.5. Following blocking with 2% BSA-PBS, serum dilutions in antibody buffer (0.1% gelatin, 0.05% proclin, 0.05% Tween-20, 0.1 M NaCl, 0.1 M $NaPO_4$, pH 7.4) were incubated in the coated wells for 2 h. For measurement of intact IgG-IFNα, wells were probed with a mouse anti-IFNα mAb (5 μg/mL in antibody buffer) for 1 h, followed by detection with HRP-conjugated goat anti-mouse IgG-Fc. For measurement of total veltuzumab IgG, wells were probed with HRP-conjugated goat anti-human IgG-Fc for 1 h.

[0213] For measurement of intact and total bsHexAbs, microtiter wells were adsorbed with WN, a rat anti-idiotype for epratuzumab. Serum dilutions were incubated in the coated wells for 2 h. For detection of intact bsHexAb, wells were probed with HRP-conjugated WR2 (1 μg/mL in antibody buffer) for 1 h. For detection of total epratuzumab IgG, wells were probed with HRP-conjugated goat anti-human IgG-Fc for 1 h.

[0214] Signal was developed with o-phenylenediamine dihydrochloride substrate solution and OD was measured at 490 nM. The concentrations of intact and total species were extrapolated from construct-specific standard curves. Pk was analyzed using the WINNONLIN® Pk software package (v5.1; Pharsight Corp.; Mountain View, CA).

[0215] *In vivo* and *ex vivo* methods - Injection and collection of sera from rabbits was performed by Lampire Biological Laboraories (Pipersville, PA). For Pk studies, 10-week old male Swiss-Webster mice (Taconic, Germantown, NY) and New Zealand White rabbits were injected subcutaneously (SC), and also intravenously (IV) for mice, with test agents diluted in PBS. Blood samples were obtained by cardiac puncture and from the ear vein for mice and rabbits, respectively. Serum was isolated from clotted blood by centrifugation, and diluted in antibody buffer, prior to analysis by ELISA.

[0216] Human blood specimens were collected from healthy donors. *In-vitro* ADCC and CDC activity were assayed as described previously (Rossi et al., 2008, *Cancer Res.* **68**, 8384-8392). For ADCC, Daudi cells were incubated for 4 h at 37°C with PBMCs, which were isolated from the blood of healthy donors, at a 50:1 effector:target ratio using test agents at 33 nM.

[0217] *In vivo* efficacy in mice - Female 8-12-week old C.B.17 homozygous SCID mice (Taconic) were inoculated intravenously with 1.5×10^7 Daudi cells on day 0. For comparison of the bsHexAbs, treatment was administered by SC injection on days 1 and 5. For comparison of the IgG-IFNα, treatments were administered as a single SC injection on day 7. Saline was used as a control treatment. Animals, monitored daily, were humanely euthanized

when hind-limb paralysis developed or if they became otherwise moribund. Additionally, mice were euthanized if they lost more than 20% of initial body weight. Survival curves were analyzed using Kaplan-Meier plots, using the Prism (v4.03) software package (GraphPad Software, Inc., San Diego, CA). Some outliers determined by critical Z test were censored from analyses.

[0218] Statistical analyses - Statistical significance ($P<0.05$) was determined using student's T-tests for all results except for the *in vivo* survival curves, which were evaluated by log-rank analysis.

Results

[0219] Synthesis of C_k-based immunoconjugates - The DNL™ synthesis produced homogeneous preparations of 22*-(20)-(20), 22-(20)-(20), 20*-2b and 20-2b. By SDS-PAGE (non-reducing), each conjugate was resolved into a tight cluster of bands with relative mobility conforming to their expected size (data not shown), and under reducing conditions, only bands representing the constituent polypeptides for each conjugate were evident, demonstrating a high degree of purity (not shown). For each conjugate, SE-HPLC resolved a major peak having a retention time consistent with their molecular size (not shown). The longer retention times observed for 22*-(20)-(20) and 20*-2b are likely due to their more compact structure, as compared to 22-(20)-(20) and 20-2b, respectively. Isoelectric focusing showed that 20*-2b and 20-2b have a similar pI (calculated pI = pH 7.22), with no evidence of unreacted IgG-AD2 (pI = pH 7.86) or IFNα2b-DDD2 (pI = pH 6.87) modules (not shown).

[0220] Both conjugates retain full binding of the parental mAbs, as shown for 20*-2b, which exhibited identical binding as veltuzumab to live Daudi cells (**FIG. 6**). Cytotoxicity also was similar between the C_k and Fc versions in Daudi cells (EC_{50} = 0.2 pM), demonstrating equivalent CD20 binding and IFNα specific activity (**FIG. 7**).

[0221] Pharmacokinetics - We reported previously that the $T_{1/2}$ for Fc-bsHexAbs were approximately half as long as their parental mAbs in mice (Rossi et al., 2009, *Blood* **113**:6161-6171). In the initial study, which measured the serum concentrations of 22*-(20)-(20), 22-(20)-(20) and epratuzumab in mice over a period of 72 h after subcutaneous (SC) injection (**FIG. 2a**), 22-(20)-(20) reached maximal concentration at 16 h and was cleared with a $T_{1/2}$ about 1 day, similar to the findings before. In comparison, both epratuzumab and 22*-(20)-(20) reached peak levels between 24 and 48 h, while clearing similarly, but slower than 22-(20)-(20). A subsequent study monitoring clearance over 5 days again found 22*-(20)-(20) with superior Pk, showing ~2-fold higher maximum concentration in serum, with

longer $T_{1/2}$ and mean residence time (MRT), culminated in a 3.8-fold greater area under the curve (AUC). **(FIG. 2b; Table 8).**

[0222] As in mice, the Pk parameters determined in rabbits were ~2-fold greater for 22*-(20)-(20), resulting in a 3.3-fold greater AUC, compared to 22-(20)-(20) **(FIG. 2c and d; Table 8)**. Importantly, the concentrations of the 22*-(20)-(20) following SC administration in both mice and rabbits were sustained for longer periods.

Table 8. Summary of pharmacokinetic parameters

Species	Route	Dose (mg)	Construct	$T_{1/2}$ (h)	T_{max} (h)	C_{max} (µg/mL)	AUC(0-∞) (h*µg/ml)	MRT (h)
Mouse	IV	1.0	20*-2b	36.2	6.0	649. 0	32516.5	55.2
			20-2b	17.1	6.0	629.8	15514.0	19.1
Mouse	SC	1.0	20*-2b	37.9	16.0	312.1	18318.2	62.1
			20-2b	16.0	16.0	146.0	6498.6	30.9
Mouse	SC	0.5	22*-(20)-(20)	106.5	24.0	50.6	6704.7	153.1
			22-(20)-(20)	54.5	16.0	26.5	1752.9	85.2
Rabbit	SC	18	22*-(20)-(20)	117.9	53.3	31.6	6079.1	179.6
			22-(20)-(20)	51.1	37.3	17.8	1838.4	89.2

$T_{1/2}$, elimination half-life; T_{max}, time of maximal concentration; C_{max}, maximal concentration; AUC, area under the curve; MRT, mean residence time.

[0223] Binding affinity (K_D) of the bsHexAbs to the neonatal Fc receptor (FcRn) was assessed by surface plasmon resonance and found to be 166 and 310 nM for 22*-(20)-(20) and 22-(20)-(20), respectively ($P = 0.01$). The affinity of epratuzumab (16 nM) was approximately 10-fold stronger than 22*-(20)-(20) (P=0.007) **(Table 9)**.

Table 9. Summary of Biacore analysis for neonatal Fc receptor binding affinity

	Epratuzumab			**22*-(20)-(20)**			**22-(20)-(20)**		
	k_d	k_a	K_D	k_d	k_a	K_D	k_d	k_a	K_D
Run 1	0.0242	$1.64x10^6$	15.0	0.0395	$2.80x10^5$	141.1	0.0458	$1.48x10^5$	309.5
Run 2	0.0218	$1.56x10^6$	17.9	0.0404	$2.26x10^5$	178.8	0.0411	$1.54x10^5$	266.9
Run 3	0.0239	$1.56x10^6$	15.8	0.0441	$2.48x10^5$	177.8	0.0419	$1.19x10^5$	352.1
Mean ±S.D	**0.0233 ±0.0013**	**$1.59x10^6$ ±$4.62x10^4$**	**16.3 ±1.5**	**0.0413 ±0.0024**	**$2.51x10^5$ ±$2.72x10^4$**	**165.9 ±21.5**	**0.0429 ±0.0025**	**$1.40x10^5$ ±$1.87x10^4$**	**309.5 ±42.6**

k_d = 1/s; k_a = 1/Ms; $K_D = k_d/k_a$ given as nM concentration

[0224] Fc-IgG-IFNα constructs, such as 20-2b, also were cleared from circulation faster than their parental mAb (Rossi et al., 2009, *Blood* **114**:3864-3871). However, when the Pk parameters of 20*-2b and 20-2b following either SC or intravenous (IV) injection were compared **(FIG. 3)**, the $T_{1/2}$, C_{max}, and MRT were each again about 2-fold higher for 20*-2b, resulting in a 2.8-fold greater AUC, compared to 20-2b **(Table 8)**. For IV administration,

20*-2b had a 2- and 2.8-fold longer $T_{1/2}$ and MRT, respectively, and a 2-fold greater AUC.

[0225] *In vivo* stability - The Fc-bsHexAbs and Fc-IgG-IFNα are stable *ex vivo* in serum (Rossi et al., 2009, *Blood* **114**:3864-3871; Rossi et al., 2009, *Blood* **113**:6161-6171). However, analysis of serum samples from earlier Pk studies suggested these constructs dissociate *in vivo* over time, presumably by intracellular processing. We compared the *in vivo* stability of 20*-2b and 20-2b by measuring the concentrations of the intact IgG-IFNα and the total veltuzumab, which allowed for differentiating the intact from the dissociated species (**FIG. 3c**). The % intact IgG-IFNα was plotted versus time (**FIG. 3d**), and *in vivo* dissociation rates for 20-2b and 20*-2b were calculated by linear regression to 0.97%/h and 0.18%/h, respectively. A similar analysis was performed on serum samples following SC injection of the bsHexAbs in mice, with *in vivo* dissociation rates for 22-(20)-(20) and 22*-(20)-(20) calculated to 0.55%/h and 0.19%/h, respectively (**FIG. 8**). Interestingly, both 22-(20)-(20) and 22*-(20)-(20) were completely stable *in vivo* following SC injections in rabbits (**FIG. 9**). The reason for the difference in *in vivo* stabilities between mice and rabbits is not known.

[0226] Effector function - We reported that Fc-IgG-IFNα and Fc-bsHexAbs did not induce measurable CDC *in vitro*, even when their parental mAb had potent activity (Rossi et al., 2009, *Blood* **114**:3864-3871; Rossi et al., 2009, *Blood* **113**:6161-6171). Consistent with the prior results, veltuzumab exhibited strong CDC, yet no activity was evident for 20-2b (**FIG. 4a**). Hoever, 20*-2b induced strong CDC, which approached the potency of veltuzumab (**FIG. 4a**). Under these *in vitro* conditions, epratuzumab lacked CDC, whereas 22-(20)-(20) achieved a modest increase, and 22*-(20)-(20) induced even greater activity, which was ~10-fold less potent than veltuzumab (**Fig. 4b**).

[0227] Unlike CDC, the Fc-based conjugates did not have reduced ADCC, but instead, 20-2b exhibited enhanced ADCC compared to veltuzumab (Rossi et al., 2009, *Blood* **114**:3864-3871). Depending on the PBMC donor, epratuzumab induced little or no ADCC *in vitro*, and not surprisingly, 22-(20)-(20) did not show a statistically significant improvement (**FIG. 4c**). However, the ADCC associated with 22*-(20)-(20) was not significantly different from veltuzumab, when PBMCs of a high-ADCC donor were used (**FIG. 4c**). With a low-ADCC PBMC donor, 22*-(20)-(20) had enhanced activity (11.4% lysis), compared to epratuzumab (2.3%) and 22-(20)-(20) (4.3%), but it was lower than veltuzumab (18.5%) (P=0.0326, data not shown).

[0228] *In vivo* efficacy - As reported previously, 20-2b is remarkably potent in treating mice bearing human Daudi Burkitt lymphoma xenografts, which are highly sensitive to direct

killing by IFNα (Rossi et al., 2009, *Blood* **114**:3864-3871). Using the same model, the C_k-based conjugates demonstrated even more potent anti-tumor activity than their Fc-based counterparts (**FIG. 5a**). While both 20-2b and 20*-2b at a single 1 μg-dose cured the majority of the animals, with median survival time (MST) greater than 189 days, 20*2b, but not 20-2b, at 0.25 μg maintained its potency, providing evidence of significantly improved therapeutic efficacy (MST >189 days with 7/8 cures for 20*2b vs. 134.5 days with just 3/8 survivors for 20-2b; P=0.0351). A molar equivalent of veltuzumab (0.6 μg) to 1 μg of 20-2b increased the MST by only 12.5 days over saline control, The superiority of another different C_k construct over the Fc-parental construct was shown again in the disseminated Daudi model, where animals were administered two injections (days 1 and 5) of high (1 mg) or low (10 μg) doses of 22*-(20)-(20) or 22-(20)-(20) (**FIG. 5b**). For the high dose, the MST was >123 and 71 days with 100% and 10% survival for 22*-(20)-(20) and 22-(20-(20), respectively (P<0.0001). With the low-dose treatment, the MST was 91 days for 22*-(20)-(20) with 2 mice surviving, compared to 50.5 days for 22-(20-(20) with no survivors (P=0.0014). High doses of each bsHexAb improved survival significantly more (P<0.0001) than either epratuzumab alone or in combination with C_H1-DDD2-Fab-veltuzumab, which were given at a molar equivalent to the 1-mg dose of bsHexAb. At the 100-fold lower dosing, both bsHexAbs were superior to high-dose epratuzumab (P<0.003), and 22*-(20)-(20), but not 22-(20)-(20), was superior to high-dose epratuzumab plus C_H1-DDD2-Fab-veltuzumab (P<0.0001).

Discussion

[0229] The various formats of antibody-based fusion proteins, including bsAbs (Kontermann, 2010, *Curr Opin Mol Ther* **12**:176-183) and immunocytokines (Kontermann, 2012, *Arch Biochem Biophys* 526:194-205), can largely be categorized into three groups, based on where additional moieties are fused to a whole IgG, an Fc, or an antigen-binding fragment such as Fab, scFv or diabody. Whereas Fc-fusion may increase $T_{1/2}$, and fusion to antigen-binding fragments should impart targeting, only fusion to IgG could expect to achieve antibody targeting, full Fc effector function and markedly extended Pk. Because not all IgG-fusion designs are created equal, effector activities and Pk are known to vary widely among the different formats and even between particular constructs of the same design.

[0230] DNL™ complexes are exceptional for producing immunoconjugates that retain full antigen-binding avidity of the targeting antibody and biological activity of the appending effector molecules (e.g., cytokines), and have potent efficacy both *in vitro* and *in vivo* (Rossi

et al., 2012, *Bioconjug. Chem* **23**:309-323; Rossi et al., 2009, *Blood* **114**:3864-3871; Rossi et al., 2009, *Blood* **113**:6161-6171; Rossi et al., 2010, *Cancer Res.* **70**:7600-7609; Rossi et al., 2011, *Blood* **118**:1877-1884). However, Fc-bsHexAbs and Fc-IgG-IFNα were cleared from circulation at approximately twice the rate of their parental mAbs. Sub-optimal Pk is a common deficiency associated with immunoconjugates that is primarily attributed to impaired dynamic binding to the FcRn (Kuo & Aveson, 2011, *MAbs.* **3**:422-430). To improve Pk, we engineered a new class of IgG-AD2 module having the AD2 peptide fused at the C-terminal end of the light chain. The new module was used to assemble C_k-bsHexAbs and C_k-IgG-IFNα, which not only exhibited comparable *in vitro* properties to their Fc-based homologues, including antigen binding, IFNα specific activity and *in vitro* cytotoxicity, but also had superior Pk, *in vivo* stability and Fc effector activity, which together resulted in increased *in vivo* efficacy, compared to the already potent Fc-based counterparts.

[0231] The superior Pk of the C_k-bsHexAbs and C_k-IgG-IFNα is most likely attributed to their increased binding affinity to the FcRn, which was twice as strong at pH 6.0 for 22*-(20)-(20), compared to 22-(20)-(20). FcRn binding is mediated by portions of the C_H2 and C_H3 domains of IgG, with critical contact sites located near the C-terminal end of the Fc (Huber et al., 1993, *J Mol Biol* **230**:1077-1083; Raghavan et al., 1994, *Immunity.* **1**:303-315). Considering that the $T_{1/2}$ of 22*-(20)-(20) was in the range of epratuzumab (Rossi et al., 2009, *Blood* **113**:6161-6171), it was unanticipated that FcRn binding was approximately 10-fold weaker for the former (155 nM). However, using this same method, we measured the FcRn K_D at 42 and 92 nM for other humanized mAbs, which typically have Pk similar to epratuzumab (data not shown). $T_{1/2}$ is not necessarily directly correlated with FcRn K_D at pH 6.0 (Dall'Acqua, 2002, *J Immunol* **169**:5171-5180; Gurbaxani et al., 2006, *Mol Immunol* **43**, 1462-1473). It has been suggested that the rate of dissociation at pH 7.4 is equally or perhaps more important in determining $T_{1/2}$ (Wang, 2011, *Drug Metab Dispos.* **39**:1469-1477). Although FcRn:IgG contacts are limited to the Fc domain, the antigen-binding domain can negatively impact FcRn binding, as evidenced by the fact that most therapeutic antibodies share a very similar Fc (IgG_1), yet vary widely in FcRn K_D and $T_{1/2}$ (Suzuki, 2010, *J Immunol* **184**:1968-1976). Additional factors include endocytosis, ligand:antibody ratio, antibody structural stability, antibody pI, and methionine oxidation (Kuo & Aveson, 2011, *MAbs.* **3**:422-430).

[0232] For fusion proteins, the FcRn K_D and $T_{1/2}$ can be influenced by the nature and location of the fusion partner (Suzuki et al., 2010, *J Immunol* **184**:1968-1976; Lee et al., 2003, *Clin*

Pharmacol Ther **73**, 348-365). We observed that the $T_{1/2}$ of each IgG-IFNα was shorter than the corresponding bsHexAb that was assembled using the same class of IgG-AD2 module. For example, the $T_{1/2}$ of 20*-2b (37.9 h) was markedly shorter than that of 22*-(20)-(20) (106.5 h), suggesting that, independent of their location, the IFNα groups negatively impact FcRn binding, perhaps by lowering the pI of the adduct.

[0233] The present Example identifies the C-terminal end of the light chain as the most advantageous location for fusion to IgG. An immunocytokine of single-chain IL-12 fused to the N-terminal end of the heavy chain of an anti-HER2 IgG_3 retained HER2 binding (Peng et al., 1999, *J Immunol* **163**:250-258)[17]. We applied a similar strategy using DNL™ by constructing an IgG-AD2 module having the AD2 peptide fused to the N-terminal end of veltuzumab heavy chain. However, bsHexAbs and IgG-IFNα made with this module did not bind CD20 on cells (data not shown). This might have been because of the large size of the additional $(Fab)_2$ or $(IFN\alpha 2b)_2$ groups. That these conjugates bound to anti-idiotype mAbs suggests that the nature of the antigen, which is a small extracellular loop of CD20, might be a factor. The C-terminal end of the heavy chain is the most common and convenient location for fusion to IgG(Kontermann, 2012, *Arch Biochem Biophys* 526:194-205). However, this is also the most likely location to impact FcRn binding and Pk negatively. For example, an immunocytokine of GM-CSF fused at the C-terminus of the heavy chain of an anti-HER2 IgG_3 exhibited markedly reduced $T_{1/2}$ (10 hours) compared to the parental mAb (110 hours) (Dela Cruz et al., 2000, *J Immunol* **165**:5112-5121). Fc-based bsAbs also suffer from diminished Pk. As an example, a bsAb having an anti-IGF-1R scFv fused to the C-terminal end of the heavy chain of an anti-EGFR IgG cleared from circulation in mice twice as fast ($T_{1/2}$ = 9.93 h), compared to the parental mAb ($T_{1/2}$ = 20.36 h) (Dong et al., 2011, *MAbs.* **3**:273-288).

[0234] Croasdale and colleagues systematically studied the effect of fusion location with IgG-scFv tetravalent bsAbs using an anti-IGF-1R IgG_1 fused at the N- or C-termini of the heavy or light chains, with an anti-EGFR scFv (Croasdale et al., 2012, *Arch. Biochem Biophys* 526:206-18). Fusion of scFv to the IgG at the C-terminus of the light chain produced the highest yields, had the longest $T_{1/2}$ and was the most effective *in vivo*. The authors indicated that each construct bound FcRn and FcγRIIIa; however, K_D was not reported. Among the different formats, the C-terminal heavy chain fusion had the shortest $T_{1/2}$. Fusion at the N- or C-terminus of the heavy chain resulted in substantially reduced or complete loss, respectively, of ADCC. Alternatively, fusion at the C-terminus of the light chain did not

decrease ADCC.

[0235] Our results show that fusion location can impact ADCC. For the bsHexAbs comprising epratuzumab as the IgG, which has minimal ADCC, strong ADCC was measured for 22*-(20)-(20), but not 22-(20)-(20), suggesting that this Fc effector function was provided by the addition of the four anti-CD20 Fabs, and that their fusion location is critical. Additionally, 22*-(20)-(20) showed moderate CDC, which was not detected for epratuzumab, and only modestly increased for 22-(20)-(20), suggesting that this effector function also can be bestowed to a CDC-lacking mAb by the addition of Fabs of a CDC-inducing mAb, and that, the activity is sensitive to the location of the fusion site. This was demonstrated clearly with the IgG-IFNα, where the Fc-IgG-IFN, 20-2b, did not have detectable CDC and 20*-2b induced potent activity, similar to veltuzumab.

[0236] Although the Fc-bsHexAbs and Fc-IgG-IFNα are quite stable in human or mouse sera and whole blood (Rossi et al., 2009, *Blood* **114**:3864-3871; Rossi et al., 2009, *Blood* **113**:6161-6171), the Fc-fusions, in particular, were not completely stable *in vivo*. The Fc-based conjugates dissociated at a rate of 0.5 – 1.0%/h in mice, compared to <0.2%/h for the C_k-based constructs. Because dissociation has never been observed *ex vivo*, we presume it occurs by an intracellular process. Interestingly, there was no evidence of *in-vivo* instability in rabbits, even after 5 days. The C-terminal lysine residue of the heavy chain is often cleaved proteolytically during antibody production. The common Fc-based fusion proteins, where additional groups are fused to the C-terminal lysine, potentially can be cleaved *in vivo* by proteases, such as plasmin, which cleave after exposed lysine residues (Gillies et al., 1992, *Proc Natl Acad Sci U. S. A* **89**, 1428-1432).

[0237] In summary, this study demonstrates the superior *in vivo* properties of bsAbs and immunocytokines made as DNL™ complexes with fusion at the C-terminal end of the light chain, suggesting that the C-terminus of the light chain is the preferred fusion location for most immunoconjugates with intended clinical use.

Example 2. Production and Use of C_k-based DNL™ Complexes For Treatment of Autoimmune Disease

Background

[0238] Systemic lupus erythematosus (SLE) has been classified as an autoimmune disease that may involve many organ systems, as an inflammatory multisystem rheumatic disorder, or as a collagen vascular disease. Corticosteroids remain the foundation for long-term management with most patients, even those in clinical remission, maintained using low

doses. High-dose steroids, particularly 0.5–1.0 g pulse i.v. methylprednisolone, are standard treatment for management of an acute flare, with immunosuppressants (azathioprine, cyclophosphamide, methotrexate, etc.) generally used in severe cases when other treatments are ineffective. The cytotoxicity associated with immunosuppressants as well as the problems of long-term systemic corticosteroid therapy provide incentives to develop targeted and less toxic therapies, particularly those with steroid-sparing effects. No new agent has been approved as a therapeutic for SLE in over 50 years until the recent approval of Benlysta (belimumab) in March of 2011.

[0239] Although the conventional view of B cells is as precursors of immunoglobulin-producing plasma cells, they may also play other roles in the pathogenesis of SLE, such as presenting autoantigens, promoting the breakdown of peripheral T-cell tolerance, and possibly by activating populations of T cells with low affinity toward autoantigens (Looney, 2010, *Drugs* 70:529-540; Mok, 2010, *Int J Rheum Dis* 13:3-11; Goldenberg, 2006, *Expert Rev Anticancer Ther* 6:1341-1353; Thaunat et al., 2010, *Blood* 116:515-521). Because of the central role of B cells in the pathogenesis of autoimmunity, targeted anti-B-cell immunotherapies are expected to offer therapeutic value in for SLE. For example, Benlysta is a monoclonal antibody (mAb) that inhibits activation of B cells by blocking B-cell activating factor.

[0240] Another B-cell target is CD22, a 135-kD glycoprotein that is a B-lymphocyte-restricted member of the immunoglobulin superfamily, and a member of the sialoadhesin family of adhesion molecules that regulate B cell activation and interaction with T cells (e.g., Carnahan et al., 2007, *Mol Immunol* 44:1331-1341; Haas et al., 2006, *J Immunol* 177:3063-3073; Haas et al., 2010, *J Immunol* 184:4789-4800). CD22 has 7 extracellular domains and is rapidly internalized when cross-linked with its natural ligand, producing a potent costimulatory signal in primary B cells. CD22 is an attractive molecular target for therapy because of its restricted expression; it is not exposed on embryonic stem or pre-B cells nor is it normally shed from the surface of antigen-bearing cells.

[0241] Epratuzumab is a humanized anti-CD22 antibody that is in advanced clinical trials. Clinical trials with epratuzumab have been undertaken for patients with non-Hodgkin's lymphoma, leukemias, Waldenström's macroglobulinemia, Sjögren's syndrome and SLE, and encompass an experience in more than 1000 patients. In the initial clinical study with epratuzumab in non-Hodgkin's lymphoma (NHL) or other B-cell malignancies, patients received 4 consecutive weekly epratuzumab infusions at doses of ranging from 120 to 1000 mg/m^2/week (Goldenberg, 2006, *Expert Rev Anticancer Ther* 6:1341-1353; Goldenberg et al., 2006, *Arthritis Rheum* 54:2344-2345; Leonard et al., 2003, *J Clin Oncol* 21:3051-3059; Leonard et

al., 2008, *Cancer* 113:2714-2723). Treatment-related toxicity typically involved nausea, chills/rigors, fever and other transient mild or moderate infusion reactions occurring primarily during the first weekly infusion. Peripheral B-cell levels decreased following epratuzumab therapy, but otherwise no consistent changes were seen in RBC, ANC, platelets, immunoglobulins, or T-cell levels following treatment. Epratuzumab blood levels after the 4th weekly infusion increased in a dose-dependent manner, and epratuzumab remained in circulation with a half-life of 23 days. Interestingly, enhanced anti-tumor effects in indolent and aggressive forms of NHL were reported when epratuzumab was combined with the anti-CD20 rituximab (Goldenberg, 2006, *Expert Rev Anticancer Ther* 6:1341-1353; Leonard et al., 2005, *J Clin Oncol* 23:5044-5051; Leonard et al., 2008, *Cancer* 113:2714-2723; Strauss et al., 2006, *J Clin Oncol* 24:3880-3886). Epratuzumab is entering two Phase-III registration trials for the treatment of SLE patients. Also noteworthy is that rituximab has also shown activity in patients with SLE (Ramos-Casals et al., 2009, *Lupus* 18:767-776).

[0242] Since the combination of rituximab and epratuzumab showed improved anti-lymphoma efficacy without increased toxicity in patients (Leonard et al., 2008, *Cancer* 113:2714-2723), we engineered and evaluated bsAbs against both CD20 and CD22, including an earlier design based on the IgG-(scFv)$_2$ format (Qu et al., 2008, *Blood* 111:2211-2219) and the more recent DNL™ design based on the hexavalent IgG-(Fab)$_4$ format, which resulted in 22-(20)-(20) and 20-(22)-(22) (Rossi et al., 2009 *Blood* 113:6161-6171). Specifically, 22-(20)-(20) comprises epratuzumab and 4 additional Fabs of veltuzumab, and thus binds CD22 bivalently and CD20 tetravalently. Likewise, the other bsAb, 20-(22)-(22), comprising veltuzumab and 4 Fabs of epratuzumab, binds CD20 bivalently and CD22 tetravalently. For the original HexAbs, referred to henceforth as C_H3-HexAbs, the two types of modules are C_H3-AD2-IgG and C_H1-DDD2-Fab. Each of these modules is produced as a fusion protein in myeloma cells and purified by protein A (C_H3-AD2-IgG) or KappaSelect (C_H1-DDD2-Fab) affinity chromatography.

[0243] A HexAb can be either monospecific or bispecific. The C_H3-HexAbs comprise a pair of Fab-DDD2 dimers linked to a full IgG at the carboxyl termini of the two heavy chains, thus having six Fab-arms and a common Fc domain. For example, the code of 20-(22)-(22) designates the bispecific HexAb comprising a divalent anti-CD20 IgG of veltuzumab and a pair of dimeric anti-CD22 Fab-arms of epratuzumab, whereas 22-(20)-(20) specifies the bispecific HexAb comprising a divalent anti-CD22 IgG of epratuzumab and a pair of dimeric anti-CD20 Fab-arms of veltuzumab.

[0244] As discussed in Example 1 above, we have developed an alternative HexAb format by

utilizing a new IgG-AD2 module, C_k-AD2-IgG, which has the AD2 peptide fused to the carboxyl end of the kappa light chain, instead of at the end of the Fc. Combination with C_H1-DDD2-Fab results in a C_k-HexAb structure, having a different architecture, but similar composition (6 Fabs and an Fc), to the C_H3-HexAb, having the four additional Fabs linked at the end of the light chain. As discussed above, the C_k-HexAbs exhibit superior effector functions and have significantly improved pharmacokinetics (Pk), compared to the original C_H3-HexAbs.

[0245] The C_k-HexAbs are particularly well suited for *in vivo* applications as they display favorable Pk, are stable *in vivo*, and may be less immunogenic as both DDD- and AD-peptides are derived from human proteins and the constitutive antibody components are humanized. In addition, each of the anti-CD22/CD20 potently induce direct cytotoxicity against various CD20/CD22-expressing lymphoma and leukemic cell lines *in vitro* without the need for a secondary antibody to effect hypercrosslinking, which is required for the parental mAbs. I*n vivo* studies confirmed the efficacy of the bsAbs to inhibit growth of Burkitt lymphoma xenografts in mice, thus indicating their larger size has not affected tumor targeting and tissue penetration.

Preliminary Results

[0246] Clinical Experience with Epratuzumab - Clinical studies have been conducted to examine the efficacy of epratuzumab in indolent and aggressive forms of NHL alone in combination with rituximab. The published data show that the antibody can be given weekly for 4 weeks in a <1-h infusion up to doses of 1,000 mg/m^2, with the optimal dose appearing to be 360 mg/m^2, and resulting in very durable objective responses in 43% of follicular patients given this optimal dose, with one-third comprising CRs. When combined weekly for four weeks with rituximab, follicular, indolent NHL patients showed an overall 67% objective response (7% PR and 60% CR/Cru), with only one patient relapsing at 19 months follow-up. We and others have studied the combination of rituximab and epratuzumab at their recommended full doses weekly x 4 in multicenter US and European trials, with results indicating a higher CR rate than observed in historical studies with rituximab alone in similar patient populations.

[0247] For lupus, completed studies have enrolled 331 unique individuals who received at least one dose of epratuzumab (Shoenfeld et al. (Eds.), Immunotherapeutic Agents for SLE. Future Medicine Ltd; 2012). In the initial study, Dörner *et al.* administered 360 mg/m^2 to 14 patients with moderately active SLE (Dorner et al., 2006, *Arthritis Res Ther* 8:R74). Patients received 360 mg/m^2 epratuzumab intravenously every 2 weeks for four doses, with

analgesic/antihistamine premedications (but no steroids), and were followed for up to 32 weeks. The drug had effects as early as 6 weeks, with 93% demonstrating improvements in British Isles Lupus Activity Group (BILAG) Index in at least one B- or C-level disease activity at 6 weeks, and all patients achieved improvement in at least one BILAG body system at 10 weeks. Epratuzumab was well tolerated and had a median infusion time of 32 min. Blood B-cell levels decreased by an average of 35% at 6 weeks and remained decreased at 6 months post-therapy. No adverse safety signals were detected. B-cell levels decreased post-treatment by about 40%, which is much less than the experience with anti-CD20 mAbs. Post-treatment T-cell levels, immunoglobulins and other standard safety laboratory tests remained unchanged from baseline. No evidence of HAHA was found in these patients. No consistent changes in autoantibodies and other disease-related laboratory tests were seen.

[0248] This led to two Phase III studies known as ALLEVIATE I and II (SL0003/SL0004; ClinicalTrials.gov registry: NCT00111306 and NCT00383214) that were intended to be 48-week, randomized, double-blind, placebo-controlled trials, followed by an open-label, long-term, safety study for patients in the USA (SL0006). The protocol included infusing patients with epratuzumab at 360 or 720 mg/m^2 (in addition to background therapy, which included corticosteroids and immunosuppressives) over four consecutive 12-week cycles: in the first cycle, four infusions were given at weeks 0, 1, 2 and 3; for the three subsequent retreatment cycles, two infusions were given at weeks 0 and 1. The primary efficacy end point was a BILAG responder analysis at week 12, since too few patients completed the originally intended 24 patient response variable evaluation. Responders had a reduction of BILAG A or B by one level, no new BILAG A or less than two new Bs, and no introduction of immunosuppression or increase in steroid doses during the treatment period. Initiated in 2005, the study was prematurely discontinued in 2006 due to drug supply interruption. At that point, only 90 patients had been studied long enough for analysis and the two groups were pooled.

[0249] A total of 29 US patients were given open-label follow-up therapy in SL0006. Subjects generally had serious lupus: the mean BILAG score was 13.2 and 43% had at least one BILAG A. In total, 63% were on immunosuppressive agents and 43% were on 25 mg or more of prednisone daily. A total of 91% received four infusions and 69% reached week 24. Using an intention-to-treat analysis, a BILAG response was achieved at week 12 in 44.1, 20 and 30.3% of the 360 mg/m^2, 720 mg/m^2 and placebo groups, respectively, with responses seen within 6 weeks. Epratuzumab demonstrated significant steroid-sparing properties and correlated with improvements in health-related quality of life. The improvements were

sustained in those who stayed in the open label follow-up. No significant intergroup differences were found in adverse events or serious adverse events. B-cell depletion was approximately 20–40% among treated patients.

[0250] EMBLEM was a Phase IIb, 12-week, double-blind study of six different dosing regimens for patients with at least one BILAG A and/or two BILAG B's (ClinicalTrials.gov registry: NCT00624351). This study included 227 SLE patients with a mean total BILAG score of 15.2 and a mean SLE disease activity index of 14.8 who were on a mean 14 mg of prednisone daily, and the majority were also taking immunosuppressive agents. Study participants thus had more multisystem disease activity than has been seen in any other published lupus clinical trial. Four weekly infusions, two infusions every other week, or placebo, were given against a background of prednisone and, for most, immunosuppressive therapy. Those who received a combined dose of 2400 mg had meaningful and statistically significant improvements, with 37.9% achieving an 'enhanced BILAG improvement', whereby at least two levels (e.g., A to C, B to D) of improvement were noted. Again, there were no safety signals or significant immunosuppression. Only four out of 187 (2.1%) patients developed HAHA.

[0251] EMBODY, a pivotal 48-week trial consisting of two large cohorts totaling nearly 2000 patients, was initiated in December 2010 (ClinicalTrials.gov registry: NCT01262365).

[0252] Clinical experience with veltuzumab - We have studied veltuzumab in over 80 NHL patients refractory/relapsed to prior therapies, including rituximab, and it has been found to have about a 43% objective response and a 27% complete response rate in FL patients at all doses summarized, which appear to be durable (15-25 months) (Morchhauser et al., 2009, *J Clin Oncol* 27:3346-3353). Activity was seen even at doses of 80 mg/m^2. Importantly, the infusion profile appears better than rituximab's, with no grade 3-4 adverse reactions and infusion times of $\leq$2 h (compared to 4-8 h for rituximab). Veltuzumab has been examined also in a subcutaneous (SC) formulation in B-cell lymphoma (Negrea et al., 2011, *Haematologica* 96:567-573).

[0253] Veltuzumab has also been studied in patients with immune thrombocytopenia (ITP) (ClinicalTrials.gov registry: NCT00547066), and has been shown to be active in this disease, even when low doses have been administered (twice, on weeks 1 and 3) intravenously and subcutaneously (data not shown). Forty-one patients received 2 doses of veltuzumab 2 weeks apart. Veltuzumab was well-tolerated (limited Grade 1-2 transient reactions, except one Grade 3 infusion reaction), with no other safety issues. Of 38 assessable patients, 9 with newly-diagnosed or persistent disease (ITP $\leq$1 year) previously treated only with steroids

and/or immunoglobulins, had 7 (78%) responses including 3 (33%) CRs and 4 (44%) PRs, while 29 with chronic disease up to 31 years and additional prior therapies had 20 (69%) responses, including 4 (13%) CRs and 10 (35%) PRs. For the 27 responders, median time to relapse increased with response category (MR: 2.4, PR: 5.5, CR: 14.4 months) with 10 (37%) responding > 1 year (3 ongoing at 3.0-3.8 years). Eight responders were retreated, with 3 again achieving PRs, including one retreated 4 times. Both IV and SC routes depleted B cells after the first injection at all doses. Eight patients developed low HAHA titers of uncertain clinical significance. Thus, veltuzumab is a promising therapeutic on its own, both in NHL and in an autoimmune disease.

[0254] Hexavalent bsAbs made by DNL™ - The molecular engineering, production, purification and biochemical/biological characterization of 22-(20)-(20) and 20-(22)-(22) have been reported (Rossi et al., 2009, *Blood* 113:6161-6171). A detailed examination of the mechanism of action and cell signaling induced by 22-(20)-(20) and 20-(22)-(22) has also been published (Gupta et al., 2010, *Blood* 116:3258-3267). The key findings are as follows.

[0255] Both 22-(20)-(20) and 20-(22)-(22) retained the binding properties of their parental Fab/IgGs with all 6 Fabs capable of binding simultaneously. Competitive ELISAs showed that each construct possesses the functional valency as designed, and that each Fab binds with a similar affinity to those of the parental mAb. Flow cytometry demonstrate bispecific binding to live NHL cells with longer retention than the parental mAbs. The internalization rate of the bsAbs is largely influenced by both valency and the internalizing nature of the constitutive antibodies. Specifically, 22-(20)-(20) with four Fabs from the slowly internalizing veltuzumab and two Fabs from the rapidly internalizing epratuzumab behaves similar to veltuzumab, showing a slow internalization rate. Conversely 20-(22)-(22) with four Fabs from the rapidly internalizing epratuzumab and two Fabs from the slowly internalizing veltuzumab exhibits rapid internalization, similar to epratuzumab.

[0256] The two anti-CD20/CD22 bsAbs induced caspase-independent apoptosis more potently than veltuzumab or epratuzumab, either alone or in combination. Despite the incorporation of veltuzumab, which alone displays potent CDC, neither bsAb is able to induce CDC. Both bsAbs exhibit ADCC, with 20-(22)-(22) more potent than 22-(20)-(20), presumably due to the higher density of CD20 than CD22 in normal B cells and NHL as well as the fact that veltuzumab mediates ADCC more efficiently than epratuzumab.

[0257] The bsAbs inhibit lymphoma cells without immobilization (required for epratuzumab) or hypercrosslinking with a secondary antibody (required for veltuzumab). Such direct cytotoxicity is about 50-fold more potent in Daudi Burkitt lymphoma cells than the

combination of both parental mAbs in the absence of immobilization or hypercrosslinking. In Raji and Ramos cells, 22-(20)-(20) is 8- to 10-fold more potent than 20-(22)-(22), which is in turn 8- to 10-fold more potent than the combination of both parental Abs. Thus, 22-(20)-(20) can be 100-fold more potent than the parental mAbs given in combination in vitro in the absence of other factors, such as effect cells.

[0258] Both bsAbs induce extensive translocation of CD22 (as well as CD20) into lipid rafts. Both bsAbs induce strong homotypic adhesion in lymphoma cells, whereas under the same conditions the parental mAbs are ineffective, indicating that crosslinking CD20 and CD22 leads to homotypic adhesion, which may contribute to the enhanced in vitro cytotoxicity.

[0259] Pk analyses show that the circulating half-life of the bsAbs in mice is 2-3-fold shorter than that of the parental mAbs. Biodistribution studies in mice show that both bsAbs have tissue uptakes similar to veltuzumab and epratuzumab, indicating that the bsAbs are not cleared more rapidly than their parental mAbs because of increased uptake in normal tissues.

[0260] *In vivo* studies in Daudi xenografts reveal 20-(22)-(22), despite having a shorter serum half-life, had anti-tumor efficacy comparable to equimolar veltuzumab. Although 22-(20)-(20) is less potent than 20-(22)-(22), it is still more effective than epratuzumab and the control bsAbs. The greatly enhanced direct toxicity of the bsAbs correlates with their ability to alter the basal expression of various intracellular proteins involved in regulating cell growth, survival, and apoptosis, with the net outcome leading to cell death. In an ex vivo setting, both 22-(20)-(20) and 20-(22)-(22) deplete NHL cells as well as normal B cells from whole blood of healthy volunteers.

[0261] Because Pk analyses revealed that the circulating half-life of the C_H3-HexAbs in mice is 2-3-fold shorter than that of the parental mAbs, we have developed the alternative C_k-HexAb format, with the goal of improving the Pk. The studies in Example 1 above indicate that the increased rate of blood clearance observed for the C_H3-based HexAbs is due to the location of the additional Fab groups at the end of the Fc, interfering with the binding (and/or release) of the neonatal Fc receptor (FcRn), which is responsible for recirculation of IgG following endocytosis, resulting in greatly extended Pk. Indeed, 22*-(20)-(20) exhibited markedly superior Pk compared to 22-(20)-(20) (Example 1). Following subcutaneous injection in normal mice, 22*-(20)-(20) achieved a two-fold greater C_{max} and three-fold longer circulating half-life, resulting in a three-fold greater area under the curve, compared to 22-(20)-(20). Additionally, 22*-(20)-(20) was found to be highly stable *in vivo* over the entire 5-day Pk study. This was evident because two different ELISA formats, one of which detects any form of epratuzumab, and the other quantifying only intact 22*-(20)-(20), generated

essentially overlapping Pk curves.

Use in SLE

[0262] The 22*-(20)-(20) DNL™ construct is selected for therapeutic use in SLE. 22*-(20)-(20) is derived from veltuzumab, the humanized anti-CD20 monoclonal antibody (mAb) and epratuzumab, the humanized anti-CD22 mAb, to form a covalent conjugate with four Fab fragments of veltuzumab attached to one IgG of epratuzumab (see Example 1). Both epratuzumab and veltuzumab have shown clinical activity in autoimmune disease and combination therapy with both mAbs will be more effective than either as monotherapies. A more potent therapy, using two different mechanisms of action (B-cell depletion by anti-CD20 mAb and B-cell modulation by anti-CD22 mAb), is accomplished by using a bispecific antibody capable of targeting both CD20 and CD22 that is more convenient and economical than administering two different mAbs sequentially, which presently requires patients to be infused for many hours in each treatment session.

[0263] Use of 22*-(20)-(20) as a therapeutic agent for SLE is evaluated in an SCID mouse model, in which animals are engrafted with peripheral blood lymphocytes (PBL) from SLE patients (Mauermann et al., 2004, *Clin Exp Immunol* 137:513-520). The efficacy of the bsAb is compared to epratuzumab and veltuzumab independently and in combination by monitoring the serum level of anti-dsDNA antibody, a hallmark of SLE.

[0264] Blood samples are collected from SLE patients. For engraftment, $3x10^7$ PBLs obtained from individual SLE patients are injected intraperitoneally (i.p.) into an 8 -10 week old female SCID mouse. Thus, each animal represents an individual lupus patient. Approximately two-thirds of the mice have successful engraftment, with evidence of human antibody production in concentrations ≥100 μg/mL within 2 weeks, with peak production within 4 weeks. Mice having evidence of engraftment, are used for treatment. To monitor the effect of treatment, mice are bled on days 24, 34, 44, and 54 and the sera are tested by ELISA or Protein-A HPLC for the presence of total hIgG, anti-dsDNA (measurement of lupus disease state) and anti-tetanus toxoid antibodies (to demonstrate functional human humoral immune system).

[0265] Human anti-dsDNA antibodies in the recipient mouse sera, as an indicator of SLE, are determined using maxisorb 96-well microtitre plates coated with poly L-lysine (5 mg/ml, Sigma, St. Louis, MO, USA), followed by coating with lambda phage dsDNA (5 mg/well, Boehringer Mannheim, Germany). Plates are blocked with 10% fetal calf serum (FCS) in PBS, and incubated with mouse sera (diluted 1 : 5–1 : 40) for 2 h. Bound anti-dsDNA is

detected with a goat antihuman IgG antibody conjugated to horseradish peroxidase (Jackson).

[0266] The effect of using the 22*-(20)-(20) DNL™ on SLE mice is examined. Prior studies with the 22-(20)-(20) bsAb *in vitro* found it was effective in killing human B-cell lymphoma cell lines at concentrations of ~ 1 nM (~350 μg/mL), and *in vivo*, three 10-μg doses of 22-(20)-(20) in 1 week controlled the outgrowth of IV implanted Daudi B-cell lymphoma cell line in SCID mice (Rossi et al., 2009, *Blood* 113:6161-6171). However, the bsAbs were less effective in killing normal B-cells *ex vivo* (**FIG. 10**). Based on these results, SLE-engrafted SCID mice are treated initially with 400 μg of 22*-(20)-(20) i.p. twice weekly for 2 weeks (starting on day 14). If titers return, a second cycle of treatment is initiated, continuing until study termination on day 60. If disease control at 400 μg is insufficient after 2 weeks of treatment, treatment in subsequent groups of animals given 400 μg is uninterrupted for 4 sequential weeks. If disease control is significantly improved after 2 weeks with 400 μg, a lower dose of 40 μg using the same twice weekly schedule for 2 weeks is followed by an observation period. Equal numbers of animals receive only the excipient (buffer) dosing so that a baseline for disease progression is established. Our goal is to establish a treatment protocol using a minimum dose that significantly decreases antibody production, proteinuria, and evidence of renal damage. In addition to the buffer control, the effects are determined of the parental mAbs of 22*-(20)-(20), epratuzumab, veltuzumab and a combination of epratuzumab and veltuzumab IgG, as well as veltuzumab-DDD2 (bivalent Fab), each given at equal molar amounts and following the same dosing schedule as the 22*-(20)-(20) test group.

[0267] The primary comparator among treatment groups is the change in anti-dsDNA andibody serum titer following treatment. Based on the results of Maurermann et al. using this model system, the anti-dsDNA titer in control mice peaks at 30 - 40 days, before slowly declining. Successful therapy results in a much lower C_{max} and more rapid decline in anti-dsDNA titer, to levels below those at the onset of therapy. The C_{max} and the change in anti-dsDNA titer from day 14 to day 70 ($\Delta C_{70/14}$) are measured for each animal. At the end of the therapy study, animals are assessed for proteinuria and inflammatory glomerulonephritis as additional measurements of disease progression or control.

[0268] It is observed that SLE mice treated with a 400 μg dose of 22*-(20)-(20) twice weekly for four weeks show a significant decrease in anti-dsDNA titer, with lower levels of proteinuria and inflammatory glomerulonephritis, compared to the buffer control, either epratuzumab or veltuzumab administered alone, or the combination of epratuzumab and veltuzumab, when administered at the same molar dosages and schedules as 22*-(20)-(20).

Example 3. General Techniques for DOCK-AND-LOCK™

[0269] The general techniques discussed below were used to generate DNL™ complexes with AD or DDD moieties attached to the C-terminal end of the antibody heavy chain. Light chain appended AD moieties were constructed as described in Example 1 above. With the exception of superior Pk, *in vivo* stability and improved efficacy, the C_k DNL™ constructs were found to function similarly to their C_H counterparts.

Expression Vectors

[0270] The plasmid vector pdHL2 has been used to produce a number of antibodies and antibody-based constructs. See Gillies et al., J Immunol Methods (1989), 125:191-202; Losman et al., Cancer (Phila) (1997), 80:2660-6. The di-cistronic mammalian expression vector directs the synthesis of the heavy and light chains of IgG. The vector sequences are mostly identical for many different IgG-pdHL2 constructs, with the only differences existing in the variable domain (V_H and V_L) sequences. Using molecular biology tools known to those skilled in the art, these IgG expression vectors can be converted into Fab-DDD or Fab-AD expression vectors.

[0271] To generate Fab-DDD expression vectors, the coding sequences for the hinge, CH2 and CH3 domains of the heavy chain were replaced with a sequence encoding the first 4 residues of the hinge, a 14 residue Gly-Ser linker and a DDD moiety, such as the first 44 residues of human RIIα (referred to as DDD1, SEQ ID NO:1). To generate Fab-AD expression vectors, the sequences for the hinge, CH2 and CH3 domains of IgG were replaced with a sequence encoding the first 4 residues of the hinge, a 15 residue Gly-Ser linker and an AD moiety, such as a 17 residue synthetic AD called AKAP-*IS* (referred to as AD1, SEQ ID NO:3), which was generated using bioinformatics and peptide array technology and shown to bind RIIα dimers with a very high affinity (0.4 nM). See Alto, et al. Proc. Natl. Acad. Sci., U.S.A (2003), 100:4445-50. Two shuttle vectors were designed to facilitate the conversion of IgG-pdHL2 vectors to either Fab-DDD1 or Fab-AD1 expression vectors, as described below.

Preparation of CH1

[0272] The CH1 domain was amplified by PCR using the pdHL2 plasmid vector as a template. The left PCR primer consisted of the upstream (5') end of the CH1 domain and a SacII restriction endonuclease site, which is 5' of the CH1 coding sequence. The right primer consisted of the sequence coding for the first 4 residues of the hinge (PKSC, SEQ ID NO:123) followed by four glycines and a serine, with the final two codons (GS) comprising a Bam HI restriction site. The 410 bp PCR amplimer was cloned into the PGEMT® PCR

cloning vector (PROMEGA®, Inc.) and clones were screened for inserts in the T7 (5') orientation.

[0273] A duplex oligonucleotide was synthesized to code for the amino acid sequence of DDD1 preceded by 11 residues of the linker peptide, with the first two codons comprising a BamHI restriction site. A stop codon and an EagI restriction site are appended to the 3'end. The encoded polypeptide sequence is shown below.

GSGGGGSGGGGSHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA (SEQ ID NO:124)

[0274] Two oligonucleotides, designated RIIA1-44 top and RIIA1-44 bottom, which overlap by 30 base pairs on their 3' ends, were synthesized and combined to comprise the central 154 base pairs of the 174 bp DDD1 sequence. The oligonucleotides were annealed and subjected to a primer extension reaction with Taq polymerase. Following primer extension, the duplex was amplified by PCR. The amplimer was cloned into PGEMT® and screened for inserts in the T7 (5') orientation.

[0275] A duplex oligonucleotide was synthesized to code for the amino acid sequence of AD1 preceded by 11 residues of the linker peptide with the first two codons comprising a BamHI restriction site. A stop codon and an EagI restriction site are appended to the 3'end. The encoded polypeptide sequence is shown below.

GSGGGGSGGGGSQIEYLAKQIVDNAIQQA (SEQ ID NO:125)

[0276] Two complimentary overlapping oligonucleotides encoding the above peptide sequence, designated AKAP-IS Top and AKAP-IS Bottom, were synthesized and annealed. The duplex was amplified by PCR. The amplimer was cloned into the PGEMT® vector and screened for inserts in the T7 (5') orientation.

Ligating DDD1 with CH1

[0277] A 190 bp fragment encoding the DDD1 sequence was excised from PGEMT® with BamHI and NotI restriction enzymes and then ligated into the same sites in CH1-PGEMT® to generate the shuttle vector CH1-DDD1-PGEMT®.

Ligating AD1 with CH1

[0278] A 110 bp fragment containing the AD1 sequence was excised from PGEMT® with BamHI and NotI and then ligated into the same sites in CH1-PGEMT® to generate the shuttle vector CH1-AD1-PGEMT®.

[0279] With this modular design either CH1-DDD1 or CH1-AD1 can be incorporated into any IgG construct in the pdHL2 vector. The entire heavy chain constant domain is replaced with one of the above constructs by removing the SacII/EagI restriction fragment (CH1-CH3) from pdHL2 and replacing it with the SacII/EagI fragment of CH1-DDD1 or CH1-AD1, which is excised from the respective PGEMT® shuttle vector.

C-DDD2-Fd-hMN-14-pdHL2

[0280] C-DDD2-Fd-hMN-14-pdHL2 is an expression vector for production of C-DDD2-Fab-hMN-14, which possesses a dimerization and docking domain sequence of DDD2 (SEQ ID NO:2) appended to the carboxyl terminus of the Fd of hMN-14 via a 14 amino acid residue Gly/Ser peptide linker. The fusion protein secreted is composed of two identical copies of hMN-14 Fab held together by non-covalent interaction of the DDD2 domains.

[0281] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides, which comprise the coding sequence for part of the linker peptide and residues 1-13 of DDD2, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 PNK, resulting in overhangs on the 5' and 3' ends that are compatible for ligation with DNA digested with the restriction endonucleases BamHI and PstI, respectively.

[0282] The duplex DNA was ligated with the shuttle vector CH1-DDD1-PGEMT®, which was prepared by digestion with BamHI and PstI, to generate the shuttle vector CH1-DDD2-PGEMT®. A 507 bp fragment was excised from CH1-DDD2-PGEMT® with SacII and EagI and ligated with the IgG expression vector hMN-14(I)-pdHL2, which was prepared by digestion with SacII and EagI. The final expression construct was designated C-DDD2-Fd-hMN-14-pdHL2. Similar techniques have been utilized to generated DDD2-fusion proteins of the Fab fragments of a number of different humanized antibodies.

h679-Fd-AD2-pdHL2

[0283] h679-Fab-AD2, was designed to pair to C-DDD2-Fab-hMN-14. h679-Fd-AD2-pdHL2 is an expression vector for the production of h679-Fab-AD2, which possesses an anchoring domain sequence of AD2 (SEQ ID NO:4) appended to the carboxyl terminal end of the CH1 domain via a 14 amino acid residue Gly/Ser peptide linker. AD2 has one cysteine residue preceding and another one following the anchor domain sequence of AD1.

[0284] The expression vector was engineered as follows. Two overlapping, complimentary oligonucleotides (AD2 Top and AD2 Bottom), which comprise the coding sequence for AD2 and part of the linker sequence, were made synthetically. The oligonucleotides were annealed and phosphorylated with T4 PNK, resulting in overhangs on the 5' and 3' ends that

are compatible for ligation with DNA digested with the restriction endonucleases BamHI and SpeI, respectively.

[0285] The duplex DNA was ligated into the shuttle vector CH1-AD1-PGEMT®, which was prepared by digestion with BamHI and SpeI, to generate the shuttle vector CH1-AD2-PGEMT®. A 429 base pair fragment containing CH1 and AD2 coding sequences was excised from the shuttle vector with SacII and EagI restriction enzymes and ligated into h679-pdHL2 vector that prepared by digestion with those same enzymes. The final expression vector is h679-Fd-AD2-pdHL2.

Generation of TF2 DNL™ Construct

[0286] A trimeric DNL™ construct designated TF2 was obtained by reacting C-DDD2-Fab-hMN-14 with h679-Fab-AD2. A pilot batch of TF2 was generated with >90% yield as follows. Protein L-purified C-DDD2-Fab-hMN-14 (200 mg) was mixed with h679-Fab-AD2 (60 mg) at a 1.4:1 molar ratio. The total protein concentration was 1.5 mg/ml in PBS containing 1 mM EDTA. Subsequent steps involved TCEP reduction, HIC chromatography, DMSO oxidation, and IMP 291 affinity chromatography. Before the addition of TCEP, SE-HPLC did not show any evidence of a_2b formation. Addition of 5 mM TCEP rapidly resulted in the formation of a_2b complex consistent with a 157 kDa protein expected for the binary structure. TF2 was purified to near homogeneity by IMP 291 affinity chromatography (not shown). IMP 291 is a synthetic peptide containing the HSG hapten to which the 679 Fab binds (Rossi et al., 2005, Clin Cancer Res 11:7122s-29s). SE-HPLC analysis of the IMP 291 unbound fraction demonstrated the removal of a_4, a_2 and free kappa chains from the product (not shown).

[0287] The functionality of TF2 was determined by BIACORE® assay. TF2, C-DDD1-hMN-14+h679-AD1 (used as a control sample of noncovalent a_2b complex), or C-DDD2-hMN-14+h679-AD2 (used as a control sample of unreduced a_2 and b components) were diluted to 1 .mu.g/ml (total protein) and passed over a sensorchip immobilized with HSG. The response for TF2 was approximately two-fold that of the two control samples, indicating that only the h679-Fab-AD component in the control samples would bind to and remain on the sensorchip. Subsequent injections of WI2 IgG, an anti-idiotype antibody for hMN-14, demonstrated that only TF2 had a DDD-Fab-hMN-14 component that was tightly associated with h679-Fab-AD as indicated by an additional signal response. The additional increase of response units resulting from the binding of WI2 to TF2 immobilized on the sensorchip corresponded to two fully functional binding sites, each contributed by one subunit of C-

DDD2-Fab-hMN-14. This was confirmed by the ability of TF2 to bind two Fab fragments of WI2 (not shown).

Production of TF10 DNL™ Construct

[0288] A similar protocol was used to generate a trimeric TF10 DNL™ construct, comprising two copies of a C-DDD2-Fab-hPAM4 and one copy of C-AD2-Fab-679. The TF10 bispecific ([hPAM4]$_2$ x h679) antibody was produced using the method disclosed for production of the (anti CEA)$_2$ x anti HSG bsAb TF2, as described above. The TF10 construct bears two humanized PAM4 Fabs and one humanized 679 Fab.

[0289] The two fusion proteins (hPAM4-DDD2 and h679-AD2) were expressed independently in stably transfected myeloma cells. The tissue culture supernatant fluids were combined, resulting in a two-fold molar excess of hPAM4-DDD2. The reaction mixture was incubated at room temperature for 24 hours under mild reducing conditions using 1 mM reduced glutathione. Following reduction, the reaction was completed by mild oxidation using 2 mM oxidized glutathione. TF10 was isolated by affinity chromatography using IMP291-affigel resin, which binds with high specificity to the h679 Fab.

Example 4. Production of AD- and DDD-linked Fab and IgG Fusion Proteins From Multiple Antibodies

[0290] Using the techniques described in the preceding Examples, the IgG and Fab fusion proteins shown in **Table 10** were constructed and incorporated into DNL™ constructs. The fusion proteins retained the antigen-binding characteristics of the parent antibodies and the DNL™ constructs exhibited the antigen-binding activities of the incorporated antibodies or antibody fragments.

Table 10. Fusion proteins comprising IgG or Fab

Fusion Protein	Binding Specificity
C-AD1-Fab-h679	HSG
C-AD2-Fab-h679	HSG
C-(AD)$_2$-Fab-h679	HSG
C-AD2-Fab-h734	Indium-DTPA
C-AD2-Fab-hA20	CD20
C-AD2-Fab-hA20L	CD20
C-AD2-Fab-hL243	HLA-DR
C-AD2-Fab-hLL2	CD22
N-AD2-Fab-hLL2	CD22

C-AD2-IgG-hMN-14	CEACAM5
C-AD2-IgG-hR1	IGF-1R
C-AD2-IgG-hRS7	EGP-1
C-AD2-IgG-hPAM4	MUC
C-AD2-IgG-hLL1	CD74
C-DDD1-Fab-hMN-14	CEACAM5
C-DDD2-Fab-hMN-14	CEACAM5
C-DDD2-Fab-h679	HSG
C-DDD2-Fab-hA19	CD19
C-DDD2-Fab-hA20	CD20
C-DDD2-Fab-hAFP	AFP
C-DDD2-Fab-hL243	HLA-DR
C-DDD2-Fab-hLL1	CD74
C-DDD2-Fab-hLL2	CD22
C-DDD2-Fab-hMN-3	CEACAM6
C-DDD2-Fab-hMN-15	CEACAM6
C-DDD2-Fab-hPAM4	MUC
C-DDD2-Fab-hR1	IGF-1R
C-DDD2-Fab-hRS7	EGP-1
N-DDD2-Fab-hMN-14	CEACAM5

Example 5. Antibody-Dendrimer DNL™ Complex for siRNA

[0291] Cationic polymers, such as polylysine, polyethylenimine, or polyamidoamine (PAMAM)-based dendrimers, form complexes with nucleic acids. However, their potential applications as non-viral vectors for delivering therapeutic genes or siRNAs remain a challenge. One approach to improve selectivity and potency of a dendrimeric nanoparticle may be achieved by conjugation with an antibody that internalizes upon binding to target cells.

[0292] We synthesized and characterized a novel immunoconjugate, designated E1-G5/2, which was made by the DNL™ method to comprise half of a generation 5 (G5) PAMAM dendrimer (G5/2) site-specifically linked to a stabilized dimer of Fab derived from hRS7, a humanized antibody that is rapidly internalized upon binding to the Trop-2 antigen expressed on various solid cancers.

Methods

[0293] E1-G5/2 was prepared by combining two self-assembling modules, AD2-G5/2 and hRS7-Fab-DDD2, under mild redox conditions, followed by purification on a Protein L column. To make AD2-G5/2, we derivatized the AD2 peptide with a maleimide group to react with the single thiol generated from reducing a G5 PAMAM with a cystamine core and used reversed-phase HPLC to isolate AD2-G5/2. We produced hRS7-Fab-DDD2 as a fusion protein in myeloma cells, as described in the Examples above.

[0294] The molecular size, purity and composition of E1-G5/2 were analyzed by size-exclusion HPLC, SDS-PAGE, and Western blotting. The biological functions of E1-G5/2 were assessed by binding to an anti-idiotype antibody against hRS7, a gel retardation assay, and a DNase protection assay.

Results

[0295] E1-G5/2 was shown by size-exclusion HPLC to consist of a major peak (>90%) flanked by several minor peaks (not shown). The three constituents of E1-G5/2 (Fd-DDD2, the light chain, and AD2-G5/2) were detected by reducing SDS-PAGE and confirmed by Western blotting (not shown). Anti-idiotype binding analysis revealed E1-G5/2 contained a population of antibody-dendrimer conjugates of different size, all of which were capable of recognizing the anti-idiotype antibody, thus suggesting structural variability in the size of the purchased G5 dendrimer (not shown). Gel retardation assays showed E1-G5/2 was able to maximally condense plasmid DNA at a charge ratio of 6:1 (+/–), with the resulting dendriplexes completely protecting the complexed DNA from degradation by DNase I (not shown).

Conclusion

[0296] The DNL™ technique can be used to build dendrimer-based nanoparticles that are targetable with antibodies. Such agents have improved properties as carriers of drugs, plasmids or siRNAs for applications *in vitro* and *in vivo*. In preferred embodiments, anti-B-cell antibodies, such as anti-CD20 and/or anti-CD22, may be utilized to deliver cytotoxic or cytostatic siRNA species to targeted B-cells for therapy of lymphoma, leukemia, autoimmune or other diseases and conditions.

Example 6. Targeted Delivery of siRNA Using Protamine Linked Antibodies

Summary

[0297] RNA interference (RNA*i*) has been shown to down-regulate the expression of various proteins such as HER2, VEGF, Raf-1, bcl-2, EGFR and numerous others in preclinical studies. Despite the potential of RNA*i* to silence specific genes, the full therapeutic potential

of RNA*i* remains to be realized due to the lack of an effective delivery system to target cells *in vivo*.

[0298] To address this critical need, we developed novel DNL™ constructs having multiple copies of human protamine tethered to a tumor-targeting, internalizing hRS7 (anti-Trop-2) antibody for targeted delivery of siRNAs *in vivo*. A DDD2-L-thP1 module comprising truncated human protamine (thP1, residues 8 to 29 of human protamine 1) was produced, in which the sequences of DDD2 and thP1 were fused respectively to the N- and C-terminal ends of a humanized antibody light chain (not shown). The sequence of the truncated hP1 (thP1) is shown below. Reaction of DDD2-L-thP1 with the antibody hRS7-IgG-AD2 under mild redox conditions, as described in the Examples above, resulted in the formation of an E1-L-thP1 complex (not shown), comprising four copies of thP1 attached to the carboxyl termini of the hRS7 heavy chains.

tHP1

RSQSRSRYYRQRQRSRRRRRRS (SEQ ID NO:126)

[0299] The purity and molecular integrity of E1-L-thP1 following Protein A purification were determined by size-exclusion HPLC and SDS-PAGE (not shown). In addition, the ability of E1-L-thP1 to bind plasmid DNA or siRNA was demonstrated by the gel shift assay (not shown). E1-L-thP1 was effective at binding short double-stranded oligonucleotides (not shown) and in protecting bound DNA from digestion by nucleases added to the sample or present in serum (not shown).

[0300] The ability of the E1-L-thP1 construct to internalize siRNAs into Trop-2-expressing cancer cells was confirmed by fluorescence microscopy using FITC-conjugated siRNA and the human Calu-3 lung cancer cell line (not shown).

Methods

[0301] The DNL™ technique was employed to generate E1-L-thP1. The hRS7 IgG-AD module, constructed as described in the Examples above, was expressed in myeloma cells and purified from the culture supernatant using Protein A affinity chromatography. The DDD2-L-thP1 module was expressed as a fusion protein in myeloma cells and was purified by Protein L affinity chromatography. Since the CH3-AD2-IgG module possesses two AD2 peptides and each can bind to a DDD2 dimer, with each DDD2 monomer attached to a protamine moiety, the resulting E1-L-thP1 conjugate comprises four protamine groups. E1-L-thp1 was formed in nearly quantitative yield from the constituent modules and was purified to near homogeneity (not shown) with Protein A.

[0302] DDD2-L-thP1 was purified using Protein L affinity chromatography and assessed by size exclusion HPLC analysis and SDS-PAGE under reducing and nonreducing conditions (data not shown). A major peak was observed at 9.6 min (not shown). SDS-PAGE showed a major band between 30 and 40 kDa in reducing gel and a major band about 60 kDa (indicating a dimeric form of DDD2-L-thP1) in nonreducing gel (not shown). The results of Western blotting confirmed the presence of monomeric DDD2-L-tP1 and dimeric DDD2-L-tP1 on probing with anti-DDD antibodies (not shown).

[0303] To prepare the E1-L-thP1, hRS7-IgG-AD2 and DDD2-L-thP1 were combined in approximately equal amounts and reduced glutathione (final concentration 1 mM) was added. Following an overnight incubation at room temperature, oxidized glutathione was added (final concentration 2 mM) and the incubation continued for another 24 h. E1-L-thP1 was purified from the reaction mixture by Protein A column chromatography and eluted with 0.1 M sodium citrate buffer (pH 3.5). The product peak (not shown) was neutralized, concentrated, dialyzed with PBS, filtered, and stored in PBS containing 5% glycerol at 2 to 8°C. The composition of E1-L-thP1 was confirmed by reducing SDS-PAGE (not shown), which showed the presence of all three constituents (AD2-appended heavy chain, DDD2-L-htP1, and light chain).

[0304] The ability of DDD2-L-thP1 and E1-L-thP1 to bind DNA was evaluated by gel shift assay. DDD2-L-thP1 retarded the mobility of 500 ng of a linear form of 3-kb DNA fragment in 1% agarose at a molar ratio of 6 or higher (not shown). E1-L-thP1 retarded the mobility of 250 ng of a linear 200-bp DNA duplex in 2% agarose at a molar ratio of 4 or higher (not shown), whereas no such effect was observed for hRS7-IgG-AD2 alone (not shown). The ability of E1-L-thP1 to protect bound DNA from degradation by exogenous DNase and serum nucleases was also demonstrated (not shown).

[0305] The ability of E1-L-thP1 to promote internalization of bound siRNA was examined in the Trop-2 expressing ME-180 cervical cell line (not shown). Internalization of the E1-L-thP1 complex was monitored using FITC conjugated goat anti-human antibodies. The cells alone showed no fluorescence (not shown). Addition of FITC-labeled siRNA alone resulted in minimal internalization of the siRNA (not shown). Internalization of E1-L-thP1 alone was observed in 60 minutes at 37°C (not shown). E1-L-thP1 was able to effectively promote internalization of bound FITC-conjugated siRNA (not shown). E1-L-thP1 (10 μg) was mixed with FITC-siRNA (300 nM) and allowed to form E1-L-thP1-siRNA complexes which were then added to Trop-2-expressing Calu-3 cells. After incubation for 4 h at 37°C the cells were checked for internalization of siRNA by fluorescence microscopy (not shown).

[0306] The ability of E1-L-thP1 to induce apoptosis by internalization of siRNA was examined. E1-L-thP1 (10 μg) was mixed with varying amounts of siRNA (AllStars Cell Death siRNA, Qiagen, Valencia, CA). The E1-L-thP1-siRNA complex was added to ME-180 cells. After 72 h of incubation, cells were trypsinized and annexin V staining was performed to evaluate apoptosis. The Cell Death siRNA alone or E1-L-thP1 alone had no effect on apoptosis (not shown). Addition of increasing amounts of E1-L-thP1-siRNA produced a dose-dependent increase in apoptosis (not shown). These results show that E1-L-thP1 could effectively deliver siRNA molecules into the cells and induce apoptosis of target cells.

Conclusions

[0307] The DNL™ technology provides a modular approach to efficiently tether multiple protamine molecules to the anti-Trop-2 hRS7 antibody resulting in the novel molecule E1-L-thP1. SDS-PAGE demonstrated the homogeneity and purity of E1-L-thP1. DNase protection and gel shift assays showed the DNA binding activity of E1-L-thP1. E1-L-thP1 internalized in the cells like the parental hRS7 antibody and was able to effectively internalize siRNA molecules into Trop-2-expressing cells, such as ME-180 and Calu-3.

[0308] The skilled artisan will realize that the DNL™ technique is not limited to any specific antibody or siRNA species. Rather, the same methods and compositions demonstrated herein can be used to make targeted delivery complexes comprising any antibody (e.g., anti-CD20 or anti-CD22), any siRNA carrier and any siRNA species. The use of a bivalent IgG in targeted delivery complexes would result in prolonged circulating half-life and higher binding avidity to target cells, resulting in increased uptake and improved efficacy.

Example 7. Ribonuclease Based DNL™ Immunotoxins Comprising Quadruple Ranpirnase (Rap) Conjugated to B-Cell Targeting Antibodies

[0309] We applied the DNL™ method to generate a novel class of immunotoxins, each of which comprises four copies of Rap site-specifically linked to a bivalent IgG. We combined a recombinant Rap-DDD module, produced in *E. coli*, with recombinant, humanized IgG-AD modules, which were produced in myeloma cells and targeted B-cell lymphomas and leukemias via binding to CD20 (hA20, veltuzumab), CD22 (hLL2, epratuzumab) or HLA-DR (hL243, IMMU-114), to generate 20-Rap, 22-Rap and C2-Rap, respectively. For each construct, a dimer of Rap was covalently tethered to the C-terminus of each heavy chain of the respective IgG. A control construct, 14-Rap, was made similarly, using labetuzumab (hMN-14), that binds to an antigen (CEACAM5) not expressed on B-cell lymphomas/leukemias.

Rap-DDD2

pQDWLTFQKKHITNTRDVDCDNIMSTNLFHCKDKNTFIYSRPEPVKAICKGIIASKNV LTTSEFYLSDCNVTSRPCKYKLKKSTNKFCVTCENQAPVHFVGVGSC*GGGGSLE***CG HIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARA***VE*HHHHHH (SEQ ID NO:127)

[0310] The deduced amino acid sequence of secreted Rap-DDD2 is shown above (SEQ ID NO:127). Rap, underlined; linker, italics; DDD2, bold; pQ, amino-terminal glutamine converted to pyroglutamate. Rap-DDD2 was produced in *E. coli* as inclusion bodies, which were purified by IMAC under denaturing conditions, refolded and then dialyzed into PBS before purification by Q-Sepharose anion exchange chromatography. SDS-PAGE under reducing conditions resolved a protein band with a Mr appropriate for Rap-DDD2 (18.6 kDa) (not shown). The final yield of purified Rap-DDD2 was 10 mg/L of culture.

[0311] The DNL™ method was employed to rapidly generate a panel of IgG-Rap conjugates. The IgG-AD modules were expressed in myeloma cells and purified from the culture supernatant using Protein A affinity chromatography. The Rap-DDD2 module was produced and mixed with IgG-AD2 to form a DNL™ complex. Since the CH3-AD2-IgG modules possess two AD2 peptides and each can tether a Rap dimer, the resulting IgG-Rap DNL™ construct comprises four Rap groups and one IgG. IgG-Rap is formed nearly quantitatively from the constituent modules and purified to near homogeneity with Protein A.

[0312] Prior to the DNL™ reaction, the CH3-AD2-IgG exists as both a monomer, and a disulfide-linked dimer (not shown). Under non-reducing conditions, the IgG-Rap resolves as a cluster of high molecular weight bands of the expected size between those for monomeric and dimeric CH3-AD2-IgG (not shown). Reducing conditions, which reduces the conjugates to their constituent polypeptides, shows the purity of the IgG-Rap and the consistency of the DNL™ method, as only bands representing heavy-chain-AD2 (HC-AD2), kappa light chain and Rap-DDD2 were visualized (not shown).

[0313] Reversed phase HPLC analysis of 22-Rap (not shown) resolved a single protein peak at 9.10 min eluting between the two peaks of CH3-AD2-IgG-hLL2, representing the monomeric (7.55 min) and the dimeric (8.00 min) forms. The Rap-DDD2 module was isolated as a mixture of dimer and tetramer (reduced to dimer during DNL™), which were eluted at 9.30 and 9.55 min, respectively (not shown).

[0314] LC/MS analysis of 22-Rap was accomplished by coupling reversed phase HPLC using a C8 column with ESI-TOF mass spectrometry (not shown). The spectrum of unmodified 22-Rap identifies two major species, having either two G0F (G0F/G0F) or one

G0F plus one G1F (G0F/G1F) N-linked glycans, in addition to some minor glycoforms (not shown). Enzymatic deglycosylation resulted in a single deconvoluted mass consistent with the calculated mass of 22-Rap (not shown). The resulting spectrum following reduction with TCEP identified the heavy chain-AD2 polypeptide modified with an N-linked glycan of the G0F or G1F structure as well as additional minor forms (not shown). Each of the three subunit polypeptides comprising 22-Rap were identified in the deconvoluted spectrum of the reduced and deglycosylated sample (not shown). The results confirm that both the Rap-DDD2 and HC-AD2 polypeptides have an amino terminal glutamine that is converted to pyroglutamate (pQ); therefore, 22-Rap has 6 of its 8 constituent polypeptides modified by pQ.

[0315] *In vitro* cytotoxicity was evaluated in three NHL cell lines. Each cell line expresses CD20 at a considerably higher surface density compared to CD22; however, the internalization rate for hLL2 (anti-CD22) is much faster than hA20 (anti-CD20). 14-Rap shares the same structure as 22-Rap and 20-Rap, but its antigen (CEACAM5) is not expressed by the NHL cells. Cells were treated continuously with IgG-Rap as single agents or with combinations of the parental MAbs plus rRap. Both 20-Rap and 22-Rap killed each cell line at concentrations above 1 nM, indicating that their action is cytotoxic as opposed to merely cytostatic (not shown). 20-Rap was the most potent IgG-Rap, suggesting that antigen density may be more important than internalization rate. Similar results were obtained for Daudi and Ramos, where 20-Rap (EC50~0.1 nM) was 3 – 6-fold more potent than 22-Rap (not shown). The rituximab-resistant mantle cell lymphoma line, Jeko-1, exhibits increased CD20 but decreased CD22, compared to Daudi and Ramos. Importantly, 20-Rap exhibited very potent cytotoxicity (EC_{50} ~ 20 pM) in Jeko-1, which was 25-fold more potent than 22-Rap (not shown).

[0316] The DNL™ method provides a modular approach to efficiently tether multiple cytotoxins onto a targeting antibody, resulting in novel immunotoxins that are expected to show higher *in vivo* potency due to improved pharmacokinetics and targeting specificity. LC/MS, RP-HPLC and SDS-PAGE demonstrated the homogeneity and purity of IgG-Rap. Targeting Rap with a MAb to a cell surface antigen enhanced its tumor-specific cytotoxicity. Antigen density and internalization rate are both critical factors for the observed *in vitro* potency of IgG-Rap. *In vitro* results show that CD20-, CD22-, or HLA-DR-targeted IgG-Rap have potent biologic activity for therapy of B-cell lymphomas and leukemias.

Example 8. Production and Use of a DNL™ Construct Comprising Two Different Antibody Moieties and a Cytokine

[0317] In certain embodiments, trimeric DNL™ constructs may comprise three different effector moieties, for example two different antibody moieties and a cytokine moiety. We report here the generation and characterization of the first bispecific MAb-IFNα, designated 20-C2-2b, which comprises two copies of IFN-α2b and a stabilized $F(ab)_2$ of hL243 (humanized anti-HLA-DR; IMMU-114) site-specifically linked to veltuzumab (humanized anti-CD20). *In vitro*, 20-C2-2b inhibited each of four lymphoma and eight myeloma cell lines, and was more effective than monospecific CD20-targeted MAb-IFNα or a mixture comprising the parental antibodies and IFNα in all but one ($HLA\text{-}DR^-/CD20^-$) myeloma line (not shown), suggesting that 20-C2-2b should be useful in the treatment of various hematopoietic disorders. The 20-C2-2b displayed greater cytotoxicity against KMS12-BM ($CD20^+/HLA\text{-}DR^+$ myeloma) than monospecific MAb-IFNα that targets only HLA-DR or CD20 (not shown), indicating that all three components in 20-C2-2b can contribute to toxicity. Our findings indicate that a given cell's responsiveness to MAb-IFNα depends on its sensitivity to IFNα and the specific antibodies, as well as the expression and density of the targeted antigens.

[0318] Because 20-C2-2b has antibody-dependent cellular cytotoxicity (ADCC), but not CDC, and can target both CD20 and HLA-DR, it is useful for therapy of a broad range of hematopoietic disorders that express either or both antigens.

Antibodies

[0319] The abbreviations used in the following discussion are: 20 (C_H3-AD2-IgG-v-mab, anti-CD20 IgG DNL™ module); C2 (C_H1-DDD2-Fab-hL243, anti-HLA-DR Fab_2 DNL™ module); 2b (dimeric IFNα2B-DDD2 DNL™ module); 734 (anti-in-DTPA IgG DNL™ module used as non-targeting control). The following MAbs were provided by Immunomedics, Inc.: veltuzumab or v-mab (anti-CD20 IgG_1), hL243γ4p (Immu-114, anti-HLA-DR IgG_4), a murine anti-IFNα MAb, and rat anti-idiotype MAbs to v-mab (WR2) and hL243 (WT).

DNL™ constructs

[0320] Monospecific MAb-IFNα (20-2b-2b, 734-2b-2b and C2-2b-2b) and the bispecific HexAb (20-C2-C2) were generated by combination of an IgG-AD2-module with DDD2-modules using the DNL™ method, as described in the preceding Examples. The 734-2b-2b, which comprises tetrameric IFNα2b and MAb h734 [anti-Indium-DTPA IgG_1], was used as a non-targeting control MAb-IFNα.

[0321] The construction of the mammalian expression vector as well as the subsequent

generation of the production clones and the purification of C_H3-AD2-IgG-v-mab are disclosed in the preceding Examples. The expressed recombinant fusion protein has the AD2 peptide linked to the carboxyl terminus of the C_H3 domain of v-mab via a 15 amino acid long flexible linker peptide. Co-expression of the heavy chain-AD2 and light chain polypeptides results in the formation of an IgG structure equipped with two AD2 peptides. The expression vector was transfected into Sp/ESF cells (an engineered cell line of Sp2/0) by electroporation. The pdHL2 vector contains the gene for dihydrofolate reductase, thus allowing clonal selection, as well as gene amplification with methotrexate (MTX). Stable clones were isolated from 96-well plates selected with media containing 0.2 μM MTX. Clones were screened for C_H3-AD2-IgG-vmab productivity via a sandwich ELISA. The module was produced in roller bottle culture with serum-free media.

[0322] The DDD-module, IFNα2b-DDD2, was generated as discussed above by recombinant fusion of the DDD2 peptide to the carboxyl terminus of human IFNα2b via an 18 amino acid long flexible linker peptide. As is the case for all DDD-modules, the expressed fusion protein spontaneously forms a stable homodimer.

[0323] The C_H1-DDD2-Fab-hL243 expression vector was generated from hL243-IgG-pdHL2 vector by excising the sequence for the C_H1-Hinge-C_H2-C_H3 domains with SacII and EagI restriction enzymes and replacing it with a 507 bp sequence encoding C_H1-DDD2, which was excised from the C-DDD2-hMN-14-pdHL2 expression vector with the same enzymes. Following transfection of C_H1-DDD2-Fab-hL243-pdHL2 into Sp/ESF cells by electroporation, stable, MTX-resistant clones were screened for productivity via a sandwich ELISA using 96-well microtiter plates coated with mouse anti-human kappa chain to capture the fusion protein, which was detected with horseradish peroxidase-conjugated goat anti-human Fab. The module was produced in roller bottle culture.

[0324] Roller bottle cultures in serum-free H-SFM media and fed-batch bioreactor production resulted in yields comparable to other IgG-AD2 modules and cytokine-DDD2 modules generated to date. C_H3-AD2-IgG-v-mab and IFNα2b-DDD2 were purified from the culture broths by affinity chromatography using MABSELECT™ (GE Healthcare) and HIS-SELECT® HF Nickel Affinity Gel (Sigma), respectively, as described previously (Rossi et al., Blood 2009, 114:3864-71). The culture broth containing the C_H1-DDD2-Fab-hL243 module was applied directly to KAPPASELECT® affinity gel (GE-Healthcare), which was washed to baseline with PBS and eluted with 0.1 M Glycine, pH 2.5.

Generation of 20-C2-2b by DNL™

[0325] Three DNL™ modules (C_H3-AD2-IgG-v-mab, C_H1-DDD2-Fab-hL243, and IFN-α2b-DDD2) were combined in equimolar quantities to generate the bsMAb-IFNα, 20-C2-2b. Following an overnight docking step under mild reducing conditions (1mM reduced glutathione) at room temperature, oxidized glutathione was added (2mM) to facilitate disulfide bond formation (locking). The 20-C2-2b was purified to near homogeneity using three sequential affinity chromatography steps. Initially, the DNL™ mixture was purified with Protein A (MABSELECT™), which binds the C_H3-AD2-IgG-v-MAb group and eliminates un-reacted IFNα2b-DDD2 or C_H1-DDD2-Fab-hL243. The Protein A-bound material was further purified by IMAC using HIS-SELECT® HF Nickel Affinity Gel, which binds specifically to the IFNα2b-DDD2 moiety and eliminates any constructs lacking this group. The final process step, using an hL243-anti-idiotype affinity gel removed any molecules lacking C_H1-DDD2-Fab-hL243.

[0326] The skilled artisan will realize that affinity chromatography may be used to purify DNL™ complexes comprising any combination of effector moieties, so long as ligands for each of the three effector moieties can be obtained and attached to the column material. The selected DNL™ construct is the one that binds to each of three columns containing the ligand for each of the three effector moieties and can be eluted after washing to remove unbound complexes.

[0327] The following Example is representative of several similar preparations of 20-C2-2b. Equimolar amounts of C_H3-AD2-IgG-v-mab (15 mg), C_H1-DDD2-Fab-hL243 (12 mg), and IFN-α2b-DDD2 (5 mg) were combined in 30-mL reaction volume and 1 mM reduced glutathione was added to the solution. Following 16 h at room temperature, 2 mM oxidized glutathione was added to the mixture, which was held at room temperature for an additional 6 h. The reaction mixture was applied to a 5-mL Protein A affinity column, which was washed to baseline with PBS and eluted with 0.1 M Glycine, pH 2.5. The eluate, which contained ~20 mg protein, was neutralized with 3 M Tris-HCl, pH 8.6 and dialyzed into HIS-SELECT® binding buffer (10 mM imidazole, 300 mM NaCl, 50 mM NaH_2PO_4, pH 8.0) prior to application to a 5-mL HIS-SELECT® IMAC column. The column was washed to baseline with binding buffer and eluted with 250 mM imidazole, 150 mM NaCl, 50 mM NaH_2PO_4, pH 8.0.

[0328] The IMAC eluate, which contained ~11.5 mg of protein, was applied directly to a WP (anti-hL243) affinity column, which was washed to baseline with PBS and eluted with 0.1 M glycine, pH 2.5. The process resulted in 7 mg of highly purified 20-C2-2b. This was

approximately 44% of the theoretical yield of 20-C2-2b, which is 50% of the total starting material (16 mg in this example) with 25% each of 20-2b-2b and 20-C2-C2 produced as side products.

Generation and characterization of 20-C2-2b

[0329] The bispecific MAb-IFNα was generated by combining the IgG-AD2 module, C_H3-AD2-IgG-v-mab, with two different dimeric DDD-modules, C_H1-DDD2-Fab-hL243 and IFNα2b-DDD2. Due to the random association of either DDD-module with the two AD2 groups, two side-products, 20-C2-C2 and 20-2b-2b are expected to form, in addition to 20-C2-2b.

[0330] Non-reducing SDS-PAGE (not shown) resolved 20-C2-2b (~305 kDa) as a cluster of bands positioned between those of 20-C2-C2 (~365 kDa) and 20-2b-2b (255 kDa). Reducing SDS-PAGE resolved the five polypeptides (v-mab HC-AD2, hL243 Fd-DDD2, IFNα2b-DDD2 and co-migrating v-mab and hL243 kappa light chains) comprising 20-C2-2b (not shown). IFNα2b-DDD2 and hL243 Fd-DDD2 are absent in 20-C2-C2 and 20-2b-2b. MABSELECT™ binds to all three of the major species produced in the DNL™ reaction, but removes any excess IFNα2b-DDD2 and C_H1-DDD2-Fab-hL243. The HIS-SELECT® unbound fraction contained mostly 20-C2-C2 (not shown). The unbound fraction from WT affinity chromatography comprised 20-2b-2b (not shown). Each of the samples was subjected to SE-HPLC and immunoreactivity analyses, which corroborated the results and conclusions of the SDS-PAGE analysis.

[0331] Following reduction of 20-C2-2b, its five component polypeptides were resolved by RP-HPLC and individual ESI-TOF deconvoluted mass spectra were generated for each peak (not shown). Native, but not bacterially-expressed recombinant IFNα2, is O-glycosylated at Thr-106 (Adolf et al., Biochem J 1991;276 (Pt 2):511-8). We determined that ~15% of the polypeptides comprising the IFNα2b-DDD2 module are O-glycosylated and can be resolved from the non-glycosylated polypeptides by RP-HPLC and SDS-PAGE (not shown). LC/MS analysis of 20-C2-2b identified both the O-glycosylated and non-glycosylated species of IFNα2b-DDD2 with mass accuracies of 15 ppm and 2 ppm, respectively (not shown). The observed mass of the O-glycosylated form indicates an O-linked glycan having the structure NeuGc-NeuGc-Gal-GalNAc, which was also predicted (<1 ppm) for 20-2b-2b (not shown). LC/MS identified both v-mab and hL243 kappa chains as well as hL243-Fd-DDD2 (not shown) as single, unmodified species, with observed masses matching the calculated ones (<35 ppm). Two major glycoforms of v-mab HC-AD2 were identified as having masses of

53,714.73 (70%) and 53,877.33 (30%), indicating G0F and G1F N-glycans, respectively, which are typically associated with IgG (not shown). The analysis also confirmed that the amino terminus of the HC-AD2 is modified to pyroglutamate, as predicted for polypeptides having an amino terminal glutamine.

[0332] SE-HPLC analysis of 20-C2-2b resolved a predominant protein peak with a retention time (6.7 min) consistent with its calculated mass and between those of the larger 20-C2-C2 (6.6 min) and smaller 20-2b-2b (6.85 min), as well as some higher molecular weight peaks that likely represent non-covalent dimers formed via self-association of IFNα2b (not shown).

[0333] Immunoreactivity assays demonstrated the homogeneity of 20-C2-2b with each molecule containing the three functional groups (not shown). Incubation of 20-C2-2b with an excess of antibodies to any of the three constituent modules resulted in quantitative formation of high molecular weight immune complexes and the disappearance of the 20-C2-2b peak (not shown). The HIS-SELECT® and WT affinity unbound fractions were not immunoreactive with WT and anti-IFNα, respectively (not shown). The MAb-IFNα showed similar binding avidity to their parental MAbs (not shown).

IFNα biological activity

[0334] The specific activities for various MAb-IFNα were measured using a cell-based reporter gene assay and compared to peginterferon alfa-2b (not shown). Expectedly, the specific activity of 20-C2-2b (2454 IU/pmol), which has two IFNα2b groups, was significantly lower than those of 20-2b-2b (4447 IU/pmol) or 734-2b-2b (3764 IU/pmol), yet greater than peginterferon alfa-2b ($P<0.001$) (not shown). The difference between 20-2b-2b and 734-2b-2b was not significant. The specific activity among all agents varies minimally when normalized to IU/pmol of total IFNα. Based on these data, the specific activity of each IFNα2b group of the MAb-IFNα is approximately 30% of recombinant IFNα2b (~4000 IU/pmol).

[0335] In the *ex-vivo* setting, the 20-C2-2b DNL™ construct depleted lymphoma cells more effectively than normal B cells and had no effect on T cells (not shown). However, it did efficiently eliminate monocytes (not shown). Where v-mab had no effect on monocytes, depletion was observed following treatment with hL243α4p and MAb-IFNα, with 20-2b-2b and 734-2b-2b exhibiting similar toxicity (not shown). Therefore, the predictably higher potency of 20-C2-2b is attributed to the combined actions of anti-HLA-DR and IFNα, which may be augmented by HLA-DR targeting. These data suggest that monocyte depletion may be a pharmacodynamic effect associated anti-HLA-DR as well as IFNα therapy; however,

this side affect would likely be transient because the monocyte population should be repopulated from hematopoietic stem cells.

[0336] The skilled artisan will realize that the approach described here to produce and use bispecific immunocytokine, or other DNL™ constructs comprising three different effector moieties, may be utilized with any combinations of antibodies, antibody fragments, cytokines or other effectors that may be incorporated into a DNL™ construct, for example the combination of anti-CD20 and anti-CD22 with IFNα2b.

Example 9. Anti-HIV DNL™ Complex

[0337] Among the various antibodies that neutralize HIV-1, the murine anti-gp120 antibody, P4/D10, is distinguished by its ability to induce antibody-dependent cellular cytotoxicity (ADCC) to eliminate infected T cells that express the antigenic gp120 epitope bound by P4/D10 (Broliden et al., 1990, J Virol 64:936-40). Enhanced potency was also shown for doxorubicin-conjugated P4/D10 to neutralize and inhibit intercellular spread of HIV infection *in vitro*, as well as to protect against HIV-1/MuLV infection *in vivo* (Johansson et al., 2006, AIDS 20:1911-15).

[0338] DNL™ complexes comprising P4/D10 IgG, or other anti-HIV antibodies or fragments thereof, along with one or more anti-HIV agents are prepared. In a preferred embodiment illustrated herein, the anti-HIV agent is the T20 HIV fusion inhibitor (enfuvirtide, FUZEON®) (Asboe, 2004, HIV Clin Trials 5:1-6).

[0339] In a preferred embodiment a novel class of anti-HIV agents that comprise multiple copies of enfuvirtide (T20) linked to a chimeric, human or humanized antibody with specificity for HIV-1, such as P4/D10 are prepared as DNL™ complexes. Such conjugates allow less frequent dosing than with unconjugated T20 to block entry of HIV-1 into T cells, neutralize free HIV-1 and eliminate HIV-infected cells. In an exemplary DNL™ construct, The C-terminal end of each light chain of an IgG antibody is attached via a short linker to an AD2 moiety (SEQ ID NO:4) and expressed as a fusion protein as described in the Examples above. The T20 HIV fusion inhibitor is attached to a DDD2 moiety (SEQ ID NO:2) and also expressed as a fusion protein. Two copies of the DDD2 moiety spontaneously form a dimer that binds to the AD2 moiety, forming a DNL™ complex comprising one IgG antibody and four copies of T20.

[0340] The DDD2-T20 amino acid sequence is shown below in SEQ ID NO:128. The sequence of DDD2 is underlined. This is followed by a short linker and hinge region and a polyhistidine tag for affinity purification. The sequence of T20 at the C-terminal end is in

bold. DDD2-T20 has been produced and used to make DNL™ complexes, as described below.

DDD2-T20

MCGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTRLREARAEFPKPSTPPGSSG HHHHHHGS**YTSLIHSLIEESQNQQEKNEQELLELDKWASLWNWF** (SEQ ID NO:128)

[0341] P4/D10 is a murine antibody that may induce human anti-mouse antibodies (HAMA) when administered to human subjects. Chimeric or humanized forms of P4/D10 would be more suitable for human therapeutic use. A chimeric P4/D10 (cP4/D10) was constructed by substituting human antibody constant region sequences for the murine constant region sequences of P4/D10. cP4/D10 was prepared and its binding affinity for gp160 (comprising both gp120 and gp41) was compared to the murine P4/D10 and a control non-targeting T4-2 (anti-CD4) antibody. The affinity (not shown) and *in vitro* activity (not shown) of cP4/D10 were determined to be about two-fold lower than the parental P4/D10, which is acceptable and may be further improved by additional subcloning and humanization. Control non-targeting antibody did not bind to gp160.

[0342] The primary target HIV patient population is individuals failing HAART therapy, where several doses of the DNL™ conjugates may effectively reduce the number of infected cells and circulating virions. A secondary patient population is individuals on effective HAART, with the goal to reach and delete the few persisting, virus-producing cells.

[0343] The DDD2-T20 is combined with cP4/D10-AD2 to produce a DNL™ construct that is specific for HIV. When the results are compared on a molar concentration basis for T20, the T20-DDD2 construct is more efficacious than unconjugated T20 and the *cP4/D10-T20 DNL™ construct is more than an order of magnitude more efficacious than unconjugated T20. The DNL™ construct also exhibits a significantly greater half-life *in vivo*, of about 24 hours compared to 2.8 hours for T20. These results show that a DNL™ complex comprising T20 exhibits a substantially longer half-life in circulation and a substantially higher efficacy than unconjugated T20.

Example 10. Generation of a DNL conjugate comprising four IFN-α2b-DDD2 moieties linked to C_{H3}-AD2-IgG

[0344] A DNL complex comprising four IFN-α2b-DDD2 moieties linked to C_k-AD2-IgG is made as follows. Briefly, a select C_k-AD2-IgG is combined with approximately two mole-

equivalents of IFN-α2b-DDD2 and the mixture is reduced under mild conditions overnight at room temperature after adding 1 mM EDTA and 2 mM reduced glutathione (GSH). Oxidized glutathione is added to 2 mM and the mixture is held at room temperature for an additional 12-24 hours. The DNL conjugate is purified over a Protein A affinity column. A DNL conjugate designated *20-2b, comprising four copies of IFN-α2b anchored on C_k-AD2-IgG-hA20 (with specificity for CD20) is prepared. SE-HPLC analyses of *20-2b generated from mammalian (m) or *E. coli* (e)-produced IFN-α2b-DDD2 each show a major peak having a retention time consistent with a covalent complex composed of an IgG and 4 IFN-α2b groups. Similar SE-HPLC profiles are observed for the other three IFN-IgG conjugates.

[0345] The *in vitro* IFNα biological activity of *20-2b is compared to that of commercial PEGylated IFNα2 agents, PEGASYS® and PEG-INTRON®, using cell-based reporter, viral protection, and lymphoma proliferation assays. Specific activities are determined using a cell-based kit, which utilizes a transgenic human pro-monocyte cell line carrying a reporter gene fused to an interferon-stimulated response element. The specific activity of *20-2b is greater than both PEGASYS® and PEG-INTRON®. Having four IFNα2b groups contributes to the enhanced potency of MAb-IFNα. When normalized to IFNα equivalents, the specific activity/IFNα is about 10-fold greater than PEGASYS® and only about 2-fold less than PEG-INTRON®.

[0346] Comparison of *20-2b, PEGASYS® and PEG-INTRON® in an *in vitro* viral protection assay demonstrates that *20-2b retains IFNα2b antiviral activity with specific activities similar to PEG-INTRON® and 10-fold greater than PEGASYS®.

[0347] IFNα2b can have a direct antiproliferative or cytotoxic effect on some tumor lines. The activity of *20-2b is measured in an *in vitro* proliferation assay with a Burkitt lymphoma cell line (Daudi) that is highly sensitive to IFNα. Each of the IFNα2 agents efficiently inhibits (>90%) Daudi *in vitro* with high potency. However, *20-2b is about 30-fold more potent than the non-targeting MAb-IFNα constructs.

[0348] The pharmacokinetic (PK) properties of *20-2b are evaluated in male Swiss-Webster mice and compared to those of PEGASYS®, PEG-INTRON and α2b-413 (Pegylated IFN made by DNL™). Concentrations of IFN-α in the serum samples at various times are determined by ELISA following the manufacturer's instructions. Briefly, the serum samples are diluted appropriately according to the human IFN-α standard provided in the kit. An antibody bound to the microtiter plate wells captures interferon. A second antibody is then

used to reveal the bound interferon, which is quantified by anti-secondary antibody conjugated to horseradish peroxidase (HRP) following the addition of Tetramethyl benzidine (TMB). The plates are read at 450nm. The results of the PK analysis, which show significantly slower elimination and longer serum residence of *20-2b compared to the other agents.

Example 11. Generation of DDD module based on CD20 Xenoantigen

[0349] The cDNA sequence for murine CD20 is amplified by PCR, resulting in a sequence in which CD20 xenoantigen is fused at its C-terminus to a polypeptide consisting of SEQ ID NO:129.

KSHHHHHHGSGGGGSGGGCGHIQIPPGLTELLQGYTVEVLRQQPPDLVEFAVEYFTR LREARA (SEQ ID NO:129)

[0350] PCR amplification is accomplished using a full length murine CD20 cDNA clone as a template and selected PCR primers. The PCR amplimer is cloned into the PGEMT® vector (PROMEGA®). A DDD2-pdHL2 mammalian expression vector is prepared for ligation with CD20 by digestion with XbaI and Bam HI restriction endonucleases. The CD20 amplimer is excised from PGEMT® with XbaI and Bam HI and ligated into the DDD2-pdHL2 vector to generate the expression vector CD20-DDD2-pdHL2.

[0351] CD20-DDD2-pdHL2 is linearized by digestion with SalI enzyme and stably transfected into Sp/EEE myeloma cells by electroporation (see, e.g., U.S. Patent 7,537,930, the Examples section of which is incorporated herein by reference). Two clones are found to have detectable levels of CD20 by ELISA. One of the two clones is adapted to growth in serum-free media without substantial decrease in productivity. The clone is subsequently amplified with increasing methotrexate (MTX) concentrations from 0.1 to 0.8 μM over five weeks. At this stage, it is sub-cloned by limiting dilution and the highest producing sub-clone is expanded.

[0352] The clone is expanded to 34 roller bottles containing a total of 20 L of serum-free Hybridoma SFM with 0.8 μM MTX and allowed to reach terminal culture. The supernatant fluid is clarified by centrifugation and filtered (0.2 μM). The filtrate is diafiltered into 1X Binding buffer (10 mM imidazole, 0.5 M NaCl, 50 mM NaH_2PO_4, pH 7.5) and concentrated to 310 mL in preparation for purification by immobilized metal affinity chromatography (IMAC). The concentrate is loaded onto a 30-mL Ni-NTA column, which is washed with 500 mL of 0.02% Tween 20 in 1X binding buffer and then 290 mL of 30 mM imidazole, 0.02% Tween 20, 0.5 M NaCl, 50 mM NaH_2PO_4, pH 7.5. The product is eluted with 110 mL of 250

mM imidazole, 0.02% Tween 20, 150 mM NaCl, 50 mM NaH_2PO_4, pH 7.5. Approximately 6 mg of CD20-DDD2 is purified. The purity of CD20-DDD2 is assessed by SDS-PAGE under reducing conditions. CD20-DDD2 is the most heavily stained band and accounts for approximately 50% of the total protein.

Example 12. Generation of hLL1 Fab-$(CD20)_2$ by DNL

[0353] A C_k-AD2-IgG-hLL1 (anti-CD74) moiety is produced as described in Example 1. A DDD2-mCD20 moiety is produced as described in Example 11. A DNL reaction is performed by the addition of reduced and lyophilized hLL1 IgG-AD2 to CD20-DDD2 in 250 mM imidazole, 0.02% Tween 20, 150 mM NaCl, 1 mM EDTA, 50 mM NaH_2PO_4, pH 7.5. After 6 h at room temperature in the dark, the reaction mixture is dialyzed against CM Loading Buffer (150 mM NaCl, 20 mM NaAc, pH 4.5) at 4°C in the dark. The solution is loaded onto a 1-mL Hi-Trap CM-FF column (AMERSHAM®), which is pre-equilibrated with CM Loading buffer. After sample loading, the column is washed with CM loading buffer to baseline, followed by washing with 15 mL of 0.25 M NaCl, 20 mM NaAc, pH 4.5. The product is eluted with 12.5 mL of 0.5 M NaCl, 20 mM NaAc, pH 4.5. The DNL reaction results in the site-specific and covalent conjugation of hLL1 IgG with a dimer of mCD20. Both the IgG and CD20 moieties retain their respective physiological activities in the DNL construct by cell culture assay.

[0354] The hLL1-mCD20 DNL construct is administered to subjects with multiple myeloma (MM) and found to induce an immune response against $CD138^{neg}CD20^{+}$ putative MM stem cells. The immune response is effective to reduce or eliminate MM disease cells in the subjects.

* * *

[0355] All of the COMPOSITIONS and METHODS disclosed and claimed herein can be made and used without undue experimentation in light of the present disclosure. While the compositions and methods have been described in terms of preferred embodiments, it is apparent to those of skill in the art that variations maybe applied to the COMPOSITIONS and METHODS and in the steps or in the sequence of steps of the METHODS described herein without departing from the concept, spirit and scope of the invention. More specifically, certain agents that are both chemically and physiologically related may be substituted for the agents described herein while the same or similar results would be achieved. All such similar substitutes and modifications apparent to those skilled in the art are deemed to be within the spirit, scope and concept of the invention as defined by the appended claims.

What is Claimed is:

1. A fusion protein comprising:

   a) an antibody; and

   b) an AD (anchoring domain) moiety from an AKAP protein attached to the C-terminal end of each light chain of the antibody.

2. The fusion protein according to claim 1, wherein the antibody is attached to two copies of the AD moiety.

3. The fusion protein according to claim 1, wherein the antibody binds to an antigen selected from the group consisting of AFP, α4 integrin, B7, carbonic anhydrase IX, complement factors C1q, C1r, C1s, C2a, C2b, C3, C3a, C3b, C4, C4a, C4b, C5a, C5aR, C5b, C5, C6, C7, C8, C9n, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD3R, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD44, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD86, CD95, CD126, CD133, CD138, CD147, CD154, CEACAM-5, CEACAM-6, CSAp, ED-B of fibronectin, EGFR, EGP-1 (TROP-2), EGP-2, ErbB2, Factor H, FHL-1, fibrin, Flt-3, folate receptor, glycoprotein IIb/IIIa, gp41, gp120, GRO-β, HLA-DR, HM1.24, HM1.24, HMGB-1, hypoxia inducible factor (HIF), Ia, ICAM-1, IFN-α, IFN-β, IFN-γ, IFN-λ, IgE, IGF-1R, IL-1, IL-1Ra, IL-2, IL-4R, IL-6, IL-6R, IL-8, IL-13R, IL-15R, IL-15, IL-17, IL-17R, IL-18, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin-like growth factor-1 (ILGF-1), IP-10, Le(y), lipopolysaccharide (LPS), MAGE, MCP-1, mCRP, MIF, MIP-1A, MIP-1B, MUC1, MUC2, MUC3, MUC4, MUC5ac, NCA-90, NCA-95, NF-κB, PlGF, PSMA, RANTES, T101, TAC, TAG-72, tenascin, Thomson-Friedenreich antigens, thrombin, tissue factor, Tn antigen, TNF-α, TRAIL receptor (R1 and R2), tumor necrosis antigens, VEGF, VEGFR and an oncogene product.

4. The fusion protein according to claim 1, wherein the antibody is selected from the group consisting of hR1 (anti-IGF-1R), hPAM4 (anti-mucin), KC4 (anti-mucin), hA20 (anti-CD20), hA19 (anti-CD19), hIMMU31 (anti-AFP), hLL1 (anti-CD74), hLL2 (anti-CD22), RFB4 (anti-CD22), hMu-9 (anti-CSAp), hL243 (anti-HLA-DR), hMN-14 (anti-CEACAM5), hMN-15 (anti-CEACAM6), hRS7 (anti-TROP-2), hMN-3 (anti-

CEACAM6), CC49 (anti- TAG-72), J591 (anti-PSMA), D2/B (anti-PSMA), G250 (anti-carbonic anhydrase IX), infliximab (anti- TNF-α), certolizumab pegol (anti- TNF-α), adalimumab (anti- TNF-α), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20), panitumumab (anti-EGFR), rituximab (anti-CD20), tositumomab (anti-CD20), GA101 (anti-CD20), trastuzumab (anti-ErbB2), tocilizumab (anti-IL-6 receptor), basiliximab (anti-CD25), daclizumab (anti-CD25), efalizumab (anti-CD11a), muromonab-CD3 (anti-CD3 receptor), natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

5. The fusion protein of claim 1, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of residues 1-44 of RIIα, 1-44 of RIIβ, 12-61 of RIα and 13-66 of RIβ.

6. The fusion protein of claim 1, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:26, SEQ ID NO:27, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:30, SEQ ID NO:31, SEQ ID NO:87 and SEQ ID NO:89.

7. A multimeric complex comprising:

   a) a first fusion protein comprising (i) a first antibody, and (ii) an AD (anchoring domain) moiety from an AKAP protein attached to the C-terminal end of each light chain of the antibody; and

   b) a second fusion protein comprising (iii) an effector moeity, and (iv) a DDD (dimerization and docking domain) moiety from protein kinase A (PKA) regulatory subunit RIα, RIβ, RIIα or RIIβ;

wherein two copies of the DDD moiety form a dimer that binds to one copy of the AD moiety to form the complex.

8. The complex of claim 7, wherein the effector moiety is selected from the group consisting

of a second antibody or antigen-binding fragment thereof, a cytokine, an interferon, a toxin, an antigen, a xenoantigen, a hapten, a protamine, a hormone, an enzyme, a ligand-binding protein, a pro-apoptotic agent and an anti-angiogenic agent.

9. The complex of claim 7, wherein the effector moiety is a second antibody or antigen-binding fragment thereof, a cytokine, an interferon or a toxin.

10. The complex of claim 7, wherein the first antibody is attached to two AD moieties and each AD moiety binds to a dimer of DDD moieties.

11. The complex of claim 7, wherein the first antibody binds to an antigen selected from the group consisting of AFP, α4 integrin, B7, carbonic anhydrase IX, complement factors C1q, C1r, C1s, C2a, C2b, C3, C3a, C3b, C4, C4a, C4b, C5a, C5aR, C5b, C5, C6, C7, C8, C9n, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD3R, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD44, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD86, CD95, CD126, CD133, CD138, CD147, CD154, CEACAM-5, CEACAM-6, CSAp, ED-B of fibronectin, EGFR, EGP-1 (TROP-2), EGP-2, ErbB2, Factor H, FHL-1, fibrin, Flt-3, folate receptor, glycoprotein IIb/IIIa, gp41, gp120, GRO-β, HLA-DR, HM1.24, HM1.24, HMGB-1, hypoxia inducible factor (HIF), Ia, ICAM-1, IFN-α, IFN-β, IFN-γ, IFN-λ, IgE, IGF-1R, IL-1, IL-1Ra, IL-2, IL-4R, IL-6, IL-6R, IL-8, IL-13R, IL-15R, IL-15, IL-17, IL-17R, IL-18, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin-like growth factor-1 (ILGF-1), IP-10, Le(y), lipopolysaccharide (LPS), MAGE, MCP-1, mCRP, MIF, MIP-1A, MIP-1B, MUC1, MUC2, MUC3, MUC4, MUC5ac, NCA-90, NCA-95, NF-κB, PlGF, PSMA, RANTES, T101, TAC, TAG-72, tenascin, Thomson-Friedenreich antigens, thrombin, tissue factor, Tn antigen, TNF-α, TRAIL receptor (R1 and R2), tumor necrosis antigens, VEGF, VEGFR and an oncogene product.

12. The complex of claim 7, wherein the first antibody is selected from the group consisting of hR1 (anti-IGF-1R), hPAM4 (anti-mucin), KC4 (anti-mucin), hA20 (anti-CD20), hA19 (anti-CD19), hIMMU31 (anti-AFP), hLL1 (anti-CD74), hLL2 (anti-CD22), RFB4 (anti-CD22), hMu-9 (anti-CSAp), hL243 (anti-HLA-DR), hMN-14 (anti-CEACAM5), hMN-15 (anti-CEACAM6), hRS7 (anti-TROP-2), hMN-3 (anti-CEACAM6), CC49 (anti-TAG-72), J591 (anti-PSMA), D2/B (anti-PSMA), G250 (anti-carbonic anhydrase IX),

infliximab (anti- TNF-α), certolizumab pegol (anti- TNF-α), adalimumab (anti- TNF-α), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20), panitumumab (anti-EGFR), rituximab (anti-CD20), tositumomab (anti-CD20), GA101 (anti-CD20), trastuzumab (anti-ErbB2), tocilizumab (anti-IL-6 receptor), basiliximab (anti-CD25), daclizumab (anti-CD25), efalizumab (anti-CD11a), muromonab-CD3 (anti-CD3 receptor), natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

13. The complex of claim 8, wherein the second antibody or antigen-binding fragment thereof binds to an antigen selected from the group consisting of AFP, α4 integrin, B7, carbonic anhydrase IX, complement factors C1q, C1r, C1s, C2a, C2b, C3, C3a, C3b, C4, C4a, C4b, C5a, C5aR, C5b, C5, C6, C7, C8, C9n, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD3R, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD44, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD86, CD95, CD126, CD133, CD138, CD147, CD154, CEACAM-5, CEACAM-6, CSAp, ED-B of fibronectin, EGFR, EGP-1 (TROP-2), EGP-2, ErbB2, Factor H, FHL-1, fibrin, Flt-3, folate receptor, glycoprotein IIb/IIIa, gp41, gp120, GRO-β, HLA-DR, HM1.24, HM1.24, HMGB-1, HSG, hypoxia inducible factor (HIF), Ia, ICAM-1, IFN-α, IFN-β, IFN-γ, IFN-λ, IgE, IGF-1R, IL-1, IL-1Ra, IL-2, IL-4R, IL-6, IL-6R, IL-8, IL-13R, IL-15R, IL-15, IL-17, IL-17R, IL-18, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin-like growth factor-1 (ILGF-1), IP-10, Le(y), lipopolysaccharide (LPS), MAGE, MCP-1, mCRP, MIF, MIP-1A, MIP-1B, MUC1, MUC2, MUC3, MUC4, MUC5ac, NCA-90, NCA-95, NF-κB, PlGF, PSMA, RANTES, T101, TAC, TAG-72, tenascin, Thomson-Friedenreich antigens, thrombin, tissue factor, Tn antigen, TNF-α, TRAIL receptor (R1 and R2), tumor necrosis antigens, VEGF, VEGFR and an oncogene product.

14. The complex of claim 8, wherein the second antibody is selected from the group consisting of hR1 (anti-IGF-1R), hPAM4 (anti-mucin), KC4 (anti-mucin), hA20 (anti-CD20), hA19 (anti-CD19), hIMMU31 (anti-AFP), hLL1 (anti-CD74), hLL2 (anti-CD22), RFB4 (anti-CD22), hMu-9 (anti-CSAp), hL243 (anti-HLA-DR), hMN-14 (anti-CEACAM5), hMN-15 (anti-CEACAM6), hRS7 (anti-TROP-2), hMN-3 (anti-CEACAM6), CC49 (anti- TAG-72), J591 (anti-PSMA), D2/B (anti-PSMA), G250 (anti-

carbonic anhydrase IX), infliximab (anti- TNF-α), certolizumab pegol (anti- TNF-α), adalimumab (anti- TNF-α), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20), panitumumab (anti-EGFR), rituximab (anti-CD20), tositumomab (anti-CD20), GA101 (anti-CD20), trastuzumab (anti-ErbB2), tocilizumab (anti-IL-6 receptor), basiliximab (anti-CD25), daclizumab (anti-CD25), efalizumab (anti-CD11a), muromonab-CD3 (anti-CD3 receptor), natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

15. The complex of claim 8, wherein the antibody fragment is selected from the group consisting of a $F(ab')_2$, a $F(ab)_2$, a Fab', a Fab, a Fv, a sFv, a scFv and a dAb.

16. The complex of claim 7, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of residues 1-44 of RIIα, 1-44 of RIIβ, 12-61 of RIα and 13-66 of RIβ.

17. The complex of claim 7, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:26, SEQ ID NO:27, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:30, SEQ ID NO:31, SEQ ID NO:87 and SEQ ID NO:89.

18. The complex of claim 7, wherein the amino acid sequence of the AD moiety is selected from the group consisting of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:7, SEQ ID NO:32, SEQ ID NO:33, SEQ ID NO:34, SEQ ID NO:35, SEQ ID NO:36, SEQ ID NO:37, SEQ ID NO:38, SEQ ID NO:39, SEQ ID NO:40, SEQ ID NO:41, SEQ ID NO:42, SEQ ID NO:43, SEQ ID NO:44, SEQ ID NO:45, SEQ ID NO:46, SEQ ID NO:47, SEQ ID NO:48, M SEQ ID NO:49, SEQ ID NO:50, SEQ ID NO:51, SEQ ID NO:52, SEQ ID NO:53, SEQ ID NO:54, SEQ ID NO:55, SEQ ID NO:56, SEQ ID NO:57, SEQ ID NO:58, M SEQ ID NO:59, SEQ ID NO:60, SEQ ID NO:61, SEQ ID NO:62, SEQ ID NO:63, SEQ ID NO:64, SEQ ID NO:65, SEQ ID NO:66, SEQ ID NO:67, SEQ ID NO:68, SEQ ID NO:69, SEQ ID NO:70, SEQ ID NO:71, SEQ ID NO:72, SEQ ID NO:73, SEQ ID NO:74, SEQ ID NO:75, SEQ ID NO:76, SEQ ID

NO:77, SEQ ID NO:78, M SEQ ID NO:79, SEQ ID NO:80, SEQ ID NO:81, SEQ ID NO:82, SEQ ID NO:83, SEQ ID NO:44 and SEQ ID NO:88.

19. The complex according to claim 8, wherein the toxin is selected from the group consisting of a bacterial toxin, a plant toxin, ricin, abrin, alpha toxin, saporin, ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, Pseudomonas endotoxin, ranpirnase (Rap) and Rap (N69Q).

20. The complex according to claim 19, wherein the toxin is ranpirnase (Rap).

21. The complex of claim 8, wherein the cytokine is selected from the group consisting of human growth hormone, N-methionyl human growth hormone, bovine growth hormone, parathyroid hormone, thyroxin, insulin, proinsulin, relaxin, prorelaxin, follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), luteinizing hormone (LH), hepatic growth factor, prostaglandin, fibroblast growth factor, prolactin, placental lactogen, OB protein, tumor necrosis factor-α, tumor necrosis factor-β, mullerian-inhibiting substance, mouse gonadotropin-associated peptide, inhibin, activin, vascular endothelial growth factor, integrin, thrombopoietin (TPO), a nerve growth factor (NGF), NGF-β, platelet-growth factor, a transforming growth factors (TGF), TGF-α, TGF-β, insulin-like growth factor-I, insulin-like growth factor-II, erythropoietin (EPO), an osteoinductive factor, an interferon, interferon-α, interferon-β, interferon-γ, interferon-λ, a colony stimulating factors (CSF), macrophage-CSF (M-CSF), granulocyte-macrophage-CSF (GM-CSF), granulocyte-CSF (G-CSF), interleukin-1 (IL-1), IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, LIF, kit-ligand, FLT-3, angiostatin, thrombospondin, endostatin, tumor necrosis factor and LT (lymphotoxin).

22. The complex of claim 8, wherein the xenoantigen is selected from the group consisting of carbonic anhydrase IX, alpha-fetoprotein, .alpha.-actinin-4, A3, antigen specific for A33 antibody, ART-4, B7, Ba 733, BAGE, BrE3-antigen, CA125, CAMEL, CAP-1, CASP-8/m, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD95, CD126, CD133, CD138,

CD147, CD154, CDC27, CDK-4/m, CDKN2A, colon-specific antigen-p (CSAp), CEA (CEACAM5), CEACAM6, DAM, EGFR, EGFRvIII, EGP-1, EGP-2, ELF2-M, Ep-CAM, Flt-1, Flt-3, folate receptor, G250 antigen, GAGE, gp100, GROB, HLA-DR, HM1.24, human chorionic gonadotropin (HCG) and its subunits, HER2/neu, HMGB-1, hypoxia inducible factor (HIF-1), HSP70-2M, HST-2, Ia, IGF-1R, IFN-.gamma., IFN-.alpha., IFN-.beta., IL-2, IL-4R, IL-6R, IL-13R, IL-15R, IL-17R, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin growth factor-1 (IGF-1), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, LDR/FUT, macrophage migration inhibitory factor (MIF), MAGE, MAGE-3, MART-I, MART-2, NY-ESO-1, TRAG-3, mCRP, MCP-1, MIP-1A, MIP-1B, MIF, MUC1, MUC2, MUC3, MUC4, MUM-1/2, MUM-3, NCA66, NCA95, NCA90, antigen specific for PAM-4 antibody, placental growth factor, p53, prostatic acid phosphatase, PSA, PRAME, PSMA, PlGF, ILGF, ILGF-1R, IL-6, IL-25, RS5, RANTES, T101, SAGE, 5100, survivin, survivin-2B, TAC, TAG-72, tenascin, TRAIL receptors, TNF-.alpha., Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGFR, ED-B fibronectin, WT-1, 17-1A-antigen, complement factors C3, C3a, C3b, C5a, C5, an angiogenesis marker, bcl-2, bcl-6, Kras, cMET, an oncogene marker and an oncogene product.

23. A method of treating a disease, comprising administering to a subject a multimeric complex comprising:

a) a first fusion protein comprising (i) a first antibody, and (ii) an AD (anchoring domain) moiety from an AKAP protein attached to the C-terminal end of each light chain of the antibody; and

b) a second fusion protein comprising (iii) an effector moeity, and (iv) a DDD (dimerization and docking domain) moiety from protein kinase A (PKA) regulatory subunit RIα, RIβ, RIIα or RIIβ;

wherein two copies of the DDD moiety form a dimer that binds to one copy of the AD moiety to form the complex.

24. The method of claim 23, wherein the disease is cancer, an autoimmune disease, an immune system dysfunction, an infectious disease, a metabolic disease, a cardiovascular disease and a neurologic disease.

25. The method of claim 24, wherein the cancer is selected from the group consisting of non-Hodgkin's lymphoma, B cell lymphoma, B cell leukemia, T cell lymphoma, T cell leukemia, acute lymphoid leukemia, chronic lymphoid leukemia, Burkitt lymphoma, Hodgkin's lymphoma, hairy cell leukemia, acute myeloid leukemia, chronic myeloid leukemia, multiple myeloma, glioma, Waldenstrom's macroglobulinemia, carcinoma, melanoma, sarcoma, glioma, skin cancer, oral cavity cancer, gastrointestinal tract cancer, colon cancer, stomach cancer, pulmonary tract cancer, lung cancer, breast cancer, ovarian cancer, prostate cancer, uterine cancer, endometrial cancer, cervical cancer, urinary bladder cancer, pancreatic cancer, bone cancer, liver cancer, gall bladder cancer, kidney cancer, and testicular cancer.

26. The method of claim 24, wherein the autoimmune disease is selected from the group consisting of acute idiopathic thrombocytopenic purpura, chronic idiopathic thrombocytopenic purpura, dermatomyositis, Sydenham's chorea, myasthenia gravis, systemic lupus erythematosus, lupus nephritis, rheumatic fever, polyglandular syndromes, bullous pemphigoid, diabetes mellitus, Henoch-Schonlein purpura, post-streptococcal nephritis, erythema nodosum, Takayasu's arteritis, Addison's disease, rheumatoid arthritis, multiple sclerosis, sarcoidosis, ulcerative colitis, erythema multiforme, IgA nephropathy, polyarteritis nodosa, ankylosing spondylitis, Goodpasture's syndrome, thromboangitis obliterans, Sjogren's syndrome, primary biliary cirrhosis, Hashimoto's thyroiditis, thyrotoxicosis, scleroderma, chronic active hepatitis, polymyositis/dermatomyositis, polychondritis, pemphigus vulgaris, Wegener's granulomatosis, membranous nephropathy, amyotrophic lateral sclerosis, tabes dorsalis, giant cell arteritis/polymyalgia, pernicious anemia, rapidly progressive glomerulonephritis, psoriasis, and fibrosing alveolitis.

27. The method of claim 23, wherein the effector moiety is selected from the group consisting of a second antibody or antigen-binding fragment thereof, a cytokine, an interferon, a toxin, an antigen, a xenoantigen, a hapten, a protamine, a hormone, an enzyme, a ligand-binding protein, a pro-apoptotic agent and an anti-angiogenic agent.

28. The method of claim 23, wherein the effector moiety is a second antibody or antigen-binding fragment thereof, a cytokine, an interferon or a toxin.

29. The method of claim 23, wherein the first antibody is attached to two AD moieties and

each AD moiety binds to a dimer of DDD moieties.

30. The method of claim 23, wherein the first antibody binds to an antigen selected from the group consisting of AFP, α4 integrin, B7, carbonic anhydrase IX, complement factors C1q, C1r, C1s, C2a, C2b, C3, C3a, C3b, C4, C4a, C4b, C5a, C5aR, C5b, C5, C6, C7, C8, C9n, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD3R, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD44, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD86, CD95, CD126, CD133, CD138, CD147, CD154, CEACAM-5, CEACAM-6, CSAp, ED-B of fibronectin, EGFR, EGP-1 (TROP-2), EGP-2, ErbB2, Factor H, FHL-1, fibrin, Flt-3, folate receptor, glycoprotein IIb/IIIa, gp41, gp120, GRO-β, HLA-DR, HM1.24, HM1.24, HMGB-1, hypoxia inducible factor (HIF), Ia, ICAM-1, IFN-α, IFN-β, IFN-γ, IFN-λ, IgE, IGF-1R, IL-1, IL-1Ra, IL-2, IL-4R, IL-6, IL-6R, IL-8, IL-13R, IL-15R, IL-15, IL-17, IL-17R, IL-18, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin-like growth factor-1 (ILGF-1), IP-10, Le(y), lipopolysaccharide (LPS), MAGE, MCP-1, mCRP, MIF, MIP-1A, MIP-1B, MUC1, MUC2, MUC3, MUC4, MUC5ac, NCA-90, NCA-95, NF-κB, PlGF, PSMA, RANTES, T101, TAC, TAG-72, tenascin, Thomson-Friedenreich antigens, thrombin, tissue factor, Tn antigen, TNF-α, TRAIL receptor (R1 and R2), tumor necrosis antigens, VEGF, VEGFR and an oncogene product.

31. The method of claim 23, wherein the first antibody is selected from the group consisting of hR1 (anti-IGF-1R), hPAM4 (anti-mucin), KC4 (anti-mucin), hA20 (anti-CD20), hA19 (anti-CD19), hIMMU31 (anti-AFP), hLL1 (anti-CD74), hLL2 (anti-CD22), RFB4 (anti-CD22), hMu-9 (anti-CSAp), hL243 (anti-HLA-DR), hMN-14 (anti-CEACAM5), hMN-15 (anti-CEACAM6), hRS7 (anti-TROP-2), hMN-3 (anti-CEACAM6), CC49 (anti-TAG-72), J591 (anti-PSMA), D2/B (anti-PSMA), G250 (anti-carbonic anhydrase IX), infliximab (anti- TNF-α), certolizumab pegol (anti- TNF-α), adalimumab (anti- TNF-α), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20), panitumumab (anti-EGFR), rituximab (anti-CD20), tositumomab (anti-CD20), GA101 (anti-CD20), trastuzumab (anti-ErbB2), tocilizumab (anti-IL-6 receptor), basiliximab (anti-CD25), daclizumab (anti-CD25), efalizumab (anti-CD11a), muromonab-CD3 (anti-CD3 receptor), natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

32. The method of claim 27, wherein the second antibody or antigen-binding fragment thereof binds to an antigen selected from the group consisting of AFP, α4 integrin, B7, carbonic anhydrase IX, complement factors C1q, C1r, C1s, C2a, C2b, C3, C3a, C3b, C4, C4a, C4b, C5a, C5aR, C5b, C5, C6, C7, C8, C9n, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD3R, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD44, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD86, CD95, CD126, CD133, CD138, CD147, CD154, CEACAM-5, CEACAM-6, CSAp, ED-B of fibronectin, EGFR, EGP-1 (TROP-2), EGP-2, ErbB2, Factor H, FHL-1, fibrin, Flt-3, folate receptor, glycoprotein IIb/IIIa, gp41, gp120, GRO-β, HLA-DR, HM1.24, HM1.24, HMGB-1, HSG, hypoxia inducible factor (HIF), Ia, ICAM-1, IFN-α, IFN-β, IFN-γ, IFN-λ, IgE, IGF-1R, IL-1, IL-1Ra, IL-2, IL-4R, IL-6, IL-6R, IL-8, IL-13R, IL-15R, IL-15, IL-17, IL-17R, IL-18, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin-like growth factor-1 (ILGF-1), IP-10, Le(y), lipopolysaccharide (LPS), MAGE, MCP-1, mCRP, MIF, MIP-1A, MIP-1B, MUC1, MUC2, MUC3, MUC4, MUC5ac, NCA-90, NCA-95, NF-κB, PlGF, PSMA, RANTES, T101, TAC, TAG-72, tenascin, Thomson-Friedenreich antigens, thrombin, tissue factor, Tn antigen, TNF-α, TRAIL receptor (R1 and R2), tumor necrosis antigens, VEGF, VEGFR and an oncogene product.

33. The method of claim 27, wherein the second antibody is selected from the group consisting of hR1 (anti-IGF-1R), hPAM4 (anti-mucin), KC4 (anti-mucin), hA20 (anti-CD20), hA19 (anti-CD19), hIMMU31 (anti-AFP), hLL1 (anti-CD74), hLL2 (anti-CD22), RFB4 (anti-CD22), hMu-9 (anti-CSAp), hL243 (anti-HLA-DR), hMN-14 (anti-CEACAM5), hMN-15 (anti-CEACAM6), hRS7 (anti-TROP-2), hMN-3 (anti-CEACAM6), CC49 (anti- TAG-72), J591 (anti-PSMA), D2/B (anti-PSMA), G250 (anti-carbonic anhydrase IX), infliximab (anti- TNF-α), certolizumab pegol (anti- TNF-α), adalimumab (anti- TNF-α), alemtuzumab (anti-CD52), bevacizumab (anti-VEGF), cetuximab (anti-EGFR), gemtuzumab (anti-CD33), ibritumomab tiuxetan (anti-CD20), panitumumab (anti-EGFR), rituximab (anti-CD20), tositumomab (anti-CD20), GA101 (anti-CD20), trastuzumab (anti-ErbB2), tocilizumab (anti-IL-6 receptor), basiliximab (anti-CD25), daclizumab (anti-CD25), efalizumab (anti-CD11a), muromonab-CD3 (anti-CD3 receptor), natalizumab (anti-α4 integrin) and omalizumab (anti-IgE).

34. The method of claim 27, wherein the antibody fragment is selected from the group consisting of a $F(ab')_2$, a $F(ab)_2$, a Fab', a Fab, a Fv, a sFv, a scFv and a dAb.

35. The method of claim 23, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of residues 1-44 of RIIα, 1-44 of RIIβ, 12-61 of RIα and 13-66 of RIβ.

36. The method of claim 23, wherein the amino acid sequence of the DDD moiety is selected from the group consisting of SEQ ID NO:1, SEQ ID NO:2, SEQ ID NO:5, SEQ ID NO:6, SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO:20, SEQ ID NO:22, SEQ ID NO:22, SEQ ID NO:23, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:26, SEQ ID NO:27, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:30, SEQ ID NO:31, SEQ ID NO:87 and SEQ ID NO:89.

37. The method of claim 23, wherein the amino acid sequence of the AD moiety is selected from the group consisting of SEQ ID NO:3, SEQ ID NO:4, SEQ ID NO:7, SEQ ID NO:32, SEQ ID NO:33, SEQ ID NO:34, SEQ ID NO:35, SEQ ID NO:36, SEQ ID NO:37, SEQ ID NO:38, SEQ ID NO:39, SEQ ID NO:40, SEQ ID NO:41, SEQ ID NO:42, SEQ ID NO:43, SEQ ID NO:44, SEQ ID NO:45, SEQ ID NO:46, SEQ ID NO:47, SEQ ID NO:48, M SEQ ID NO:49, SEQ ID NO:50, SEQ ID NO:51, SEQ ID NO:52, SEQ ID NO:53, SEQ ID NO:54, SEQ ID NO:55, SEQ ID NO:56, SEQ ID NO:57, SEQ ID NO:58, M SEQ ID NO:59, SEQ ID NO:60, SEQ ID NO:61, SEQ ID NO:62, SEQ ID NO:63, SEQ ID NO:64, SEQ ID NO:65, SEQ ID NO:66, SEQ ID NO:67, SEQ ID NO:68, SEQ ID NO:69, SEQ ID NO:70, SEQ ID NO:71, SEQ ID NO:72, SEQ ID NO:73, SEQ ID NO:74, SEQ ID NO:75, SEQ ID NO:76, SEQ ID NO:77, SEQ ID NO:78, M SEQ ID NO:79, SEQ ID NO:80, SEQ ID NO:81, SEQ ID NO:82, SEQ ID NO:83, SEQ ID NO:44 and SEQ ID NO:88.

38. The method according to claim 27, wherein the toxin is selected from the group consisting of a bacterial toxin, a plant toxin, ricin, abrin, alpha toxin, saporin, ribonuclease (RNase), DNase I, Staphylococcal enterotoxin-A, pokeweed antiviral protein, gelonin, diphtheria toxin, Pseudomonas exotoxin, Pseudomonas endotoxin, ranpirnase (Rap) and Rap (N69Q).

39. The method according to claim 38, wherein the toxin is ranpirnase (Rap).

40. The method of claim 27, wherein the cytokine is selected from the group consisting of human growth hormone, N-methionyl human growth hormone, bovine growth hormone, parathyroid hormone, thyroxin, insulin, proinsulin, relaxin, prorelaxin, follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), luteinizing hormone (LH), hepatic growth factor, prostaglandin, fibroblast growth factor, prolactin, placental lactogen, OB protein, tumor necrosis factor-α, tumor necrosis factor-β, mullerian-inhibiting substance, mouse gonadotropin-associated peptide, inhibin, activin, vascular endothelial growth factor, integrin, thrombopoietin (TPO), a nerve growth factor (NGF), NGF-β, platelet-growth factor, a transforming growth factors (TGF), TGF-α, TGF-β, insulin-like growth factor-I, insulin-like growth factor-II, erythropoietin (EPO), an osteoinductive factor, an interferon, interferon-α, interferon-β, interferon-γ, interferon-λ, a colony stimulating factors (CSF), macrophage-CSF (M-CSF), granulocyte-macrophage-CSF (GM-CSF), granulocyte-CSF (G-CSF), interleukin-1 (IL-1), IL-1α, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, IL-21, LIF, kit-ligand, FLT-3, angiostatin, thrombospondin, endostatin, tumor necrosis factor and LT (lymphotoxin).

41. The method of claim 27, wherein the xenoantigen is selected from the group consisting of carbonic anhydrase IX, alpha-fetoprotein, .alpha.-actinin-4, A3, antigen specific for A33 antibody, ART-4, B7, Ba 733, BAGE, BrE3-antigen, CA125, CAMEL, CAP-1, CASP-8/m, CCCL19, CCCL21, CD1, CD1a, CD2, CD3, CD4, CD5, CD8, CD11A, CD14, CD15, CD16, CD18, CD19, CD20, CD21, CD22, CD23, CD25, CD29, CD30, CD32b, CD33, CD37, CD38, CD40, CD40L, CD45, CD46, CD52, CD54, CD55, CD59, CD64, CD66a-e, CD67, CD70, CD74, CD79a, CD80, CD83, CD95, CD126, CD133, CD138, CD147, CD154, CDC27, CDK-4/m, CDKN2A, colon-specific antigen-p (CSAp), CEA (CEACAM5), CEACAM6, DAM, EGFR, EGFRvIII, EGP-1, EGP-2, ELF2-M, Ep-CAM, Flt-1, Flt-3, folate receptor, G250 antigen, GAGE, gp100, GROB, HLA-DR, HM1.24, human chorionic gonadotropin (HCG) and its subunits, HER2/neu, HMGB-1, hypoxia inducible factor (HIF-1), HSP70-2M, HST-2, Ia, IGF-1R, IFN-.gamma., IFN-.alpha., IFN-.beta., IL-2, IL-4R, IL-6R, IL-13R, IL-15R, IL-17R, IL-18R, IL-6, IL-8, IL-12, IL-15, IL-17, IL-18, IL-25, insulin growth factor-1 (IGF-1), KC4-antigen, KS-1-antigen, KS1-4, Le-Y, LDR/FUT, macrophage migration inhibitory factor (MIF), MAGE, MAGE-

3, MART-I, MART-2, NY-ESO-1, TRAG-3, mCRP, MCP-1, MIP-1A, MIP-1B, MIF, MUC1, MUC2, MUC3, MUC4, MUM-1/2, MUM-3, NCA66, NCA95, NCA90, antigen specific for PAM-4 antibody, placental growth factor, p53, prostatic acid phosphatase, PSA, PRAME, PSMA, PlGF, ILGF, ILGF-1R, IL-6, IL-25, RS5, RANTES, T101, SAGE, 5100, survivin, survivin-2B, TAC, TAG-72, tenascin, TRAIL receptors, TNF-.alpha., Tn antigen, Thomson-Friedenreich antigens, tumor necrosis antigens, VEGFR, ED-B fibronectin, WT-1, 17-1A-antigen, complement factors C3, C3a, C3b, C5a, C5, an angiogenesis marker, bcl-2, bcl-6, Kras, cMET, an oncogene marker and an oncogene product.

42. The method of claim 23, further comprising administering to the subject a therapeutic agent selected from the group consisting of an antibody, an antibody fragment, a drug, a toxin, an enzyme, a hormone, an immunomodulator, an antisense oligonucleotide, a small interfering RNA (siRNA), a boron compound and a radioisotope.

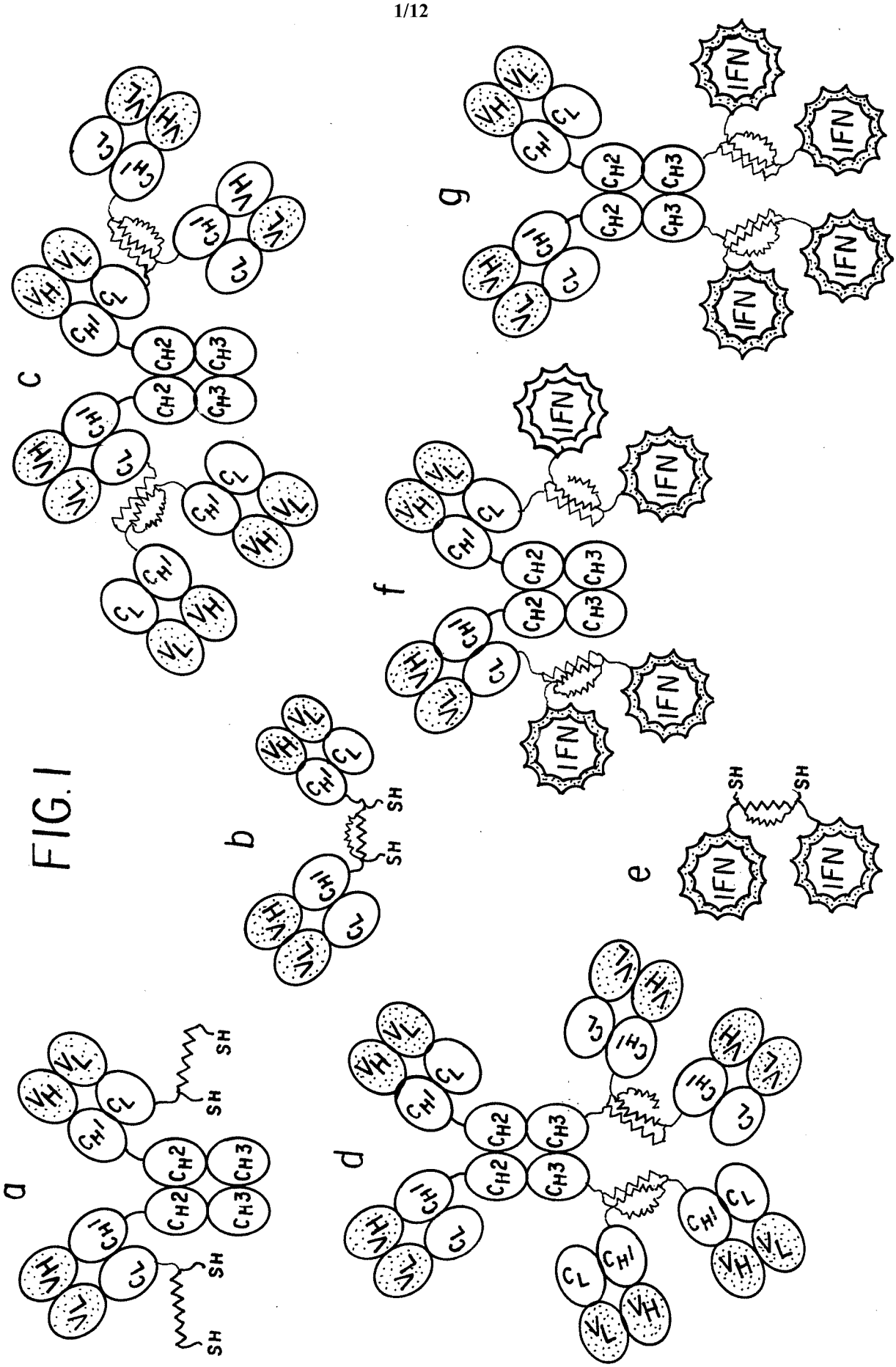
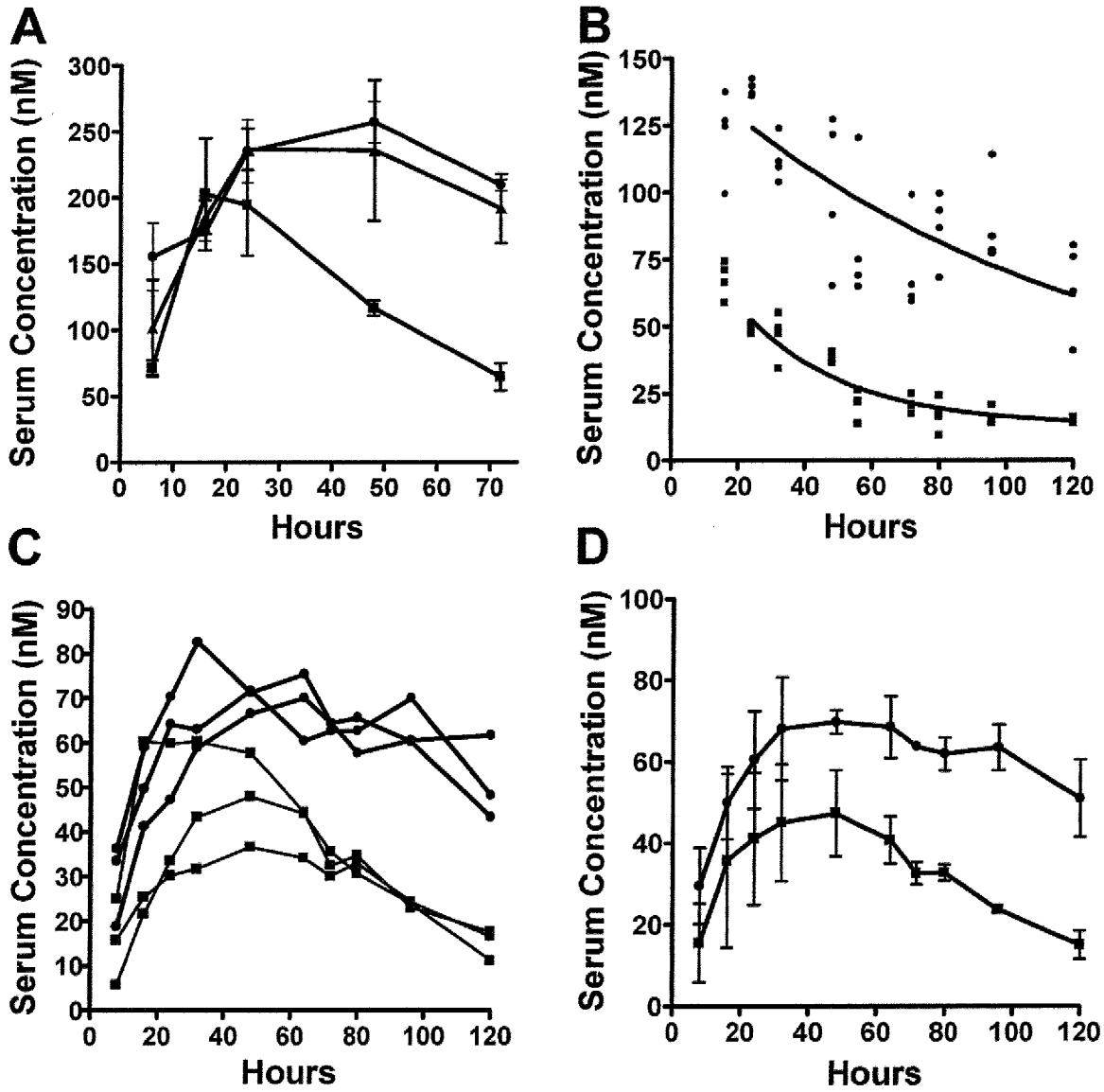


FIG. 1

FIG. 2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200
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100
50
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Hours
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125
100
75
50
25
0
0 20 40 60 80 100 120
Hours
C
Serum Concentration (nM)
90
80
70
60
50
40
30
20
10
0
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D
Serum Concentration (nM)
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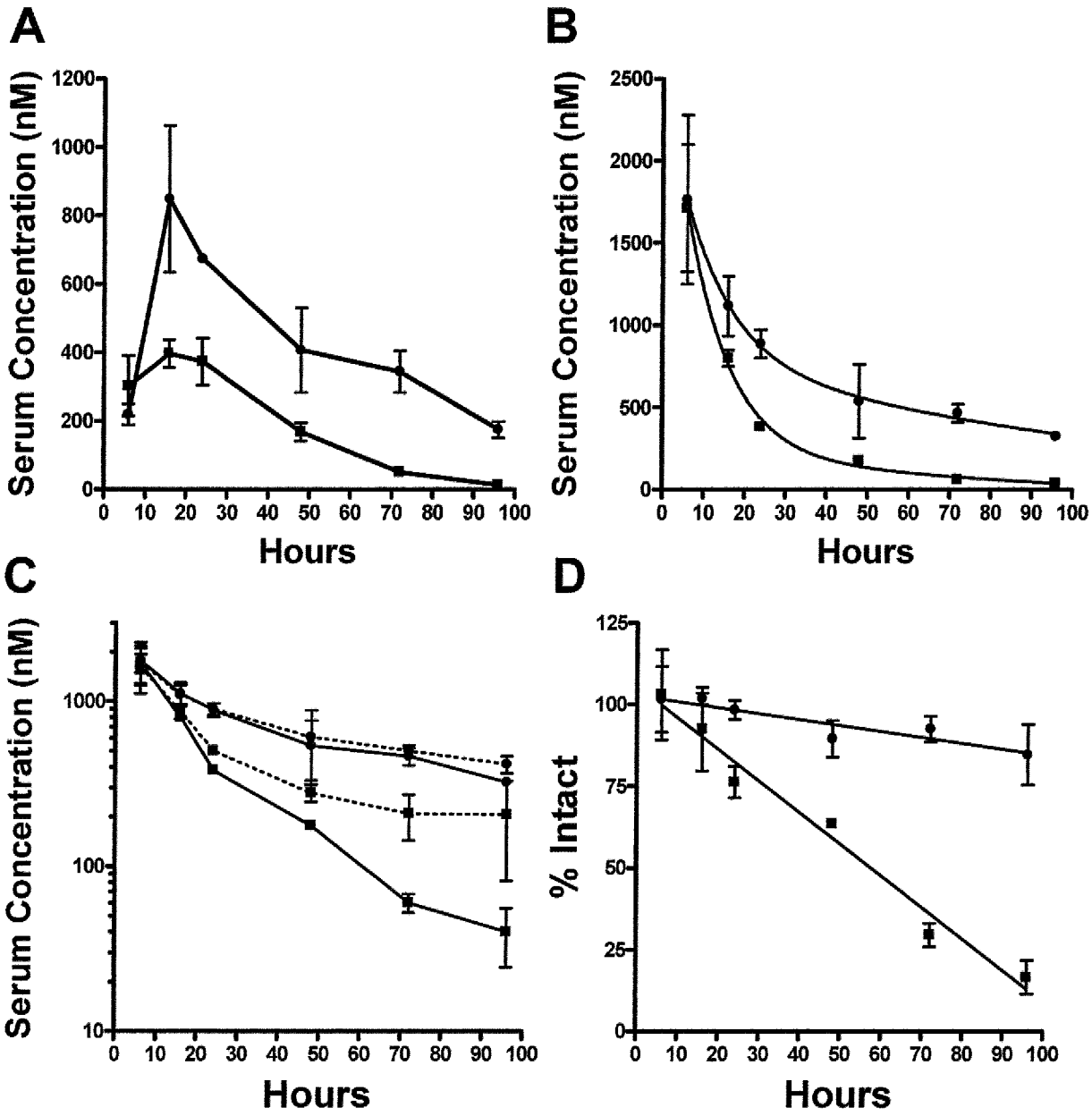
80
60
40
20
0
0 20 40 60 80 100 120
Hours

FIG. 3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400
200
0
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Hours
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2500
2000
1500
1000
500
0
0 10 20 30 40 50 60 70 80 90 100
Hours
C
Serum Concentration (nM)
1000
100
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D
% Intact
125
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50
25
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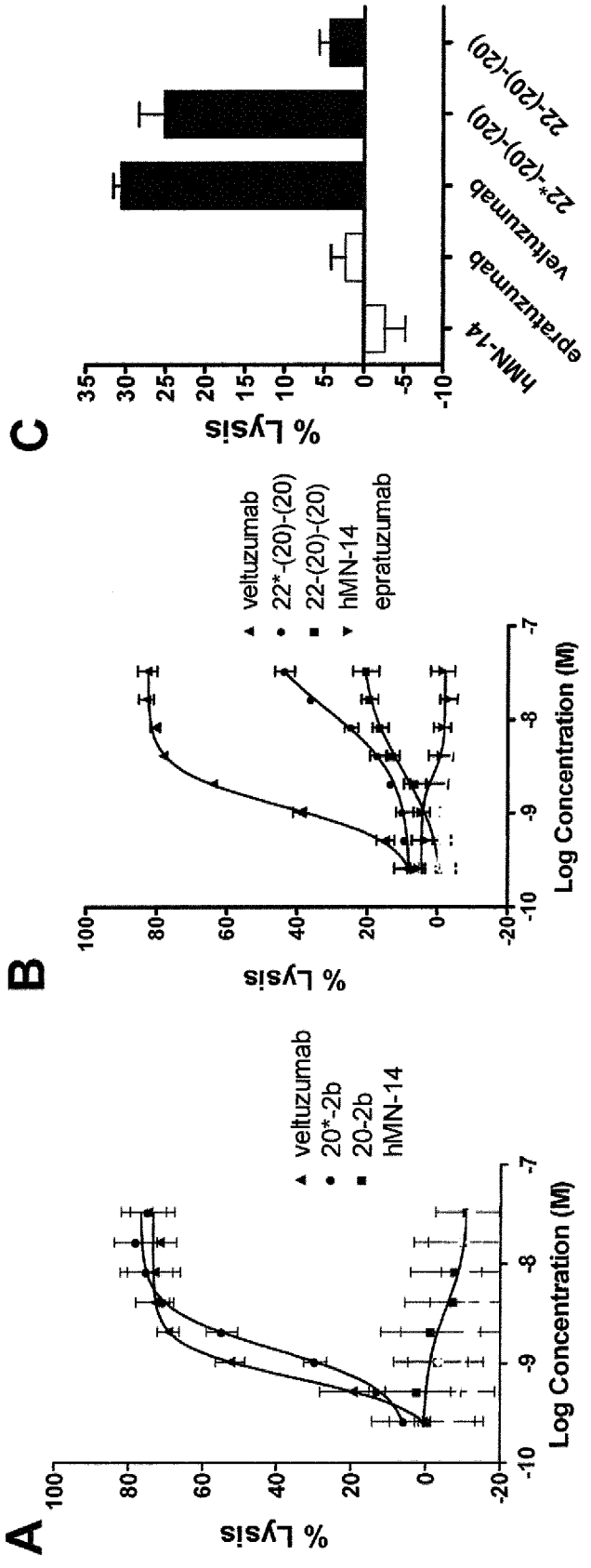
Hours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Log Concentration (M)
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20*-2b
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hMN-14
B
% Lysis
Log Concentration (M)
veltuzumab
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22-(20)-(20)
hMN-14
epratuzumab
C
% Lysis
hMN-14
epratuzumab
veltuzumab
22*-(20)-(20)
22-(20)-(20)

FIG. 4

FIG. 5

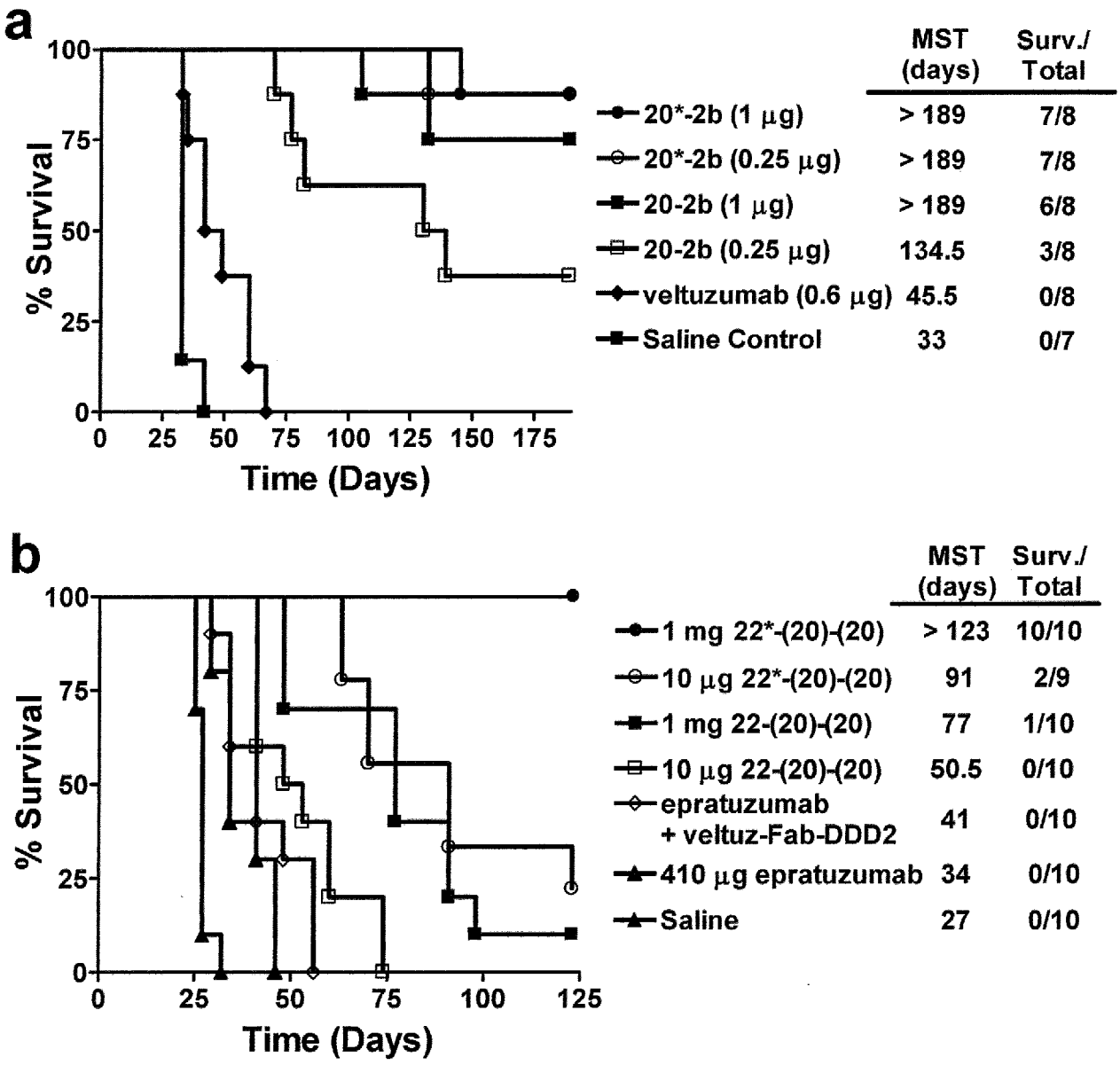

a
100
75
50
25
0
% Survival
0 25 50 75 100 125 150 175
Time (Days)
MST (days) Surv./ Total
20*-2b (1 μg) > 189 7/8
20*-2b (0.25 μg) > 189 7/8
20-2b (1 μg) > 189 6/8
20-2b (0.25 μg) 134.5 3/8
veltuzumab (0.6 μg) 45.5 0/8
Saline Control 33 0/7
b
100
75
50
25
0
% Survival
0 25 50 75 100 125
Time (Days)
MST (days) Surv./ Total
1 mg 22*-(20)-(20) > 123 10/10
10 μg 22*-(20)-(20) 91 2/9
1 mg 22-(20)-(20) 77 1/10
10 μg 22-(20)-(20) 50.5 0/10
epratuzumab + veltuz-Fab-DDD2 41 0/10
410 μg epratuzumab 34 0/10
Saline 27 0/10

FIG. 6

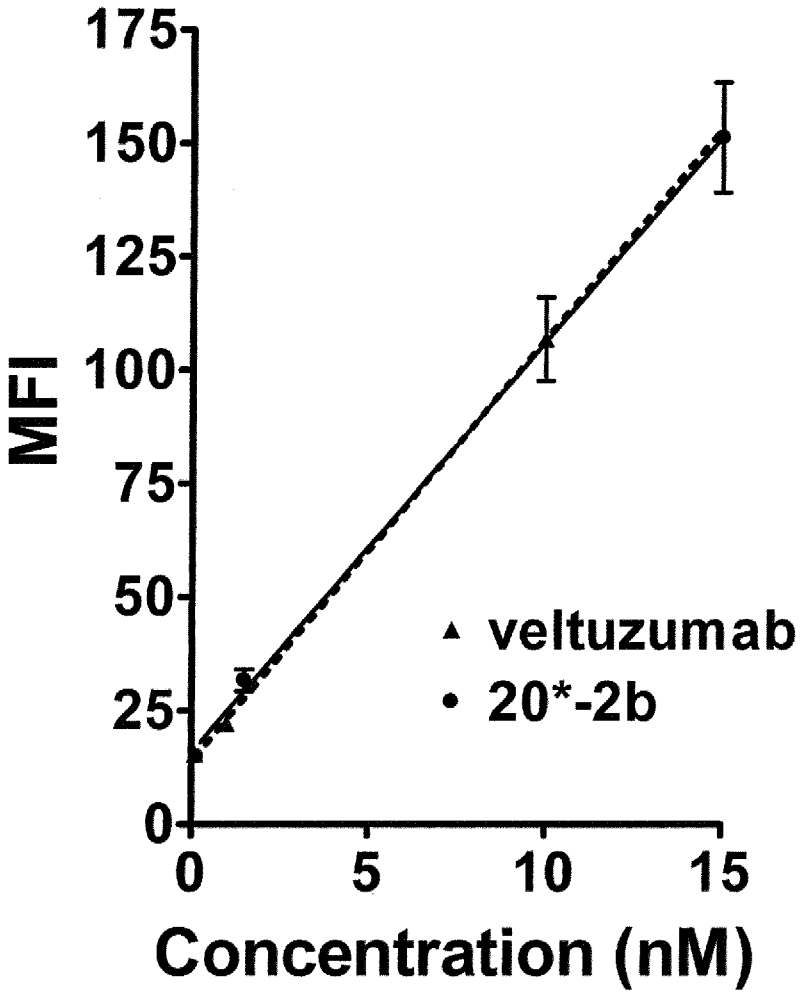

175
150
125
100
75
50
25
0
MFI
0
5
10
15
Concentration (nM)
veltuzumab
20*-2b

FIG. 7

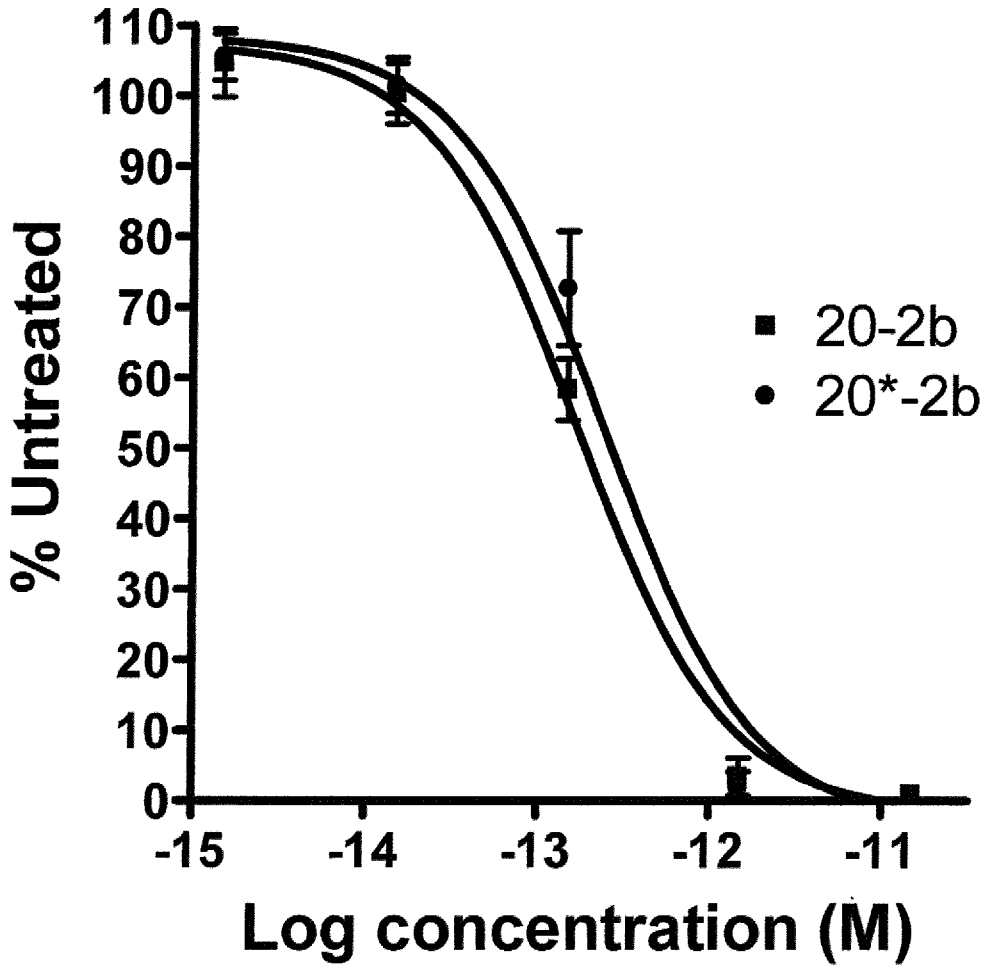
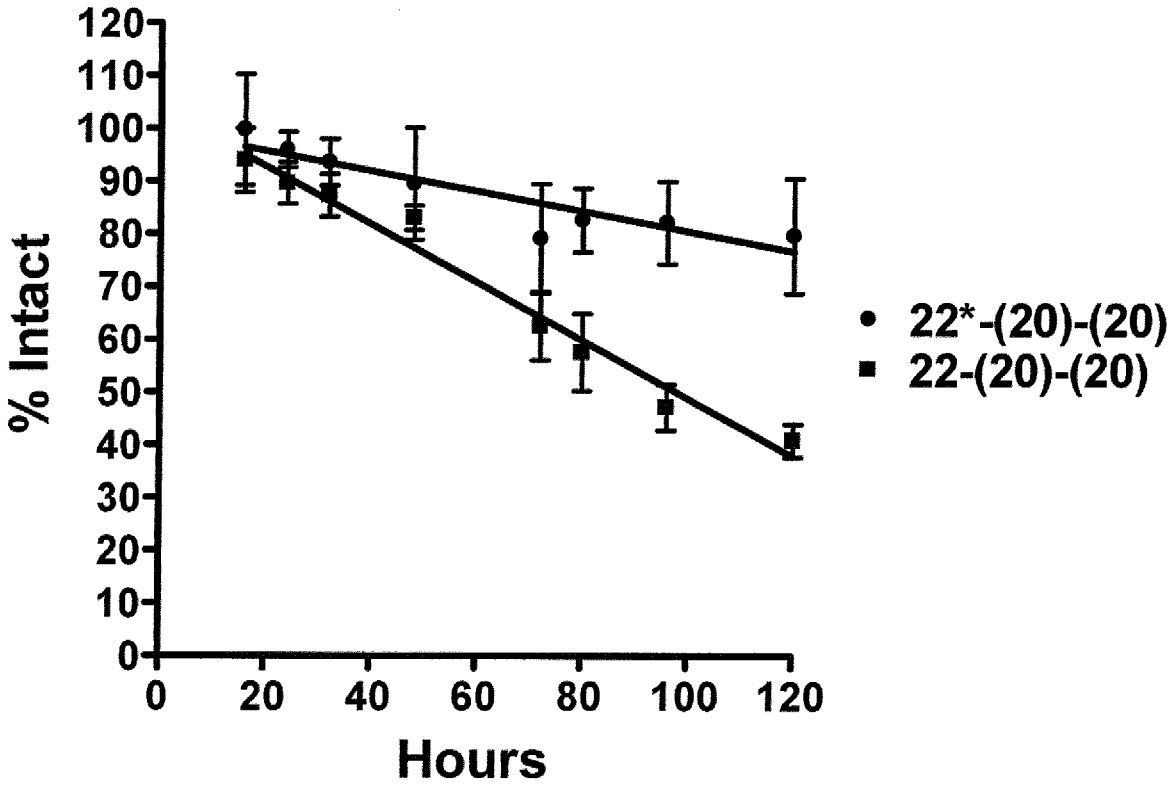

110
100
90
80
70
60
50
40
30
20
10
0
% Untreated
-15
-14
-13
-12
-11
Log concentration (M)
20-2b
20*-2b

FIG. 8


120
110
100
90
80
70
60
50
40
30
20
10
0
% Intact
0
20
40
60
80
100
120
Hours
22*-(20)-(20)
22-(20)-(20)

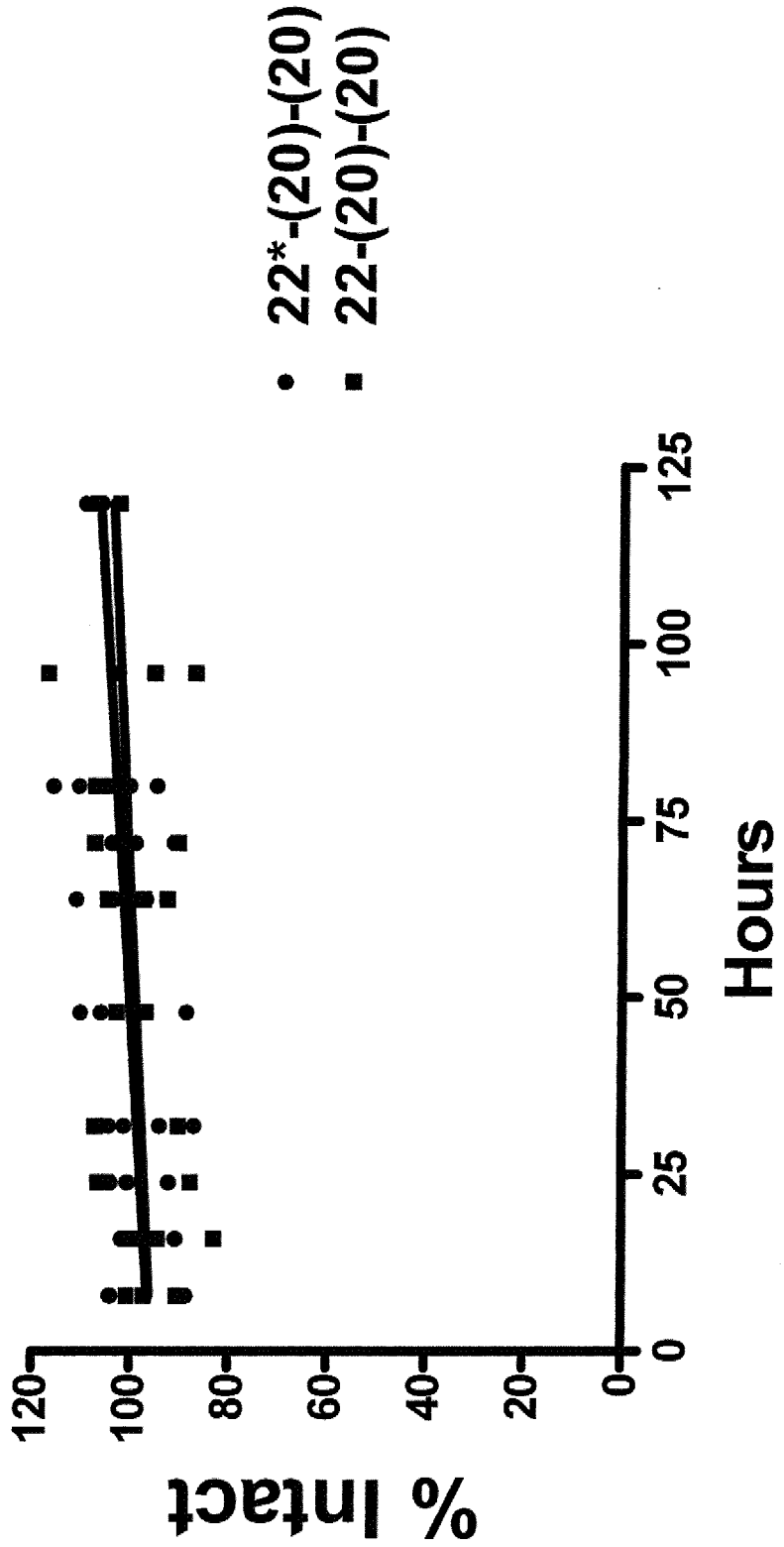

22*-(20)-(20)
22-(20)-(20)
% Intact
120
100
80
60
40
20
0
0
25
50
75
100
125
Hours

FIG. 9

FIG. 10

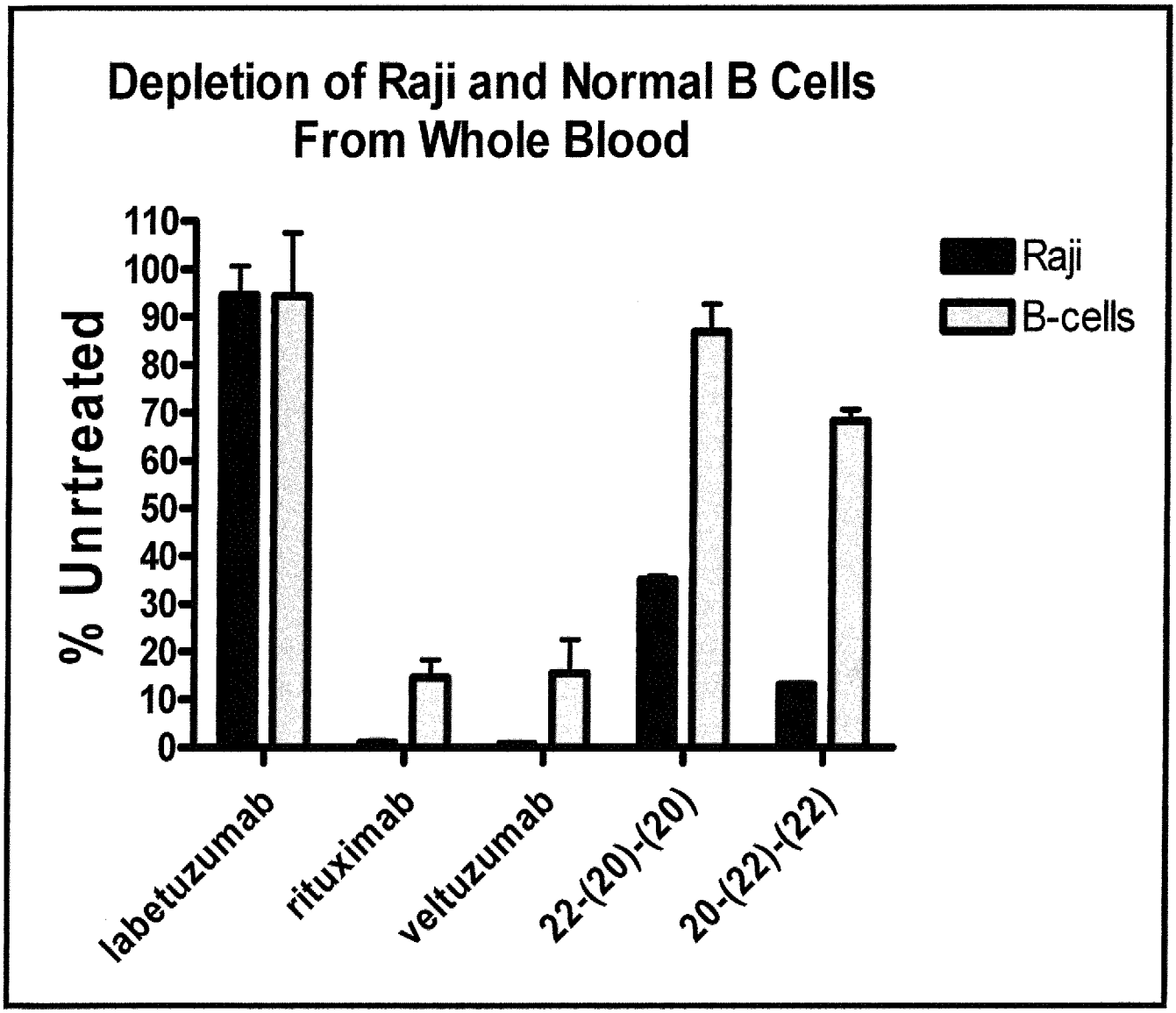

Depletion of Raji and Normal B Cells From Whole Blood
% Unrtreated
110
100
90
80
70
60
50
40
30
20
10
0
Raji
B-cells
labetuzumab
rituximab
veltuzumab
22-(20)-(20)
20-(22)-(22)

FIG. 11

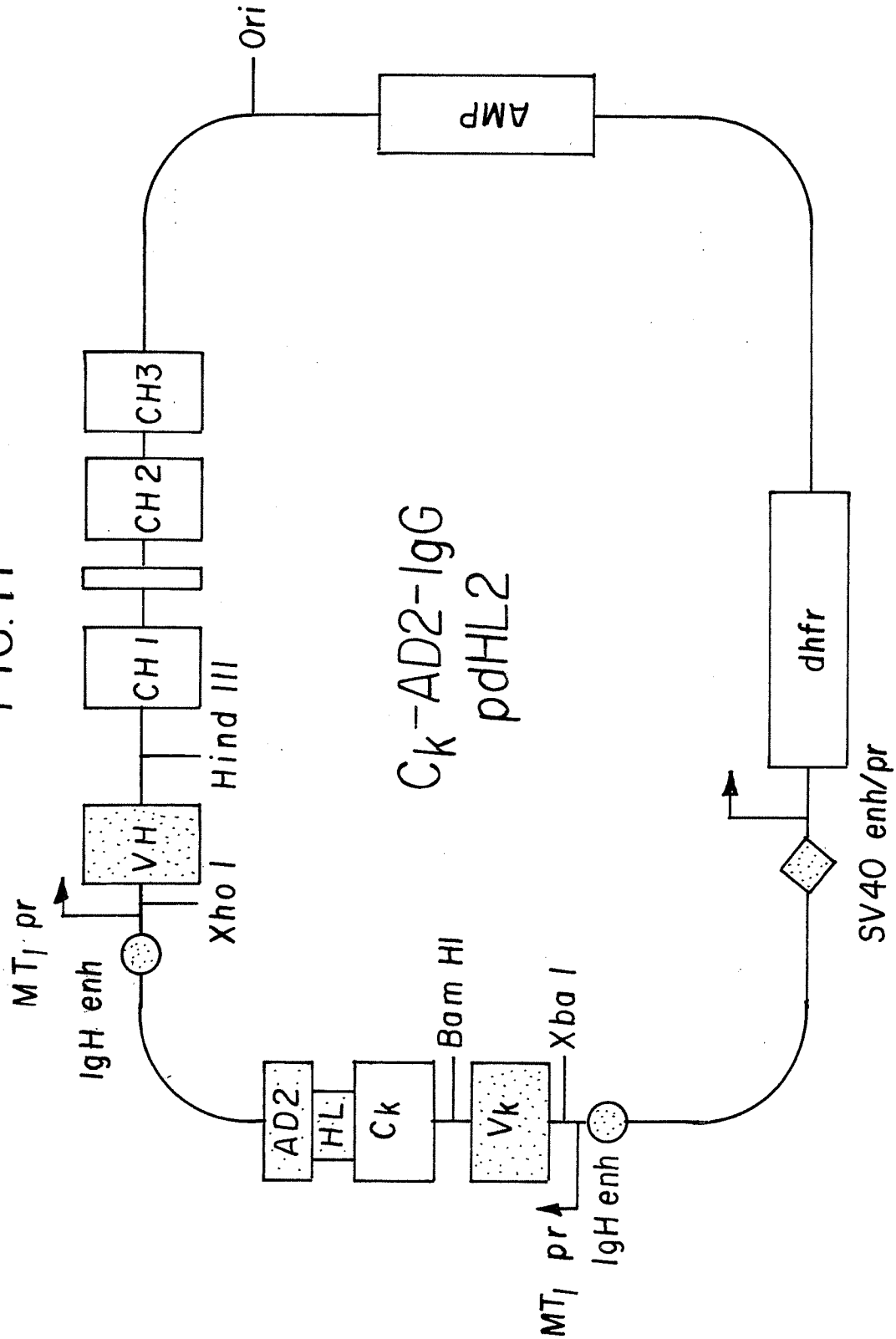
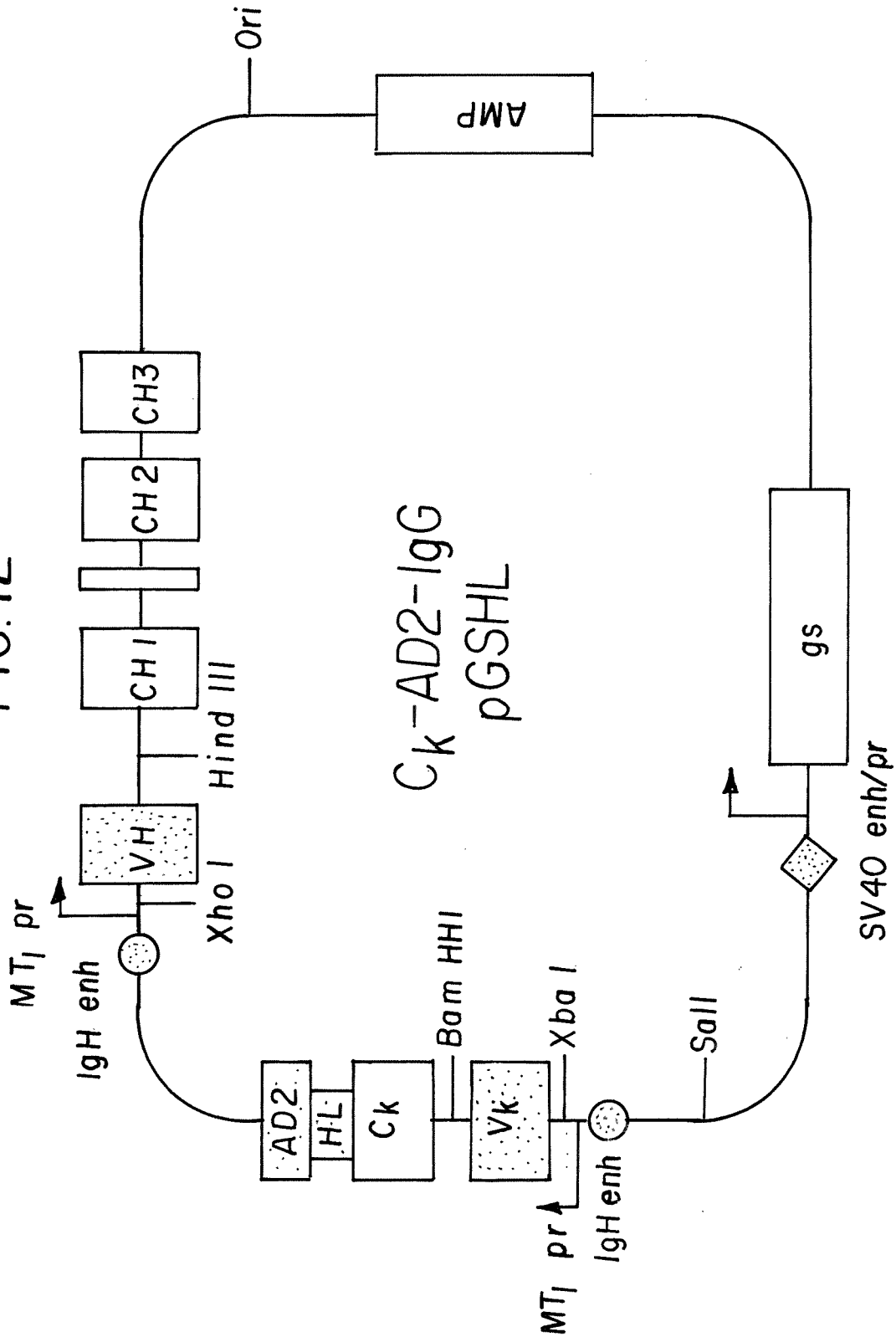

Ori
AMP
CH3
CH2
CH1
VH
Hind III
Xho I
MT1 pr
IgH enh
Ck-AD2-IgG
pdHL2
dhfr
SV40 enh/pr
AD2
HL
Ck
Bam HI
Vk
Xba I
IgH enh
MT1 pr

FIG. 12


Ori
AMP
CH3
CH2
CH1
Hind III
VH
Xho I
MT1 pr
IgH enh
Ck-AD2-IgG
pGSHL
AD2
HL
Ck
Bam HHI
Vk
Xba I
MT1 pr
IgH enh
SalI
gs
SV40 enh/pr