ANTI-VLA-4 ANTIBODIES

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 61/324,944, filed April 16, 2010, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to alpha-4 binding antibodies, and fragments thereof.

BACKGROUND OF INVENTION

Humanized antibodies can be used as therapeutic agents in place of murine antibodies to avoid the undesirable immune response in humans termed the HAMA (Human Anti-Mouse Antibody) response. Humanized antibodies are generally constructed by replacing the complementary determining regions (CDRs) of a human antibody with the CDRs of another species, typically a mouse antibody.

VLA-4 (also called $\alpha4\beta1$) is a member of the $\beta1$ integrin family of cell surface receptors. VLA-4 contains an $\alpha4$ chain and a $\beta1$ chain and is involved in cell-cell interactions. Its expression is mainly restricted to lymphoid and myeloid cells. VLA-4 binds the endothelial cell ligand VCAM-1 (Vascular Cell Adhesion Molecule-1), and can mediate T and B lymphocyte attachment to the heparin II binding fragment of human plasma fibronectin.

SUMMARY OF INVENTION

The inventors have discovered that germline variable region frameworks can be used to optimize CDR-grafted alpha-4 binding antibodies, such as anti-VLA-4 antibodies. Accordingly, the invention features anti-VLA-4 variable heavy (VH) and variable light (VL) chains and antibody molecules including such frameworks.

In one aspect, the invention features an anti-α4 antibody VH chain having CDRs from a donor anti-α4 antibody, *e.g.*, an anti-α4 antibody described herein, and a VH framework having regions 1, 2, 3, and 4 from the sequence of, or having no more than 5, 10 or 15 differences from a germline variable region sequence for the VH chain. In one embodiment, variable framework region 4 (FR4) is a human consensus sequence. In one embodiment, the complete VH chain framework regions FR1, FR2, FR3 and FR4, are present. In another embodiment, the chain is an antigen-binding fragment of a VH region.

In one embodiment, the germline sequence is human IGHV1-f (SEQ ID NO:2), depicted in FIG. 1. In certain embodiments, the VH framework sequence can differ by at least one, but by no more than 2, 3, 4, 5, 10 or 15 amino acid residues from a germline sequence, *e.g.*, SEQ ID NO:2. In one embodiment, the VH framework further includes other than the corresponding human residues. For example, the VH chain includes non-human residues, at one or more of framework positions 24, 67, 76, 80, and 94 (Kabat numbering) of SEQ ID NO:2.

In one embodiment, at least one or more of the complementary determining regions (CDRs) of the variable domains are derived from a donor non-human α4-binding antibody. In one embodiment, the antigen binding regions of the CDR-grafted heavy chain variable domain include the CDRs corresponding to positions 26-34 (CDR1), 50-65 (CDR2) and 95-102 (CDR3) (Kabat numbering; Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5th ed., vol. 4, 1991, U.S. Department of Health and Human Services, NIH, USA).

Thus, in one embodiment, the variable heavy chain (VH) framework has an acceptor sequence derived from human antibody germline sequence IGHV1-f.

In another embodiment, at least one amino acid, and less than 2, 3, 4, 5, or 10 amino acid residues, in the FR1 region of the VH is other than the corresponding human germline residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived. In one embodiment, the amino acid residue at Kabat position 24 is mutated to be identical to the nonhuman antibody framework region.

In another embodiment, at least one amino acid, and less than 2, 3, 4, 5, or 10 amino acid residues, in the FR2 region of the VH is other than the corresponding human

germline residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived.

In yet another embodiment, at least one amino acid, and less than 2, 3, 4, 5, or 10 amino acid residues, in FR3 of the VH chain is other than the corresponding human germline residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived. In one embodiment, the amino acid residue at Kabat position 94 is identical to the nonhuman antibody framework region. In yet another embodiment, the amino acid residues at Kabat positions 67, 76, 80, and 94 are identical to the nonhuman antibody framework region.

In certain embodiments, the VH chain of the antibody has the sequence of SEQ ID NO:3, SEQ ID NO:4, or SEQ ID NO:5.

In one aspect, the invention features, an anti-VLA-4 VL chain having CDRs from a donor anti-VLA-4 antibody, *e.g.*, an anti-VLA-4 antibody described herein, and a VL framework having regions 1, 2, 3, and 4 from the sequence of, or having no more than 5, 10 or 15 differences (either per/region or in total) from, a germline variable region sequence for the VL chain. In one embodiment, variable framework region 4 (FR4) is a human consensus sequence. In one embodiment, the complete VL chain framework regions FR1, FR2, FR3 and FR4, are present. In another embodiment, the chain is an antigen-binding fragment of a VL region.

In another embodiment, the germline sequence is IGKV4-1 (SEQ ID NO:7), depicted in FIG. 2. In yet other embodiments, the VL framework sequence can differ by at least one, but no more than 2, 3, 4, 5, 10 or 15 amino acid residues from a germline framework sequence, *e.g.*, SEQ ID NO:7. In another embodiment, the VL further includes other than the corresponding human amino acid residues. For example, the VL chain further includes non-human residues at one or more of framework positions 1, 73, and 87 (Kabat numbering) of SEQ ID NO:7.

In one embodiment, the sequence is AAH7035.1 (SEQ ID NO:12) or its germline engineered version (SEQ ID NO:13), depicted in FIG. 2. In some embodiments, the VL framework sequence can differ by at least one, but not more than 5, 10, 15, 20, or 25 amino acid residues from a germline engineered framework sequence, *e.g.*, SEQ ID NO:13. In

one embodiment, the VL chain includes other than the corresponding human residues. For example, the VL chain includes non-human residues at one or more of framework positions 1 and 87 (Kabat numbering) of SEQ ID NO:12. In another embodiment, the VL includes amino acid substitutions in the framework regions to resemble a different human germline framework sequence, such as from germline sequence IGKV4-1. In certain embodiments, the VL framework sequence is altered to be identical to the IGKV4-1 germline sequence at positions 1-3, 5-23, 35-37, 39-42, 45-49, 57, 59-61, 63-64, 70-72, 74-84,86-88, 99-106 (Kabat numbering) of SEQ ID NO:12.

In one embodiment, at least one or more of the complementary determining regions (CDRs) of the variable domains are derived from a donor non-human α4-binding antibody. In another embodiment, the antigen binding regions of the CDR-grafted heavy chain variable domain include the CDRs corresponding to positions 24-31 (CDR1), 50-56 (CDR2) and 89-97 (CDR3) (Kabat numbering). Thus, in one embodiment, the VL framework has an acceptor sequence constructed from IGKV4-1 germline sequence, from antibody AAH70335.1 or from germline engineered antibody AAH70335.1.

In yet another embodiment, at least one amino acid, and less than 2, 3, 4, 5, 10, or 15 residues, in FR1 of the VL chain is other than the corresponding human residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived. In one embodiment, the amino acid residue at the N-terminal position of FR1 is mutated to be identical to the nonhuman antibody framework region.

In another embodiment, at least one amino acid, and less than 2, 3, 4, 5, 10, or 15 residues, in FR2 of the VL chain is other than the corresponding human residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived.

In yet another embodiment, at least one amino acid, and less than 2, 3, 4, 5, 10, or 15 residues, in FR3 of the VL is other than the corresponding human residue. One or more of such residues can, for example, be identical to the nonhuman antibody framework region from which the CDR sequences are derived. In another embodiment, the amino acid residue at Kabat position 87 is mutated to be identical to the nonhuman antibody

framework region. In yet another embodiment, the amino acid residues at Kabat positions 67 and 87 are mutated to be identical to the nonhuman antibody framework sequence. In yet another embodiment, the amino acid residues at Kabat positions 67, 73, and 87 of SEQ ID NO:7 are mutated to be identical to the nonhuman antibody framework sequence.

In other embodiments, the VL chain of the antibody has the sequence of SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10, or SEQ ID NO:11.

In one embodiment, the CDRs of the VH and VL acceptor framework sequences are selected to resemble the CDR sequences of a nonhuman (*e.g.*, murine) antibody sequence, where the nonhuman antibody binds integrin alpha-4 or a fragment thereof. In another embodiment, the sequences of the CDRs are selected to resemble the sequences of the CDRs of a non-human antibody that binds the B1 epitope of the VLA-4 α4 chain. In one embodiment, the CDRs are selected to resemble a murine monoclonal antibody, *e.g.*, HP1/2, HP2/1, HP2/4, L25, P4C2, or 21.6 (Pulido et al., J. Biol. Chem. 266:10241-10245, 1991; U.S. Patent No. 6,033,665). Modification can mean, *e.g.*, excision and insertion or alteration, *e.g.*, by directed mutagenesis.

In another aspect, the invention features an antibody, or antigen binding fragment thereof, including:

- an anti-VLA-4 VL chain described herein, *e.g.*, an anti-VLA-4 VL chain having CDR's from a donor anti-VLA-4 antibody, *e.g.*, an anti-VLA-4 antibody described herein, and a VL framework having LC framework regions 1, 2 and 3 from the sequence of, or having no more than 5, 10, or 15 differences from, a germline variable region sequence for the VL chain. In one embodiment, variable region 4 is a human consensus sequence; and

- an anti-VLA-4 VH chain described herein, *e.g.*, an anti-VLA-4 VL chain having CDRs from a donor anti-VLA-4 antibody, *e.g.*, an anti-VLA-4 antibody described herein, and a VL framework having LC framework regions 1, 2 and 3 from the sequence of, or having no more than 5, 10 or 15 differences from, a germline variable region sequence for the VL chain. In one embodiment, variable region 4 is a human consensus sequence.

In one embodiment, the antibody binds one or both of α4β1 and α4β7.

In another aspect, a VL or VH chain, or antibody, or fragment thereof, described herein is detectably labeled.

In yet another aspect, the invention features a vector containing DNA encoding an antibody heavy chain, or an α4 binding fragment thereof, described herein. In some embodiments, the DNA of the vector encodes a VH having the sequence of SEQ ID NO:3, SEQ ID NO:4, or SEQ ID NO:5.

In yet another aspect, the invention features a vector containing DNA encoding an antibody light chain, or an α4 binding fragment thereof, described herein. In some embodiments, the DNA of the vector encodes a VL chain having the sequence of SEQ ID NO:8, SEQ ID NO:9, SEQ ID NO:10 or SEQ ID NO:11.

In yet another aspect, the invention features a vector containing DNA encoding an antibody heavy chain, or an α4 binding fragment thereof, described herein and an antibody light chain, or an α4 binding fragment thereof, described herein.

In another aspect, the invention features a host cell containing a vector described herein, *e.g.*, one capable of expressing a heavy and/or light chain antibody or antibody fragment described herein.

In one aspect, the invention features a method of making a recombinant anti-α4 antibody, or an α4-binding fragment thereof, by providing a host cell transfected with (a) a DNA sequence encoding an antibody heavy chain described herein, or an α4-binding fragment thereof, and (b) a DNA sequence encoding an antibody light chain, or an α4-binding fragment thereof, and culturing the transfected cell to produce the recombinant anti-α4 antibody molecule or α4 binding fragment thereof. The DNA encoding the antibody heavy and light chains can be produced on the same vector or on different vectors.

In one aspect, the invention features a method of making a recombinant anti-α4 antibody, or an α4-binding fragment thereof, by providing a host cell transfected with (a) a DNA sequence encoding an antibody heavy chain, or an α4-binding fragment thereof, *e.g.*, where the DNA sequence has the sequence of SEQ ID NOs:3, 4, or 5, and (b) a DNA sequence encoding an antibody light chain, or an α4-binding fragment thereof, *e.g.*, wherein the DNA sequence has the sequence of SEQ ID NOs: 8, 9, 10, or 11, and culturing the transfected cell line to produce the recombinant anti-α4 antibody molecule or α4

binding fragment thereof. The DNA encoding the antibody heavy and light chains can be produced on the same vector or on different vectors.

In another aspect, the invention features a method of treating a disease or disorder mediated by an α4 integrin, *e.g.*, an α4β1 (VLA-4) or α4β7 integrin, by administering an α4 antibody or antibody fragment described herein, or a pharmaceutical composition containing the antibody or fragment, to a subject in need of such treatment. The subject can have or be at risk for developing, for example, inflammatory, immune, or autoimmune disorders (*e.g.*, inflammation of the central nervous system, such as multiple sclerosis, meningitis, neuromyelitis optica, neurosarcoidosis, CNS vasculitis, encephalitis, and transverse myelitis), tissue or organ graft rejection or graft-versus-host disease, acute CNS injury, such as stroke, traumatic brain injury (TBI), or spinal cord injury (SCI); chronic renal disease; allergy, *e.g.*, allergic asthma; type 1 diabetes mellitus; inflammatory bowel disorders, such as Crohn's disease, ulcerative colitis; myasthenia gravis; fibromyalgia; arthritic disorders, such as rheumatoid arthritis, psoriatic arthritis; inflammatory/immune skin disorders, such as psoriasis, vitiligo, dermatitis, lichen planus; systemic lupus erythematosus; Sjogren's Syndrome; hematological cancers, such as multiple myeloma, leukemia, lymphoma; solid cancers, such as sarcomas or carcinomas, *e.g.*, of the lung, breast, prostate, brain; and fibrotic disorders, such as pulmonary fibrosis, myelofibrosis, liver cirrhosis, mesangial proliferative glomerulonephritis, crescentic glomerulonephritis, diabetic nephropathy, and renal interstitial fibrosis.

In another aspect, the invention features a method of treating a patient by administering to the patient an α4-binding antibody or antibody fragment. In one embodiment, the patient has a cancer, such as a solid tumor or a hematological malignancy. For example, a patient treated with an α4-binding antibody or antibody fragment can have acute myelogenous leukemia (AML) or multiple myeloma (MM).

In another embodiment, the patient has an inflammatory disorder, such as multiple sclerosis, asthma (e.g., moderate to severe asthma), rheumatoid arthritis, diabetes, or Crohn's disease. In another embodiment, the composition is administered as a regimen. In yet another embodiment, the method further includes selecting a patient suitable for treatment with the composition. A patient suitable for treatment, for example, has

demonstrated a sign or symptom indicative of disease onset, such as a sign or symptom indicative of MS.

In yet another embodiment, the method further includes administering to the patient a second therapeutic agent, such as, a chemotherapeutic agent, a thrombolytic agent, a neuroprotective agent, an anti-inflammatory agent, a steroid, a cytokine, or a growth factor.

In one embodiment, the patient is administered a humanized anti-VLA-4 antibody, or fragment thereof, described herein, such as HuHP1/2, H1L1, H1L2 or H1L3.

In one embodiment, the composition containing an α4-binding antibody is administered as a regimen, such at regular intervals. For example, the composition can be administered once daily, weekly or monthly; once per week, twice per week, three times per week, four times per week or more; or once every two weeks, once every three weeks, once every four weeks or more.

In one embodiment, dosing can be adjusted according to a patient's rate of clearance of a prior administration of anti- α4 antibody. For example, in one embodiment, a patient will not be administered a second or follow-on dose before the level of anti-α4 antibodies in the patient's system has dropped below a pre-determined level. In one embodiment, a sample from a patient (e.g., plasma, serum, blood or urine sample) is assayed for the presence of anti-α4 antibodies, and if the level of anti-α4 antibodies is above a pre-determined level, the patient will not be administered a second or follow-on dose. If the level of anti-α4 antibodies in the patient's system is below a pre-determined level, then the patient is administered a second or follow-on dose.

In one embodiment, the composition is administered continuously, *e.g.*, over a period of more than 30 minutes but less than 1, 2, 4, or 12 hours. The composition containing the antibody and the second agent can be administered by any appropriate method, *e.g.*, subcutaneously, intramuscularly, or intravenously.

In some embodiments, each of the antibody and the second agent is administered at the same dose as each is prescribed for monotherapy. In other embodiments, the antibody is administered at a dosage that is equal to or less than an amount required for

efficacy if administered alone. Likewise, the second agent can be administered at a dosage that is equal to or less than an amount required for efficacy if administered alone.

Another aspect featured in the disclosure is a method of evaluating a patient by determining if the patient meets a preselected criterion, and if the patient meets the preselected criterion approving, providing, prescribing, or administering a VLA-4 binding antibody formulation described herein to the patient. In one embodiment, the preselected criterion is the failure of the patient to adequately respond to a prior alternate therapeutic treatment or regimen, *e.g.*, for treatment of MS. In another embodiment, the preselected criterion is the absence of any signs or symptoms of progressive multifocal leukoencephalopathy (PML), or the absence of any diagnosis of PML. In some cases, the selection is based on the absence of a risk factor for PML, for example, the subject does not test positive for JC virus DNA or does not test positive for JC virus antibodies. In another embodiment, the criterion is as described in PCT/US07/75577 (published as WO2008/021954), hereby incorporated by reference, which describes methods and systems for drug distribution and for providing drugs to patients.

In another aspect, a method of distributing a composition described herein is provided. The composition contains an alpha-4 binding antibody. The method includes providing a recipient (*e.g.*, an end user, patient, physician, retail or wholesale pharmacy, distributor, or pharmacy department at a hospital, nursing home clinic or HMO) with a package containing sufficient unit dosages of the drug to treat a patient for at least 6, 12, 24, 36, or 48 months. In another aspect, the invention features a method of evaluating the quality of a package or lot of packages (*e.g.*, to determine if it has expired) of a composition described herein containing an alpha-4 binding antibody. The method includes evaluating whether the package has expired. The expiration date is at least 6, 12, 24, 36, or 48 months, e.g., greater than 24 or 36 months, from a preselected event, such as manufacturing, assaying, or packaging. In some embodiments, a decision or step is taken as a result of the analysis. For example, depending on the right analysis, the antibody in the package is used or discarded, classified, selected, released or withheld, shipped, moved to a new location, released into commerce, sold, or offered for sale, withdrawn

from commerce or no longer offered for sale, depending on whether the product has expired.

In another aspect, the invention features a package containing at least two unit doses of an aqueous composition containing an α4 binding antibody. In one embodiment, all of the unit doses contain the same amount of antibody, and in other embodiments there are unit dosages of two or more strengths, or two or more different formulations, *e.g.*, having different strengths or release properties.

In another aspect, the invention includes a method of instructing a recipient on the administration of a formulation containing α4 binding antibody. The method includes instructing the recipient (*e.g.*, an end user, patient, physician, retail or wholesale pharmacy, distributor, or pharmacy department at a hospital, nursing home clinic or HMO) that the antibody should be administered to a patient according to a regimen described herein. The method can also include instructing the recipient that the antibody should be administered prior to the expiration date. The expiration date is at least 6, 12, 24, 36, or 48 months, e.g., greater than 24 or 36 months, from a preselected event, such as manufacturing, assaying, or packaging. In one embodiment, the recipient also receives a supply of the antibody, *e.g.*, a supply of unit dosages of the antibody.

In another aspect, the invention features a method of making an antibody which includes CDRs from a donor antibody, such as a non-human, *e.g.*, a murine antibody, and one or both heavy and light chain variable region frameworks derived from human germline variable region framework region or regions. The method includes one or both of 1 and 2, where 1 and 2 are as follows:

1. identifying or selecting a stable human acceptor heavy chain variable framework which has the same residues as the non-human donor heavy chain at one or more of the residues in one or more of a), b) and c):

a) VH Kabat # 2, 4, 24, 26, 27, 29, 36, 38, 46, 47, 48, 49, 66, 67, 69, 71, 78, 93, and 94, which, without being bound by theory, are believed to be important for maintaining CDR conformations;

b) VH Kabat # 1, 2, 27, 28, 30, 43, 66, 68, 70, 72, 73, 74, and 75 which, without being bound by theory, are believed to be able to interact with antigen; and

c) VH Kabat # 37, 39, 44, 45, 47, 91, 93 and 103, which, without being bound by theory, are believed to be important for VH/VL interface integrity; and

2. identifying or selecting a stable acceptor light chain variable framework which has the same residues as the donor light chain at one or more of the residues in one or more of a), b) and c):

a) VL Kabat # 2, 4, 38, 43, 44, 48, 58, 64, 71, and 73, which without being bound by theory, are believed to be important for maintaining CDR conformations;

b) VL Kabat # 1, 2, 49, 57, 60, 63, 65, 66, 67, 68, 69, and 70 which without being bound by theory, are believed to potentially be able to interact with antigen; and

c) VL Kabat # 36, 38, 43, 44, 46, 49, 87, and 98, which without being bound by theory, are believed to be important for VH/VL interface integrity;

3. providing a variable region having donor CDRs and the selected germline framework having matched residues identified in 1 or 2, such as by selecting a germline sequence and further backmutating additional residues identified in 1 or 2 of the germline to murine sequence so as to further maximize matching at the residues identified in 1 and 2; and

4. evaluating each matched position, such as by 3D structural analysis or modeling, and if a position meets a predetermined standard for risk of, for example, interfering with CDR conformations, antigen interactions or VH/VL interface integrity, then reintroducing an equivalent murine residue, or a common human antibody residue, compatible with antibody structure.

In one embodiment, at least 3, 4 or 5 of the residues identified in (1.a) are matched. For example, in one embodiment, residues 24, 29, or 94 are matched.

In one embodiment, at least 3, 4 or 5 of the residues identified in (1.b) are matched. For example, in one embodiment, residues 1, 73, or 75 are matched.

In one embodiment, at least 3, 4 or 5 of the residues identified in (1.c) are matched. For example, in one embodiment, residues 37, 93, or 103 are matched.

In one embodiment, at least 3, 4 or 5 of the residues identified in (2.a) are matched. For example, in one embodiment, residues 2, 71 and 73 are matched.

In one embodiment, at least 3, 4 or 5 of the residues identified in (2.b) are matched. For example, in one embodiment, residues 1, 68, or 70 are matched.

In one embodiment, at least 3, 4 or 5 of the residues identified in (2.c) are matched. For example, in one embodiment, residues 46, 87, or 98 are matched.

In one embodiment, residue 6 in (1.a), residue 2 in (1.b), and residue 4 in (1.c) are matched.

In another embodiment, residue 4 in (2.a), residue 2 in (2.b), and residue 4 in (2.c) are matched.

In one embodiment, the heavy chain germline sequence is of VH3, VH1 and VH5 germline class. In another embodiment, the light chain germline sequence is a Vkappa or Vlambda sequence.

The term "treating" refers to administering a therapy in an amount, manner, and/or mode effective to improve a condition, symptom, or parameter associated with a disorder or to prevent progression of a disorder, to either a statistically significant degree or to a degree detectable to one skilled in the art. An effective amount, manner, or mode can vary depending on the subject and may be tailored to the subject.

An "α4 binding antibody" refers to an antibody that binds to the α4 subunit of the VLA-4 (α4β1) integrin, and at least partially inhibits an activity of VLA-4, particularly a binding activity of a VLA-4 integrin or a signaling activity, *e.g.*, ability to transduce a VLA-4 mediated signal. For example, a VLA-4 binding antibody may inhibit binding of VLA-4 to a cognate ligand of VLA-4, *e.g.*, a cell surface protein such as VCAM-1 (Vascular Cell Adhesion Molecule-1), or to an extracellular matrix component, such as fibronectin or osteopontin. An alpha-4 binding antibody may bind to both α4β1 or α4β7. Typically, the antibody binds to the B1 epitope of α4. An α4 binding antibody may bind to VLA-4 with a K_d of less than about 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}, 10^{-10}, or 10^{-11} M.

As used herein, the term "antibody" refers to a protein that includes at least one immunoglobulin variable region, *e.g.*, an amino acid sequence that provides an immunoglobulin variable domain or immunoglobulin variable domain sequence. For example, an antibody can include a heavy (H) chain variable region (abbreviated herein as VH), and a light (L) chain variable region (abbreviated herein as VL). In another example, an antibody includes two heavy (H) chain variable regions and two light (L)

chain variable regions. The light chains of the immunoglobulin may be of types kappa or lambda. In one embodiment, the antibody is glycosylated. An antibody can be functional for antibody dependent cytotoxicity and/or complement-mediated cytotoxicity, or may be non-functional for one or both of these activities.

The VH and VL regions can be further subdivided into regions of hypervariability, termed "complementarity determining regions" ("CDR"), interspersed with regions that are more conserved, termed "framework regions" (FR). The extent of the FRs and CDRs has been precisely defined (see, Kabat, E.A., *et al.* (1991) Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242; and Chothia, C. *et al.* (1987) J. Mol. Biol. 196:901-917). Kabat definitions are used herein. Each VH and VL is typically composed of three CDRs and four FRs, arranged from amino-terminus to carboxyl-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4.

An "immunoglobulin domain" refers to a domain from the variable or constant domain of immunoglobulin molecules. Immunoglobulin domains typically contain two β-sheets formed of about seven β-strands, and a conserved disulphide bond (see, *e.g.*, A. F. Williams and A. N. Barclay (1988) Ann. Rev. Immunol. 6:381-405).

As used herein, an "immunoglobulin variable domain sequence" refers to an amino acid sequence that can form the structure of an immunoglobulin variable domain. For example, the sequence may include all or part of the amino acid sequence of a naturally-occurring variable domain. For example, the sequence may omit one, two or more N- or C-terminal amino acids, internal amino acids, may include one or more insertions or additional terminal amino acids, or may include other alterations. In one embodiment, a polypeptide that includes an immunoglobulin variable domain sequence can associate with another immunoglobulin variable domain sequence to form a target binding structure (or "antigen binding site"), *e.g.*, a structure that interacts with VLA-4.

The VH or VL chain of the antibody can further include all or part of a heavy or light chain constant region, to thereby form a heavy or light immunoglobulin chain, respectively. In one embodiment, the antibody is a tetramer of two heavy

immunoglobulin chains and two light immunoglobulin chains. The heavy and light immunoglobulin chains can be connected by disulfide bonds. The heavy chain constant region typically includes three constant domains, CH1, CH2 and CH3. The light chain constant region typically includes a CL domain. The variable region of the heavy and light chains contains a binding domain that interacts with an antigen. The constant regions of the antibodies typically mediate the binding of the antibody to host tissues or factors, including various cells of the immune system (*e.g.*, effector cells) and the first component (Clq) of the classical complement system.

The term "immunoglobulin" comprises various broad classes of polypeptides that can be distinguished biochemically. Those skilled in the art will appreciate that heavy chains are classified as gamma, mu, alpha, delta, or epsilon (γ, μ, α, δ, ε) with some subclasses among them (*e.g.*, γ1- γ4). It is the nature of this chain that determines the "class" of the antibody as IgG, IgM, IgA IgD, or IgE, respectively. The immunoglobulin subclasses (isotypes) *e.g.*, IgG1, IgG2, IgG3, IgG4, IgA1, etc. are well characterized and are known to confer functional specialization. Modified versions of each of these classes and isotypes are readily discernable to the skilled artisan in view of the instant disclosure and, accordingly, are within the scope of the instant invention. All immunoglobulin classes are clearly within the scope of the present invention. Light chains are classified as either kappa or lambda (κ, λ). Each heavy chain class may be bound with either a kappa or lambda light chain.

The term "antigen-binding fragment" of a full length antibody refers to one or more fragments of a full-length antibody that retain the ability to specifically bind to a target of interest, *e.g.*, VLA-4. Examples of binding fragments encompassed within the term "antigen-binding fragment" of a full length antibody include (i) a Fab fragment, a monovalent fragment consisting of the VL, VH, CL and CH1 domains; (ii) a $F(ab')_2$ fragment, a bivalent fragment including two Fab fragments linked by a disulfide bridge at the hinge region; (iii) an Fd fragment consisting of the VH and CH1 domains; (iv) an Fv fragment consisting of the VL and VH domains of a single arm of an antibody, (v) a dAb fragment (Ward *et al.*, (1989) Nature 341:544-546), which consists of a VH domain; and

(vi) an isolated complementarity determining region (CDR) that retains functionality. Furthermore, although the two domains of the Fv fragment, VL and VH, are coded for by separate genes, they can be joined, using recombinant methods, by a synthetic linker that enables them to be made as a single protein chain in which the VL and VH regions pair to form monovalent molecules known as single chain Fv (scFv). See *e.g.*, Bird *et al.* (1988) Science 242:423-426; and Huston *et al.* (1988) Proc. Natl. Acad. Sci. USA 85:5879-5883.

In some embodiments, the above-described antibodies are pegylated.

In some embodiments, the above-described antibodies or fragments thereof are multispecific. In further embodiments, the above-described antibodies or fragments thereof are monovalent or bispecific.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 displays the three sequence variants of HP1/2 heavy chain to a human heavy germline IGHV1-f. The lower case letters above the sequence represent insertions according to the Kabat numbering scheme.

FIG. 2 displays the four sequence variants of HP1/2 light chain to a germline IGKV4-1 antibody sequence (Design L0, L1, and L2) or human kappa germline engineered AAH7033.1 antibody sequence (Design L3). The lower case letters above the sequence represent insertions according to the Kabat numbering scheme.

FIG. 3 is a graph depicting the results of ELISA assays.

FIG. 4 is a graph depicting the results of ELISA assays.

FIG. 5 is the amino acid sequence of an IgG4 Fc (hinge + CH2 + CH3 domain) (SEQ ID NO: 14). The hinge region is depicted in bold, and the CH3 domain is underlined. The boxed "S" is Ser228. The circled "N" is Asn297.

FIG. 6 is a graph depicting flow cytometry data from binding of HuHP1/2 to various tumor cell lines. "HP1/2" refers to humanized HP1/2.

FIGs. 7A-7C is a panel of graphs depicting inhibition of binding of AML cell lines to fibronectin or VCAM1-Ig coated wells by HuHP1/2. FIG. 7A depicts inhibition of binding of HL60 and KG1 cells to FN-coated wells. FIG. 7B depicts inhibition of binding of KG1 cells to VCAM1-Ig-coated wells. FIG. 7C depicts inhibition of binding of HL60 cells to FN- and VCAM1-Ig-coated wells when incubated with 20 μg/mL HuHP1/2 (Solid bars). Clear bars indicate percent cell adhesion in the presence of an isotype control. "HP1/2" refers to humanized HP1/2.

FIGs. 8A-8C make up a panel of graphs depicting inhibition of binding of MM cell lines to fibronectin or VCAM1-Ig coated wells by HuHP1/2. FIG. 8A depicts inhibition of binding of U266 and H929 cells to FN-coated wells. FIG. 8B depicts inhibition of binding of U266 and H929 cells to VCAM1-Ig-coated wells. FIG. 8C depicts inhibition of binding of U266 cells to FN- and VCAM1-Ig-coated wells when incubated with 20 μg/mL HuHP1/2 (Solid bars). Clear bars indicate percent cell adhesion in the presence of an isotype control. "HP1/2" refers to humanized HP1/2.

FIGs. 9A-9C makes up a panel of graphs depicting inhibition of binding of CLL cell lines to fibronectin or VCAM1-Ig coated wells by HuHP1/2. FIG. 9A depicts inhibition of binding of Mec1 and JM1 cells to FN-coated wells. FIG. 9B depicts inhibition of binding of Mec1 and JM1 cells to VCAM1-Ig-coated wells. FIG. 9C depicts inhibition of binding of Mec1 cells to FN- and VCAM1-Ig-coated wells when incubated with 20 μg/mL HuHP1/2 (Solid bars). Clear bars indicate percent cell adhesion in the presence of an isotype control. "HP1/2" refers to humanized HP1/2.

DETAILED DESCRIPTION

Antibodies against VLA-4 have been demonstrated to be useful in treating disease. For example, natalizumab (Tysabri®), an anti-VLA-4 antibody is used for treating relapsing multiple sclerosis and Crohn's disease. However, for treatment of certain conditions, for example acute conditions such as spinal cord injury (SCI) or traumatic brain injury (TBI), or treatments that are administered in a finite number such as treatment of

cancer, it may be advantageous to treat with an anti-VLA-4 antibody that binds with an affinity different than natalizumab, e.g., a higher affinity. In addition, treatment with anti-VLA-4 antibodies is associated with a rare but sometimes fatal disorder, progressive multifocal leukoencephalopathy (PML), for which a part of the treatment requires removal of antibody from the treated subject, for example using plasma exchange or immunoabsorption. Because of the need to remove antibody, it is also desirable to balance the advantages of an antibody that has increased affinity for VLA-4 with the disadvantage of an antibody that binds so tightly as to make removal difficult or to create a risk associated with a slow turnover rate. Such antibodies may also be useful for treating conditions such as multiple sclerosis in that less frequent treatment may be required or administration by means other than infusion may be more efficient. Enabling treatment with lower doses may also lower the risk of adverse events such as PML. Accordingly, the present invention provides antibodies having such desirable properties.

The invention is based at least in part on the unexpected characteristics of newly designed humanized α4-binding antibodies that have a binding affinity for α4 that is 10-fold higher than that of the anti-α4 antibody natalizumab.

Alpha-4 binding antibodies, and fragments thereof, are provided where the variable light chain (VL) and variable heavy chain (VH) frameworks have acceptor sequences constructed from germline or germline engineered antibody sequences, such as IGKV4-1 or geAAH70335.1 or IGHV1-f antibodies. The CDR sequences are derived from nonhuman anti-α4 binding antibodies such as the anti-VLA-4 antibody HP1/2. Antibodies described herein can have an increase of at least 1.5, 2.0, 2.5, 3.0 fold in affinity, *e.g.*, relative to its murine parent. In one embodiment, the increase in affinity is at least 1.5, 2.0, 2.5, 3.0 fold but is respectively, less than 25, 20, or 15 fold.

Pharmaceutical Compositions

An α4 binding agent, such as a VLA-4 binding antibody, can be formulated as a pharmaceutical composition. Typically, a pharmaceutical composition includes a pharmaceutically acceptable carrier. As used herein, "pharmaceutically acceptable

carrier" includes any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like that are physiologically compatible.

A "pharmaceutically acceptable salt" refers to a salt that retains the desired biological activity of the parent compound and does not impart any undesired toxicological effects (see *e.g.*, Berge, S.M., *et al.* (1977) J. Pharm. Sci. 66:1-19). Examples of such salts include acid addition salts and base addition salts. Acid addition salts include those derived from nontoxic inorganic acids, such as hydrochloric, nitric, phosphoric, sulfuric, hydrobromic, hydroiodic, and the like, as well as from nontoxic organic acids such as aliphatic mono- and dicarboxylic acids, phenyl-substituted alkanoic acids, hydroxy alkanoic acids, aromatic acids, aliphatic and aromatic sulfonic acids and the like. Base addition salts include those derived from alkaline earth metals, such as sodium, potassium, magnesium, calcium and the like, as well as from nontoxic organic amines, such as N,N'-dibenzylethylenediamine, N-methylglucamine, chloroprocaine, choline, diethanolamine, ethylenediamine, procaine and the like.

The antibody compositions described herein can be formulated according to methods known in the art. Pharmaceutical formulation is a well-established art, and is further described in Gennaro (ed.), Remington: The Science and Practice of Pharmacy, 20th ed., Lippincott, Williams & Wilkins (2000) (ISBN: 0683306472); Ansel *et al.*, Pharmaceutical Dosage Forms and Drug Delivery Systems, 7th Ed.., Lippincott Williams & Wilkins Publishers (1999) (ISBN: 0683305727); and Kibbe (ed.), Handbook of Pharmaceutical Excipients American Pharmaceutical Association, 3rd ed. (2000) (ISBN: 091733096X).

In one embodiment, the α4 antibody can be formulated with excipient materials, such as sodium chloride, sodium dibasic phosphate heptahydrate, sodium monobasic phosphate, and polysorbate 80. In another embodiment, the α4 antibody can be formulated in a citrate buffer, *e.g.*, at pH 5, 5.5, 6, 6.5, 7, or 7.5. In yet another embodiment, the α4 antibody can be formulated in a solution including 2, 4, 5, 6, 8, 10,

12, 14, or 15 % sucrose. It can be provided, for example, in a buffered solution at a concentration of about 20 mg/ml and can be stored at 2-8°C.

Pharmaceutical compositions may also be in a variety of other forms. These include, for example, liquid, semi-solid and solid dosage forms, such as liquid solutions (*e.g.,* injectable and infusible solutions), dispersions or suspensions, tablets, pills, powders, liposomes and suppositories. The form can depend on the intended mode of administration and therapeutic application. Typically, compositions for the agents described herein are in the form of injectable or infusible solutions.

Such compositions can be administered by a parenteral mode (*e.g.*, intravenous, subcutaneous, intraperitoneal, or intramuscular injection). The phrases "parenteral administration" and "administered parenterally" as used herein mean modes of administration other than enteral and topical administration, usually by injection, and include, without limitation, intravenous, intramuscular, intraarterial, intrathecal, intracapsular, intraorbital, intracardiac, intradermal, intraperitoneal, transtracheal, subcutaneous, subcuticular, intraarticular, subcapsular, subarachnoid, intraspinal, epidural and intrasternal injection and infusion.

Pharmaceutical compositions typically must be sterile and stable under the conditions of manufacture and storage. A pharmaceutical composition can also be tested to insure it meets regulatory and industry standards for administration.

The composition can be formulated as a solution, microemulsion, dispersion, liposome, or other ordered structure suitable to high drug concentration. Sterile injectable solutions can be prepared by incorporating an agent described herein in the required amount in an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating an agent described herein into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, typical methods of preparation are vacuum drying and freeze-drying that yields a powder of an agent described herein plus any additional desired ingredient from a previously

sterile-filtered solution thereof. The proper fluidity of a solution can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. Prolonged absorption of injectable compositions can be brought about by including in the composition an agent that delays absorption, for example, monostearate salts and gelatin.

Administration

An α4 binding antibody can be administered to a subject, *e.g.*, a human subject, by a variety of methods. For many applications, the route of administration is one of: intravenous injection or infusion, subcutaneous injection, or intramuscular injection. An α4 binding antibody can be administered as a fixed dose, or in a mg/kg dose. The antibody can be administered intravenously (IV) or subcutaneously (SC). For example, the antibody can be administered at a fixed unit dose of between about 50-600 mg IV, *e.g.*, every 4 weeks, or between about 50-100 mg SC (*e.g.*, 75 mg), *e.g.*, at least once a week (*e.g.*, twice a week). In one embodiment, the antibody is administered IV at a fixed unit dose of 50 mg, 60 mg, 80 mg, 100 mg, 120 mg, 130 mg, 140 mg, 150 mg, 160 mg, 180 mg, 200 mg, 300 mg, 400 mg, 500 mg, or 600 mg or more. Administration of the IV dose can be once or twice or three times or more per week, or once every two, three, four, or five weeks, or less frequently.

In one embodiment, the antibody is administered SC at a fixed unit dose of 50 mg, 60 mg, 70 mg, 75 mg, 80 mg, 100 mg, or 120 mg or more. Administration of the SC dose can be once or twice or three times or more per week, or once every two, three, four, or five weeks, or less frequently.

An anti-α4 antibody can also be administered in a bolus at a dose of between about 1 and 10 mg/kg, *e.g.*, about 6.0 mg/kg, 4.0 mg/kg, 3.0 mg/kg, 2.0 mg/kg, 1.0 mg/kg. Modified dose ranges include a dose that is less than about 600 mg/subject, about 400 mg/subject, about 300 mg/subject, about 250 mg/subject, about 200 mg/subject, or about 150 mg/subject, typically for administration every fourth week or once a month.

The α4 binding antibody can be administered, for example, every three to five weeks, *e.g.*, every fourth week, or monthly.

Dosing can be adjusted according to a patient's rate of clearance of a prior administration of anti-α4 antibody. For example, a patient may not be administered a second or follow-on dose before the level of anti-α4 antibodies in the patient's system has dropped below a pre-determined level. In one embodiment, a sample from a patient (e.g., plasma, serum, blood, urine, or cerebrospinal fluid (CSF)) is assayed for the presence of anti-α4 antibodies, and if the level of anti-α4 antibodies is above a pre-determined level, the patient will not be administered a second or follow-on dose. If the level of anti-α4 antibodies in the patient's system is below a pre-determined level, then the patient is administered a second or follow-on dose. A patient whose anti-α4 levels are determined to be too high (above the pre-determined level) can be tested again after one or two or three days, or a week, and if the level of anti-α4-antibody in the patient samples has dropped below the pre-determined level, the patient may be administered a second or follow-on dose of antibody.

The dose can also be chosen to reduce or avoid production of antibodies against the α4 binding antibody, to achieve greater than 40, 50, 70, 75, or 80% saturation of the α4 subunit, to achieve less than 80, 70, 60, 50, or 40% saturation of the α4 subunit, or to prevent an increase in the level of circulating white blood cells

In certain embodiments, the active agent may be prepared with a carrier that will protect the compound against rapid release, such as a controlled release formulation, including implants, and microencapsulated delivery systems. Biodegradable, biocompatible polymers can be used, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, collagen, polyorthoesters, and polylactic acid. Many methods for the preparation of such formulations are patented or generally known. *See, e.g.*, Controlled Drug Delivery (Drugs and the Pharmaceutical Sciences), Second Edition, J. Robinson and V. H. L. Lee, eds., Marcel Dekker, Inc., New York, 1987.

Pharmaceutical compositions can be administered with a medical device. For example, pharmaceutical compositions can be administered with a needleless hypodermic injection device, such as the devices disclosed in U.S. Patent Nos. 5,399,163; 5,383,851; 5,312,335; 5,064,413; 4,941,880; 4,790,824; or 4,596,556. Examples of well-known implants and modules are discussed in, *e.g.*, U.S. Patent No. 4,487,603, which discloses an implantable micro-infusion pump for dispensing medication at a controlled rate; U.S. Patent No. 4,486,194, which discloses a therapeutic device for administering medicaments through the skin; U.S. Patent No. 4,447,233, which discloses a medication infusion pump for delivering medication at a precise infusion rate; U.S. Patent No. 4,447,224, which discloses a variable flow implantable infusion apparatus for continuous drug delivery; U.S. Patent No. 4,439,196, which discloses an osmotic drug delivery system having multi-chamber compartments; and U.S. Patent No. 4,475,196, which discloses an osmotic drug delivery system. Of course, many other such implants, delivery systems, and modules are also known.

This disclosure also features a device for administering a first and second agent. The device can include, for example, one or more housings for storing pharmaceutical preparations, and can be configured to deliver unit doses of the first and second agent. The first and second agents can be stored in the same or separate compartments. For example, the device can combine the agents prior to administration. It is also possible to use different devices to administer the first and second agent.

Dosage regimens are adjusted to provide the desired response, such as a therapeutic response or a combinatorial therapeutic effect. Generally, any combination of doses (either separate or co-formulated) of the VLA-4 binding agent and the second agent can be used in order to provide a subject with both agents in bioavailable quantities.

Dosage unit form or "fixed dose" as used herein refers to physically discrete units suited as unitary dosages for the subjects to be treated; each unit contains a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier and optionally in association with the other agent.

A pharmaceutical composition may include a "therapeutically effective amount" of an agent described herein. Such effective amounts can be determined based on the combinatorial effect of the administered first and second agent. A therapeutically effective amount of an agent may also vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of the compound to elicit a desired response in the individual, such as amelioration of at least one disorder parameter, *e.g.*, a multiple sclerosis parameter, or amelioration of at least one symptom of the disorder, *e.g.*, a symptom of multiple sclerosis, such as muscle atrophy, ataxia, and tremors. A therapeutically effective amount is also one in which any toxic or detrimental effects of the composition are outweighed by the therapeutically beneficial effects.

Devices and Kits

Formulations containing an antibody described herein can be administered with a medical device. The device can be designed with features such as portability, room temperature storage, and ease of use so that it can be used in emergency situations, such as by an untrained subject or by emergency personnel in the field, removed to medical facilities and other medical equipment. The device can include, for example, one or more housings for storing pharmaceutical preparations that include an α4-binding antibody, and can be configured to deliver one or more unit doses of the agent.

For example, the pharmaceutical composition can be administered with a transcutaneous delivery device, such as a syringe, including a hypodermic or multichamber syringe. Other suitable delivery devices include stents, catheters, microneedles, and implantable controlled release devices. The composition can be administered intravenously with standard IV equipment, including, *e.g.*, IV tubings, with or without in-line filters. In certain embodiments, the device will be a syringe for use in SC or IM administration.

Pharmaceutical compositions can be administered with medical devices. For example, pharmaceutical compositions can be administered with a needleless hypodermic injection device, such as the devices disclosed in U.S. Patent Nos. 5,399,163; 5,383,851; 5,312,335; 5,064,413; 4,941,880; 4,790,824; or 4,596,556. Examples of well-known implants and modules are described in, *e.g.*, U.S. Patent No. 4,487,603, which discloses

an implantable micro-infusion pump for dispensing medication at a controlled rate; U.S. Patent No. 4,486,194, which discloses a therapeutic device for administering medicants through the skin; U.S. Patent No. 4,447,233, which discloses a medication infusion pump for delivering medication at a precise infusion rate; U.S. Patent No. 4,447,224, which discloses a variable flow implantable infusion apparatus for continuous drug delivery; U.S. Patent No. 4,439,196, which discloses an osmotic drug delivery system having multi-chamber compartments; and U.S. Patent No. 4,475,196, which discloses an osmotic drug delivery system. The therapeutic composition can also be in the form of a biodegradable or nonbiodegradable sustained release formulation for subcutaneous or intramuscular administration. Methods for such compositions are known in the art. Continuous administration can also be achieved using an implantable or external pump. The administration can also be conducted intermittently, such as by single daily injection, or continuously at a low dose, such as in a sustained release formulation. The delivery device can be modified to be optimally suited for administration of an α4-binding antibody. For example, a syringe can be siliconized to an extent that is optimal for storage and delivery of the antibody. Of course, many other such implants, delivery systems, and modules are also known.

This disclosure also features a device for administering a first and second agent (*e.g.*, an antibody and a second agent). The device can include, for example, one or more housings for storing pharmaceutical preparations, and can be configured to deliver unit doses of the first and second agent. The first and second agents can be stored in the same or separate compartments. In one embodiment, the device combines the agents prior to administration. In some embodiments, the first and second agents are administered by different devices.

An α4-binding antibody can be provided in a kit. In one embodiment, the kit includes (a) a container that contains a composition that includes a high concentration of VLA-4-binding antibody, optionally (b) a container that contains a composition that includes a second agent, and optionally (c) informational material. The informational material can be descriptive, instructional, marketing or other material that relates to the

methods described herein and/or the use of the agents for therapeutic benefit. In one embodiment, the kit also includes a second agent. For example, the kit includes a first container that contains a composition that includes the α4-binding antibody, and a second container that includes the second agent.

The informational material of the kits is not limited in its form. In one embodiment, the informational material can include information about production of the antibody, concentration, date of expiration, batch or production site information, and so forth. In one embodiment, the informational material relates to methods of administering the α4-binding antibody, *e.g.*, in a suitable dose, dosage form, or mode of administration (*e.g.*, a dose, dosage form, or mode of administration described herein), to treat a subject who has an acute disorder such as a spinal cord injury or traumatic brain injury, or an inflammatory disease (*e.g.*, MS), or who is at risk for experiencing an episode associated with an inflammatory disease. The information can be provided in a variety of formats, including printed text, computer readable material, video recording, or audio recording, or information that provides a link or address to substantive material.

In addition to the agent, the composition in the kit can include other ingredients, such as a solvent or buffer, a stabilizer, or a preservative. The agent can be provided in any form, *e.g.*, liquid, dried or lyophilized form, and substantially pure and/or sterile. When the agents are provided in a liquid solution, the liquid solution typically is an aqueous solution. When the agents are provided as a dried form, reconstitution generally is by the addition of a suitable solvent. The solvent, *e.g.*, sterile water or buffer, can optionally be provided in the kit.

The kit can include one or more containers for the composition or compositions containing the agents. In some embodiments, the kit contains separate containers, dividers or compartments for the composition and informational material. For example, the composition can be contained in a bottle, vial, or syringe, and the informational material can be contained in a plastic sleeve or packet. In other embodiments, the separate elements of the kit are contained within a single, undivided container. For example, the composition is contained in a bottle, vial or syringe that has attached thereto the informational material in the form of a label. In some embodiments, the kit includes a

plurality (*e.g.*, a pack) of individual containers, each containing one or more unit dosage forms (*e.g.*, a dosage form described herein) of the agents. The containers can include a combination unit dosage, *e.g.*, a unit that includes both the α4 binding antibody and the second agent, such as in a desired ratio. For example, the kit can include a plurality of syringes, ampoules, foil packets, blister packs, or medical devices each containing, for example, a single combination unit dose. The containers of the kits can be air tight, waterproof (*e.g.*, impermeable to changes in moisture or evaporation), and/or light-tight.

The kit optionally includes a device suitable for administering the composition, *e.g.*, a syringe or other suitable delivery device. The device can be provided pre-loaded with one or both of the agents or can be empty but suitable for loading.

Oncology

The α4-binding antibodies and methods described herein can be used to treat cancer, including solid cancers and hematological malignancies. Exemplary solid cancers include sarcomas and carcinomas, such as of the lung, breast, pancreas, colon, prostate, bladder and brain. Hemotological malignancies include cancers such as multiple myeloma, leukemia, and lymphoma.

Methods are provided for treating a patient having a hematological malignancy with a composition containing an α4-binding antibody, such as anti-VLA-4 antibody described herein. Hematological malignancies are cancers of the body's blood-forming and immune systems. Cancers of this type affect the blood, bone marrow, and/or lymph nodes. Hematological malignancies include leukemias, such as acute lymphoblastic leukemia (ALL), acute myelogenous leukemia (AML), chronic myelogenous leukemia (CML), chronic lymphocytic leukemia (CLL), acute promyelocytic leukemia, acute erythroleukemia, and hairy cell leukemia (HCL); lymphomas, such as Hodgkin's disease and Non-Hodgkin's lymphoma; and multiple myeloma; Waldenstrom's macroblobulinemia; myelodysplastic syndrome (MDS) (which can culminate in AML); a myeloproliferative disease, such as polycythemia vera (also called PV, PCV or

polycythemia rubra vera (PRV)), Essential thrombocytosis (ET), myelofibrosis, heavy chain disease; and amyloid due to light-chain disease.

Patients having a hematological malignancy may be identified by analysis of blood count and blood film by, for example, light microscopy, which is useful for identifying malignant cells. A biopsy, such as from bone marrow, can also be used to identify malignant cells, and a biopsy from a lymph node can be useful for identifying a lymphadenopathy.

An α4-binding antibody (e.g., a humanized anti-VLA-4 antibody, such as HuHP1/2, H1L0, H1L1, H1L2 or H1L3) is useful for the treatment of a leukemia, such as AML. Leukemias are cancers that originate in the bone marrow, where the malignant cells are white blood cells (leukocytes). AML (also called acute myelocytic leukemia, acute myeloblastic leukemia, acute granulocytic leukemia, and acute nonlymphocytic leukemia) is a malignancy that arises in either granulocytes or monocytes. AML is characterized by the uncontrolled, exaggerated growth and accumulation of cells called leukemic blasts, which fail to function as normal blood cells, and the blockade of the production of normal marrow cells, leading to a deficiency of red cells (anemia), and platelets (thrombocytopenia) and normal white cells (especially neutrophils, *i.e.*, neutropenia) in the blood.

All subtypes of AML are suitable for treatment with a VLA-4 binding antibody. The subtypes of AML are classified based on the stage of development myeloblasts have reached at the time of diagnosis. The categories and subsets allow the physician to decide what treatment works best for the cell type and how quickly the disease may develop. The subsets are: M0, myeloblastic, on special analysis; M1, Myeloblastic, without maturation; M2, Myeloblastic, with maturation; M3, Promyelocytic; M4, Myelomonocytic; M5, Monocytic; M6, Erythroleukemia; and M7, Megakaryocytic. A VLA-4 antibody can be administered with a secondary agent that is particularly suited to the subtype of AML. For example, acute promyelocytic leukemia (APL) and acute monocytic leukemia are subtypes of AML that need different treatment than other subtypes of AML. A second agent for treatment of APL can include all-trans retinoic

acid (ATRA) or an antimetabolite, such as cytarabine. A second agent for treatment of acute monocytic leukemia can include a deoxyadenosine analog, such as 2-chloro-2'-deoxyadenosine (2-CDA).

Risk factors of AML include the presence of certain genetic disorders, such as Down syndrome, Fanconi anemia, Shwachman-Diamond syndrome and others. A patient having AML and a genetic disorder can be administered a VLA-4 binding antibody and a second agent to treat a symptom of the genetic disorder. For example, a patient with AML and Fanconi anemia can be administered a VLA-4 binding antibody and an antibiotic.

Other risk factors for AML include chemotherapy or radiotherapy for treatment of a different cancer, tobacco smoke, and exposure to large amounts of benzene.

Other cancers suitable for treatment with an α4-binding antibody include, solid tumors such as sarcomas and carcinomas (*e.g.*, fibrosarcoma, myxosarcoma, liposarcoma, chondrosarcoma, osteogenic sarcoma, chordoma, angiosarcoma, endotheliosarcoma, lymphangiosarcoma, lymphangioendotheliosarcoma, synovioma, mesothelioma, Ewing's tumor, leiomyosarcoma, rhabdomyosarcoma, ovarian 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, uterine cancer, testicular cancer, small cell lung carcinoma, epithelial carcinoma, glioma, astrocytoma, medulloblastoma, craniopharyngioma, ependymoma, pinealoma, hemangioblastoma, acoustic neuroma, oligodendroglioma, schwannoma, meningioma, melanoma, neuroblastoma, and retinoblastoma).

Other Disorders

The formulations and methods described herein can also be used to treat other inflammatory, immune, or autoimmune disorders, *e.g.*, inflammation of the central nervous system (*e.g.*, in addition to multiple sclerosis, meningitis, neuromyelitis optica, neurosarcoidosis, CNS vasculitis, encephalitis, and transverse myelitis); tissue or organ graft rejection or graft-versus-host disease; acute CNS injury, *e.g.*, stroke or spinal cord injury (SCI); chronic renal disease; allergy, *e.g.*, allergic asthma, moderate to severe allergic rhinitis, ocular allergy; type 1 diabetes mellitus; inflammatory bowel disorders, *e.g.*, Crohn's disease, ulcerative colitis (e.g., for treatment or maintenance of remission); eosinophilic gastroenteritis; myasthenia gravis; fibromyalgia; disorders associated with rheumatology/immunology, such as arthritic disorders, *e.g.*, rheumatoid arthritis, psoriatic arthritis; dermatological disorders, such as inflammatory/immune skin disorders, *e.g.*, psoriasis, vitiligo, dermatitis (e.g., atopic dermatitis), lichen planus, moderate to severe chronic urticaria; systemic lupus erythematosus (SLE; e.g., lupus nephritis); scleroderma (e.g., Progressive Systemic Sclerosis (PSS), such as PSS of the lung); acute or chronic primary eosinophilic pneumonia; Sjogren's Syndrome; acute coronary syndrome (ACS); acute myocardial infarction; atherosclerosis; and fibrotic disorders, *e.g.*, pulmonary fibrosis (e.g., idiopathic pulmonary fibrosis), lung fibrosis (e.g., XRT induced), myelofibrosis, liver cirrhosis, mesangial proliferative glomerulonephritis, crescentic glomerulonephritis, diabetic nephropathy, and renal interstitial fibrosis.

The formulations and methods described herein can also be used to treat neurological disorders, such as cerebral ischemia, including prevention in patients with transient ischemic attacks and/or arterial stenosis. Other exemplary neurological disorders include chronic inflammatory demyelinating polyneuropathy (CIDP); Guillian-Barre Syndrome (GBS); ocular diseases, such as macular degeneration (e.g., wet macular degeneration), and anteriorischemic optic neuropathy; neuropathic pain (e.g., symptomatic neuropathic pain); Alzheimer's Disease; Amyotrophic Lateral Sclerosis (ALS) (e.g., disease modifying ALS)' and Parkinson's Disease.

The formulations and methods described herein can also be used to treat patients who have undergone transplantation, such as renal, heart, or bone marrow transplantation.

Multiple Sclerosis

Formulations containing an alpha-4 binding antibody described herein are useful for the treatment of inflammatory diseases, such as multiple sclerosis (MS). Multiple sclerosis is a central nervous system disease that is characterized by inflammation and loss of myelin sheaths.

Patients having MS may be identified by criteria establishing a diagnosis of clinically definite MS as defined by the workshop on the diagnosis of MS (Poser *et al.*, Ann. Neurol. 13:227, 1983). For example, an individual with clinically definite MS has had two attacks and clinical evidence of either two lesions or clinical evidence of one lesion and paraclinical evidence of another, separate lesion. Definite MS may also be diagnosed by evidence of two attacks and oligoclonal bands of IgG in cerebrospinal fluid or by combination of an attack, clinical evidence of two lesions and oligoclonal band of IgG in cerebrospinal fluid. The McDonald criteria can also be used to diagnose MS. (McDonald *et al.*, 2001, "Recommended diagnostic criteria for multiple sclerosis: guidelines from the International Panel on the Diagnosis of Multiple Sclerosis," *Ann. Neurol.* 50:121-127). The McDonald criteria include the use of MRI evidence of CNS impairment over time to be used in diagnosis of MS, in the absence of multiple clinical attacks. Effective treatment of multiple sclerosis may be evaluated in several different ways. The following parameters can be used to gauge effectiveness of treatment. Two exemplary criteria include: EDSS (extended disability status scale), and appearance of exacerbations on MRI (magnetic resonance imaging). The EDSS is a method for grading clinical impairment due to MS (Kurtzke, Neurology 33:1444, 1983). Eight functional systems are evaluated for the type and severity of neurologic impairment. Briefly, prior to treatment, patients are evaluated for impairment in the following systems: pyramidal, cerebella, brainstem, sensory, bowel and bladder, visual, cerebral, and other. Follow-ups are conducted at defined intervals. The scale ranges from 0 (normal) to 10 (death due to

MS). A decrease of one full step indicates an effective treatment (Kurtzke, *Ann. Neurol.* 36:573-79, 1994). Patients may also be diagnosed using other criteria used by those in the art.

Exacerbations are defined as the appearance of a new symptom that is attributable to MS and accompanied by an appropriate new neurologic abnormality (IFNB MS Study Group, supra). In addition, the exacerbation must last at least 24 hours and be preceded by stability or improvement for at least 30 days. Briefly, patients are given a standard neurological examination by clinicians. Exacerbations are either mild, moderate, or severe according to changes in a Neurological Rating Scale (Sipe *et al.*, *Neurology* 34:1368, 1984). An annual exacerbation rate and proportion of exacerbation-free patients are determined.

Therapy can be deemed to be effective if there is a statistically significant difference in the rate or proportion of exacerbation-free or relapse-free patients between the treated group and the placebo group for either of these measurements. In addition, time to first exacerbation and exacerbation duration and severity may also be measured. A measure of effectiveness as therapy in this regard is a statistically significant difference in the time to first exacerbation or duration and severity in the treated group compared to control group. An exacerbation-free or relapse-free period of greater than one year, 18 months, or 20 months is particularly noteworthy. Efficacy may also be assessed using any method used in the art, for example to assess symptoms of MS, including mobility improvement using a timed walk test used alone or in combination with other criteria,

Efficacy of administering a first agent and, optionally, a second agent, can also be evaluated based on one or more of the following criteria: frequency of MBP reactive T cells determined by limiting dilution, proliferation response of MBP reactive T cell lines and clones, cytokine profiles of T cell lines and clones to MBP established from patients. Efficacy is indicated by decrease in frequency of reactive cells, a reduction in thymidine incorporation with altered peptide compared to native, and a reduction in TNF and IFN-α.

Clinical measurements include the relapse rate in one and two-year intervals, and a change in EDSS, including time to progression from baseline of 1.0 unit on the EDSS

that persists for six months. On a Kaplan-Meier curve, a delay in sustained progression of disability shows efficacy. Other criteria include a change in area and volume of T2 images on MRI, and the number and volume of lesions determined by gadolinium enhanced images.

MRI can be used to measure active lesions using gadolinium-DTPA-enhanced imaging (McDonald *et al. Ann. Neurol.* 36:14, 1994) or the location and extent of lesions using T_2 -weighted techniques. Briefly, baseline MRIs are obtained. The same imaging plane and patient position are used for each subsequent study. Positioning and imaging sequences can be chosen to maximize lesion detection and facilitate lesion tracing. The same positioning and imaging sequences can be used on subsequent studies. The presence, location and extent of MS lesions can be determined by radiologists. Areas of lesions can be outlined and summed slice by slice for total lesion area. Three analyses may be done: evidence of new lesions, rate of appearance of active lesions, percentage change in lesion area (Paty *et al.*, Neurology 43:665, 1993). Improvement due to therapy can be established by a statistically significant improvement in an individual patient compared to baseline or in a treated group versus a placebo group.

Exemplary symptoms associated with multiple sclerosis, which can be treated with the methods described herein, include: optic neuritis, diplopia, nystagmus, ocular dysmetria, internuclear ophthalmoplegia, movement and sound phosphenes, afferent pupillary defect, paresis, monoparesis, paraparesis, hemiparesis, quadraparesis, plegia, paraplegia, hemiplegia, tetraplegia, quadraplegia, spasticity, dysarthria, muscle atrophy, spasms, cramps, hypotonia, clonus, myoclonus, myokymia, restless leg syndrome, footdrop, dysfunctional reflexes, paraesthesia, anaesthesia, neuralgia, neuropathic and neurogenic pain, l'hermitte's, proprioceptive dysfunction, trigeminal neuralgia, ataxia, intention tremor, dysmetria, vestibular ataxia, vertigo, speech ataxia, dystonia, dysdiadochokinesia, frequent micturation, bladder spasticity, flaccid bladder, detrusor-sphincter dyssynergia, erectile dysfunction, anorgasmy, frigidity, constipation, fecal urgency, fecal incontinence, depression, cognitive dysfunction, dementia, mood swings,

emotional lability, euphoria, bipolar syndrome, anxiety, aphasia, dysphasia, fatigue, uhthoff's symptom, gastroesophageal reflux, and sleeping disorders.

Each case of MS displays one of several patterns of presentation and subsequent course. Most commonly, MS first manifests itself as a series of attacks followed by complete or partial remissions as symptoms mysteriously lessen, only to return later after a period of stability. This is called relapsing-remitting (RR) MS. Primary-progressive (PP) MS is characterized by a gradual clinical decline with no distinct remissions, although there may be temporary plateaus or minor relief from symptoms. Secondary-progressive (SP) MS begins with a relapsing-remitting course followed by a later primary-progressive course. Rarely, patients may have a progressive-relapsing (PR) course in which the disease takes a progressive path punctuated by acute attacks. PP, SP, and PR are sometimes lumped together and called chronic progressive MS.

A few patients experience malignant MS, defined as a swift and relentless decline resulting in significant disability or even death shortly after disease onset. This decline may be arrested or decelerated by administration of a combination therapy described herein.

Administration of an anti-α4 antibody featured herein can be effective to relieve one or more symptoms of MS, such as one or more of the symptoms described above. For example, administration of an anti-α4 antibody described herein can be used to treat primary or secondary progressive multiple sclerosis (PPMS or SPMS, respectively), and treatment with an anti-α4 antibody can be effective to prevent relapse.

In addition to or prior to human studies, an animal model can be used to evaluate the efficacy of using the two agents. An exemplary animal model for multiple sclerosis is the experimental autoimmune encephalitis (EAE) mouse model, *e.g.*, as described in (Tuohy *et al.* (J. Immunol. (1988) 141: 1126-1130), Sobel *et al.* (J. Immunol. (1984) 132: 2393-2401), and Traugott (Cell Immunol. (1989) 119: 114-129). Mice can be administered a first and second agent described herein prior to EAE induction. Then the mice are evaluated for characteristic criteria to determine the efficacy of using the two agents in the model.

Antibody Generation

Recombinant antibodies that bind to alpha-4 can be generated by *in vivo* or *in vitro* methods such as phage display. The methods can be used to supply anti-α4 CDRs for use in CDR grafted antibodies described herein. In addition, methods such as phage display can be used to select such CDRs in the context of the germline frameworks disclosed herein, such as by using a library where the framework is a germline framework.

EP 239 400 (Winter *et al.*) describes altering antibodies by substitution (within a given variable region) of their complementarity determining regions (CDRs) for one species with those from another. CDR-substituted antibodies can be less likely to elicit an immune response in humans compared to true chimeric antibodies because the CDR-substituted antibodies contain considerably less non-human components. (Riechmann *et al.*, 1988, Nature 332, 323-327; Verhoeyen *et al.*, 1988, Science 239, 1534-1536). Typically, CDRs of a murine antibody substituted into the corresponding regions in a human antibody by using recombinant nucleic acid technology to produce sequences encoding the desired substituted antibody. Human constant region gene segments of the desired isotype (usually gamma I for CH and kappa for CL) can be added and the heavy and light chain genes can be co-expressed in mammalian cells to produce soluble antibody. Large nonimmunized phage display libraries may also be used to isolate high affinity antibodies that can be developed as human therapeutics using standard phage technology (see, *e.g.*, Hoogenboom *et al.* (1998) Immunotechnology 4:1-20; and Hoogenboom *et al.* (2000) Immunol Today 2:371-8; U.S. 2003-0232333).

An anti-α4 antibody or antibody fragment described herein can recognize epitopes of the α4 subunit that are involved in binding to a cognate ligand, *e.g.*, VCAM-1 or fibronectin. The antibodies described herein can inhibit binding of to one or more of the cognate ligands (*e.g.*, VCAM-1 and fibronectin).

In some embodiments, the antibodies featured herein, can interact with VLA-4 on cells, *e.g.*, lymphocytes, but do not cause cell aggregation.

An exemplary α4 binding antibody has one or more CDRs, *e.g.*, all three heavy chain (HC) CDRs and/or all three light chain (LC) CDRs of a particular antibody disclosed herein, or CDRs that are, in sum, at least 80, 85, 90, 92, 94, 95, 96, 97, 98, 99% identical to such an antibody. In one embodiment, the H1 and H2 hypervariable loops have the same canonical structure as those of an antibody described herein. In one embodiment, the L1 and L2 hypervariable loops have the same canonical structure as those of an antibody described herein.

In one embodiment, the amino acid sequence of the HC and/or LC variable domain sequence is at least 70, 80, 85, 90, 92, 95, 97, 98, 99, or 100% identical to the amino acid sequence of the HC and/or LC variable domain of an antibody described herein. The amino acid sequence of the HC and/or LC variable domain sequence can differ by at least one amino acid, but no more than ten, eight, six, five, four, three, or two amino acids from the corresponding sequence of an antibody described herein. For example, the differences may be primarily or entirely in the framework regions.

The amino acid sequences of the HC and LC variable domain sequences can be encoded by a nucleic acid sequence that hybridizes under high stringency conditions to a nucleic acid sequence described herein or one that encodes a variable domain or an amino acid sequence described herein. In one embodiment, the amino acid sequences of one or more framework regions (*e.g.*, FR1, FR2, FR3, and/or FR4) of the HC and/or LC variable domain are at least 70, 80, 85, 90, 92, 95, 97, 98, 99, or 100% identical to corresponding framework regions of the HC and LC variable domains of an antibody described herein. In one embodiment, one or more heavy or light chain framework regions (*e.g.*, HC FR1, FR2, and FR3) are at least 70, 80, 85, 90, 95, 96, 97, 98, or 100% identical to the sequence of corresponding framework regions from a human germline antibody.

Calculations of "homology" or "sequence identity" between two sequences (the terms are used interchangeably herein) are performed as follows. The sequences are aligned for optimal comparison purposes (*e.g.*, gaps can be introduced in one or both of a

first and a second amino acid or nucleic acid sequence for optimal alignment and non-homologous sequences can be disregarded for comparison purposes). The optimal alignment is determined as the best score using the GAP program in the GCG software package with a Blossum 62 scoring matrix with a gap penalty of 12, a gap extend penalty of 4, and a frameshift gap penalty of 5. The amino acid residues or nucleotides at corresponding amino acid positions or nucleotide positions are then compared. When a position in the first sequence is occupied by the same amino acid residue or nucleotide as the corresponding position in the second sequence, then the molecules are identical at that position (as used herein amino acid or nucleic acid "identity" is equivalent to amino acid or nucleic acid "homology"). The percent identity between the two sequences is a function of the number of identical positions shared by the sequences.

As used herein, the term "hybridizes under high stringency conditions" describes conditions for hybridization and washing. Guidance for performing hybridization reactions can be found in Current Protocols in Molecular Biology, John Wiley & Sons, N.Y. (1989), 6.3.1-6.3.6, which is incorporated by reference. Aqueous and nonaqueous methods are described in that reference and either can be used. High stringency hybridization conditions include hybridization in 6X SSC at about 45°C, followed by one or more washes in 0.2X SSC, 0.1% SDS at 65°C, or substantially similar conditions.

Antibody Production

Antibodies can be produced in prokaryotic and eukaryotic cells. In one embodiment, the antibodies (*e.g.*, scFvs) are expressed in a yeast cell such as *Pichia* (see, *e.g.*, Powers *et al.* (2001) J. Immunol. Methods 251:123-35), *Hanseula,* or *Saccharomyces.*

In one embodiment, antibodies, particularly full length antibodies, *e.g.*, IgGs, are produced in mammalian cells. Exemplary mammalian host cells for recombinant expression include Chinese Hamster Ovary (CHO cells) (including dhfr- CHO cells, described in Urlaub and Chasin (1980) Proc. Natl. Acad. Sci. USA 77:4216-4220, used with a DHFR selectable marker, *e.g.*, as described in Kaufman and Sharp (1982) Mol.

Biol. 159:601-621), lymphocytic cell lines, *e.g.*, NS0 myeloma cells and SP2 cells, COS cells, K562, and a cell from a transgenic animal, *e.g.*, a transgenic mammal. For example, the cell is a mammary epithelial cell.

In addition to the nucleic acid sequence encoding the immunoglobulin domain, the recombinant expression vectors may carry additional nucleic acid sequences, such as sequences that regulate replication of the vector in host cells (*e.g.*, origins of replication) and selectable marker genes. The selectable marker gene facilitates selection of host cells into which the vector has been introduced (see *e.g.*, U.S. Patent Nos. 4,399,216, 4,634,665 and 5,179,017). Exemplary selectable marker genes include the dihydrofolate reductase (DHFR) gene (for use in *dhfr*- host cells with methotrexate selection/amplification) and the *neo* gene (for G418 selection).

In an exemplary system for recombinant expression of an antibody (*e.g.*, a full length antibody or an antigen-binding portion thereof), a recombinant expression vector encoding both the antibody heavy chain and the antibody light chain is introduced into *dhfr*- CHO cells by calcium phosphate-mediated transfection. Within the recombinant expression vector, the antibody heavy and light chain genes are each operatively linked to enhancer/promoter regulatory elements (*e.g.*, derived from SV40, CMV, adenovirus and the like, such as a CMV enhancer/AdMLP promoter regulatory element or an SV40 enhancer/AdMLP promoter regulatory element) to drive high levels of transcription of the genes. The recombinant expression vector also carries a DHFR gene, which allows for selection of CHO cells that have been transfected with the vector using methotrexate selection/amplification. The selected transformant host cells are cultured to allow for expression of the antibody heavy and light chains and intact antibody is recovered from the culture medium. Standard molecular biology techniques are used to prepare the recombinant expression vector, to transfect the host cells, to select for transformants, to culture the host cells, and to recover the antibody from the culture medium. For example, some antibodies can be isolated by affinity chromatography with a Protein A or Protein G. For example, purified α4-binding antibodies can be concentrated to about 100

mg/mL to about 200 mg/mL using protein concentration techniques that are known in the art.

Antibodies may also include modifications, *e.g.*, modifications that alter Fc function, *e.g.*, to decrease or remove interaction with an Fc receptor or with C1q, or both. For example, the human IgG4 constant region can have a Ser to Pro mutation at residue 228 to fix the hinge region. The amino acid sequence of an IgG4 Fc (hinge + CH2 + CH3 domain) is provided in FIG. 5.

In another example, the human IgG1 constant region can be mutated at one or more residues, *e.g.*, one or more of residues 234 and 237, *e.g.*, according to the numbering in U.S. Patent No. 5,648,260. Other exemplary modifications include those described in U.S. Patent No. 5,648,260.

For some antibodies that include an Fc domain, the antibody production system may be designed to synthesize antibodies in which the Fc region is glycosylated. In another example, the Fc domain of IgG molecules is glycosylated at asparagine 297 in the CH2 domain (see FIG. 5). This asparagine is the site for modification with biantennary-type oligosaccharides. This glycosylation participates in effector functions mediated by Fcγ receptors and complement C1q (Burton and Woof (1992) Adv. Immunol. 51:1-84; Jefferis *et al.* (1998) Immunol. Rev. 163:59-76). The Fc domain can be produced in a mammalian expression system that appropriately glycosylates the residue corresponding to asparagine 297. The Fc domain can also include other eukaryotic post-translational modifications.

Other suitable Fc domain modifications include those described in WO2004/029207. For example, the Fc domain can be an XmAb® Fc (Xencor, Monrovia, CA). The Fc domain, or a fragment thereof, can have a substitution in an Fcγ Receptor (FcγR) binding region, such as the domains and fragments described in WO05/063815. In some embodiments, the Fc domain, or a fragment thereof, has a substitution in a neonatal Fc Receptor (FcRn) binding region, such as the domains and fragments described in WO05047327. In other embodiments, the Fc domain is a single chain, or

fragment thereof, or modified version thereof, such as those described in WO2008143954. Other suitable Fc modifications are known and described in the art.

Antibodies can also be produced by a transgenic animal. For example, U.S. Patent No. 5,849,992 describes a method for expressing an antibody in the mammary gland of a transgenic mammal. A transgene is constructed that includes a milk-specific promoter and nucleic acid sequences encoding the antibody of interest, *e.g.*, an antibody described herein, and a signal sequence for secretion. The milk produced by females of such transgenic mammals includes, secreted therein, the antibody of interest, *e.g.*, an antibody described herein. The antibody can be purified from the milk, or for some applications, used directly.

Antibodies can be modified, *e.g.*, with a moiety that improves its stabilization and/or retention in circulation, *e.g.*, in blood, serum, lymph, bronchoalveolar lavage, or other tissues, *e.g.*, by at least 1.5, 2, 5, 10, or 50 fold.

For example, a VLA-4 binding antibody can be associated with a polymer, *e.g.*, a substantially non-antigenic polymer, such as a polyalkylene oxide or a polyethylene oxide. Suitable polymers will vary substantially by weight. Polymers having molecular number average weights ranging from about 200 to about 35,000 daltons (or about 1,000 to about 15,000, and 2,000 to about 12,500) can be used.

For example, a VLA-4 binding antibody can be conjugated to a water soluble polymer, *e.g.*, a hydrophilic polyvinyl polymer, *e.g.* polyvinylalcohol or polyvinylpyrrolidone. A non-limiting list of such polymers include polyalkylene oxide homopolymers such as polyethylene glycol (PEG) or polypropylene glycols, polyoxyethylenated polyols, copolymers thereof and block copolymers thereof, provided that the water solubility of the block copolymers is maintained. Additional useful polymers include polyoxyalkylenes such as polyoxyethylene, polyoxypropylene, and block copolymers of polyoxyethylene and polyoxypropylene (Pluronics); polymethacrylates; carbomers; branched or unbranched polysaccharides that comprise the saccharide monomers D-mannose, D- and L-galactose, fucose, fructose, D-xylose, L-arabinose, D-glucuronic acid, sialic acid, D-galacturonic acid, D-mannuronic acid (*e.g.*

polymannuronic acid, or alginic acid), D-glucosamine, D-galactosamine, D-glucose and neuraminic acid including homopolysaccharides and heteropolysaccharides such as lactose, amylopectin, starch, hydroxyethyl starch, amylose, dextrane sulfate, dextran, dextrins, glycogen, or the polysaccharide subunit of acid mucopolysaccharides, *e.g.* hyaluronic acid; polymers of sugar alcohols such as polysorbitol and polymannitol; heparin or heparon.

Exemplary second agents

In some cases, the formulations described herein, *e.g.*, formulations containing an alpha-4 binding antibody, include a second agent, or are administered in combination with a formulation containing a second agent.

In one implementation, the α4 binding antibody and second agent is provided as a co-formulation, and the co-formulation is administered to the subject. It is further possible, *e.g.*, at least 24 hours before or after administering the co-formulation, to administer separately one dose of the α4 binding antibody formulation and then one dose of a formulation containing the second agent. In another implementation, the antibody and the second agent are provided as separate formulations, and the step of administering includes sequentially administering the antibody and the second agent. The sequential administrations can be provided on the same day (*e.g.*, within one hour of one another or at least 3, 6, or 12 hours apart) or on different days.

Generally, the antibody and the second agent are each administered as a plurality of doses separated in time. The antibody and the second agent are generally each administered according to a regimen. The regimen for one or both may have a regular periodicity. The regimen for the antibody can have a different periodicity from the regimen for the second agent, *e.g.*, one can be administered more frequently than the other. In one implementation, one of the antibody and the second agent is administered once weekly and the other once monthly. In another implementation, one of the antibody and the second agent is administered continuously, *e.g.*, over a period of more than 30 minutes but less than 1, 2, 4, or 12 hours, and the other is administered as a bolus. The

antibody and the second agent can be administered by any appropriate method, *e.g.*, subcutaneously, intramuscularly, or intravenously.

In some embodiments, each of the antibody and the second agent is administered at the same dose as each is prescribed for monotherapy. In other embodiments, the antibody is administered at a dosage that is equal to or less than an amount required for efficacy if administered alone. Likewise, the second agent can be administered at a dosage that is equal to or less than an amount required for efficacy if administered alone.

Non-limiting examples of second agents for treating multiple sclerosis in combination with an α4 binding antibody include:

- interferons, *e.g.*, human interferon beta-1a (*e.g.*, AVONEX® or Rebif®)) and interferon beta-1b (BETASERON™; human interferon beta substituted at position 17; Berlex/Chiron);
- glatiramer acetate (also termed Copolymer 1, Cop-1; COPAXONE™; Teva Pharmaceutical Industries, Inc.);
- Rituxan® (rituximab) or another anti-CD20 antibody, *e.g.*, one that competes with or binds an overlapping epitope with rituximab;
- mixtoxantrone (NOVANTRONE®, Lederle);
- a chemotherapeutic, *e.g.*, clabribine (LEUSTATIN®), azathioprine (IMURAN®), cyclophosphamide (CYTOXAN®), cyclosporine-A, methotrexate, 4-aminopyridine, and tizanidine;
- a corticosteroid, *e.g.*, methylprednisolone (MEDRONE®, Pfizer), prednisone;
- an immunoglobulin, *e.g.*, Rituxan® (rituximab); CTLA4 Ig; alemtuzumab (MabCAMPATH®) or daclizumab (an antibody that binds CD25);
- statins; and
- TNF antagonists.

Glatiramer acetate is a protein formed from a random chain of amino acids - glutamic acid, lysine, alanine and tyrosine (hence GLATiramer). Glatiramer acetate can

be synthesized in solution from these amino acids at a ratio of approximately 5 parts alanine to 3 parts lysine, 1.5 parts glutamic acid and 1 part tyrosine using N-carboxyamino acid anhydrides.

Additional second agents include antibodies or antagonists of other human cytokines or growth factors, for example, TNF, LT, IL-1, IL-2, IL-6, IL-7, IL-8, IL-12 IL-15, IL-16, IL-18, EMAP-11, GM-CSF, FGF, and PDGF. Still other exemplary second agents include antibodies to cell surface molecules such as CD2, CD3, CD4, CD8, CD25, CD28, CD30, CD40, CD45, CD69, CD80, CD86, CD90 or their ligands. For example, daclizubmab is an anti-CD25 antibody that may ameliorate multiple sclerosis.

Still other exemplary antibodies include antibodies that provide an activity of an agent described herein, such as an antibody that engages an interferon receptor, *e.g.*, an interferon beta receptor. Typically, in implementations in which the second agent includes an antibody, it binds to a target protein other than VLA-4 or other than α4 integrin, or at least an epitope on VLA-4 other than one recognized by the first agent.

Still other additional exemplary second agents include: FK506, rapamycin, mycophenolate mofetil, leflunomide, non-steroidal anti-inflammatory drugs (NSAIDs), for example, phosphodiesterase inhibitors, adenosine agonists, antithrombotic agents, complement inhibitors, adrenergic agents, agents that interfere with signaling by proinflammatory cytokines as described herein, IL- 1β converting enzyme inhibitors (*e.g.*, Vx740), anti-P7s, PSGL, TACE inhibitors, T-cell signaling inhibitors such as kinase inhibitors, metalloproteinase inhibitors, sulfasalazine, azathloprine, 6-mercaptopurines, angiotensin converting enzyme inhibitors, soluble cytokine receptors and derivatives thereof, as described herein, anti-inflammatory cytokines (*e.g.* IL-4, IL-10, IL-13 and TGF).

In some embodiments, a second agent may be used to treat one or more symptoms or side effects of MS. Such agents include, *e.g.*, amantadine, baclofen, papaverine, meclizine, hydroxyzine, sulfamethoxazole, ciprofloxacin, docusate, pemoline, dantrolene, desmopressin, dexamethasone, tolterodine, phenytoin, oxybutynin, bisacodyl, venlafaxine, amitriptyline, methenamine, clonazepam, isoniazid, vardenafil,

nitrofurantoin, psyllium hydrophilic mucilloid, alprostadil, gabapentin, nortriptyline, paroxetine, propantheline bromide, modafinil, fluoxetine, phenazopyridine, methylprednisolone, carbamazepine, imipramine, diazepam, sildenafil, bupropion, and sertraline. Many second agents that are small molecules have a molecular weight between 150 and 5000 Daltons.

Examples of TNF antagonists include chimeric, humanized, human or *in vitro* generated antibodies (or antigen-binding fragments thereof) to TNF (*e.g.*, human TNF α), such as D2E7, (human TNFα antibody, U.S. Patent No. 6,258,562; BASF), CDP-571/CDP-870/BAY-10-3356 (humanized anti-TNFα antibody; Celltech/Pharmacia), cA2 (chimeric anti-TNFα antibody; REMICADE™, Centocor); anti-TNF antibody fragments (*e.g.*, CPD870); soluble fragments of the TNF receptors, *e.g.*, p55 or p75 human TNF receptors or derivatives thereof, *e.g.*, 75 kdTNFR-IgG (75 kD TNF receptor-IgG fusion protein, ENBREL™; Immunex; see *e.g.*, Arthritis & Rheumatism (1994) Vol. 37, S295; J. Invest. Med. (1996) Vol. 44, 235A), p55 kdTNFR-IgG (55 kD TNF receptor-IgG fusion protein (LENERCEPT™)); enzyme antagonists, *e.g.*, TNFα converting enzyme (TACE) inhibitors (*e.g.*, an alpha-sulfonyl hydroxamic acid derivative, WO 01/55112, and N-hydroxyformamide TACE inhibitor GW 3333, -005, or -022); and TNF-bp/s-TNFR (soluble TNF binding protein; see *e.g.*, Arthritis & Rheumatism (1996) Vol. 39, No. 9 (supplement), S284; Amer. J. Physiol. - Heart and Circulatory Physiology (1995) Vol. 268, pp. 37-42).

In addition to a second agent, it is also possible to deliver other agents to the subject. However, in some embodiments, no protein or no biologic, other than the α4 binding antibody and second agent, are administered to the subject as a pharmaceutical composition. The α4 binding antibody and the second agent may be the only agents that are delivered by injection. In embodiments in which the second agent is a recombinant protein, the α4 binding antibody and second agent may be the only recombinant agents administered to the subject, or at least the only recombinant agents that modulate immune or inflammatory responses. In still other embodiments, the α4 binding antibody alone is the only recombinant agent or the only biologic administered to the subject.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

EXAMPLE

Example 1. Variant anti-VLA-4 antibodies are more potent than humanized HP1/2.

Anti-VLA-4 antibodies were constructed using the germline framework IGKV4-1 (or design L1 and L2) or germline-engineered AAH7033.1 (for design L3) for the VL chain and germline framework IGHV1-f for VH. These antibodies had fewer back mutations than the humanized HP1/2 antibody described in U.S. Patent No. 6,602,503.

Heavy chain variations

The sequences of three variations of the heavy chain are shown in FIG. 1 as Design H0, Design H1 and Design H2. Each design has the CDR's of murine HP1/2 grafted into the IGHV1-f framework. Design H0 includes no back mutations of the framework regions, while Designs H1 and H2 have various degrees of back mutations in the framework regions sequences to optimize the affinity of the humanized antibody.

Light chain variations

The sequences of four variations of the light chain are shown in FIG. 2 as Design L0, Design L1, Design L2 and Design L3 (also called L0, L1, L2, L3). Each design has the CDR's of murine HP1/2 grafted into the germline framework. The IGKV4-1 germline framework was used for Designs L0, L1, and L2, and the AAH70335 germline engineered framework was used for Design L3. Design L0 includes no back mutations of

the framework regions, while Designs L1, L2, and L3 have various degrees of back mutations in the framework regions to optimize the affinity of the humanized antibody.

The results of competition ELISA assays are shown in Table 1 and FIG. 3. In this experiment $\alpha 4\beta 1$ was preincubated with testing mAb and then murine HP1/2 was used as competing reagent. The results of this experiment indicated that the antibodies having light chains L2 or L3 were more potent than the humanized antibody HuHP1/2 described in U.S. Patent No. 6,602,503. The results are shown in Table 1 below, and in FIG. 3. The heavy chain (H1) in the antibodies for this assay had the "Design H1" sequence shown in FIG. 1, whereas L1 refers to Design L1 in FIG. 2.

Table 1. Competition Assay by ELISA

mAb	IC50 nM
Chimeric HP1/2	1.06
H1L0	1.87
H1L1	1.67
H1L2	0.9
H1L3	0.49
HuHP1/2	1.05

In Table 1, the chimeric mAb is chimerized HP1/2 antibody, where murine variable heavy and light chains are genetically fused to human IgG1 constant regions. This antibody is essentially identical in binding affinity to the original murine HP1/2 antibody (Sanchez-Madrid *et al.*, Eur. J. Immunol. 16:1343-1349, 1996). The results of the experiment indicate that it is possible to improve the affinity of the monoclonal antibody relative to its murine parental sequence through humanization on germline-engineered acceptor framework.

Another competition assay compares the binding affinity of the new antibodies with the humanized 21.6 anti-α4 antibody (Tysabri® (natalizumab)) described in U.S. 5,840,299. In this experiment the binding of mixture of mouse HP1/2 with testing

mAb to α4β1 was assayed. The results of this experiment are shown in FIG. 4 and in Table 2 below, and indicate that the newly designed antibodies are about 10-fold more potent than natalizumab.

Table 2. Competition Assay by ELISA

mAb	IC50 nM
Chimeric HP1/2	1.64
H1L0	4.46
H1L1	4.55
H1L2	1.34
HuHP1/2	1.41
Tysabri®	10.9

Example 2. Humanized HP1/2 (HuHP1/2) binds VLA-4 on tumor cell lines.

Binding of anti-VLA-4 antibody HuHP1/2 to a variety of cell lines was tested by flow cytometry. Binding was tested on CLL (chronic lymphocytic leukemic) cell lines Mec1 and JM1; on MM (multiple myeloma) cell lines U266 and H929; and on AML (acute myelogenous leukemic) cell lines HL60 and KG1. HuHP1/2 bound all tumor cell lines tested (FIG. 6). The flow cytometry data was used to calculate the EC50 values for antibody binding to each of the different cell lines. This information is ahown below in Table 3.

HuHP1/2 was also found to block adhesion of AML cell lines to fibronectin (FN) and VCAM1-Ig fusion protein. To test whether the antibody could block adhesion, AML cell lines HL60 or KG1 were allowed to adhere to FN-coated wells (FIG. 7A) or VCAM1-Ig-coated wells (FIG. 7B) in the presence of increasing concentrations of HP1/2 or isotype control antibody. HuHP1/2 blocked adhesion of both cell types to FN-coated wells and VCAM1-Ig-coated wells. The maximal inhibition of HL60 cell binding to both ligands was achieved with 20μg/ml HuHP1/2 (FIG. 7C).

HuHP1/2 was also found to block adhesion of MM cell lines to FN and VCAM1-Ig fusion protein. The MM cell lines U266 and H929 were allowed to adhere to FN-coated wells (FIG. 8A) or VCAM1-Ig-coated wells (FIG. 8B) in the presence of increasing concentrations of HP1/2 or isotype control antibody. HuHP1/2 blocked adhesion of both types of cell lines to FN- and VCAM1-Ig-coated wells. The maximal inhibition of U266 cell binding to both ligands was achieved with 20μg/mL HuHP1/2 (FIG. 8C).

HuHP1/2 was also found to block adhesion of CLL cell lines to FN and VCAM1-Ig fusion protein. The CLL cell lines Mec1 and JM1 were allowed to adhere to FN-coated wells (FIG. 9A) or VCAM1-Ig-coated wells (FIG. 9B) in the presence of increasing concentrations of HP1/2 or isotype control antibody. HuHP1/2 blocked adhesion of both types of cell lines to FN- and VCAM1-Ig-coated wells. The maximal inhibition of Mec1 cell binding to both ligands was achieved with 20μg/ml HuHP1/2 (FIG. 9C).

The IC50 values for HuHP1/2 binding to the tumor cell lines were calculated from the data shown in FIGs. 7-9. These data are shown in Table 3.

Table 3. Quantitation of HuHP1/2 on tumor cell lines

		EC_{50} (nM)	IC_{50} (nM)	
			Fibronectin	**VCAM**
CLL	Mec1	0.11	0.10	0.07
	JM1	0.21	--	0.12
MM	U266	0.46	0.14	0.13
	H929	0.91	0.21	1.35
AML	HL60	0.11	0.16	0.91
	KG1	0.19	0.05	0.1

Other embodiments are in the claims.

SEQUENCE LISTING

<110> BIOGEN IDEC MA INC.

<120> ANTI-VLA-4 ANTIBODIES

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<140> PCT/US11/32641
<141> 2011-04-15

<150> 61/324,944
<151> 2010-04-16

<160> 15

<170> PatentIn version 3.5

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Ser Val Lys Leu Ser Cys Thr Ala Ser Gly Phe Asn Ile Lys Asp Thr
20 25 30

Tyr Met His Trp Val Lys Gln Arg Pro Glu Gln Gly Leu Glu Trp Ile
35 40 45

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

Gln Val Lys Ala Thr Ile Thr Ala Asp Thr Ser Ser Asn Thr Ala Trp
65 70 75 80

Leu Gln Leu Ser Ser Leu Thr Ser Glu Asp Thr Ala Val Tyr Tyr Cys
85 90 95

Ala Asp Gly Met Trp Val Ser Thr Gly Tyr Ala Leu Asp Phe Trp Gly
100 105 110

Gln Gly Thr Thr Val Thr Val Ser Ser
115 120

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Thr Val Lys Ile Ser Cys Lys Val Ser Gly Tyr Thr Phe Thr Asp Tyr
20 25 30

Tyr Met His Trp Val Gln Gln Ala Pro Gly Lys Gly Leu Glu Trp Met
35 40 45

```
Gly Leu Val Asp Pro Glu Asp Gly Glu Thr Ile Tyr Ala Glu Lys Phe
    50                  55                  60

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

Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
                85                  90                  95

Ala Thr
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1               5                   10                  15

Thr Val Lys Ile Ser Cys Lys Val Ser Gly Phe Asn Ile Lys Asp Thr
            20                  25                  30

Tyr Met His Trp Val Gln Gln Ala Pro Gly Lys Gly Leu Glu Trp Met
        35                  40                  45

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

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

Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
                85                  90                  95

Ala Thr Gly Met Trp Val Ser Thr Gly Tyr Ala Leu Asp Phe Trp Gly
            100                 105                 110

Gln Gly Thr Leu Val Thr Val Ser Ser
        115                 120
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Glu Val Gln Leu Val Gln Ser Gly Ala Glu Val Lys Lys Pro Gly Ala
1               5                   10                  15

Thr Val Lys Ile Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys Asp Thr
            20                  25                  30
```

```
Tyr Met His Trp Val Gln Gln Ala Pro Gly Lys Gly Leu Glu Trp Met
        35                  40                  45

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

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

Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
                85                  90                  95

Ala Asp Gly Met Trp Val Ser Thr Gly Tyr Ala Leu Asp Phe Trp Gly
            100                 105                 110

Gln Gly Thr Leu Val Thr Val Ser Ser
        115                 120
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1               5                   10                  15

Thr Val Lys Ile Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys Asp Thr
            20                  25                  30

Tyr Met His Trp Val Gln Gln Ala Pro Gly Lys Gly Leu Glu Trp Ile
        35                  40                  45

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

Gln Val Arg Ala Thr Ile Thr Ala Asp Thr Ser Thr Asn Thr Ala Tyr
65                  70                  75                  80

Leu Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala Val Tyr Tyr Cys
                85                  90                  95

Ala Asp Gly Met Trp Val Ser Thr Gly Tyr Ala Leu Asp Phe Trp Gly
            100                 105                 110

Gln Gly Thr Leu Val Thr Val Ser Ser
        115                 120
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Asp Arg Val Thr Ile Thr Cys Lys Ala Ser Gln Ser Val Thr Asn Asp
            20                  25                  30

Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Ser Pro Lys Leu Leu Ile
        35                  40                  45

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

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

Glu Asp Leu Ala Val Tyr Phe Cys Gln Gln Asp Tyr Ser Ser Pro Tyr
                85                  90                  95

Thr Phe Gly Gly Gly Thr Lys Leu Glu Ile Lys
            100                 105


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Glu Arg Ala Thr Ile Asn Cys Lys Ser Ser Gln Ser Val Leu Tyr Ser
            20                  25                  30

Ser Asn Asn Lys Asn Tyr Leu Ala Trp Tyr Gln Gln Lys Pro Gly Gln
        35                  40                  45

Pro Pro Lys Leu Leu Ile Tyr Trp Ala Ser Thr Arg Glu Ser Gly Val
    50                  55                  60

Pro Asp Arg Phe Ser Gly Ser Gly Ser Gly Thr Asp Phe Thr Leu Thr
65                  70                  75                  80

Ile Ser Ser Leu Gln Ala Glu Asp Val Ala Val Tyr Tyr Cys Gln Gln
                85                  90                  95

Tyr Tyr Ser Thr Pro
            100


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Glu Arg Ala Thr Ile Asn Cys Lys Ala Ser Gln Ser Val Thr Asn Asp
            20                  25                  30
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Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Pro Pro Lys Leu Leu Ile
35 40 45

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

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

Glu Asp Val Ala Val Tyr Tyr Cys Gln Gln Asp Tyr Ser Ser Pro Tyr
85 90 95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys
100 105

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<213> Artificial Sequence

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1 5 10 15

Glu Arg Ala Thr Ile Asn Cys Lys Ala Ser Gln Ser Val Thr Asn Asp
20 25 30

Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Pro Pro Lys Leu Leu Ile
35 40 45

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

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

Glu Asp Val Ala Val Tyr Phe Cys Gln Gln Asp Tyr Ser Ser Pro Tyr
85 90 95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys
100 105

<210> 10
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1 5 10 15

Glu Arg Ala Thr Ile Asn Cys Lys Ala Ser Gln Ser Val Thr Asn Asp
20 25 30

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Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Pro Pro Lys Leu Leu Ile
        35                  40                  45

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

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

Glu Asp Val Ala Val Tyr Phe Cys Gln Gln Asp Tyr Ser Ser Pro Tyr
                85                  90                  95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys
            100                 105
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Glu Arg Ala Thr Ile Asn Cys Lys Ala Ser Gln Ser Val Thr Asn Asp
            20                  25                  30

Val Ala Trp Tyr Gln Gln Lys Pro Gly Gln Pro Pro Lys Leu Leu Ile
        35                  40                  45

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

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

Glu Asp Val Ala Thr Tyr Phe Cys Gln Gln Asp Tyr Ser Ser Pro Tyr
                85                  90                  95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys
            100                 105
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1               5                   10                  15

Asp Arg Val Thr Ile Thr Cys Gln Ala Ser Gln Asp Ile Lys Thr Tyr
            20                  25                  30

Leu Ser Trp Phe Gln Gln Lys Pro Gly Lys Pro Pro Lys Leu Leu Ile
```

```
        35                  40                  45

Ser Asp Ala Ser Gly Phe Gln Pro Gly Val Pro Ser Arg Phe Ser Gly
    50                  55                  60

Ser Gly Tyr Gly Thr Asp Phe Ser Phe Thr Ile Thr Ser Leu Arg Pro
65                  70                  75                  80

Asp Asp Thr Ala Thr Tyr Tyr Cys Gln Gln Tyr Glu Lys Val Pro Phe
                85                  90                  95

Thr Phe Gly Pro Gly Lys Val Gly Phe Asn Arg
            100                 105


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Glu Arg Ala Thr Ile Asn Cys Gln Ala Ser Gln Asp Ile Lys Thr Tyr
            20                  25                  30

Leu Ser Trp Tyr Gln Gln Lys Pro Gly Gln Pro Pro Lys Leu Leu Ile
        35                  40                  45

Tyr Asp Ala Ser Gly Phe Gln Pro Gly Val Pro Asp Arg Phe Ser Gly
    50                  55                  60

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

Glu Asp Val Ala Thr Tyr Tyr Cys Gln Gln Tyr Glu Lys Val Pro Tyr
                85                  90                  95

Thr Phe Gly Gln Gly Thr Lys Val Glu Ile Lys
            100                 105


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1               5                   10                  15

Leu Gly Gly Pro Ser Val Phe Leu Phe Pro Pro Lys Pro Lys Asp Thr
            20                  25                  30

Leu Met Ile Ser Arg Thr Pro Glu Val Thr Cys Val Val Val Asp Val
```

35 40 45

Ser Gln Glu Asp Pro Glu Val Gln Phe Asn Trp Tyr Val Asp Gly Val
50 55 60

Glu Val His Asn Ala Lys Thr Lys Pro Arg Glu Glu Gln Phe Asn Ser
65 70 75 80

Thr Tyr Arg Val Val Ser Val Leu Thr Val Leu His Gln Asp Trp Leu
85 90 95

Asn Gly Lys Glu Tyr Lys Cys Lys Val Ser Asn Lys Gly Leu Pro Ser
100 105 110

Ser Ile Glu Lys Thr Ile Ser Lys Ala Lys Gly Gln Pro Arg Glu Pro
115 120 125

Gln Val Tyr Thr Leu Pro Pro Ser Gln Glu Glu Met Thr Lys Asn Gln
130 135 140

Val Ser Leu Thr Cys Leu Val Lys Gly Phe Tyr Pro Ser Asp Ile Ala
145 150 155 160

Val Glu Trp Glu Ser Asn Gly Gln Pro Glu Asn Asn Tyr Lys Thr Thr
165 170 175

Pro Pro Val Leu Asp Ser Asp Gly Ser Phe Phe Leu Tyr Ser Arg Leu
180 185 190

Thr Val Asp Lys Ser Arg Trp Gln Glu Gly Asn Val Phe Ser Cys Ser
195 200 205

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Leu Ser Leu Gly
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<213> Homo sapiens

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20 25 30

Leu Ser Ala Ser Val Gly Asp Arg Val Thr Ile Thr Cys Gln Ala Ser
35 40 45

Gln Asp Ile Lys Thr Tyr Leu Ser Trp Phe Gln Gln Lys Pro Gly Lys
50 55 60

Pro Pro Lys Leu Leu Ile Ser Asp Ala Ser Gly Phe Gln Pro Gly Val
65 70 75 80

```
Pro Ser Arg Phe Ser Gly Ser Gly Tyr Gly Thr Asp Phe Ser Phe Thr
                85                  90                  95

Ile Thr Ser Leu Arg Pro Asp Asp Thr Ala Thr Tyr Tyr Cys Gln Gln
            100                 105                 110

Tyr Glu Lys Val Pro Phe Thr Phe Gly Pro Gly Thr Lys Val Gly Phe
        115                 120                 125

Asn Arg Thr Val Ala Ala Pro Ser Val Phe Ile Phe Pro Pro Ser Asp
    130                 135                 140

Glu Gln Leu Lys Ser Gly Thr Ala Ser Val Val Cys Leu Leu Asn Asn
145                 150                 155                 160

Phe Tyr Pro Arg Glu Ala Lys Val Gln Trp Lys Val Asp Asn Ala Leu
                165                 170                 175

Gln Ser Gly Asn Ser Gln Glu Ser Val Thr Glu Gln Asp Ser Lys Asp
            180                 185                 190

Ser Thr Tyr Ser Leu Ser Ser Thr Leu Thr Leu Ser Lys Ala Asp Tyr
        195                 200                 205

Glu Lys His Lys Val Tyr Ala Cys Glu Val Thr His Gln Gly Leu Ser
    210                 215                 220

Ser Pro Val Thr Lys Ser Phe Asn Arg Gly Glu Cys
225                 230                 235
```

WHAT IS CLAIMED IS:

1. A recombinant antibody molecule, or an α4-binding fragment thereof, comprising a variable light chain framework comprising an acceptor sequence from IGKV4-1 and a variable heavy chain framework comprising an acceptor sequence from IGHV1-f and having heavy and light chain CDRs derived from murine antibody HP1/2 or from murine antibody 21.6.

2. A recombinant antibody molecule, or an α4-binding fragment thereof, capable of binding α4, comprising a variable light chain framework comprising an acceptor sequence from germline engineered AAH70335.1 (SEQ ID NO: 15) and a variable heavy chain framework comprising an acceptor sequence from IGHV1-f.

3. The recombinant antibody molecule, or α4-binding fragment thereof, of claims 1 or 2, further comprising CDRs derived from murine antibody HP1/2.

4. The recombinant antibody molecule, or α4-binding fragment thereof, of claims 1 or 2, further comprising CDRs derived from murine antibody 21.6.

5. The recombinant antibody molecule, or α4-binding fragment thereof, of claims 1 or 2, wherein the heavy chain variable region comprises the sequence of SEQ ID NO:3, SEQ ID NO:4, or SEQ ID NO:5.

6. The recombinant antibody molecule, or α4-binding fragment thereof, of claim 1, wherein the light chain variable region comprises the sequence of SEQ ID NO:8, SEQ ID NO:9, or SEQ ID NO:10.

7. The recombinant antibody molecule, or α4-binding fragment thereof, of claim 2, wherein the light chain variable region comprises the sequence of SEQ ID NO:11.

8. The antibody of claims 1 or 2, wherein the antibody binds VLA-4.

9. A vector comprising DNA encoding an antibody heavy chain, or an α4-binding fragment thereof, comprising the sequences of SEQ ID NOs:3, 4, or 5.

10. A vector comprising DNA encoding an antibody light chain, or an α4-binding fragment thereof, comprising SEQ ID NOs:8, 9, 10, or 11.

11. A method of making a recombinant anti-α4 antibody, or an α4-binding fragment thereof, comprising

(a) providing a host cell comprising (i) a DNA sequence encoding an antibody heavy chain, or an α4-binding fragment thereof, wherein the DNA sequence comprises the sequence of SEQ ID NOs:3, 4, or 5, and (ii) a DNA sequence encoding an antibody light chain, or an α4-binding fragment thereof, wherein the DNA sequence comprises the sequence of SEQ ID NOs:8, 9, 10, or 11, and

(b) culturing the cell to produce the recombinant anti-α4 antibody molecule or α4 binding fragment thereof.

12. A use of the composition of claims 1 or 2 for the preparation of a medicament for treating a patient.

13. The use of claim 12, wherein the patient has a cancer.

14. The use of claim 13, wherein the patient has a solid tumor.

15. The use of claim 13, wherein the patient has a hematological malignancy.

16. The use of claim 13, wherein the patient has a multiple myeloma or acute myelogeneous leukemia (AML).

17. The use of claim 12, wherein the patient has an inflammatory disorder.

18. The use of claim 12, wherein the patient has multiple sclerosis, asthma, rheumatoid arthritis, diabetes, optic neuritis, or Crohn's disease.

19. The use of claim 12, wherein the patient has an acute disorder.

20. The use of claim 12, wherein the patient has a spinal cord injury or traumatic brain injury.

21. The use of claim 12, wherein the medicament is administered as a regimen.

22. The use of claim 12, wherein the medicament further comprises a second therapeutic agent.

23. The use of claim 22, wherein the second therapeutic agent is a thrombolytic agent, a chemotherapeutic agent, a neuroprotective agent, an anti-inflammatory agent, a steroid, a cytokine, or a growth factor.

24. A composition of claims 1 or 2 for treating a patient.

25. The composition of claim 24, wherein the patient has a cancer.

26. The composition of claim 25, wherein the patient has a solid tumor.

27. The composition of claim 25, wherein the patient has a hematological malignancy.

28. The composition of claim 25, wherein the patient has a multiple myeloma or acute myelogeneous leukemia (AML).

29. The composition of claim 24, wherein the patient has an inflammatory disorder.

30. The composition of claim 24, wherein the patient has multiple sclerosis, asthma, rheumatoid arthritis, diabetes, optic neuritis, or Crohn's disease.

31. The composition of claim 24, wherein the patient has an acute disorder.

32. The composition of claim 24, wherein the patient has a spinal cord injury or traumatic brain injury.

33. The composition of claim 24, wherein the composition is administered as a regimen.

34. The composition of claim 24, further comprising a second therapeutic agent.

35. The composition of claim 34, wherein the second therapeutic agent is a thrombolytic agent, a chemotherapeutic agent, a neuroprotective agent, an anti-inflammatory agent, a steroid, a cytokine, or a growth factor.