DESCRIPTION

COMPOSITIONS AND METHODS FOR TREATING INFLAMMATORY DISORDERS

Field of the Invention

The present invention features compositions and methods related to antibodies that bind fractalkine.

Background of the Invention

Fractalkine (FKN) is a transmembrane chemokine that is expressed on the surface of activated endothelial cells and binds to the CX3CR1 receptor. The binding of membrane-bound FKN to membrane-bound CX3CR1 mediates strong cell-cell adhesion without the involvement of selectins or integrins. Secreted FKN, which is shed from membrane-bound FKN, also binds to CX3CR1 and induces the activation of integrin and cell chemotaxis.

Expression of FKN is induced on the surface of endothelial cells by proinflammatory cytokines. The elevated expression of FKN and the accumulation of $CX3CR1^+$ cytotoxic effector lymphocytes and macrophages have been reported in subjects with numerous disorders, including inflammatory and autoimmune disorders, including ulcerative colitis (UC), Crohn's disease (CD), rheumatoid arthritis (RA), autoimmune hepatitis (AIH), multiple sclerosis (MS), and diabetes mellitus. Umehara et al., *Arterioscler. Thromb. Vasc. Biol.* 24:34-40 (2004) describes the role of FKN in atherosclerosis and vascular injury. Nishimura et al., *Ann. NY Acad. Sci.* 1173:350-356 (2009) discusses FKN as a potential therapeutic target for inflammatory bowel disease such as UC and CD.

Antibodies and FKN-binding fragments of antibodies are desirable therapeutic agents because of their specificity. Antibodies and FKN-binding fragments may be used to target specific cells or tissues, thereby minimizing the potential side effects of non-

specific targeting. There is a need to identify and characterize therapeutic antibodies useful in the treatment of inflammatory disorders, including those that are described herein.

Summary of the Invention

In one aspect, the invention features an anti-fractalkine antibody or fractalkine-binding fragment thereof, wherein the antibody or fragment thereof comprises:

(a) a CDR-H1 consisting of the amino acid sequence of SEQ ID NO: 28;

(b) a CDR-H2 consisting of the amino acid sequence of SEQ ID NO: 29;

(c) a CDR-H3 consisting of the amino acid sequence of SEQ ID NO: 30;

(d) a CDR-L1 consisting of the amino acid sequence of SEQ ID NO: 31;

(e) a CDR-L2 consisting of the amino acid sequence of SEQ ID NO: 32; and

(f) a CDR-L3 consisting of the amino acid sequence of SEQ ID NO: 33.

The antibody may be an intact antibody. In one example, the antibody is a humanized antibody. The heavy chain variable domain of the humanized antibody may include the amino acid sequence of SEQ ID NO: 36, SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 42, or SEQ ID NO: 43, and the light chain variable domain of the humanized antibody may include the amino acid sequence of SEQ ID NO: 38, SEQ ID NO: 44, or SEQ ID NO: 45.

In one aspect, there is provided an anti-fractalkine antibody or fractalkine-binding fragment thereof, wherein the antibody or fragment thereof comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 37 and a light chain comprising the amino acid sequence of SEQ ID NO: 44.

The antibody may also be a chimeric antibody. In one example, the heavy chain variable domain of the chimeric antibody includes the amino acid sequence of SEQ ID NO: 26, and the light chain variable domain of the chimeric antibody includes the amino acid sequence of SEQ ID NO: 27.

fractalkine-binding fragments of an antibody are also contemplated. The fractalkine-binding fragment may be a Fab, Fab', F(ab')2, or Fv fragment that retains the binding specificity to FKN.

In certain examples, when the antibody or fractalkine-binding fragment thereof includes a human constant region, the constant region is of the IgG isotype (e.g., the IgG2 isotype). In other examples, the antibody or fractalkine-binding fragment includes a mutated Fc region such that the antibody has reduced ADCC and/or complement activation relative to the Fc region lacking the mutation. For example, the Fc region may be mutated at one or more of amino acid residues V234, G237, C131, or C219.

Desirably, the antibody or fractalkine-binding fragment substantially reduces or inhibits binding of fractalkine to its receptor, CX3CR1, by at least 50%, 60%, 70%, 80%, 90%, or greater, or substantially inhibits neutralized hFKN in a chemotaxis assay such as the one described herein.

In one aspect, there is provided an anti-fractalkine antibody or fractalkine-binding fragment thereof, wherein the antibody or fragment thereof comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 37 and a light chain comprising the amino acid sequence of SEQ ID NO: 44.

In one aspect, there is provided a pharmaceutical composition comprising the antibody or fractalkine-binding fragment thereof as defined above.

In one example, there is provided a pharmaceutical composition that includes the antibody or fractalkine-binding fragment of the present invention and a pharmaceutically acceptable carrier or excipient. In certain examples, the composition includes one or more additional therapeutic agents, such as those described below.

In one aspect, there is provided a nucleic acid encodingthe antibody or fractalkine-binding fragment thereof of the present invention. In one example, the nucleic acid encodes all or a portion of the heavy chain of the antibody or fractalkine-binding fragment thereof. In another example, the nucleic acid encodes all or a portion of the light chain of the antibody or fractalkine-binding fragment thereof. In one aspect, there is provided a vector comprising the nucleic acid of the present invention. An example is an expression vector.

In one aspect, there is provided a host cell comprising one or more vectors of the invention. In one example, the host cell includes two vectors, the first vector including a nucleic acid encoding a heavy chain and the second vector including a nucleic acid encoding a light chain of an antibody or fractalkine-binding fragment described herein. The expression of the heavy and light chain in the host cell produces an antibody or fractalkine-binding fragment. In one example, the host cell is prokaryotic. In another

example, the host cell is eukaryotic. Exemplary mammalian cells useful for producing antibodies and fractalkine-binding fragments are CHO cells and NS0 cells.

There is also provided a method for making an anti-fractalkine antibody or fractalkine-binding fragment thereof, said method comprising (a) expressing a vector of the invention in a suitable host cell, and (b) recovering the antibody or fractalkine binding fragment thereof. The antibody or fractalkine-binding fragment may be secreted by the host cell into culture media. In one example, the antibody or fractalkine-binding fragment thereof is purified to remove at least 95% or greater purity of the non-antibody marterials.

In one aspect, there is provided the antibody or fractalkine-binding fragment thereof as defined above, for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.

In another aspect, there is provided the pharmaceutical composition of the present invention, for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.

In another aspect, there is provided the use of an antibody or fractalkine-binding fragment thereof as defined above in the preparation of a medicament for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.

Methods for treating an inflammatory disorder by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure are also contemplated. Exemplary inflammatory disorders are inflammatory bowel disease, Crohn's disease, and ulcerative colitis. For these disorders, the method may further include administering one or more additional therapeutic agents. Exemplary therapeutic agents are opiates, 5-aminosalicylic acid, 6-mercaptopurine, azathioprine, glucocorticoids, methotrexate, cyclosporine, and metronidazole. Other suitable therapeutic agents are described below.

Inflammatory disorders that may be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure also include autoimmune hepatobiliary diseases (e.g., autoimmune hepatitis, primary biliary cirrhosis, or primary sclerosing cholangitis). For these disorders, the method may further include administering 6-mercaptopurine, ursodeoxycholic acid, azathioprine, a glucocorticoid, a thiazide diuretic, an anti-aldosterone diuretic, cyclosporine, albumin, or spironolactone.

Rheumatoid arthritis (RA) may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure. In the treatment of RA, the method may further include administering a non-steroidal anti-inflammatory drug (NSAID), methotrexate, leflunomide, bucillamine, 5-aminosalicylic acid, a glucocorticoid, hydrochloroquine, vitamin D, calcium, or alendronate.

Systemic lupus erythematosus (e.g., lupus of the central nervous system or lupus nephritis) may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment, either alone or in combination with one or more additional therapeutic agents. Exemplary additional therapeutic agents are glucocorticoids, cyclophosphamide, methotrexate, cyclosporine, and tacrolimus.

Multiple sclerosis and neuromyelitis optica may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment. Treatment may further include administerin ne or more additional therapeutic agents, such as a glucocorticoid, interferon-β, or Copaxone®.

Demyelinating polyradiculopathy (e.g., Guillain-Barré syndrome or chronic inflammatory demyelinating polyradiculopathy) may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment. Again, cotherapy is also contemplated, and treatment may further include administering one or more additional therapeutic agents, such as a glucocorticoid or an intravenous immunoglobulin.

Administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment may also be useful for the treatment of neuropathic pain, either alone or in combination with an additional therapeutic agent. Exemplary additional agents for the treatment of neuropathic pain are lamotrigine, topiramate, oxcarbazepine, levetiracetam, fentanyl, tramadol, capsaicin, cloridine, an NSAID, amitriptyline, pregabalin, lidocaine, duloxetine, and carbamazepine.

Alzheimer's disease may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment. The method may further include administering one or more additional therapeutic agents, such as tacrine hydrochloride, donepezil hydrochloride, rivastigmine tartrate, galantamine hydrobromide, memantine hydrochloride, paroxetine, risperidone, quetiapine, or perospirone.

Visceral pain associated with cancer may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment, either alone or in combination with one or more additional therapeutic agents, such as morphine, an NSAID, phentanyl, lidocaine, pentazocine, or clonidine.

Atherosclerosis may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment. The method may further include administering one or more additional therapeutic agents, such as prostacyclin, aspirin, clopidogrel, ticlopidine, limaprost, prostaglandin E1, an HMG CoA reductase inhibitor, bezafibrate, lidocaine, mexiletine, a diuretic, digitalis, dopamine, a β-adrenergic receptor agonist, isosorbide dinitrate, nitroglycerin, a natriuretic peptide, warfarin, heparin, tissue plasminogen activator, urokinase, or procainamide.

Vasculopathies (e.g., age-related macular degeneration, Behcet's disease, Harada's disease, and sarcoidosis-origined uveitis) may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure. The method may further include administering one or more additional therapeutic agents selected from glucocorticoids, cyclophosphamide, pegaptanib, ranibizumab, NSAIDs, colchicine, chlorambucil, thalidomide, and verteporfin.

Nephropathies (e.g., lupus nephritis, glomerulonephritis, or diabetic nephropathy) may also be treated by administering an effective amount of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure. Glucocorticoids, sulfonylurea, cyclophosphamide, glinides, cyclosporine, tacrolimus, mycophenolate mofetil, mizoribine, diuretics, insulin, biguanide, α-glucosidase inhibitors, angiotensin receptor blockers, thiazolidinedione, angiotensin converting enzyme (ACE) inhibitors, calcium channel blockers, or β-adrenergic receptor inhibitors may be included in the treatment methods. adrenergic receptor inhibitors may be included in the treatment methods.

The disclosure also relates to the use of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the invention in the treatment of any of the inflammatory disorders described herein.

The disclosure also relates to the use of an anti-fractalkine antibody or fractalkine-binding fragment in accordance with the disclosure in the preparation of a medicament for the treatment of any of the inflammatory disorders described herein.

The disclosure also features a method of inhibiting the recruitment of leukocytes to an inflammation site in a subject by administering an effective amount of an anti-fractalkine

antibody or fractalkine-binding fragment to a subject in need of such treatment, whereby the recruitment of leukocytes to an inflammation site is inhibited.

An *ex vivo* strategy can also be used for therapeutic applications. *Ex vivo* strategies involve transfecting or transducing cells obtained from the subject with a polynucleotide encoding an antibody or antibody fragment. The transfected or transduced cells are then returned to the subject. The cells can be any of a wide range of types including, without limitation, hemopoietic cells (e.g., bone marrow cells, macrophages, monocytes, dendritic cells, T cells, or B cells), fibroblasts, epithelial cells, endothelial cells, keratinocytes, or muscle cells.

For the purpose of the present disclosure, the following abbreviations and terms are defined below.

The term "antibody" (used herein interchangeably with "immunoglobulin") includes intact monoclonal and polyclonal antibodies, multispecific antibodies (e.g., bispecific antibodies), and antibody fragments that exhibit the desired biological activity (e.g., the ability to bind FKN and modulate the interaction between FKN and CX3CR1). "Intact antibodies" are heterotetrameric glycoproteins of about 150,000 Daltons, composed of two identical light (L) chains and two identical heavy (H) chains. Each light chain is linked to a heavy chain by one covalent disulfide bond, while the number of disulfide linkages varies among the heavy chains of different immunoglobulin isotypes. Each heavy and light chain also has regularly spaced intrachain disulfide bridges. Each heavy chain has at one end a variable domain (VH) followed by a number of constant domains. Each light chain has a variable domain at one end (VL) and a constant domain at its other end. The constant domain of the light chain is aligned with the first constant domain of the heavy chain, and the light chain variable domain is aligned with the variable domain of the heavy chain. Particular amino acid residues are believed to form an interface between the light chain and heavy chain variable domains.

There are five major classes of immunoglobulins: IgA, IgD, IgE, IgG, and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG_1, IgG_2, IgG_3, IgG_4, IgA_1, and IgA_2. An antibody may be part of a larger fusion molecule, formed

by covalent or non-covalent association of the antibody with one or more other proteins or peptides. An antibody may also be part of an immunoconjugate, wherein the antibody is conjugated to a second molecule (e.g., a toxin, radioisotope, or label.)

The term "monoclonal antibody," as used herein, refers to an antibody obtained from a population of substantially homogeneous antibodies, i.e., the individual antibodies are identical except for possible mutations that may be present in minor amounts.

"Humanized" forms of non-human antibodies are antibodies or fragments thereof that contain a framework region (FR) having substantially the amino acid sequence of a human immunoglobulin and a complementarity determining region (CDR) having substantially the amino acid sequence of a non-human immunoglobulin (i.e., the "import" sequence). In some instances, framework region residues of the human immunoglobulin are replaced by corresponding non-human residues. Further modifications of the humanized antibody may be made to refine antibody performance.

By "complementarity determining region" or "CDR" is meant one of the three hypervariable sequences in the variable regions within each of the immunoglobulin light and heavy chains.

By "framework region" or "FR" is meant the sequences of amino acids located on either side of the three CDRs of the immunoglobulin light and heavy chains.

The FRs and CDRs of a humanized antibody need not correspond precisely to the parental sequences, e.g., the import CDR or the consensus FR may be mutagenized by substitution, insertion, or deletion of at least one residue so that the CDR or FR residue at that site does not correspond to either the consensus or the import sequence. Such mutations, however, will generally not be extensive. Usually, at least 75%, 80%, 85%, 90%, 95%, or 99% of the humanized antibody residues will correspond to the residues of the parental sequences.

The term "about," as used herein, when referring to a measurable value such as an amount, a temporal duration, and the like, is meant to encompass variations of up to ±20%, preferably ±10%, more preferably ±5%, even more preferably ±2% from the specified value, as such variations are appropriate to perform the disclosed methods.

Unless otherwise indicated, all numbers expressing quantities of ingredients, properties such as molecular weight, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the following specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques.

By "an amount sufficient" or "effective amount" is meant the amount of a therapeutic antibody or pharmaceutical composition thereof required to treat or ameliorate a disorder, such as an inflammatory disorder, in a clinically relevant manner. A sufficient amount of a therapeutic anti- FKN antibody, FKN-binding fragment or pharmaceutical composition thereof used to practice the present invention for therapeutic treatment of, e.g., an inflammatory disorder varies depending upon the manner of administration, age, and general health of the patient.

"Binding affinity" generally refers to the strength of the sum total of noncovalent interactions between a single binding site of a molecule (e.g., an antibody) and its binding partner (e.g., an antigen). Binding affinity can be represented by the dissociation constant (Kd). Affinity can be measured by methods known in the art, including radiolabeled FKN-binding assays (RIA) or by surface plasmon resonance assays (e.g., BIACORE®).

"Chimeric" or "chimerized" antibodies (i.e., immunoglobulins) refer to antibodies in which a portion of the heavy and/or light chain is identical with or homologous to corresponding sequences in antibodies derived from a particular species or belonging to a particular antibody class or subclass, while the remainder of the chain(s) is identical with or homologous to corresponding sequences in antibodies derived from another species or belonging to another antibody class or subclass, as well as fragments of such antibodies,

so long as they exhibit the desired biological activity (Morrison et al., *Proc. Natl. Acad.. Sci. U.S.A.* 81:6851-6855, 1984).

By "epitope" or "antigenic determinant" is meant a sequence of amino acids which, either as a result of linear structure or three-dimensional conformation, forms the binding site for an antibody. A conformational epitope, which may include discontinuous sections of an antigen's amino acid sequence, interacts with an antibody as a result of the tertiary structure of the epitope. In contrast, a linear epitope is an epitope that is recognized by antibodies based on its primary structure. In one embodiment, the epitope of fractalkine that forms the minimal interface with Fab includes, e.g., E66-Q69, W81-Q87, H70-F73, and H88-D90.

The terms "express" and "produce" are used synonymously herein, and refer to the biosynthesis of a gene product. These terms encompass the transcription of a gene into RNA. These terms also encompass translation of RNA into one or more polypeptides, and further encompass all naturally occurring post-transcriptional and post-translational modifications. The expression/production of an antibody can be within the cytoplasm of the cell, and/or into the extracellular milieu such as the growth medium of a cell culture.

By "fractalkine," "FKN," "FK," or "neurotactin" is meant a polypeptide that is homologous to the polypeptide defined by SEQ ID NO: 1 (Figure 1) and that has FKN biological activity (e.g., binds to the CX3CR1 receptor; chemoattracts T cells and monocytes; or promotes adhesion of leukocytes to activated endothelial cells). The biological activity of a FKN polypeptide may be assayed using any standard method. As used herein, FKN also includes any FKN family member or isoform. See, e.g., U.S. Patent No. 7,390,490, WO 2006/046739, and U.S. Patent Application Publication No. 2006/0233710, hereby incorporated by reference.

An "FKN-binding fragment" includes a portion of an intact antibody, comprising the FKN-binding region thereof and capable of binding FKN. FKN-binding fragments can be Fab, Fab', $F(ab')_2$, or Fv fragments; diabodies; triabodies; tetrabodies; miniantibodies; Affibody molecules; minibodies; linear antibodies; single-chain antibody molecules; or multispecific antibodies formed from antibody fragments.

By "homologous" is meant any gene or protein sequence that bears at least 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 99% or more homology to a known gene or protein sequence over the length of the comparison sequence. A "homologous" protein can also have at least one biological activity of the comparison protein. For polypeptides, the length of comparison sequences will generally be at least 15, 20, 25, 35 or more amino acids. For nucleic acids, the length of comparison sequences will generally be at least 50, 60, 75, 100, 125 or more nucleotides. "Homology" can also refer to a substantial similarity between an epitope used to generate antibodies and the protein or fragment thereof to which the antibodies are directed. In this case, homology refers to a similarity sufficient to elicit the production of antibodies that can specifically recognize the protein at issue.

"Human antibody" means that the antibody is either solely from human origin or any antibody in which the variable and constant domain sequences are human sequences or sequences of human antibodies. The term encompasses antibodies with sequences derived from (i.e., that utilize) human genes, but which have been changed, e.g., to decrease possible immunogenicity, increase affinity, eliminate cysteines that may cause undesirable folding, etc. The term encompasses such antibodies produced recombinantly in non-human cells, which may impart glycosylation not typical of human cells.

"Hybridoma" refers to the product of a cell-fusion between a cultured neoplastic lymphocyte and a primed B- or T-lymphocyte, which expresses the specific immune potential of the parent cell.

An "inflammatory disorder" as used herein refers to any disease, disorder, or condition in which the immune system is abnormally activated. The inflammatory disorder may be, e.g., ulcerative colitis, Crohn's disease, inflammatory bowel disease, rheumatoid arthritis, myositis, multiple sclerosis, neuromyelitis optica, atherosclerosis, psoriasis, systemic lupus erythematosus (e.g., lupus of the central nervous system or lupus nephritis), nephritis, glomerulonephritis, autoimmune hepatobiliary disease (e.g., autoimmune hepatitis, primary biliary cirrhosis, or primary sclerosing cholangitis), graft-versus-host disease, atopic dermatitis, asthma, neurodegenerative disease (e.g.,

Alzheimer's disease), demyelinating polyradiculopathy (e.g., Guillain-Barré syndrome or chronic inflammatory demyelinating polyradiculopathy), neuropathic pain, visceral pain of cancer, atherosclerosis, age-related macular degeneration, diabetic nephropathy, sarcoidosis-origined uveitis, or diabetes mellitus.

Alternatively, the disease, disorder, or condition is a disease of the upper or lower respiratory tract, for example, lymphomatous tracheobronchitis; allergic hypersensitivity or a hypersecretion condition, such as chronic bronchitis and cystic fibrosis; pulmonary fibrosis of various etiologies (e.g., idiopathic pulmonary fibrosis); chronic obstructive pulmonary disease (COPD); sarcoidosis; allergic and non-allergic rhinitis; allergic or non-allergic urticaria; a skin-related disease characterized by deregulated inflammation, tissue remodeling, angiogenesis, and neoplasm; a disease of the gastrointestinal tract, such as Hirschsprung's disease, diarrhea, malabsorption conditions, and inflammatory conditions; a disorder of the central and peripheral nervous system, such as depression, anxiety states, Parkinson's disease, migraine and other forms of cranial pain, strokes, and emesis; a disease of the immune system, such as in the splenic and lymphatic tissues, an autoimmune disease, or other immune-related disease; a disease of the cardiovascular system, such as pulmonary edema, hypertension, pre-eclampsia, complex regional pain syndrome type 2, and stroke; chronic inflammatory disease, such as arthritis; a bone-related disease; chronic pain, such as fibromyalgia; and other disorders in which the action of neurokinins, tachykinins, or other related substances (e.g., hemokinins) are involved in the pathogenesis, pathology, and etiology.

Additional examples of inflammatory disorders are acne vulgaris; acute respiratory distress syndrome; Addison's disease; allergic intraocular inflammatory diseases; ANCA-associated small-vessel vasculitis; ankylosing spondylitis; autoimmune hemolytic anemia; Behcet's disease; Bell's palsy; bullous pemphigoid; cerebral ischemia; cirrhosis; Cogan's syndrome; contact dermatitis; Cushing's syndrome; dermatomyositis; discoid lupus erythematosus; eosinophilic fasciitis; erythema nodosum; exfoliative dermatitis; focal glomerulosclerosis; focal segmental glomerulosclerosis; segmental glomerulosclerosis; giant cell arteritis; gout; gouty arthritis; hand eczema; Henoch-

Schonlein purpura; herpes gestationis; hirsutism; idiopathic ceratoscleritis; idiopathic thrombocytopenic purpura; immune thrombocytopenic purpura inflammatory bowel or gastrointestinal disorders; inflammatory dermatoses; lichen planus; lymphomatous tracheobronchitis; macular edema; myasthenia gravis; nonspecific fibrosing lung disease; osteoarthritis; pancreatitis; pemphigoid gestationis; pemphigus vulgaris; periodontitis; polyarteritis nodosa; polymyalgia rheumatica; pruritus scroti; pruritis/inflammation; psoriatic arthritis; pulmonary histoplasmosis; relapsing polychondritis; rosacea; sarcoidosis; scleroderma; septic shock syndrome; shoulder tendinitis or bursitis; Sjogren's syndrome; Still's disease; Sweet's disease; systemic sclerosis; Takayasu's arteritis; temporal arteritis; toxic epidermal necrolysis; transplant-rejection and transplant-rejection-related syndromes; tuberculosis; type-1 diabetes; vasculitis; Vogt-Koyanagi-Harada (VKH) disease; and Wegener's granulomatosis.

"Isolated" or "purified" means altered "by the hand of man" from the natural state. If a molecule or composition occurs in nature, it has been "isolated" or "purified" if it has been changed or removed from its original environment, or both. For example, a polynucleotide or a polypeptide naturally present in a living plant or animal is not "isolated" or "purified," but the same polynucleotide or polypeptide separated from the coexisting materials of its natural state is "isolated" or "purified" as the term is employed herein.

The term "operably linked" or "operably inserted" means that the regulatory sequences necessary for expression of the coding sequence are placed in a nucleic acid molecule in the appropriate positions relative to the coding sequence so as to enable expression of the coding sequence. By way of example, a promoter is operably linked with a coding sequence when the promoter is capable of controlling the transcription or expression of that coding sequence. Coding sequences can be operably linked to promoters or regulatory sequences in a sense or antisense orientation. The term "operably linked" is sometimes applied to the arrangement of other transcription control elements (e.g., enhancers) in an expression vector.

"Polynucleotide," synonymously referred to as "nucleic acid molecule," refers to any polyribonucleotide or polydeoxyribonucleotide, which may be unmodified RNA or DNA or modified RNA or DNA. "Polynucleotides" include, without limitation, single- and double-stranded DNA, DNA that is a mixture of single- and double-stranded regions, single- and double-stranded RNA, and RNA that is mixture of single- and double-stranded regions, hybrid molecules comprising DNA and RNA that may be single-stranded, or, more typically, double-stranded or a mixture of single- and double-stranded regions. In addition, "polynucleotide" refers to triple-stranded regions comprising RNA or DNA or both RNA and DNA. The term polynucleotide also includes DNAs or RNAs containing one or more modified bases and DNAs or RNAs with backbones modified for stability or for other reasons. "Modified" bases include, for example, tritylated bases and unusual bases such as inosine. A variety of modifications can be made to DNA and RNA; thus, "polynucleotide" embraces chemically, enzymatically, or metabolically modified forms of polynucleotides as typically found in nature, as well as the chemical forms of DNA and RNA characteristic of viruses and cells. "Polynucleotide" also embraces relatively short nucleic acid chains, often referred to as oligonucleotides.

"Polypeptide" refers to both short chains, commonly referred to as peptides, oligopeptides or oligomers, and to longer chains, generally referred to as proteins. Polypeptides may contain amino acids other than the 20 gene-encoded amino acids. "Polypeptides" include amino acid sequences modified either by natural processes, such as post-translational processing, or by chemical modification techniques which are well known in the art. Such modifications are well described in basic texts and in more detailed monographs, as well as in a voluminous research literature. Modifications can occur anywhere in a polypeptide, including the peptide backbone, the amino acid side-chains, and the amino or carboxyl termini. It will be appreciated that the same type of modification may be present in the same or varying degrees at several sites in a given polypeptide. Also, a given polypeptide may contain many types of modifications. Polypeptides may be branched as a result of ubiquitination, and they may be cyclic, with or without branching. Cyclic, branched and branched cyclic polypeptides may result

from natural posttranslational processes or may be made by synthetic methods. Modifications include, e.g., acetylation, acylation, ADP-ribosylation, amidation, covalent attachment of flavin, covalent attachment of a heme moiety, covalent attachment of a nucleotide or nucleotide derivative, covalent attachment of a lipid or lipid derivative, covalent attachment of phosphotidylinositol, cross-linking, cyclization, disulfide bond formation, demethylation, formation of covalent cross-links, formation of cystine, formation of pyroglutamate, formylation, gamma-carboxylation, glycosylation, GPI anchor formation, hydroxylation, iodination, methylation, myristoylation, oxidation, proteolytic processing, phosphorylation, prenylation, racemization, selenoylation, sulfation, and transfer-RNA mediated addition of amino acids to proteins such as arginylation, and ubiquitination. See, for instance, Proteins - Structure and Molecular Properties, 2nd Ed., T. E. Creighton, W. H. Freeman and Company, New York, 1993 and Wold, F., Posttranslational Protein Modifications: Perspectives and Prospects, pgs. 1-12 in Posttranslational Covalent Modification of Proteins, B. C. Johnson, Ed., Academic Press, New York, 1983; Seifter et al., Analysis for Protein Modifications and Nonprotein Cofactors, Meth Enzymol (1990) 182:626-646 and Rattan et al., Protein Synthesis: Posttranslational Modifications and Aging, Ann NY Acad Sci (1992) 663:48-62.

By "specifically binds" is meant an antibody or fragment thereof recognizes and binds an antigen (e.g., FKN or a fragment thereof), but that does not substantially recognize and bind other molecules in a sample (e.g., a biological sample). "Specifically" is meant to distinguish the low-level, non-specific stickiness that can sometimes occur between random proteins, e.g., with exposed hydrophilic domains. It is not meant to imply that the antibody will not bind to any protein other than antigen of the invention. Antibodies could cross-react (and "bind specifically") with any protein that includes the relevant epitope.

By "subject" is meant is meant any animal, e.g., a mammal (e.g., a human). A subject who is being treated for, e.g., an inflammatory disorder is one who has been diagnosed by a medical or veterinary practitioner as the case may be as having such a

condition. Diagnosis may be performed by any suitable means. One in the art will understand that subjects of the invention may have been subjected to standard tests or may have been identified, without examination, as one at high risk due to the presence of one or more risk factors, such as age, genetics, or family history.

A cell has been "transformed" or "transfected" by exogenous or heterologous nucleic acids such as DNA when such DNA has been introduced inside the cell. The transforming DNA may or may not be integrated (e.g., covalently linked) into the genome of the cell. In prokaryotes, yeast, and mammalian cells, for example, the transforming DNA may be maintained on an episomal element such as a plasmid. With respect to eukaryotic cells, a stably transformed cell, or "stable cell" is one in which the transforming DNA has become integrated into a chromosome so that it is inherited by daughter cells through chromosome replication. This stability is demonstrated by the ability of the eukaryotic cell to establish cell lines or clones comprised of a population of daughter cells containing the transforming DNA. A "clone" is a population of cells derived from a single cell or common ancestor by mitosis. A "cell line" is a clone of a primary cell that is capable of stable growth *in vitro* for many generations.

By "treating" is meant administering a therapeutic antibody or a pharmaceutical composition thereof for prophylactic and/or therapeutic purposes. To "treat a disease or disorder" or use for "therapeutic treatment" refers to administering treatment to a subject already suffering from a disease to improve the subject's condition. The subject may be diagnosed with an inflammatory disorder based on identification of any of the characteristic symptoms or the use of the diagnostic methods known to one of skill in the art. To "prevent a disease or disorder" refers to prophylactic treatment of a subject who is not yet ill, but who is susceptible to, or otherwise at risk of, developing a particular disease. A subject is determined to be at risk of developing an inflammatory disorder using the diagnostic methods known in the art.

A "vector" is a replicon, such as plasmid, phage, cosmid, or virus in which another nucleic acid segment may be operably inserted so as to bring about the replication or expression of the segment.

As used in this specification and the appended claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cell" includes a combination of two or more cells, and the like.

Other features and advantages of the invention will be apparent from the detailed description and from the claims.

Brief Description of the Drawings

Figure 1 is the amino acid sequence of human FKN.

Figure 2 is a table showing the binding characteristics (i.e., neutralizing activity, binding affinity, and species cross-reactivity) of anti-FKN monoclonal antibodies.

Figure 3 is an alignment of the heavy chain variable regions of the humanized anti-FKN mAb sequences (SEQ ID NOS 36-37 and 42-43, respectively, in order of appearance), the m3A5-2 sequence (SEQ ID NO: 26), the germline Ig sequence (SEQ ID NO: 40), and the AAA68427.1 sequence (SEQ ID NO: 34).

Figure 4 is an alignment of the light chain variable regions of the humanized anti-FKN mAb sequences (SEQ ID NOS 38 and 44-45, respectively, in order of appearance), the m3A5-2 sequence (SEQ ID NO: 27), the germline Ig sequence (SEQ ID NO: 41), and the ABU90602.1 sequence (SEQ ID NO: 35).

Figure 5 is a table summarizing the results from three independent chemotaxis assays. The neutralizing activities of humanized anti-hFKN mAbs were analyzed using a chemotaxis assay. All combinations of H3 and H3-2 with L2 and L4 were successfully humanized, as these mAbs showed similar neutralizing activity with the chimeric mAb. However, HK2, which was made by using narrowed key residues, showed decreased neutralizing activity in combination with L2 or L4.

Figures 6A and 6B depict a series of graphs showing the neutralizing activities of m3A5-2 mAb and chimeric mAb. Figure 6A is a graph showing the neutralizing activity of m3A5-2 mAb as determined by a chemotaxis assay. Figure 6B is a graph showing the neutralizing activity of the chimeric mAb as determined by a chemotaxis assay.

Figures 7A-7D depict a series of graphs showing the neutralizing activities of humanized anti-hFKN antibodies as determined by a chemotaxis assay. Figure 7A shows the neutralizing activity of H3L2-IgG2. Figure 7B shows the neutralizing activity of H3-L4-IgG2. Figure 7C shows the neutralizing activity of HK2L2-IgG2. Figure 7D shows the neutralizing activity of HK2L4-IgG2.

Figures 8A-8F depict a series of graphs showing the neutralizing activities of humanized anti-hFKN antibodies as determined by a chemotaxis assay. Figure 8A shows the neutralizing activity of H3-2L2-IgG2. Figure 8B shows the neutralizing activity of H3-2L4-IgG2. Figure 8C shows the neutralizing activity of H3-2L5-IgG2. Figure 8D shows the neutralizing activity of HK3L2-IgG2. Figure 8E shows the neutralizing activity of HK3L4-IgG2. Figure 8F shows the neutralizing activity of HK3L5-IgG2.

Figure 9 is a table summarizing the results from BIACORE® assays used to measure binding affinity of the mAbs to hFKN and cynomolgus monkey FKN.

Figures 10A-10C depict a series of graphs showing the binding affinities of the chimeric and humanized anti-hFKN antibodies (H3L2, H3-2L2, H3L4, H3-2L4, and HK2L4) to hFKN-SEAP and cynomolgus monkey FKN-SEAP as determined by a BIACORE® assay. Figure 10A is a bar graph showing the Ka values (1/Ms). Figure 10B is a bar graph showing the Kd values (1/s). Figure 10C is a bar graph showing the KD values (M).

Figure 11 depicts the results of epitope mapping using libraries of overlapping synthetic peptides (SEQ ID NOS 115-135, respectively, in order of appearance) from the FKN chemokine domain.

Figure 12 depicts the results of epitope mapping of hFKN using ELISA.

Figure 13 depicts the results of epitope mapping of hFKN using BIACORE®.

Figure 14 shows the results of the cross saturation experiment to identify the Fab binding site on fractalkine. The plot shows that the E66-Q69, W81-Q87, H70-F73 and H88-D90 regions of FKN are included in the minimal interface with Fab.

Detailed Description

We have designed and isolated chimeric anti-FKN antibodies, humanized anti-FKN antibodies, and FKN-binding fragments thereof. The humanized anti-FKN antibodies and FKN-binding fragments thereof featured herein may be used to treat inflammatory disorders. Such antibodies may also be used to inhibit the recruitment of leukocytes to an inflammation site. Inflammatory disorders that can be treated according to the invention include ulcerative colitis, Crohn's disease, inflammatory bowel disease, rheumatoid arthritis, myositis, multiple sclerosis, neuromyelitis optica, atherosclerosis, psoriasis, systemic lupus erythematosus (e.g., lupus of the central nervous system or lupus nephritis), nephritis, glomerulonephritis, autoimmune hepatobiliary disease (e.g., autoimmune hepatitis, primary biliary cirrhosis, or primary sclerosing cholangitis), graft-versus-host disease, atopic dermatitis, asthma, neurodegenerative disease (e.g., Alzheimer's disease), demyelinating polyradiculopathy (e.g., Guillain-Barré syndrome or chronic inflammatory demyelinating polyradiculopathy), neuropathic pain, visceral pain of cancer, atherosclerosis, age-related macular degeneration, diabetic nephropathy, sarcoidosis-origined uveitis, diabetes mellitus, lymphomatous tracheobronchitis, allergic hypersensitivity or a hypersecretion condition, such as chronic bronchitis and cystic fibrosis, pulmonary fibrosis of various etiologies (e.g., idiopathic pulmonary fibrosis), chronic obstructive pulmonary disease (COPD), sarcoidosis, allergic and non-allergic rhinitis, allergic or non-allergic urticaria, a skin-related disease characterized by deregulated inflammation, tissue remodeling, angiogenesis, and neoplasm, a disease of the gastrointestinal tract, such as Hirschsprung's disease, diarrhea, malabsorption conditions, and inflammatory conditions, a disorder of the central and peripheral nervous system, such as depression, anxiety states, Parkinson's disease, migraine and other forms of cranial pain, strokes, and emesis, a disease of the immune system, such as in the splenic and lymphatic tissues, an autoimmune disease, or other immune-related disease, a disease of the cardiovascular system, such as pulmonary edema, hypertension, pre-eclampsia, complex regional pain syndrome type 2, and stroke, chronic inflammatory disease, such as arthritis, a bone-related disease, chronic pain, such as fibromyalgia, acne

vulgaris, acute respiratory distress syndrome, Addison's disease, allergic intraocular inflammatory diseases, ANCA-associated small-vessel vasculitis, ankylosing spondylitis, autoimmune hemolytic anemia, Behcet's disease, Bell's palsy, bullous pemphigoid, cerebral ischemia, cirrhosis, Cogan's syndrome, contact dermatitis, Cushing's syndrome, dermatomyositis, discoid lupus erythematosus, eosinophilic fasciitis, erythema nodosum, exfoliative dermatitis, focal glomerulosclerosis, focal segmental glomerulosclerosis, segmental glomerulosclerosis, giant cell arteritis, gout, gouty arthritis, hand eczema, Henoch-Schonlein purpura, herpes gestationis, hirsutism, idiopathic ceratoscleritis, idiopathic thrombocytopenic purpura, immune thrombocytopenic purpura inflammatory bowel or gastrointestinal disorders, inflammatory dermatoses, lichen planus, lymphomatous tracheobronchitis, macular edema, myasthenia gravis, nonspecific fibrosing lung disease, osteoarthritis, pancreatitis, pemphigoid gestationis, pemphigus vulgaris, periodontitis, polyarteritis nodosa, polymyalgia rheumatica, pruritus scroti, pruritis/inflammation, psoriatic arthritis, pulmonary histoplasmosis, relapsing polychondritis, rosacea, sarcoidosis, scleroderma, septic shock syndrome, shoulder tendinitis or bursitis, Sjogren's syndrome, Still's disease, Sweet's disease, systemic sclerosis, Takayasu's arteritis, temporal arteritis, toxic epidermal necrolysis, transplant-rejection and transplant-rejection-related syndromes, tuberculosis, type-1 diabetes, vasculitis, Vogt-Koyanagi-Harada (VKH) disease, and Wegener's granulomatosis.

Antibodies

Methods for making and purifying antibodies or FKN-binding fragments thereof are well known in the art. See, e.g., Kohler et al., *Nature* 256:495-497 (1975); Hongo et al., *Hybridoma* 14:253-260 (1995); Harlow et al., Antibodies: A Laboratory Manual (Cold Spring Harbor Laboratory Press), 2nd ed. (1988); Hammerling et al., Monoclonal Antibodies and T-Cell Hybridomas (Elsevier), 563-681 (1981); Ni, Xiandai Mianyixue, 26:265-268 (2006); U.S. Patent Nos. 7,189,826; 7,078,492; and 7,153,507; Vollmers and Brandlein, *Histology and Histopathology* 20:927-937 (2005); Vollmers and Brandlein, *Methods and Findings in Experimental and Clinical Pharmacology* 27:185-191 (2005);

US 2006/258841; US 2006/183887; US 2006/059575; US 2005/287149; US 2005/100546; and US 2005/026229.

Chimeric Antibodies

Chimeric antibodies and methods to produce them are well known and established in the art. As used herein, the term "chimeric antibody" means an antibody, or FKN-binding fragment thereof, having at least some portion of at least one variable domain derived from the antibody amino acid sequence of a non-human mammal, a rodent, or a reptile, while the remaining portions of the antibody, or FKN-binding fragment thereof, are derived from a human. For example, a chimeric antibody may comprise a mouse antigen binding domain with a human Fc or other such structural domain.

Humanized Antibodies

The invention encompasses humanized anti-FKN antibodies and FKN-binding fragments thereof that, for example, modulate the interaction between FKN and CX3CR1. Humanization can be performed by means of the complementarity determining region (CDR)-grafting method (Kontermann and Dübel, Antibody Engineering, Springer Lab Manual (2001) and Tsurushita et al., *Methods* 36:69-83 (2005)). Humanization can be also performed following methods known in the art (see, e.g., Jones et al., *Nature* 321:522-525 (1986); Riechmann et al., *Nature* 332:323-327 (1988); and Verhoeyen et al., *Science* 239:1534-1536 (1988)) by substituting hypervariable region sequences for the corresponding sequences of a human antibody. Humanized antibodies are typically human antibodies in which some hypervariable region residues and possibly some FR residues are substituted by residues from analogous sites in non-human antibodies.

The choice of human variable domains, both light and heavy, to be used in making the humanized antibodies can be important to reduce antigenicity. According to the "best-fit" method, the sequence of the variable domain of a rodent antibody is screened against the entire library of known human variable-domain sequences. The human sequence that is closest to that of the rodent is then accepted as the human framework for

the humanized antibody. See, e.g., Sims et al., *J. Immunol.* 151:2296-2308 (1993) and Chothia et al., *J. Mol. Biol.* 196:901-917 (1987). Another method uses a particular framework derived from the consensus sequence of all human antibodies of a particular subgroup of light or heavy chains. The same framework may be used for several different humanized antibodies. See, e.g., Carter et al., *Proc. Natl. Acad. Sci. USA* 89:4285-4289 (1992) and Presta et al., *J. Immunol.* 151:2623-2632 (1993).

It is further generally desirable that antibodies be humanized with retention of high affinity for the antigen and other favorable biological properties. To achieve this goal, according to one method, humanized antibodies are prepared by a process of analysis of the parental sequences and various conceptual humanized products using three-dimensional models of the parental and humanized sequences. Three-dimensional immunoglobulin models are commonly available and are familiar to those skilled in the art. Computer programs are available which illustrate and display probable three-dimensional conformational structures of selected candidate immunoglobulin sequences. Inspection of these displays permits analysis of the likely role of the residues in the functioning of the candidate immunoglobulin sequence, i.e., the analysis of residues that influence the ability of the candidate immunoglobulin to bind its antigen. In this way, FR residues can be selected and combined from the recipient and import sequences so that the desired antibody characteristic, such as increased affinity for the target antigen(s) (e.g., FKN or a fragment thereof), is achieved. In general, the CDR residues are directly and most substantially involved in influencing antigen binding.

FKN-binding Fragments

In certain embodiments of the invention, there is provided FKN-binding fragments that modulate the interaction between FKN and CX3CR1. Such fragments may be functional antigen binding fragments of intact, humanized, and/or chimeric antibodies, such as Fab, Fab', $F(ab')_2$, Fv, or ScFv fragments (see, e.g., Bird et al., *Science* 242:423-426 (1998)) Such fragments are produced by the proteolytic digestion of intact antibodies by, e.g., papain digestion (see, e.g., WO 94/29348) directly from

recombinantly transformed host cells. FKN-binding fragments may be produced using a variety of engineering techniques described below.

Fv fragments have a lower interaction energy between their two chains than Fab fragments. To stabilize the association of the VH and VL domains, Fv fragments have been linked with peptides (see, e.g., Bird et al., *Science* 242:423-426 (1998) and Huston et al., *PNAS* 85:5879-5883 (1998)), disulfide bridges (see, e.g., Glockshuber et al., *Biochemistry* 29:1362-1367 (1990)), and "knob in hole" mutations (see, e.g., Zhu et al., *Protein Sci.* 6:781-788 (1997)). ScFv fragments can be produced by methods well known to those skilled in the art (see, e.g., Whitlow et al., *Methods Enzymol.* 2:97-105 (1991) and Huston et al., *Int. Rev. Immunol.* 10:195-217 (1993)). ScFv may be produced in bacterial cells such as *E. coli*, but may also be produced in eukaryotic cells. One disadvantage of ScFv is the monovalency of the product, which precludes an increased avidity due to polyvalent binding, and the short half-life of ScFv fragments. Attempts to overcome these problems include bivalent $(ScFv')_2$ produced from ScFV containing an additional C-terminal cysteine by chemical coupling (see, e.g., Adams et al., *Cancer Res.* 53:4026-4034 (1993) and McCartney et al., *Protein Eng.* 8:301-314 (1995)) or by spontaneous site-specific dimerization of ScFv containing an unpaired C-terminal cysteine residue (see, e.g., Kipriyanov et al., *Cell. Biophys.* 26:187-204 (1995)). Alternatively, ScFv can be forced to form multimers by shortening the peptide linker to 3 to 12 residues to form "diabodies" (see, e.g., Holliger et al., *PNAS* 90:6444-6448 (1993)). Reducing the linker further can result in ScFV trimers to form "triabodies" (see, e.g., Kortt et al., *Protein Eng.* 10:423-433 (1997)) and tetramers to form "tetrabodies" (see, e.g., Le Gall et al., *FEBS Letters* 453:164-168 (1999)). Construction of bivalent ScFV molecules can also be achieved by genetic fusion with protein dimerizing motifs to form "miniantibodies" (see, e.g., Pack et al., *Biochemistry* 31:1579-1584 (1992)) and "minibodies" (see, e.g., Hu et al., *Cancer Res.* 56:3055-3061 (1996)). ScFv-Sc-Fv tandems $((ScFV)_2)$ may also be produced by linking two ScFv units by a third peptide linker (see, e.g., Kurucz et al., *J. Immunol.* 154:4576-4582 (1995)). Bispecific diabodies can be produced through the noncovalent association of two single chain fusion products

containing a VH domain from one antibody connected by a short linker to the VL domain of another antibody (see, e.g., Kipriyanov et al., *Int. J. Can.* 77:763-772 (1998)). The stability of such bispecific diabodies can be enhanced by the introduction of disulfide bridges or "knob in hole" mutations or by the formation of single chain diabodies (ScDb), wherein two hybrid ScFv fragments are connected through a peptide linker (see, e.g., Kontermann et al., *J. Immunol. Methods* 226:179-188 (1999)). Tetravalent bispecific molecules are available by, e.g., fusing a ScFv fragment to the CH3 domain of an IgG molecule or to a Fab fragment through the hinge region (see, e.g., Coloma et al., *Nature Biotechnol.* 15:159-163 (1997)). Alternatively, tetravalent bispecific molecules are available by the fusion of bispecific single chain diabodies (see, e.g., Alt et al., *FEBS Letters* 454:90-94 (1999)). Smaller tetravalent bispecific molecules can also be formed by the dimerization of either ScFv-ScFv tandems with a linker containing a helix-loop-helix motif (DiBi miniantibodies) (see, e.g., Muller et al., *FEBS Letters* 432:45-49 (1998)) or a single chain molecule comprising four antibody variable domains (VH and VL) in an orientation preventing intramolecular pairing (tandem diabody) (see, e.g., Kipriyanov et al., *J. Mol. Biol.* 293:41-56 (1999)). Bispecific $F(ab')_2$ fragments can be created by chemical coupling of Fab' fragments or by heterodimerization through leucine zippers (see, e.g., Shalaby et al., *J. Exp. Med.* 175:217-225 (1992) and Kostelny et al., *J. Immunol.* 148:1547-1553 (1992)). Also available are isolated VH and VL domains (see, e.g., U.S. Patent Nos. 6,248,516; 6,291,158; and 6,172,197, hereby incorporated by reference).

Pharmaceutical Formulations

Therapeutic formulations comprising an antibody or FKN-binding fragment thereof of the invention may be combined with physiologically acceptable carriers, excipients, or stabilizers in the form of aqueous or dried formulations. Acceptable carriers, excipients, or stabilizers include, e.g., saline; buffers, such as phosphate, citrate, and other organic acids; antioxidants, including ascorbic acid; low molecular weight polypeptides; proteins (e.g., serum albumin, gelatin, or immunoglobulins); hydrophilic

polymers such as polyvinylpyrrolidone; amino acids; monosaccharides, disaccharides, and other carbohydrates, including glucose, mannose, or dextrins; chelating agents, such as EDTA; sugar alcohols, such as mannitol or sorbitol; salt-forming counterions, such as sodium; or nonionic surfactants, such as TWEEN™, PLURONICS™, or PEG.

The antibodies or FKN-binding fragments thereof of the invention may be entrapped in microcapsules, in colloidal drug delivery systems (e.g., liposomes, albumin microspheres, microemulsions, nanoparticles, or nanocapsules), or in macroemulsions. Where sustained release administration of the antibody is desired in a formulation with release characteristics suitable for the treatment of any disorder requiring administration of the antibody, microencapsulation of the antibody may be contemplated. Examples of sustained-release matrices include polyesters, hydrogels (for example, poly(2-hydroxyethyl-methacrylate) or poly(vinylalcohol)), polylactides (see, e.g., U.S. Patent No. 3,773,919), copolymers of L-glutamic acid and γ ethyl-L-glutamate, non-degradable ethylene-vinyl acetate, degradable lactic acid-glycolic acid copolymers such as the LUPRON DEPOT™ (injectable microspheres composed of lactic acid-glycolic acid copolymer and leuprolide acetate), and poly-D-(-)-3-hydroxybutyric acid.

The formulations to be used for *in vivo* administration must be sterile. This is readily accomplished by filtration through sterile filtration membranes.

Combination Therapies

Therapeutic antibodies or FKN-binding fragments thereof of the invention can be used either alone or in combination with other compositions in a therapy. For instance, an antibody of the invention may be co-administered with one or more of another antibody, anti-inflammatory agents, cytotoxic agents, anti-angiogenic agents, cytokines, growth inhibitory agents, or anti-TNF-α therapy. Such combined therapies include combined administration (where the two or more agents are included in the same or separate formulations) and separate administration (e.g., simultaneously or sequentially). When two or more agents are administered separately, administration of the antibody of the invention can occur prior to or following administration of the adjunct therapy.

The effective amounts of therapeutic agents administered in combination with an anti-FKN antibody or FKN-binding fragment thereof will be at a physician's discretion. The dosage determination is calculated to achieve maximal management of the conditions to be treated. The dose will additionally depend on such factors as the type of therapeutic agent to be used and the specific subject being treated. Suitable dosages can be lowered due to the combined action (synergy) of the additional therapeutic agent and the anti-FKN antibody or FKN-binding fragment thereof.

Anti-Inflammatory Agents

An anti-inflammatory compound may be administered in combination with the antibodies or FKN-binding fragments of the invention. Exemplary anti-inflammatory agents include steroids, such as a glucocorticoid, non-steroidal anti-inflammatory drugs (e.g., ibuprofen or tacrolimus), cyclooxygenase-2-specific inhibitors such as rofecoxib (Vioxx®) and celecoxib (Celebrex®), corticosteroids (e.g., prednisone or hydrocortisone), specific cytokines directed at T lymphocyte function, flubiprofen, diclofenac, and ketarolac. See, e.g., U.S. Patent Nos. 7,112,578 and 7,199,119, hereby incorporated by reference.

Other Agents

Other therapeutic agents that may be administered include, e.g., aminosalicylates (e.g., 5-aminosalicylic acid), sulfasalazine (e.g., azulfadine), mesalamine (e.g., Asacol® or Pentasa®), azathioprine (e.g., Imuran®), 6-mercaptopurine (e.g., Purinethol®), cyclosporine, methotrexate, infliximab (e.g., Remicade®), interferons (e.g., interferon-β), glatiramer acetate (e.g., Copaxone®), natalizumab (Tysabri®), anti-integrin α4, ursodeoxycholic acid, tacrine hydrochloride, HMG CoA reductase inhibitor, lidocaine, sulfonylurea, cyclophosphamide, intravenous immunoglobulin, amitriptyline, opiates (e.g., morphine), diphenoxylate, atropine, vitamin D, calcium, lamotrigine, quetiapine, prostaglandin E1, nitroglycerin, pegaptanib, ranibizumab, isosorbide dinitrate, perospirone, topiramate, oxcarbazepine, dopamine, mycophenolate mofetil, mizoribine,

levetiracetam, fentanyl, tramadol, digitalis, capsaicin, natriuretic peptide, cloridine, -dronates (e.g., alendronate), bezafibrate, mexiletine, glinides (e.g., nateglinide or repaglinide), donepezil hydrochloride, leflunomide, pregabalin, rivastigmine tartrate, phentanyl, prostacyclin, procainamide, colchicine, α-glucosidase inhibitors, diuretics (e.g., thiazide diuretics or anti-aldosterone diuretics), tacrolimus, memantine hydrochloride, pentazocine, clopidogrel, tissue plasminogen activator, thalidomide, angiotensin receptor blocker, thiazolidinedione, metronidazole, spironolactone, duloxetine, paroxetine, clonidine, ticlopidine, heparin, calcium channel blockers, insulin, albumin, bucillamine, carbamazepine, risperidone, limaprost, warfarin, verteporfin, gabapentin, galantamine hydrobromide, aspirin, urokinase, chlorambucil, angiotensin converting enzyme inhibitor, biguanides, β-adrenergic receptor inhibitors or agonists, hydrochloroquine, and mitoxantrone.

Treatment of a disorder described herein (e.g., an inflammatory disorder) may additionally involve administration of other therapies. For example, plasmapheresis (e.g., plasma exchange therapy) may be used to treat, for example, Guillain-Barré syndrome, demyelinating polyradiculopathy (e.g., chronic inflammatory demyelinating polyradiculopathy), thrombotic thrombocytopenic purpura (TTP), Behcet's disease, or multiple sclerosis.

Dosages and Administration

Alleviation or treatment of an inflammatory disorder generally involves the lessening of one or more symptoms or complications associated with the disorder. In the case of inflammatory disorders, the therapeutically effective amount of the therapeutic antibody, FKN-binding fragments, or pharmaceutical composition thereof can accomplish one or a combination of the following: reduce inflammation; reduce abdominal pain or cramping; reduce bloating; reduce or eliminate diarrhea; reduce ulceration of the digestive tract; reduce fever; reduce or relieve nausea; reduce fatigue; minimize weight loss; alleviate joint pain; reduce swelling; relieve itching or skin rashes; eliminate jaundice; and/or relieve one or more of the symptoms associated with an

inflammatory disorder. The "therapeutically effective amount" of the antibody to be administered is the minimum amount necessary to prevent, ameliorate, or treat an inflammatory disorder.

The antibodies, FKN-binding fragments, and pharmaceutical composition described herein are administered to a subject in accordance with known methods, such as intravenous administration as a bolus or by continuous infusion over a period of time, topically, orally, subcutaneously, by bronchial injection, intracerebrally, intranasally, transdermally, intraperitoneally, intramuscularly, intrapulmonary, vaginally, rectally, intraarticularly, intraarterially, intralesionally, parenterally, intraventricularly in the brain, or intraocularly. Local administration may be particularly desired if extensive side effects or toxicity is associated with the treatment.

Formulations for oral use may also be provided as chewable tablets, or as hard gelatin capsules, wherein the active ingredient is mixed with an inert solid diluent, or as soft gelatin capsules wherein the active ingredient is mixed with water or an oil medium.

An *ex vivo* strategy can also be used for therapeutic applications. *Ex vivo* strategies involve transfecting or transducing cells obtained from the subject with a polynucleotide encoding an antibody or antibody fragment. The transfected or transduced cells are then returned to the subject. The cells can be any of a wide range of types including, without limitation, hemopoietic cells (e.g., bone marrow cells, macrophages, monocytes, dendritic cells, T cells, or B cells), fibroblasts, epithelial cells, endothelial cells, keratinocytes, or muscle cells.

The dosage and the timing of administering the compositions of the present invention depend on various clinical factors, including the overall health of the subject and the severity of the symptoms of the inflammatory disorder. Treatment can be continued for a period of time ranging from 1 day to 4 years, 1 day to 3 years, 1 day to 2 years, 1 day to a year, 1 to 100 days, 1 to 60 days, 1 to 20 days, 1 to 10 days, or until the inflammatory disorder or symptoms of the inflammatory disorder are treated or alleviated. The compositions of the present invention may be administered four times per day, three times per day, twice per day, daily, weekly, bi-monthly, monthly, every two months,

every three months, or annually. Dosages vary depending on the severity of the condition and are titrated to achieve a steady-state blood serum concentration ranging from about 1 ng/mL to 10 μg/mL, or 1 to 500 ng/mL. The amount of antibody administered is typically in the range of about 0.001 to about 30 mg/kg of subject weight (e.g., 0.01 to about 10 mg/kg of subject weight).

Examples

The present invention is illustrated by the following examples, which are in no way intended to be limiting of the invention.

Example 1. Preparation of mouse anti-human fractalkine (hFKN) monoclonal antibodies

Mouse anti-hFKN monoclonal antibodies (mAbs) were generated as described previously (see, e.g., U.S. Patent No. 7,390,490, hereby incorporated by reference). Neutralizing mAb clones 1F3-1, 3A5-2, 1F3, 1G1, 2B2, 3D5, 3H7, 6D1, 7F6, and 5H7-6 were obtained.

Example 2. Selection of candidate mAb for humanization

Clones 1F3-1, 3A5-2, and 5H7-6 were analyzed using chemotaxis assays for measuring neutralizing activity, BIACORE® assays for measuring binding affinity to hFKN, and enzyme-linked immunosorbent assays (ELISA) for measuring species cross-reactivity to cynomolgus monkey FKN. The neutralizing activity, binding affinity, and species cross-reactivity to cynomolgus monkey FKN are summarized in Figure 2. Clone 3A5-2 showed the highest neutralizing activity and the highest binding affinity to hFKN. Clone 3A5-2 showed equal reactivity to cynomolgus monkey FKN and hFKN. Therefore, clone 3A5-2 was selected as a candidate for humanization.

Chemotaxis assays were performed as follows. Cells were placed in the upper wells of a transwell culture plate (MultiScreen-MIC Plate, 5.0 μm, Millipore, Catalog No. MAMIC 5S10) with ligand in the lower wells. First, recombinant human FKN (R&D

Systems, Catalog No. 362-CX/CF) (33 ng/ml final concentration) (Figure 1) was pre-incubated with purified antibodies at various concentrations (0 to 10 μg/ml) at room temperature. The composition contained the following components: 10x chemokine solution, 15 μl/well; 10x purified mAb, 15 μl/well; and 1x chemotaxis buffer (0.5% BSA, 0.5% FBS, 20 mM HEPES (pH 7.4), 50 μM 2-mercaptoethanol in RPMI1640 (Invitrogen)), 120 μl/well. After 30 minutes, B300.19 cells transfected with CX3CR1 ($2x10^5$ cells/75 μl) were applied to the upper wells and incubated in a 5%-CO_2 incubator at 37°C for 4 hours. After the incubation, 150 μl of the solution of the lower wells were harvested, fixed with 50 μl of 4% PFA/PBS, and 30 μl of the samples were applied to the FACSCantoII cell analyzer to count migrated cells.

BIACORE® assays were performed as follows. Recombinant Protein-A/G (Pierce Chemical) was immobilized on BIACORE® sensor chips (CM5) that were pre-activated with amine coupling reagents (GE Healthcare). Purified mAbs were added into the sensor chips at a concentration of 0.2 μg/ml. Soluble antigens (soluble FKN conjugated to secreted alkaline phosphatase (SEAP) or control SEAP proteins) were added into the sensor chips at various concentrations (0 to 200 nM). Association of added antigens with mAbs captured on the sensor chips was monitored continuously, and the relative binding response of the antigens was determined using a BIACORE® A100 system (GE Healthcare).

ELISAs were performed as follows. Polyclonal anti-rabbit IgG antibody (Jackson ImmunoResearch Laboratories, Catalog No. 711-005-152) was coated on the wells of a 96-well plate (Nunc, Catalog No. 442402). After overnight incubation at 4°C, the wells were blocked with 1x Block-Ace (DainipponPharma) for 1 hour at room temperature. After washing three times with 0.05% Tween 20/PBS, 10 nM rabbit polyclonal anti-PLAP antibody (Biomeda) was added to the wells (50 μl/well). After incubating for 1 hour at room temperature and washing three times as described above, culture supernatants containing hFKN-SEAP or cynomolgus monkey FKN-SEAP were added (1 nM final concentration) to the wells and incubated for 1 hour at room temperature. After washing three times, purified anti-hFKN mAbs were added to the wells at various

concentrations (0 to 10 μg/ml). After incubating for 1 hour and washing three times, horseradish peroxidase-conjugated anti-mouse IgG antibody (Jackson ImmunoResearch Laboratories, Catalog No. 715-036-151) was added at 0.16 μg/ml (50 μl/well) and incubated for 1 hour at room temperature. After washing three times, a TMB (3,3',5,5'-tetramethylbenzidine) solution was added to the wells and allowed to incubate for 15-30 minutes. An equal volume of stopping solution (2 M H_2SO_4) was added to the wells and the optical density at 450 nm was read by a microplate reader (Arvo, PerkinElmer).

Soluble hFKN-SEAP was prepared as follows. cDNA encoding the extracellular region of hFKN was amplified with 5'-SalI-hFKN primer (CGCGTCGACGCCACCAT-GGCTCCGATATCTCTGTC; SEQ ID NO: 2) and 3'-NotI-hFKN primer (GCGGGCG-GCCGCCCTCCGGGTGGCAGCCTGGG; SEQ ID NO: 3) and subcloned into pcDNA3.1 (+) dSalI SEAP vector containing SEAP cDNA. The expression vector of hFKN-SEAP was transfected into HEK293EBNA (HEK293E) cells (Invitrogen). HEK293E cells were inoculated with DMEM (Invitrogen) supplemented with 10% fetal bovine serum on the day before transfection. On the day of transfection, the medium was exchanged with OPTI-MEM II serum free media (Invitrogen). The expression vector was transfected with TransIT LT1 (TAKARA) according to the manufacturers' instructions. After 3 days of incubation (5% CO_2 at 37°C), the culture supernatant was harvested. The concentration of SEAP protein was measured using Great EscAPe SEAP Chemiluminescence Kit 2.0 (Clontech).

Soluble cynomolgus monkey FKN-SEAP was prepared as follows. cDNA encoding the extracellular region of cynomolgus monkey FKN was amplified with 5'-XhoI-cynomolgus monkey FKN primer (GCGCTCGAGGCCACCATGGCTCCGATA-TCTCTGTCGTGG; SEQ ID NO: 4) and 3'-NotI-cynomolgus monkey FKN primer (CGCGGCGGCCGCGGTGGCAGCCTGGGAGTCAGGGAC; SEQ ID NO: 5) and subcloned into pENTR1A (Invitrogen) containing SEAP cDNA. The fragment encoding cynomolgus monkey FKN and SEAP was transferred to pcDNA3.1 containing cassette B by using the GATEWAY system (Invitrogen). Culture supernatant containing cynomolgus monkey FKN-SEAP was prepared as described above.

Example 3. cDNA cloning of the variable regions of heavy and light chains of clone 3A5-2 mouse anti-hFKN mAb

cDNAs of heavy and light chains of clone 3A5-2 were amplified by RT-PCR. The total RNA was extracted from the hybridoma of clone 3A5-2 with RNeasy Mini Kit (QIAGEN). By using the total RNA, cDNAs were synthesized using a cDNA synthesis kit (TAKARA) and amplified with 5'-Mm-HC-Leader1 primer (GGGATGGRATGSAG-CTGKGTMATSCTCTT; SEQ ID NO: 6), 5'- Mm-HC-Leader2 primer (GGGATGRA-CTTCGGGYTGAGCTKGGTTTT; SEQ ID NO: 7), or 5'- Mm-HC-Leader3 primer (GGGATGGCTGTCTTGGGGCTGCTCTTCT; SEQ ID NO: 8) and 3'- Mm-IgG2a-CH3-R primer (TCATTTACCCGGAGTCCGGGAGAAGCTCTTAGTC; SEQ ID NO: 9) for the heavy chain and 5'- Mm-LC-Leader1 primer (GGGATGGAGACAGACACA-CTCCTGCTAT; SEQ ID NO: 10) or 5'- Mm-LC-Leader2 primer (GGGATGGATTTT-CAGGTGCAGATTTTCAG; SEQ ID NO: 11) or 5'- Mm-LC-Leader3 primer (GGGATGRAGTCACAKACYCAGGTCTTYRTA; SEQ ID NO: 12) or 5'- Mm-LC-Leader4 primer (GGGATGAGGKCCCCWGCTCAGYTYCTKGGR; SEQ ID NO: 13) or 5'- Mm-LC-Leader5 primer (GGGATGAAGTTGGCTGTTAGGCTGTTG; SEQ ID NO: 14) and 3'- Mm-Ckappa-R primer (CTAACACTCATTCCTGTTGAAGCTC; SEQ ID NO: 15) for the light chain, respectively. Amplified cDNAs were subcloned into pCR2.1 vector (Invitrogen). The sequences were analyzed using ABI3130XL. Full-length heavy chain and a 5'-truncated version of the L chain were obtained. To amplify the truncated region of L chain and identify precise leader sequences, 5'-rapid amplification of cDNA ends (5'-RACE) was performed. Double-stranded cDNA was prepared using a cDNA synthesis kit (TAKARA) and 5' adaptor (ad29S; ACATCACTC-CGT (SEQ ID NO: 16) and as29AS; ACGGAGTGATGTCCGTCGACGTATCTCTGC-GTTGATACTTCAGCGTAGCT (SEQ ID NO: 17) were annealed) was added. cDNA was amplified with 5'-PCR1 primer (GTATCAACGCAGAGATACGTCGACGG; SEQ ID NO: 18) for the first PCR and 5'-PCR4 primer (AGCTACGCTGAAGTATCAACGC-AG-AG; SEQ ID NO: 19) for the second PCR and 3' HC RACE primer_1 (GTACGGA-

GTACTCCAAAAATGTTG; SEQ ID NO: 20) for the first PCR or 3' HC RACE primer_2 (TCTTCAGGCTGCAGGCTGATGATC; SEQ ID NO: 21) for the second PCR for H chain, 3' LC RACE primer_3 (AAATCTTCAGGCTGCAGGCTGTTG; SEQ ID NO: 22) for the first PCR or 3' LC RACE primer_4 (CTGTTGATCTTGAGAGAATATTGTG; SEQ ID NO: 23) for the second PCR for L chain, respectively. Amplified cDNAs were subcloned and sequenced as described above. The identified sequences of variable regions are as follows.

Nucleotide sequence of the heavy (H) chain variable region:
CAGGTCCAGCTGCAGCAGTCTGGACCTGAACTGGTGAAGCCTGGGGCTTCAG
TGAAGATGTCCTGCAAGGCTTCTGGCTACACCTTCACAAACTACTATATACAC
TGGGTGAAGCAGAGGCCTGGACAGGGACTTGAGTGGATTGGATGGATTTATC
CTGGAGATGGTAGTCCTAAGTTCAATGAGAGGTTCAAGGGCAAGACCACACT
GACTGCAGACAAGTCCTCAAACACAGCCTACATGTTGCTCAGCAGCCTGACC
TCTGAAGACTCTGCGATCTATTTCTGTGCAACTGGGCCCACTGATGGCGACTA
CTTTGACTACTGGGGCCAGGGCACCACTCTCACAGTCTCCTCA (SEQ ID NO: 24)

Nucleotide sequence of the light (L) chain variable region:
GACATCCAGATGACTCAGTCTCCAGCCTCCCTATCTGCATCTGTGGGAGAAA
CTGTCACCATCACATGTCGAGCAAGCGGGAATATTCACAATTTTTTAGCATGG
TATCAGCAGAAACAGGGAAAATCTCCTCAGTTCCTGGTCTATAATGAAAAAA
CCTTAGCAGATGGTGTGCCATCAAGGTTCAGTGGCAGTGGATCAGGAACACA
ATATTCTCTCAAGATCAACAGCCTGCAGCCTGAAGATTTTGGGATTTATTTCT
GTCAACAGTTTTGGAGTACTCCGTATACGTTCGGAGGGGGGACCAAGCTGGA
AATAAAA (SEQ ID NO: 25)

Amino acid sequence of the heavy (H) chain variable region:

QVQLQQSGPELVKPGASVKMSCKASGYTFTNYYIHWVKQRPGQGLEWIGWIYP GDGSPKFNERFKGKTTLTADKSSNTAYMLLSSLTSEDSAIYFCATGPTDGDYFDY WGQGTTLTVSS (SEQ ID NO: 26)

Amino acid sequence of the light (L) chain variable region:

DIQMTQSPASLSASVGETVTITCRASGNIHNFLAWYQQKQGKSPQFLVYNEKTLA DGVPSRFSGSGSGTQYSLKINSLQPEDFGIYFCQQFWSTPYTFGGGTKLEIK (SEQ ID NO: 27)

Example 4. Design of humanized anti-FKN mAbs from clone 3A5-2

Mouse anti-hFKN mAb, clone 3A5-2, was humanized by means of the complementarity determining region (CDR)-grafting method (Kontermann and Dübel, Antibody Engineering, Springer Lab Manual (2001) and Tsurushita et al., *Methods* 36:69-83 (2005)). The amino acid sequences of the CDRs are as follows.

CDR-H1: NYYIH (SEQ ID NO: 28)
CDR-H2: WIYPGDGSPKFNERFKG (SEQ ID NO: 29)
CDR-H3: GPTDGDYFDY (SEQ ID NO: 30)
CDR-L1: RASGNIHNFLA (SEQ ID NO: 31)
CDR-L2: NEKTLAD (SEQ ID NO: 32)
CDR-L3: QQFWSTPYT (SEQ ID NO: 33)

Human acceptor frameworks were selected among the human variable region segments. Identified CDRs of 3A5-2 were grafted into the selected human acceptor frameworks. The designed humanized sequences are as follows.

H chain (designated as H3; SEQ ID NO: 36)
QVQLVQSGAEVKKPGASVKVSCKASGYTFTNYYIHWVKQAPGQGLEWIGWIYP GDGSPKFNERFKGRTTLTADKSTNTAYMLLSSLRSDDTAVYFCATGPTDGDYFD YWGQGTTVTVSS
H chain (designated as H3-2; SEQ ID NO: 37)

QVQLVQSGAEVKKPGASVKVSCKASGYTFTNYYIHWVKQAPGQGLEWIGWIYP
GDGSPKFNERFKGRTTLTADKSTNTAYMLLSSLRSEDTAVYFCATGPTDGDYFD
YWGQGTTVTVSS

L chain (designated as L2; SEQ ID NO: 38)
DIQMTQSPSSLSASVGDRVTITCRASGNIHNFLAWYQQKPGKAPKFLVYNEKTLA
DGVPSRFSGSGSGTQYTLTISSLQPEDFATYFCQQFWSTPYTFGGGTKVEIK

H chain (designated as H4; SEQ ID NO: 39)
QVQLVQSGAEVKKPGASVKVSCKASGYTFTNYYIHWVRQAPGQGLEWIGWIYP
GDGSPKFNERFKGRTTLTRDKSTNTAYMELSSLRSDDTAVYFCATGPTDGDYFD
YWGQGTTVTVSS

Germline sequences for H chain (SEQ ID NO: 40)
QVQLVQSGAEVKKPGASVKVSCKASGYTFTXXXXXWVRQAPGQGLEWMGXX
XXXXXXXXXXXXXXXRVTMTRDTSTSTAYMELSSLRSEDTAVYYCARXXXXX
XXXXXWGQGTTVTVSS

Germline sequences for L chain (SEQ ID NO: 41)
DIQMTQSPSSLSASVGDRVTITCXXXXXXXXXXXXWYQQKPGKAPKLLIYXXXX
XXXGVPSRFSGSGSGTDFTLTISSLQPEDFATYYCXXXXXXXXXFGGGTKVEIK

H chain (designated as HK2; SEQ ID NO: 42)
QVQLVQSGAEVKKPGASVKVSCKASGYTFTNYYIHWVRQAPGQGLEWIGWIYP
GDGSPKFNERFKGRTTMTADTSTSTAYMELSSLRSEDTAVYFCARGPTDGDYFD
YWGQGTTVTVSS

H chain (designated as HK3; SEQ ID NO: 43)

QVQLVQSGAEVKKPGASVKVSCKASGYTFTNYYIHWVRQAPGQGLEWIGWIYP
GDGSPKFNERFKGRTTLTADKSTSTAYMELSSLRSEDTAVYFCARGPTDGDYFD
YWGQGTTVTVSS

L chain (designated as L4; SEQ ID NO: 44)

DIQMTQSPSSLSASVGDRVTITCRASGNIHNFLAWYQQKPGKAPKLLIYNEKTLA
DGVPSRFSGSGSGTDYTLTISSLQPEDFATYFCQQFWSTPYTFGGGTKVEIK

L chain (designated as L5; SEQ ID NO: 45)

DIQMTQSPSSLSASVGDRVTITCRASGNIHNFLAWYQQKPGKAPKLLIYNEKTLA
DGVPSRFSGSGSGTQYTLTISSLQPEDFATYFCQQFWSTPYTFGGGTKVEIK

All humanized sequences were aligned (Figures 3 and 4).

Example 5. Construction of expression vectors of the humanized anti-hFKN mAbs

To select the leader sequences for expression of humanized mAbs, germline segments were searched based on the similarity to AAA68427.1 and ABU90602.1. Segments VH1-1-18 and VKI-O12 were the most similar to the AAA68427.1 and ABU90602.1, respectively. Their leader sequences were used for expression of humanized mAbs. Their leader sequences are as follows.

H chain amino acid sequence (SEQ ID NO: 46)

MDWTWSILFLVAAPTGAHS

H chain nucleotide sequences

ATGGACTGGACCTGGAGCATCCTTTTCTTGGTGGCAGCACCAACAGGTGCCC
ACTCC (for H3 and H3-2; SEQ ID NO: 47)

ATGGACTGGACATGGTCCATCCTGTTCCTGGTGGCCGCTCCAACTGGCGCAC
ACTCT (for HK2 and HK3; SEQ ID NO: 48)

L chain amino acid sequence (SEQ ID NO: 49)

MDMRVPAQLLGLLLLWLRGARC

L chain nucleotide sequence (SEQ ID NO: 50)

ATGGACATGAGGGTCCCCGCTCAGCTCCTGGGGCTCCTGCTACTCTGGCTCCG
AGGTGCCAGATGT

Variable regions of the designed humanized anti-hFKN mAbs added with leader sequences described above were generated by PCR with the following primers.

For H3 heavy chain

h3A5-2_VH3-1 primer (SEQ ID NO: 51):

ATGGACTGGACCTGGAGCATCCTTTTCTTGGTGGCAGCACCAACAGGTGC

h3A5-2_VH3-2R primer (SEQ ID NO: 52):

CCAGACTGCACCAGCTGCACCTGGGAGTGGGCACCTGTTGGTGCTGCCAC

h3A5-2_VH3-3 primer (SEQ ID NO: 53):

GTGCAGCTGGTGCAGTCTGGGGCTGAGGTGAAGAAGCCTGGGGCCTCAGT

h3A5-2_VH3-4R primer (SEQ ID NO: 54):

GTGTATCCAGAAGCCTTGCAGGAGACCTTCACTGAGGCCCCAGGCTTCTT

h3A5-2_VH3-5 primer (SEQ ID NO: 55):

TGCAAGGCTTCTGGATACACCTTCACCAACTACTATATACACTGGGTGAA

h3A5-2_VH3-6R primer (SEQ ID NO: 56):

ATCCACTCAAGCCCTTGTCCAGGGGCCTGCTTCACCCAGTGTATATAGTA

h3A5-2_VH3-7 primer (SEQ ID NO: 57):

GGACAAGGGCTTGAGTGGATAGGATGGATTTATCCTGGAGATGGTAGTCC

h3A5-2_VH3-8R primer (SEQ ID NO: 58):

GTCCTGCCCTTGAACCTCTCATTGAACTTAGGACTACCATCTCCAGGATA

h3A5-2_VH3-9 primer (SEQ ID NO: 59):
GAGAGGTTCAAGGGCAGGACCACCCTGACCGCAGACAAGTCCACGAACAC

h3A5-2_VH3-10R primer (SEQ ID NO: 60):
GATCTCAGGCTGCTCAGCAACATGTAGGCTGTGTTCGTGGACTTGTCTGC

h3A5-2_VH3-11 primer (SEQ ID NO: 61):
TTGCTGAGCAGCCTGAGATCTGACGACACGGCCGTGTATTTCTGTGCGAC

h3A5-2_VH3-12R primer (SEQ ID NO: 62):
TAGTCAAAGTAGTCGCCATCAGTGGGCCCTGTCGCACAGAAATACACGGC

h3A5-2 VH3-13 primer (SEQ ID NO: 63):
GATGGCGACTACTTTGACTACTGGGGCCAAGGGACCACGGTCACCGTCTC

h3A5-2_R primer (SEQ ID NO: 64):
GACCGATGGGCCCTTGGTGGAGGCTGAAGAGACGGTGACCGTGGTCCC

<u>For L2 light chain</u>

h3A5-2_VL2-1 primer (SEQ ID NO: 65):
GCCACCATGGACATGAGGGTCCCCGCTCAGCTCCTGGGGCTCCTGCTACTCTG
GCTCCGAGGTGCCAGAT

h3A5-2_VL2-2R primer (SEQ ID NO: 66):
TCCTACAGATGCAGACAGGGAGGATGGAGACTGGGTCATCTGGATGTCACAT
CTGGCACCTCGGAGCCAG

h3A5-2_VL2-3 primer (SEQ ID NO: 67):
CCCTGTCTGCATCTGTAGGAGACAGAGTCACCATCACTTGCCGAGCAAGCGG
GAATATTCACAATTTTTT

h3A5-2_VL2-4R primer (SEQ ID NO: 68):

GAACTTAGGGGCTTTCCCTGGTTTCTGTTGATACCATGCTAAAAAATTGTGAA
TATTCCCGCTTGCTCGG

h3A5-2_VL2-5 primer (SEQ ID NO: 69):
CAGGGAAAGCCCCTAAGTTCCTGGTCTATAATGAAAAAACCTTAGCAGATGG
GGTCCCATCAAGGTTCAG

h3A5-2_VL2-6R primer (SEQ ID NO: 70):
GTTGCAGACTGCTGATGGTGAGAGTATATTGTGTCCCAGATCCACTGCCACTG
AACCTTGATGGGACCCC

h3A5-2_VL2-7 primer (SEQ ID NO: 71):
CACCATCAGCAGTCTGCAACCTGAAGATTTTGCGACCTACTTCTGTCAACAGT
TTTGGAGTACTCCGTAT

h3A5-2_VL2-8R primer (SEQ ID NO: 72):
TTTGATCTCCACCTTGGTCCCTCCGCCGAACGTATACGGAGTACTCCAAAACT
GTTGACAGAA

h3A5-2_VL-R (SEQ ID NO: 73):
GACAGATGGTGCAGCCACAGTTCGTTTGATCTCCACCTTGGTCCCTCC

Generated H3 and L2 were amplified by PCR with 5'-Eco-Sal-h3A5-2_VH_F primer (GCGAATTCGTCGACGCCACCATGGACTGGACCTGGAGCATCCTTTT-CTTG; SEQ ID NO: 74) and 3'-NheI-h3A5-2_VH_R (CGCGCTAGCTGAAGAGAC-GGTGACCGTGGT-CCC; SEQ ID NO: 75) for H3 and 5'-h3A5-2_VL_SalI-kozac_F primer (GCGGTCGACGCCACCATGGACATGAGGGTCCCC; SEQ ID NO: 76) and 3'-h3A5-2_VL-R primer (GACAGATGGTGCAGCCACAGTTCGTTTGATCTCCAC-CTTGGTCCCTCC; SEQ ID NO: 77) for L2, respectively.

H4 was generated by Genscript USA Inc. The sequence of H4 is as follows.

H4 (SEQ ID NO: 78):
GAATTCGTCGACGCCACCATGGACTGGACATGGTCCATCCTGTTCCTGGTGGC
CGCTCCAACTGGCGCACACTCTCAGGTGCAGCTGGTGCAGAGTGGCGCTGAG

GTGAAGAAACCCGGAGCATCAGTGAAGGTGTCCTGCAAAGCCAGCGGATAC
ACCTTCACCAACTACTATATTCATTGGGTGAGGCAGGCTCCTGGACAGGGAC
TGGAGTGGATCGGATGGATCTACCCAGGGGACGGTTCCCCTAAGTTCAACGA
AAGGTTTAAAGGCCGGACCACACTGACCAGGGATAAGTCAACCAATACAGCT
TACATGGAACTGTCCAGCCTGCGCTCTGACGATACAGCAGTGTATTTCTGTGC
CACTGGGCCAACCGACGGCGACTACTTTGATTATTGGGGCCAGGGAACTACC
GTGACCGTGTCTAGTGCTAGC

The variable region of HK2 was generated by point mutations with PCR from H4 with the following primers.

3A5-2_HKG2_sal24F primer (SEQ ID NO: 79):
CGCGTCGACGCCACCATGGACTGGACATGGTCCATCCTG

h3A5-2_HKG2_280F primer (SEQ ID NO: 80):
ATGACCGCCGATACCTCAACCTCCACAGCTTACATGGAA

h3A5-2_HKG2_300R primer (SEQ ID NO: 81):
GGTTGAGGTATCGGCGGTCATTGTGGTCCG

h3A5-2_HKG2_340F primer (SEQ ID NO: 82):
GAGGATACAGCAGTGTATTTCTGTGCCCGGGGGCCAACC

h3A5-2_HKG2_370R primer (SEQ ID NO: 83):
GGCACAGAAATACACTGCTGTATCCTCAGAGCGCAG

h3A5-2_HKG2_Nhe24R (SEQ ID NO: 84):
CGCGCTAGCACTAGACACGGTCACGGTAGTTCC

The variable region of HK3 was generated by point mutations with PCR from HK2 with primers as follows.

h3A5-2_HKG2_sal24F primer (SEQ ID NO: 85):
CGCGTCGACGCCACCATGGACTGGACATGGTCCATCCTG

HKG3_R primer (SEQ ID NO: 86):
TTGACTTATCGGCGGTCAGTGTGGTCCGGCCTTTAAACCTTTC

HKG3_F primer (SEQ ID NO: 87):
ACACTGACCGCCGATAAGTCAACCTCCACAGCTTACATGGAA

h3A5-2_HKG2_Nhe24R primer (SEQ ID NO: 88):
CGCGCTAGCACTAGACACGGTCACGGTAGTTCC

The variable region of L4 was generated by point mutations with PCR from L2 with primers as follows.

h3A5-2_VL4_sal24F primer (SEQ ID NO:89):
CGCGTCGACGCCACCATGGACATGAGGGTCCCCGCTCAG

h3A5-2_VL4_200R primer (SEQ ID NO: 90):
CAGCAGCTTAGGGGCTTTCCCTGGTTTCTG

h3A5-2_VL4_190F primer (SEQ ID NO: 91):
GGGAAAGCCCCTAAGCTGCTGATCTATAATGAAAAA

h3A5-2_VL4_260R primer (SEQ ID NO: 92):
TGTCCCAGATCCACTGCCACTGAACCTTGA

h3A5-2_VL4_250F primer (SEQ ID NO: 93):
AGTGGCAGTGGATCTGGGACAGACTATACTCTCACC

h3A5-2_VL4_BsiW24R primer (SEQ ID NO: 94):
CGCCGTACGTTTGATCTCCACCTTGGTCCCTCC

The variable region of L5 was generated by point mutations with PCR from L4 with primers as follows.

h3A5-2_VL4_sal24F primer (SEQ ID NO: 95):
CGCGTCGACGCCACCATGGACATGAGGGTCCCCGCTCAG

VL5_R primer (SEQ ID NO: 96):
GGTGAGAGTATACTGTGTCCCAGATCCACTGCCACTGAAC

VL5_F primer (SEQ ID NO: 97):
GGATCTGGGACACAGTATACTCTCACCATCAGCAGTCTG

h3A5-2_VL4_BsiW24R (SEQ ID NO: 98):
cgcCGTACGTTTGATCTCCACCTTGGTCCCTCC

Constant regions of IgG2 and Igκ were amplified with 5'-NheI-IgG2_F primer (CGCGCTAGCACCAAGGGCCCATCGGTCTTCCCC; SEQ ID NO: 99) and 3'-EcoRV-IgG2_R primer (CGCGATATCTCATTTACCCGGAGACAGGGAGAG; SEQ ID NO: 100) for IgG2 and 5'-BsiWI-Igk_F primer (CGCCGTACGGTGGCTGCACCATCTGTCTTCATC; SEQ ID NO: 101) and 3'-EcoRV-Igk_R primer (CGCGATATCCTAACACTCTCCCCTGTTGAAGCT; SEQ ID NO: 102) for Igκ, respectively. Amplified constant regions were subcloned into pENTR1A dNotI in which NotI was deleted.

Generated variable regions were subcloned into pENTR1A-IgG2 or pENTR1A-Igκ by using SalI-NheI sites for heavy chains or SalI-BsiWI sites for light chains, respectively. In the case of L2, the constant region of Igκ was amplified with 5'- hIGK_F primer (CGAACTGTGGCTGCACCATCTGTC; SEQ ID NO: 103) and 3'- hIGK_NotI-R primer (CGCGCGGCCGCCTAACACTCTCCCCTGTTGAAGCTCTT; SEQ ID NO: 104). The amplified Igκ constant region and the generated L2 were combined by PCR and subcloned into pENTR1A. Subcloned variable regions and constant regions were transferred into pEE6.4 or pEE12.4 (Lonza) for the heavy chain and light chain, respectively, by using the GATEWAY system (Invitrogen).

H3-2 was generated by point mutation with the GeneTailor Site-Directed Mutagenesis System from pENTR1A-H3-IgG2 with 5'-h3A5-2_H3-2_300F primer (TTGCTGAGCAGCCTGAGATCTGAGGACACGGCC; SEQ ID NO: 105) and 3'-h3A5-2_H3-2_320R primer (AGATCTCAGGCTGCTCAGCAACATGTAGGC; SEQ ID NO: 106). GeneTailor Site-Directed Mutagenesis was performed according to

according to the manufacturers' instructions. Mutated variable region and constant region were transferred into pEE6.4 as described above.

Example 6. Preparation of humanized anti-hFKN mAbs

Expression vectors of heavy and light chains of humanized anti-hFKN mAbs were transfected into HEK293E cells. On the day of transfection, HEK293E cells were inoculated with DMEM (Invitrogen) with 10% fetal bovine serum. After incubating for 5 hours, a mixture of heavy and light chain expression vectors was transfected with Lipofectamine 2000 (Invitrogen) according to the manufacturers' instructions. On the next day of the transfection, the medium was changed to 293 Serum-Free Media (SFM) II (Invitrogen). After incubating for 5 days at 37°C, culture supernatants were harvested. For BIACORE® assays, harvested supernatants were used directly. For chemotaxis assays, supernatants were purified with a recombinant protein A Sepharose column (Pharmacia).

Example 7. Preparation of mouse-human chimeric 3A5-2 mAb

The variable region of heavy chain of mouse 3A5-2 was amplified with 5'-EcoRI-SalI-3A5-2 VH primer (GCGGAATTCGTCGACGCCACCATGCGATGGAGCTGGA-TC; SEQ ID NO: 107) and 3'-IgG overlapped 3A5-2 VH primer (GACCGATGGGCC-CTTGGTGGAGGCTGAGGAGACTGTGAGAGTGGTGCC; SEQ ID NO: 108). Human IgG2 constant region was amplified with 5'- hIgG2 primer (GCCTCCACCA-AGGGCCCATCGGTCTTCCCCCTGGCGCCCTG; SEQ ID NO: 109) and 3'-NotI-hIgG2 (CGCGCGGCCGCTCATTTACCCGGAGACAGGGAGAG; SEQ ID NO: 110). Amplified 3A5-2 VH and human IgG2 constant region were combined with PCR and subcloned into pCX-IRES-bsr, which has the blasticidin resistant gene for cell selection. The variable region of light chain of mouse 3A5-2 was amplified with 5'- 3A_VL-SalI-kozac_F primer (GCGGTCGACGCCACCATGAGTGTGCTCACTCAG; SEQ ID NO: 111) and 3'- 3A-IgG1,2_VH-R primer (GACAGATGGTGCAGCCACAGTTCGTTTT

ATTTCCAGCTTGGTCCCCCCT; SEQ ID NO: 112). Human Igκ constant region was amplified with 5'-hIGK_F primer (CGAACTGTGGCTGCACCATCTGTC; SEQ ID NO: 113) and 3'- hIGK_NotI-R (CGCGCGGCCGCCTAACACTCTCCCCTGTTGA-AGCTCTT; SEQ ID NO: 114). Amplified 3A5-2 VH and human IgG2 constant region were combined with PCR and subcloned into pMX-IRES-puro, which has the puromycin resistant gene for cell selection.

The expression vector of chimeric light chain was transfected into HEK293E cells with pE-Eco and pGp (TAKARA) for retrovirus packaging. HEK293E cells were inoculated with DMEM (Invitrogen) with 10% FBS on the day before transfection. On the day of transfection, vectors were transfected with TranIT LT1 (TAKARA). After incubating for 3 days, culture supernatant containing retrovirus was harvested and added to B300.19 cells. After incubating for 8 hours, culture supernatant was removed and RPMI1640 (Invitrogen) with 10% FBS was added. After culturing for 2 days, puromycin was added to select infected cells. Selected cells were subsequently infected with another recombinant retrovirus carrying chimeric heavy chain, which was made using a similar method as described for the light chain. After selection with blasticidin, double-selected cells were cultured with SF-O (Sanko Junyaku) containing 8 mM Glutamax, 55 μM 2-mercaptoethanol, 1x cholesterol (Invitrogen) in the Integra CELLine (Integra Bioscience). Culture supernatant was purified using a recombinant protein A Sepharose column (Pharmacia) for the chemotaxis assay and BIACORE® assay.

Example 8. Analysis of humanized anti-hFKN mAbs

Humanized anti-hFKN mAbs were analyzed using a chemotaxis assay for measuring neutralizing activity and a BIACORE® assay for measuring binding affinity to hFKN and cynomolgus monkey FKN. Representative data and results from three independent chemotaxis assays are summarized in Figure 5 and shown in Figures 6A-B, 7A-D, and 8A-F. All combinations of H3 and H3-2 for heavy chain with L2 and L4 for light chain were successfully humanized as these mAbs showed similar neutralizing activity with the chimeric mAb. However, HK2, which was made by using narrowed key

residues, showed decreased neutralizing activity in combination with L2 or L4. The results of the BIACORE® assay are summarized in Figures 9 and 10A-C. All combinations of H3 and H3-2 for heavy chain with L2 and L4 for light chain showed similar levels of affinity compared to the chimeric mAb. On the other hand, HK2L4 showed lower affinity than the others. These results suggest that 3A5-2 could not be humanized successfully by a general method using the usual key residue identification, especially in the case of the heavy chain.

Chemotaxis assays were performed as follows. Cells were placed in the upper wells of a transwell culture plate (MultiScreen-MIC Plate, 5.0 μm, Millipore, Catalog No. MAMIC 5S10) with ligand in the lower wells. First, recombinant human FKN (R&D Systems, Catalog No. 362-CX/CF) (10 ng/ml final concentration) was added with purified antibodies at various concentrations (0 to 10 μg/ml) to the lower wells. The composition contained the following components: 3x chemokine solution, 50 μl/well; 1.5x purified mAb, 100 μl/well; chemokine and purified antibodies were diluted with 1x chemotaxis buffer (described above). B300.19 cells transfected with CX3CR1 ($2x10^5$ cells/75 μl) were applied together with purified antibodies at various concentrations (0 to 10 μg/ml) to the upper wells. The composition contained the following components: 3x cell suspension, 25 μl/well; 1.5x purified mAb solution, 50 μl/well; cells and purified antibodies were diluted with 1x chemotaxis buffer. The chemotaxis assay was performed in a 5%-CO_2 incubator at 37°C for 4 hours. After the incubation, 150 μl of the lower wells were harvested, fixed with 50 μl of 4% PFA/PBS, and 30 μl of the samples were applied to the FACSCantoII cell analyzer to count migrated cells.

The BIACORE® assays were performed as described above. However, for humanized and chimeric mAbs, anti-human IgG mouse mAb (GE Healthcare) was used as the capturing antibody on the sensor chip.

Example 9. Epitope mapping using synthetic peptides from FKN chemokine domain

Epitope mapping using libraries of overlapping synthetic peptides from FKN chemokine domain was performed. The twenty-one kinds of 15 residue peptides were synthesized by Sigma Genosys. The peptides were dissolved to 10 mg/ml with DMSO. These peptides (50 μg/ml) were coated on an ELISA plate (Nunc) overnight at 4°C. The peptide solutions were removed and PBS solution containing 1% BlockAce (Dainippon Pharma) was added to each well, incubated for 1 hour at room temperature, and washed with Tris-buffered saline (pH 7.4) containing 0.05% Tween 20 (washing solution). H3-2L4 antibody solution (50 μg/ml) was added to the wells and incubated for 2 hours at room temperature. The antibody solution was removed and washed with washing solution. Peroxidase-labeled anti-human IgG antibody solution (Zymed; 400 ng/ml) was added to the wells and incubated for 1 hour at room temperature. The antibody solution was removed and washed with washing solution. TMBZ solution (Sigma) was added to each well and incubated for 10 minutes at room temperature. The reaction was terminated with 1N H_2SO_4 solution and absorbance at 450-650 nm was measured.

The results are shown in Figure 11. H3-2L4 antibody reacted with peptides from the N-terminal and middle region of human FKN.

Example 10. Preparation of alanine or serine substitution mutants

Alanine or serine substitution mutants of hFKN-SEAP were prepared as follows. cDNA encoding the extracellular region of hFKN was isolated from the expression vector of hFKN-SEAP, pcDNA3.1 (+) hFKN-SEAP, by using SalI/NotI restriction enzymes and subcloned into pENTR1A_dSEAP-(His)10 vector containing SEAP cDNA (pENTR1A was purchased from Invitrogen). Alanine or serine substitution mutations were induced by using GeneTailor™ Site-Directed Mutagenesis System (Invitrogen) according to the manufacturer's instructions. The mutation-induced cDNA fragments of hFKN-SEAP were transferred into pcDNA3.1 (+)_cassette B vector (cassette B was purchased from Invitrogen) using the Gateway system (Invitrogen). The expression vectors of the alanine

or serine substitution mutant of hFKN-SEAP were transfected into HEK293EBNA (HEK293E) cells (Invitrogen). HEK293E cells were inoculated with DMEM (Invitrogen) supplemented with 10% fetal bovine serum on the day before transfection. The expression vectors were transfected with TransIT LT1 (Takara) according to the manufacturer's instructions. After 3 of days incubation (5% CO_2 at 37°C), the culture supernatant was harvested. The concentration of SEAP proteins was measured by using Great EscAPe SEAP Chemiluminescence Kit 2.0 (Clontech).

Example 11. ELISA for epitope mapping of hFKN

Anti-hFKN polyclonal antibody (eBioscience) and H3-2L4 were each coated on wells of an ELISA plate (Nunc) overnight at 4°C. For each, the antibody solution was removed and PBS containing 1% bovine serum albumin was added to each well and incubated for 1 hour at room temperature, then washed with Tris-buffered saline (pH 7.4) containing 0.05% Tween20 (washing solution). Alanine or serine substitution mutants were diluted to 0.13 nM with PBS containing 1% BSA and 50 µl aliquots were added to the ELISA plate wells and incubated for 4 hours at room temperature. The mutant solutions were removed and washed with washing solution. p-Nitrophenyl phosphate solution (Thermo Scientific) was added to each well and incubated for 30 minutes at room temperature. The reaction was terminated with 1N NaOH solution and absorbance at 405 nm was measured. The results are shown in Figure 12. R68A mutant specifically lost reactivity with H3-2L4. Other mutants that lost reactivity with H3-2L4 also lost reactivity with polyclonal antibody. These results show that R68 is a critical epitope for H3-2L4.

Example 12. Epitope mapping of hFKN using BIACORE®

Anti-histidine-tag antibody (Bethyl) was immobilized on a CM5 sensor chip (GE Healthcare). Alanine- or serine-substituted mutant solutions were 10 times diluted with HBS-EP buffer (GE Healthcare), loaded on the chip, washed with HBS-EP, and antigen binding level was measured. H3-2L4 and anti-FKN polyclonal antibody solution were

loaded on the antigen bound chip, washed with HBS-EP, and antibody binding level was measured. [Antibody binding level/Antigen binding level] was calculated and the values calculated for each mutant were compared with that of wild type. The results are shown in Figure 13.

Example 13. Reactivity of other antibodies with the R68A mutant

Mouse anti-human FKN monoclonal antibodies (1F3, 1G1, 2B2, 3D5, 6D1, 7F6) and H3-2L4 antibody were coated on an ELISA plate (Nunc) overnight at 4°C. The antibody solutions were removed. PBS solution containing 1% BSA was added to each well and incubated for 1 hour at room temperature, and the wells were washed with Tris-buffered saline (pH 7.4) containing 0.05% Tween 20. The wild type and R68A mutated FKN-SEAP-His solution (1, 0.5, 0.25, 0.125 nM) were added to the wells and incubated for 2 hours at room temperature. The antigen solutions were removed and washed with washing solution. p-Nitrophenyl phosphate solution (Thermo Scientific) was added to each well and incubated for 30 minutes at room temperature. The reaction was terminated with 1N NaOH solution and absorbance at 405 nm was measured.

Neutralizing activity of these antibodies was tested based on a chemotaxis assay, as described above. 10 nM human FKN and various concentrations of these antibodies were added in the lower wells of a transwell plate. In the upper well of the plate, CX3CR1-expressing cells were added. After being incubated for 4 hours at 37°C, media of the lower wells were recovered and cells were fixed using a 4% formaldehyde solution. The number of cells was counted using a FACS analyzer. The relationship between neutralizing activity and reactivity with R68A mutant is shown in Table 1. Antibodies which strongly neutralize CTX activity lost their reactivity with the R68A mutant. This result shows that R68 of human FKN is the key recognition site for antibodies that can effectively neutralize the FKN function.

Table 1. Relationship between binding to R68A mutant and neutralizing activity

Antibody	R68A/wild type (%)	CTX (IC50, nM)
1F3	131	12.7
1G1	39	80<
2B2	51	80<
3D5	0	4.09
3H7	0	19.1
6D1	58	80<
7F6	56	80<
H3-2L4	0	0.2

Example 14. Epitope mapping of hFKN by NMR

Purification of Fab from H3-2L4 antibody

100 mg of purified H3-2L4 antibody solution (20 mg/ml of PBS solution) was dialyzed against 0.1 M phosphate buffer (pH 7.0) containing 2 mM EDTA. The antibody concentration was adjusted to 15 mg/ml with the dialysis buffer and 30 mM cysteine was added. 0.2 mg of papain (Sigma) was added to the antibody solution and incubated for 14 hours at 37°C. Iodoacetamide was added to the solution to terminate the enzyme reaction. The papain digested antibody solution was dialyzed against PBS solution overnight at room temperature. The solution was applied to a ProSep vA (Millipore) column and the flow-through fraction was collected. The flow-through fraction was applied to an anti-human IgG Fc antibody (Jackson ImmunoResearch Laboratories) immobilized column and flow-through was collected. The flow-through fraction was concentrated and applied to Superose 12 10/300 GL (GE Healthcare) and fractions containing Fab fragment were collected. Purity of these fractions was analyzed by SDS PAGE and Fab dominant fractions were pooled.

Identification of Fab binding site on fractalkine

In order to identify the binding site of the Fab on fractalkine, stable isotope-labeled (^{2}H,^{15}N and ^{2}H,^{13}C,^{15}N) fractalkine was prepared (Mizoue, L et al., Biochemistry, 38: 1402-1414 (1999)) and a ^{15}N-Heteronuclear Single Quantum Coherence (HSQC) based NMR experiment was executed. NMR samples were prepared in 20 mM acetate buffer (pH 5.0) and 80% D_2O (cross saturation experiment) or 5% D_2O (the other experiments). All NMR experiments were carried out on a 700 MHz Bruker Avance spectrometer equipped with cryogenic probe under the temperature of 45°C.

Addition of the unlabeled Fab induced spectral change of fractalkine, indicating the interaction between the labeled fractalkine and the Fab. Sequential assignments of backbone ^{15}N and $^{1}H_N$ of fractalkine complexed with the Fab were completed from 3D HNCA spectrum.

A cross saturation experiment is one of the most precise NMR methods to determine binding interfaces of protein-protein interactions (Takahashi, H et al., Nat. Struct. Mol. Biol., 7: 220-223 (2000)). As a result of the experiment, signal intensity of several residues was reduced by selective irradiation of the Fab (Figure 14). Those residues were located at two separate contiguous regions. The one region consists of E66-Q69, and the other region consists of W81-Q87. Furthermore, the chemical shifts of these residues were largely affected upon addition of the Fab, supporting the cross saturation data (Figure 14). From these results, we concluded that these regions are included in the interface with the Fab.

Other Embodiments

From the foregoing description, it is apparent that variations and modifications may be made to the invention described herein to adopt it to various usages and conditions. Such embodiments are also within the scope of the following claims.

All publications mentioned in this specification are herein incorporated by reference to the same extent as if each independent publication or patent application was specifically and individually indicated to be incorporated by reference.

What is claimed is:

CLAIMS

1. An anti-fractalkine antibody or fractalkine-binding fragment thereof, wherein the antibody or fragment thereof comprises:

(a) a CDR-H1 consisting of the amino acid sequence of SEQ ID NO: 28;

(b) a CDR-H2 consisting of the amino acid sequence of SEQ ID NO: 29;

(c) a CDR-H3 consisting of the amino acid sequence of SEQ ID NO: 30;

(d) a CDR-L1 consisting of the amino acid sequence of SEQ ID NO: 31;

(e) a CDR-L2 consisting of the amino acid sequence of SEQ ID NO: 32; and

(f) a CDR-L3 consisting of the amino acid sequence of SEQ ID NO: 33.

2. The antibody of claim 1, wherein the antibody is an intact antibody.

3. The antibody or fractalkine-binding fragment thereof of claim 1 or 2, wherein the antibody or fractalkine-binding fragment is humanized.

4. The antibody or fractalkine-binding fragment thereof of claim 3, wherein the antibody comprises a heavy chain and a light chain, wherein the heavy chain variable domain of said antibody or fractalkine-binding fragment comprises the amino acid sequence of SEQ ID NO: 36, SEQ ID NO: 37, SEQ ID NO: 39, SEQ ID NO: 42, or SEQ ID NO: 43, and wherein the light chain variable domain of said antibody or fractalkine-binding fragment comprises the amino acid sequence of SEQ ID NO: 38, SEQ ID NO: 44, or SEQ ID NO: 45.

5. The antibody or fractalkine-binding fragment thereof of claim 1, 2, 3, or 4, wherein the antibody or fractalkine-binding fragment is chimeric.

6. The antibody or fractalkine-binding fragment thereof of claim 5, wherein the antibody comprises a heavy chain and a light chain, wherein the heavy chain variable domain of said antibody comprises the amino acid sequence of SEQ ID NO: 26, and wherein the light chain variable domain of said antibody comprises the amino acid sequence of SEQ ID NO: 27.

7. An anti-fractalkine antibody or fractalkine-binding fragment thereof, wherein the antibody or fragment thereof comprises a heavy chain comprising the amino acid sequence of SEQ ID NO: 37 and a light chain comprising the amino acid sequence of SEQ ID NO: 44.

8. The antibody or fractalkine-binding fragment thereof of any one of claims 1-7, comprising a human constant region.

9. The antibody or fractalkine-binding fragment thereof of claim 8, comprising a constant region of an IgG isotype.

10. The antibody or fractalkine-binding fragment thereof of claim 9, comprising a constant region of the IgG2 isotype.

11. The antibody or fractalkine-binding fragment thereof of any one of claims 1-10, comprising a mutated Fc region such that said antibody has reduced ADCC and/or complement activation.

12. The antibody or fractalkine-binding fragment thereof of claim 11, wherein the Fc region is mutated at one or more of V234, G237, C131, or C219.

13. The antibody or fractalkine-binding fragment thereof of any one of claims 1 or claims 3 to 10, wherein the fractalkine-binding fragment is selected from the group consisting of a Fab, a Fab', a F(ab')2, and a Fv, and wherein the fractalkine-binding fragment retains the binding specificity to fractalkine.

14. The antibody or fractalkine-binding fragment thereof of any one of claims 1-13, wherein the antibody inhibits the binding between fractalkine and CX3CR1.

15. The antibody or fractalkine-binding fragment thereof according to any one of claims 1-14, for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.

16. A pharmaceutical composition comprising the antibody or fractalkine-binding fragment thereof of any one of claims 1-15.

17. The pharmaceutical composition of claim 16, for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.

18. The pharmaceutical composition of claim 16 or 17, wherein the composition further comprises a carrier.

19. The pharmaceutical composition of any one of claims 16-18, wherein the composition further comprises an additional therapeutic agent.

20. A nucleic acid encoding the antibody or fractalkine-binding fragment thereof of any one of claims 1-15.

21. The nucleic acid of claim 20, wherein said nucleic acid encodes all or a portion of the heavy chain of said antibody or fractalkine-binding fragment thereof.

22. The nucleic acid of claim 20or 21, wherein said nucleic acid encodes all or a portion of the light chain of said antibody or fractalkine-binding fragment thereof.

23. A vector comprising the nucleic acid of any one of claims 20-22.

24. The vector of claim 23, wherein the vector is an expression vector.

25. A host cell comprising one or more vectors of claim 23or 24.

26. The host cell of claim 25, wherein said host cell comprises a first and second vector, said first vector comprising a nucleic acid encoding a heavy chain and said second vector comprising a nucleic acid encoding a light chain of the antibody or fractalkine-binding fragment thereof of any one of claims 1-15.

27. The host cell of claim 26, wherein expression of said heavy and light chain in said host cell produces an antibody or fractalkine-binding fragment thereof of any one of claims 1-15.

28. The host cell of any one of claims 25-27, wherein the host cell is prokaryotic.

29. The host cell of any one of claims 25-27, wherein the host cell is eukaryotic.

30. The host cell of claim 29, wherein the host cell is mammalian.

31. The host cell of claim 30, wherein the cell is a CHO cell or NS0 cell.

32. A method for making an anti-fractalkine antibody or fractalkine-binding fragment thereof, said method comprising (a) expressing the vector of any one of claim 23or 24in a suitable host cell, and (b) recovering the antibody or fractalkine-binding fragment thereof.

33. The method of claim 32, wherein said antibody or fractalkine-binding fragment thereof is secreted by said host cell into culture media.

34. The method of claim 33, wherein said antibody or fractalkine-binding fragment thereof is purified to at least 95% or greater with respect to said antibody-containing culture media.

35. The use of an antibody or fractalkine-binding fragment thereof according to any one of claims 1-15 in the preparation of a medicament for use in treating an inflammatory disorder, wherein the inflammatory disorder is ulcerative colitis, Crohn's disease, or rheumatoid arthritis.