Anti-CCL17 antibodies

This application claims the benefit of U.S. Provisional Application No. 61/900,596, filed November 6, 2013, the entire contents of which are incorporated herein by reference.

Field of the Invention

The present invention relates to antibodies specifically binding CCL17, polynucleotides encoding the antibodies or fragments, and methods of making and using the foregoing.

Background of the Invention

The homeostatic chemokine, CCL17 (TARC, chemokine (C-C motif) ligand 17) is a potent lymphocyte chemoattractant. CCL17 is a ligand for CCR4, a GPCR believed to be important in the function of T cells and chemotaxis and the migration of immune cells to sites of inflammation. CCR4 is predominantly expressed on Th2 lymphocytes, natural killer cells and iNKT cells.

CCL17 has been associated with human diseases affecting various organs such as ulcerative colitis (UC), atopic dermatitis (AD), idiopathic pulmonary fibrosis (IPF) and asthma (Belperio *et al., J Immunol, 173*: 4692-469, 2004; Christophi *et al., Inflamm Bowel Dis*. doi: 10.1002/ibd.2295; Inoue *et al., Eur Respir J, 24*: 49-56, 2004; Kakinuma *et al., J Allergy Clin Immunol, 107*: 535-541, 2001; Saeki and Tamaki, *J Dermatol Sci, 43*: 75-84, 2006; Tamaki *et al., J Dermatol, 33*: 300-302, 2006). In mice, CCL17 has been linked to various inflammatory conditions and infections such as chronic pulmonary inflammation present in models of fibrosis and asthma, colitis and schistosomiasis, presumably by inducing Th2 responses through recruitment of $CCR4^+$ immune

cells. Neutralization of CCL17 ameliorates the impacts of disease in both the A. *fumigatus* and ovalbumin (OVA) models of asthma, and liver damage in the P. *acnes* mouse model of induced hepatic injury by blocking influx of T cells (Carpenter and Hogamoam *Infect Immun,* 73:7198-7207, 2005; Heiseke *et al., Gastroenterology*, 142:335-345; Hogamoam *et al., Med Mycol,* 43 Suppl 1, S197-202, 2005; Ismailoglu *et al.,* Therapeutic targeting of CCL17 via the systemic administration of a monoclonal antibody ameliorates experimental fungal asthma. Paper presented at the *Am J Respir Crit Care Med* , 2011; Jakubzick *et al., Am J Pathol,* 165:1211-122, 2004; Kawasaki *et al., J Immunol*, 166:2055-2062, 2001; Yoneyama *et al., J Clin Invest*, 102:1933-1941, 1998).

CCL22 (MDC) is a second ligand for CCR4. CCR4 interaction with each chemokine produces distinct outcomes (Allen *et al.,* Annu Rev Immunol 25:787-820, 2007; Imai *et al.,* J Biol Chem 273:1764-1768, 1998), possibly contributed by the differences in binding affinities of the two ligands for CCR4. CCL22 binds CCR4 with higher affinity and induces receptor internalization more readily than CCL17 (Baatar *et al., J Immunol* 179:1996-2004, 2007; Imai *et al., J Biol Chem* 273:1764-1768, 1998; Mariani *et al., Eur J Immunol* 34:231-240, 2004), and promotes cellular adhesion more readily than CCL17 (D'Ambrosio *et al., J Immunol* 169:2303-2312, 2002). CCL22 shows more restricted expression with production limited to immune cells, whereas CCL17 is expressed and secreted by many different cell types including non-immune cells (Alferink *et al.,J Exp Med* 197:585-599, 2003; Berin *et al., Am J Respir Cell Mol Biol* 24:382-389, 2001; Godiska *et al., J Exp Med* 185:1595-1604, 1997; Imai *et al., J Biol Chem* 271:21514-21521, 1996; Saeki and Tamaki, *J Bermatol Sci* 43:75-84, 2006). In the murine ceacal ligation and puncture (CLP) model of experimental sepsis, CCL22 promoted innate

immunity whereas CCL17 seemed to interfere and in some circumstances contribute to organ damage (Matsukawa *et al., Rev Immunogenet* 2:339-358, 2000). In the mouse model of pulmonary invasive aspergillosis, CCL22 played a protective role in the innate anti-fungal response whereas CCL17 played the role of suppressor (Carpenter and Hogaboam, *Infect Immun* 73:7198-7207, 2005). These two chemokines can play contrasting roles in establishing localized inflammation due to differential effects on Treg homeostasis in that Treg recruitment is favored by CCL22 but not CCL17 (Heiseke *et al., Gastroenterology* 142:335-345,2011; Montane *et al., J Clin Invest,* 121:3024-30, 2011; Weber *et al., J Clin Invest* 121:2898-2910, 2011).

In animal model of contact hypersensitivity, CCL17 is a major factor in initiating the inflammatory response driving contact hypersensitivity (CHS) to challenge with either FITC or DNFB, and CCL17 knockout in these mice enhanced survival of cardiac allografts compared to heterozygous mice having one functional CCL17 allele (Alferink *et al., J Exp Med* 197:585-599, 2003).

CCR4 antagonists may be non-selective and inhibit both CCL17 and CCL22 functions. Therefore, there is a need for anti-CCL17 antibodies for the potential treatment of a variety of CCL17-mediated diseases including asthma.

Summary of the invention

One embodiment of the invention is an isolated antibody specifically binding human CCL17 comprising a heavy chain variable region (VH) and a light chain variable region (VL), wherein the antibody competes for binding to human CCL17 with an antibody comprising the VH of SEQ ID NO:45 and the VL of SEQ ID NO: 52.

Another embodiment of the invention is an isolated antibody specifically binding human CCL17 having the sequence

of SEQ ID NO: 1, wherein the antibody binds human CCL17 at least within CCL17 amino acid residues 21-23, 44-45 and 60-68.

Another embodiment of the invention is an isolated antibody specifically binding human CCL17, wherein the antibody binds human CCL17 with an affinity constant (K_D) of about $1x10^{-10}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and human CCL17 for 48 hours at 4°C.

Another embodiment of the invention is an isolated antibody specifically binding human CCL17 compriseing certain HCDR1, HCDR2, HCDR3, LCDR1, LCDR2 and LCDR3 sequences.

Another embodiment of the invention is an isolated antibody specifically binding human CCL17 compriseing certain VH and VL sequences.

Another embodiment of the invention is an isolated antibody specifically binding human CCL17, wherein the antibody comprises the VH comprising the amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the VH of SEQ ID NO: 46 and the VL comprising the amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the VL of SEQ ID NO: 62.

Another embodiment of the invention is a pharmaceutical composition comprising the antibody of the invention and a pharmaceutically accepted carrier.

Another embodiment of the invention is an isolated polynucleotide encoding the VH or the VL of the invention.

Another embodiment of the invention is a vector comprising the polynucleotide of the invention.

Another embodiment of the invention is a host cell comprising the vector of the invention.

Another embodiment of the invention is a method of producing an antibody of the invention, comprising culturing the host cell of the invention in conditions that the antibody is produced.

Another embodiment of the invention is a method of treating a CCL17-mediated disease, comprising administering to a subject in need thereof the antibody of the invention for a time sufficient to treat the CCL17-mediated disease.

Another embodiment of the invention is a method of treating asthma or airway hyper-reactivity, comprising administering to a subject the antibody of the invention for a time sufficient to treat asthma.

Brief Description of the Drawings

Figure 1A shows inhibition of chemotaxis with anti-CCL17 antibody B302 induced by 1 nM human CCL17 in CCRF-CEM cells. B302 is C17B302.

Figure 1B shows inhibition of chemotaxis with anti-CCL17 antibody B311 induced by 1 nM human CCL17 in CCRF-CEM cells. B311 is C17B311.

Figure 1C shows effect of IgG2 isotype control on chemotaxis induced by 1 nM human CCL17 in CCRF-CEM cells.

Figure 1D shows effect of IgG4 isotype control on chemotaxis induced by 1 nM human CCL17 in CCRF-CEM cells.

Figure 2A shows inhibition of chemotaxis with anti-CCL17 antibody B302 induced by 1 nM cyno CCL17 in HSC-F cells. B302 is C17B302.

Figure 2B shows inhibition of chemotaxis with anti-CCL17 antibody B311 induced by 1 nM cyno CCL17 in HSC-F cells. B311 is C17B311.

Figure 2C shows effect of IgG2 isotype control on chemotaxis induced by 1 nM cyno CCL17 in HSC-F cells.

Figure 2D shows effect of IgG4 isotype control on chemotaxis induced by 1 nM cyno CCL17 in HSC-F cells.

Figure 3 shows the VH sequences of the anti-CCL17 antibodies binding to human CCL17 with a K_D of 100 nM or lower.

Figure 4 shows the consensus VH and HCDR sequences of the anti-CCL17 antibodies shown in Figure 3 that bind to human CCL17 with a K_D of 100 nM or lower.

Figure 5 shows the VL sequences of the anti-CCL17 antibodies binding to human CCL17 with a K_D of 100 nM or lower.

Figure 6A shows the consensus VL sequence of the anti-CCL17 antibodies shown in Figure 5 that bind to human CCL17 with a K_D of 100 nM or lower.

Figure 6B shows the consensus LCDR sequences of the anti- CCL17 antibodies shown in Figure 5 that bind to human CCL17 with a K_D of 100 nM or lower.

Figure 7 shows the epitope and paratope residues of antibody C17B236. VH and VL paratope residues are boxed, and CCL17 epitope residues are circled. Residue numbering is according to SEQ ID NO: 45 (VH), SEQ ID NO: 52 (VL), SEQ ID NO: 1 (CCL17).

Detailed Description of the Invention

All publications, including but not limited to patents and patent applications, cited in this specification are herein incorporated by reference as though fully set forth.

It is to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains.

Although any methods and materials similar or equivalent to those described herein can be used in the practice for testing of the present invention, exemplary

materials and methods are described herein. In describing and claiming the present invention, the following terminology will be used.

"Specific binding" or "specifically binds" or "binds" as used herein refers to antibody binding to a predetermined antigen with greater affinity than for other antigens. Typically, the antibody binds to a predetermined antigen with a dissociation constant (K_D) of about $1x10^{-7}$ M or less, for example about $1x10^{-8}$ M or less, about $1x10^{-9}$ M or less, about $1x10^{-10}$ M or less, about $1x10^{-11}$ M or less, about $1x10^{-12}$ M or less, about $1x10^{-13}$ M or less or about $1x10^{-14}$ M or less, typically with a K_D that is at least ten fold less than its K_D for binding to a non-specific antigen or epitope (e.g., BSA, casein). The dissociation constant can be measured using standard procedures. Antibodies that specifically bind to a predetermined antigen may, however, have cross-reactivity to other related antigens, for example to the same predetermined antigen from other species (homologs), such as human or monkey, for example *Macaca fascicularis* (cynomolgus, cyno) or *Pan troglodytes* (chimpanzee, chimp).

"Monoclonal antibody that specifically binds human CCL17" refers to antibodies that specifically bind human mature CCL17 having the sequence shown in SEQ ID NO: 1.

"Neutralizing" or "neutralizes" or "neutralizing antibody" or "antibody antagonist" as used herein refers to an antibody or antibody fragment that partially or completely inhibits, by any mechanism, CCL17 biological activity. Neutralizing antibodies can be identified using assays for CCL17 biological activity as described below. CCL17 neutralizing antibody may inhibit measured CCL17 biological activity by 20%, 30%, 40%, 50%, 60%, 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100%.

"Human CCL17" or "huCCL17" as used interchangeably herein refers to the human CCL17 protein having the amino

acid sequence shown in SEQ ID NO: 1. The sequence of the full length CCL17 including the signal sequence is available at GenBank; Accession Number NP_002978.

"Cyno CCL17" or "cCCL17" as used interchangeably herein refers to the *Macaca fascicularis* (cyno) CCL17 protein having the amino acid sequence shown in SEQ ID NO: 2.

"Antibodies" as used herein is meant in a broad sense and includes immunoglobulin molecules including monoclonal antibodies including murine, human, humanized and chimeric antibodies, antibody fragments, bispecific or multispecific antibodies formed from at least two intact antibodies or antibody fragments, dimeric, tetrameric or multimeric antibodies, single chain antibodies, and any other modified configuration of the immunoglobulin molecule that comprises an antigen recognition site of the required specificity.

Immunoglobulins can be assigned to five major classes, namely IgA, IgD, IgE, IgG and IgM, depending on the heavy chain constant domain amino acid sequence. IgA and IgG are further sub-classified to IgA_1, IgA_2, IgG_1, IgG_2, IgG_3 and IgG_4 isotypes. Antibody light chains of any vertebrate species can be assigned to one of two clearly distinct types, namely kappa (κ) and lambda (λ), based on the amino acid sequences of their constant domains.

The term "antibody fragments" refers to a portion of an immunoglobulin molecule that retains the heavy chain and/or the light chain antigen binding site, such as a heavy chain complementarity determining regions (HCDR) 1, 2 and 3, a light chain complementarity determining regions (LCDR) 1, 2 and 3, a heavy chain variable region (VH), or a light chain variable region (VL). Antibody fragments include a Fab fragment, a monovalent fragment consisting of the VL or the VH; a $F(ab)_2$ fragment, a bivalent fragment comprising two Fab fragments linked by a disulfide bridge at the hinge region; a Fd fragment consisting of the VH and CHI domains; a Fv

fragment consisting of the VL and VH domains of a single arm of an antibody; a dAb fragment (Ward *et al.*, *Nature* 341:544-546, 1989), which consists of a VH domain. VH and VL domains can be engineered and linked together via a synthetic linker to form various types of single chain antibody designs where the VH/VL domains pair intramolecularly, or intermolecularly in those cases when the VH and VL domains are expressed by separate single chain antibody constructs, to form a monovalent antigen binding site, such as single chain Fv (scFv) or diabody; described for example in Int. Pat. Publ. No. WO1998/44001, Int. Pat. Publ. No. WO1988/01649; Int. Pat. Publ. No. WO1994/13804; Int. Pat. Publ. No. WO1992/01047. These antibody fragments are obtained using well known techniques and the fragments are characterized in the same manner as are intact antibodies.

The phrase "isolated antibody" refers to an antibody that is substantially free of other antibodies having different antigenic specificities (e.g., an isolated antibody specifically binding human CCL17 is substantially free of antibodies that specifically bind antigens other than human CCL17). An isolated antibody specifically binding human CCL17 may, however, have cross- reactivity to other antigens, such as orthologs of human CCL17, such as *Macaca fascicularis* (cynomolgus) CCL17. Moreover, an isolated antibody may be substantially free of other cellular material and/or chemicals.

An antibody variable region consists of a “framework” region interrupted by three “antigen binding sites”. The antigen binding sites are defined using various terms: (i) Complementarity Determining Regions (CDRs), three in the VH (HCDR1, HCDR2, HCDR3) and three in the VL (LCDR1, LCDR2, LCDR3) are based on sequence variability (Wu and Kabat, *J Exp Med* 132:211-50, 1970; Kabat *et al.*, Sequences of Proteins of Immunological Interest, 5th Ed. Public Health Service,

National Institutes of Health, Bethesda, Md., 1991). (ii) "Hypervariable regions", "HVR", or "HV", three in the VH (H1, H2, H3) and three in the VL (L1, L2, L3) refer to the regions of an antibody variable domains which are hypervariable in structure as defined by Chothia and Lesk (Chothia and Lesk *Mol Biol* 196:901-17, 1987). Other terms include "IMGT-CDRs" (Lefranc *et al., Dev Comparat Immunol* 27:55-77, 2003) and "Specificity Determining Residue Usage" (SDRU) (Almagro *Mol Recognit,* 17:132-43, 2004). The International ImMunoGeneTics (IMGT) database (http://www_imgt_org) provides a standardized numbering and definition of antigen-binding sites. The correspondence between CDRs, HVs and IMGT delineations is described in Lefranc *et al., Dev Comparat Immunol* 27:55-77, 2003.

"Chothia residues" as used herein are the antibody VL and VH residues numbered according to Al-Lazikani (Al-Lazikani *et al., J Mol Biol* 273:927-48, 1997).

"Framework" or "framework sequences" are the remaining sequences of a variable region other than those sequences defined to be antigen binding site. Because the antigen binding site can be defined by various terms as described above, the exact amino acid sequence of a framework depends on how the antigen-binding site was defined.

"Humanized antibody" refers to an antibody in which the antigen binding site is derived from non-human species and the variable region frameworks are derived from human immunoglobulin sequences. Humanized antibodies may include substitutions in the framework regions so that the framework may not be an exact copy of expressed human immunoglobulin or germline gene sequences.

"Human antibody" refers to an antibody having heavy and light chain variable regions in which both the framework and the antigen binding site regions are derived from sequences of human origin. If the antibody contains a

constant region, the constant region also is derived from sequences of human origin.

Human antibody comprises heavy or light chain variable regions that are "derived from" sequences of human origin if the variable regions of the antibody are obtained from a system that uses human germline immunoglobulin or rearranged immunoglobulin genes. Such systems include human immunoglobulin gene libraries, for example libraries displayed on phage, and transgenic non-human animals such as mice carrying human immunoglobulin loci as described herein. "Human antibody" may contain amino acid differences when compared to the human germline or rearranged immunoglobulin sequences due to for example naturally occurring somatic mutations or intentional introduction of substitutions. Typically, "human antibody" is at least about 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% identical in amino acid sequence to an amino acid sequence encoded by a human germline or rearranged immunoglobulin gene. In some cases, "human antibody" may contain consensus framework sequences derived from human framework sequence analyses, for example as described in Knappik *et al.*, *J Mol Biol* 296:57-86, 2000), or synthetic HCDR3 incorporated into human immunoglobulin gene libraries displayed on phage, for example as described in Shi *et al.*, *J Mol Biol* 397:385-96, 2010 and Int. Pat. Publ. No. WO2009/08546).

Isolated humanized antibodies may be synthetic. Human antibodies, while derived from human immunoglobulin sequences, can be generated using systems such as phage display incorporating synthetic CDRs and/or synthetic frameworks, or can be subjected to *in vitro* mutagenesis to improve antibody properties, resulting in antibodies that do not naturally exist within the human antibody germline repertoire *in vivo*.

Human antibodies may include substitutions in the framework or in the antigen binding site so that they may not be exact copies of expressed human immunoglobulin or germline gene sequences. However, antibodies in which antigen binding sites are derived from a non-human species are not included in the definition of "human antibody".

The term "recombinant antibody" as used herein, includes all antibodies that are prepared, expressed, created or isolated by recombinant means, such as antibodies isolated from an animal (e.g., a mouse) that is transgenic or transchromosomal for human immunoglobulin genes or a hybridoma prepared therefrom (described further below), antibodies isolated from a host cell transformed to express the antibody, antibodies isolated from a recombinant, combinatorial antibody library, and antibodies prepared, expressed, created or isolated by any other means that involve splicing of human immunoglobulin gene sequences to other DNA sequences.

The term "monoclonal antibody" as used herein refers to a preparation of antibody molecules of single molecular composition.

The term "substantially identical" as used herein means that the two antibody variable region amino acid sequences being compared are identical or have "insubstantial differences". Insubstantial differences are substitutions of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 amino acids in an antibody variable region sequence that do not adversely affect antibody properties. Amino acid sequences substantially identical to the variable region sequences disclosed herein are within the scope of the invention. In some embodiments, the sequence identity can be about 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or higher. Percent identity can be determined for example by pairwise alignment using the default settings of the AlignX module of

Vector NTI v.9.0.0 (Invitrogen, Carlsbad, CA). The protein sequences of the present invention can be used as a query sequence to perform a search against public or patent databases to, for example, identify related sequences. Exemplary programs used to perform such searches are the XBLAST or BLASTP programs (http_//www_ncbi_nlm/nih_gov), or the GenomeQuest™ (GenomeQuest, Westborough, MA) suite using the default settings.

The term "epitope" as used herein means a portion of an antigen to which an antibody specifically binds. Epitopes usually consist of chemically active (such as polar, non-polar or hydrophobic) surface groupings of moieties such as amino acids or polysaccharide side chains and can have specific three-dimensional structural characteristics, as well as specific charge characteristics. An epitope can be composed of contiguous and/or discontiguous amino acids that form a conformational spatial unit. For a discontiguous epitope, amino acids from differing portions of the linear sequence of the antigen come in close proximity in 3-dimensional space through the folding of the protein molecule.

“Bispecific” as used herein refers to an antibody or molecule that binds two distinct antigens or two distinct epitopes within an antigen.

“Monospecific” as used herein refers to an antibody that binds one antigen or one epitope.

The term “in combination with” as used herein means that the described agents can be administered to an animal together in a mixture, concurrently as single agents or sequentially as single agents in any order.

The term “vector” means a non-natural polynucleotide capable of being duplicated within a biological system or that can be moved between such systems. Vector polynucleotides typically contain a cDNA encoding a protein

of interest and additional elements, such as origins of replication, polyadenylation signal or selection markers, that function to facilitate the duplication or maintenance of these polynucleotides in a biological system. Examples of such biological systems may include a cell, virus, animal, plant, and reconstituted biological systems utilizing biological components capable of duplicating a vector. The polynucleotide comprising a vector may be DNA or RNA molecules or a hybrid of these.

The term “expression vector” means a vector that can be utilized in a biological system or in a reconstituted biological system to direct the translation of a polypeptide encoded by a polynucleotide sequence present in the expression vector.

The term “polynucleotide” means a molecule comprising a chain of nucleotides covalently linked by a sugar-phosphate backbone or other equivalent covalent chemistry. Double and single-stranded DNAs and RNAs are typical examples of polynucleotides.

"Complementary DNA" or “cDNA” refers to a well known synthetic polynucleotide that shares the arrangement of sequence elements found in native mature mRNA species with contiguous exons, with the intervening introns present in genomic DNA are removed. The codons encoding the initiator methionine may or may not be present in cDNA. cDNA may be synthesized for example by reverse transcription or synthetic gene assembly.

“Synthetic” or “non-natural” as used herein refers to a polynucleotide or a polypeptide molecule not present in nature.

The term “polypeptide” or “protein” means a molecule that comprises at least two amino acid residues linked by a peptide bond to form a polypeptide. Small polypeptides of less than 50 amino acids may be referred to as “peptides”.

Conventional one and three-letter amino acid codes are used herein as shown in Table 1.

Table 1.

Amino Acid	Three-letter code	One-letter code
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N
Aspartate	Asp	D
Cysteine	Cys	C
Glutamate	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

Compositions of matter

The present invention provides monoclonal antibodies specifically binding human CCL17. The antibodies of the invention inhibit CCL17 biological activity in the cell, and may optionally cross-react with cyno CCL17. The present invention provides synthetic polynucleotides encoding the

antibodies and fragments thereof, vectors and host cells, and methods of making and using the antibodies of the invention.

One embodiment of the invention is an isolated antibody specifically binding human CCL17.

Another embodiment of the invention described herein is an isolated antibody specifically binding human CCL17 comprising a heavy chain variable region (VH) and a light chain variable region (VL), wherein the antibody competes for binding to human CCL17 with an antibody comprising the VH of SEQ ID NO:45 and the VL of SEQ ID NO: 52.

Competition between specific binding to human CCL17 with antibodies of the invention comprising certain VH and VL amino acid sequences can be assayed *in vitro* using well known methods. For example, binding of MSD Sulfo-Tag™ NHS-ester-labeled antibody to human CCL17 in the presence of an unlabeled antibody can be assessed by ELISA, or Biacore analyses or flow cytometry may be used to demonstrate competition with the antibodies of the current invention. The ability of a test antibody to inhibit the binding of the antibody comprising the VH of SEQ ID NO: 45 and the VL of SEQ ID NO: 52 to human CCL17 demonstrates that the test antibody can compete with these antibodies for binding to human CCL17.

Another embodiment of the invention described herein is an isolated antibody specifically binding human CCL17 having the sequence of SEQ ID NO: 1, wherein the antibody binds human CCL17 at least within CCL17 amino acid residues 21-23, 44-45 and 60-68. "At least within human CCL17 amino acid residues 21-23, 44-45 and 60-68" means that the anti-CCL17 antibody binds at least one residue residing within the amino acid stretch of residues 21-23 of SEQ ID NO: 1, and at least one residue residing within the amino acid stretch of residues 44-45 of SEQ ID NO: 1, and at least one residue residing within the amino acid stretch of residues 60-68 of SEQ ID NO: 1. The antibody may bind more than one residue

within the residues 21-23, 44-45 and 60-68, and additional residues outside of residues 21-23, 44-45 and 60-68of SEQ ID NO: 1.

In some embodiments described herein, the antibody binds human CCL17 at least at residues R22 and K23 of SEQ ID NO: 1.

In some embodiments described herein, the antibody binds human CCL17 at least at residues L21, R22, K23, V44, Q45, N60, Y64, S67 and L68 of SEQ ID NO: 1.

An exemplary antibody that binds human CCL17 within CCL17 amino acid residues 21-23, 44-45 and 60-68 of SEQ ID NO: 1 is C17B236 having VH of SEQ ID NO: 45 and VL of SEQ ID NO: 52. Based on crystal structure analyses, the main epitope residues bound by C17B236 are R22 and K23 of CCL17 of SEQ ID NO: 1, based on the number of contacts between these residues and the antibody VH residues.

Other exemplary antibodies that bind human CCL17 within CCL17 amino acid residues 21-23, 44-45 and 60-68 are affinity-matured variants of C17B236, which all antibodies are derived from affinity-maturation campaign of the same parental antibody. The VH and the VL sequences of the exemplary antibodies are shown in Figure 3 and Figure 5. Affinity maturation of antibodies typically involves amino acid substitutions in the CDRs or in the Vernier zone (framework regions that underline the CDRs). The matured variants are selected by panning the combinatorial libraries, which may contain up to 10^8 mutants. The cap on the size of the library limits the number of variable positions to 6-7 if all 20 amino acids are allowed in each position. The majority of the paratope residues are preserved in each combinatorial library, which ensures that the binding epitope is also preserved. Several crystallographic studies of the parent and matured antibodies have shown that the epitope is always preserved during affinity maturation (e.g. Fransson et

al., J. Mol. Biol. 2010, 398:214-231; Gustchina et al., PLoS Pathog. 2010, 6:e1001182; La Porte et al., MAbs 2014; 6:1059-1068).

Anti-CCL17 antibodies that bind human CCL17 within CCL17 amino acid residues 21-23, 44-45 and 60-68 bind human CCL17 with high affinity, typically with the K_D less than about $1x10^{-10}$ M.

Antibodies that bind human CCL17 within CCL17 amino acid residues 21-23, 44-45 and 60-68 may be made for example by immunizing mice with CCL17 chimeric protein that has human CCL17 sequences at residue positions 21-23, 44-45 and 60-68, or panning phage display libraries with wild type human CCL17, and cross-screening the resulting hits with CCL17 variants that have substitutuions at each or several residue positions within the reidues 21-23, 44-45 and 60-68 of human CCL17 using methods described herein.

In some embodiments of the invention described herein, the antibody specifically binding human CCL17 blocks CCL17/CCR4 interaction.

Antibodies can be tested for their ability to block CCL17/CCR4 interaction by standard flow cytometry. For example, cells expressing CCR4 are incubated with fluorescently labeled human CCL17 and the test antibody, after which the binding of the fluorescently labeled human CCL17 onto CCR4-expressing cells is assessed using standard methods. Antibodies that "block CCL17/CCR4 interaction" or "inhibit CCL17/CCR4 interaction" may inhibit binding of CCL17 to CCR4-expressing cells by 30%, 40%, 50%, 60%, 70%, 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, 99% or 100% when compared to binding of CCL17 in the absence of the antibody.

Another embodiment of the invention described herein is an isolated antibody specifically binding human CCL17, wherein the antibody binds human CCL17 with an affinity constant (K_D) of about $1x10^{-7}$ M or less, of about $1x10^{-8}$ M or

less, about $1x10^{-9}$ M or less, about $1x10^{-10}$ M or less, about $1x10^{-11}$ M or less, about $1x10^{-12}$ M or less, about $1x10^{-13}$ M or less, or about $1x10^{-14}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and human CCL17 for 48 hours at 4°C.

In some embodiments described herein, the antibody binds human CCL17 with an affinity constant (K_D) of about $1x10^{-10}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and human CCL17 for 48 hours at 4°C.

In some embodiments described herein, the antibody binds human CCL17 with the K_D of about $5x10^{-12}$ M or less.

In another embodiment described herein, the antibody of the invention specifically binding human CCL17 binds *Macaca fascicularis* (cyno) CCL17 with an affinity constant (K_D) of about $1x10^{-6}$ M or less, about $1x10^{-7}$ M or less, about $1x10^{-8}$ M or less, about $1x10^{-9}$ M or less, about $1x10^{-10}$ M or less, about $1x10^{-11}$ M or less or about $1x10^{-12}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and cyno CCL17 for 48 hours at 4°C.

In some embodiments described herein, the antibody of the invention binds *Macaca fascicularis* (cyno) CCL17 with the K_D of about $1x10^{-8}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and cyno CCL17 for 48 hours at 4°C.

The affinity of an antibody to human CCL17 having the sequence of SEQ ID NO: 1 or cyno CCL17 having the sequence of SEQ ID NO: 2 can be measured experimentally using any suitable method. Such methods may utilize Proteon, Biacore

or KinExA instrumentation, such as ProteOn XPR36 or Biacore 3000, solution equilibrium affinity (SEA), ELISA or competitive binding assays known to those skilled in the art. Exemplary methods are those described in Example 3. The measured affinity of a particular antibody/ CCL17 interaction can vary if measured under different conditions (e.g., osmolarity, pH, buffer, detergent concentration). Thus, measurements of affinity and other binding parameters (e.g., K_D, K_{on}, K_{off}) are preferably made with standardized conditions and a standardized buffer, such as the buffer described herein. Skilled in the art will appreciate that the internal error for affinity measurements for example using solution equilibrium affinity, Biacore 3000 or ProteOn (measured as standard deviation, SD) can typically be within 5-33% for measurements within the typical limits of detection. Therefore the term "about" reflects the typical standard deviation in the assay. For example, the typical SD for a K_D of $1x10^{-9}$ M is up to $\pm 0.33x10^{-9}$ M.

Another embodiment of the invention described herein is an isolated antibody specifically binding human CCL17, wherein the antibody inhibits CCL17 biological activity.

"CCL17 biological activity" as used herein refers to any activity occurring as a result of CCL17 binding to its receptor CCR4. An exemplary CCL17 biological activity results in intracellular calcium mobilization or chemotaxis of cells, for example CCRF-CEM cells (T lymophblastoid cell line from patient with acute leukemia). The antibodies of the invention can be tested for their ability to inhibit CCL17 biological activity using standard methods and those described herein. For example, ability of the antibodies of the invention to inhibit CCL17-dependent intracellular calcium mobilization can be assayed by measuring effect of the antibodies on CCL17-induced calcium mobilization using fluorescent dyes such as Fluo-8 NW, Fluo-4 AM or Fluo-3 AM.

Ability of the antibodies of the invention to inhibit CCL17-induced chemotaxis can be measured by measuring migration of CCRF-CEM cells through a semipermeable 5 μM filter in a two-chamber culture system, and measuring viability of cells migrated through the filter, The antibodies of the invention may inhibit CCL17 biological activity by about 20%, 30%, 40%, 50%, 60%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99% or 100%.

Another embodiment of the invention described herein is an antibody specifically binding CCL17, wherein the antibody inhibits 10 ng/ml human CCL17-induced calcium mobilization in CCRF-CEM cells measured using Fluo-8 NW with an IC_{50} value of about $1x10^{-7}$ M of less, about $1x10^{-8}$ M or less, or about $1x10^{-9}$ M or less.

Another embodiment of the invention described herein is an antibody specifically binding CCL17, wherein the antibody comprises heavy chain complementarity determining regions (HCDR) 1 (HCDR1), 2 (HCDR2) and 3 (HCDR3) and light chain complementarity determining regions (LCDR) 1 (LCDR1), 2 (LCDR2) and 3 (LCDR3), wherein the HCDR1, the HCDR2, the HCDR3, the LCDR1, the LCDR2 and the LCDR3 comprise the amino acid sequences of SEQ ID NOs: 4, 5, 71, 72, 73 and 74, respectively.

Antibodies comprsing the HCDR and the LCDR sequences of SEQ ID NOs: 4, 5, 71, 72, 73 and 74 bind human CCL17 with a K_D of $1x10^{-10}$ or less.

HCDR1: SYWIG (SEQ ID NO: 4)

HCDR2: IIDPSDSDTRYSPSFQG (SEQ ID NO: 5)

HCDR3 consensus sequence
VGPADVWDX$_1$FDY (SEQ ID NO: 71),
wherein

X_1 is S, A or T

LCDR1 consensus sequence:
$KSSQSVLX_1SX_2X_3NX_4NX_5LA$ (SEQ ID NO: 72),
wherein
X_1 is L, Y, S or N;
X_2 is F, P, H or I;
X_3 is D, Y, W, T or V;
X_4 is I, F, S, T, Y, N, K or V; and
X_5 is K, A, Q, T or D.

LCDR2 consensus sequence:
X_1ASTRE (SEQ ID NO: 73),
wherein
X_1 is N, H, G, E, T or D.

LCDR3 consensus sequence
$QQX_1X_2X_3X_4PX_5T$ (SEQ ID NO: 74);
wherein
X_1 is F, Y, T or H;
X_2 is Y, L, N or W;
X_3 is S, A, L, I, T, Q or H;
X_4 is V, T, I, Y, L or D; and
X_5 is S, F, A or L.

In some embodiment described herein, the HCDR1 comprises the sequence of SEQ ID NO: 4, the HCDR2 comprises the sequence of SEQ ID NO: 5 and the HCDR3 comprises the sequence of SEQ ID NOs: 6, 42, 43 or 44 in the antibody of the invention specifically binding CCL17.

In some embodiments described herein, the HCDR1 comprises the amino acid sequence of SEQ ID NO: 4, the HCDR2 comprises the amino acid sequence of SEQ ID NO: 5 and the

HCDR3 comprises the amino acid sequence of SEQ ID NOs: 6, 42 or 43.

In some embodiments described herein, the LCDR1 comprises the sequence of SEQ ID NOs: 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 or 18; the LCDR2 comprises the sequence of SEQ ID NOs: 19, 20, 21, 22, 23, 24, 25, 26, 39, 40 or 41; and the LCDR3 comprises the sequence of SEQ ID NOs: 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37 or 38 in the antibody of the invention specifically binding CCL17.

In some embodiments described herein, the LCDR1 comprises the amino acid sequence of SEQ ID NOs: 8, 9, 10, 13, 14, 15, 17 or 18, the LCDR2 comprises the amino acid sequence of SEQ ID NOs: 20, 21, 22, 24, 25 and 26 and the LCDR3 comprises the amino acid sequence of SEQ ID NOs: 28, 29, 30, 33, 34, 35, 37 or 38.

In some embodiments described herein, the antibody specifically binding CCL17 comprises the VH of SEQ ID NO: 75 and the VL of SEQ ID NO: 76.

VH consensus sequence (SEQ ID NO: 75)
EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYS
PSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDX$_1$FDYWGQGTLVTVSS

wherein

X_1 is S, A or T.

VL consensus sequence (SEQ ID NO: 76):
DIVMTQSPDSLAVSLGERATINCKSSQSVLX$_1$SX$_2$X$_3$NX$_4$NX$_5$LAWYQQKPGQPPKLLIYX$_6$A
STRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQX$_7$X$_8$X$_9$X$_{10}$PX$_{11}$TFGQGTKVEIK
; wherein

X_1 is L, Y, S or N;

X_2 is F, P, H or I;

X_3 is D, Y, W, T or V;

X_4 is I, F, S, T, Y, N, K or V;

X_5 is K, A, Q, T or D;

X_6 is N, H, G, E, T or D;

X_7 is F, Y, T or H;

X_8 is Y, L, N or W;

X_9 is S, A, L, I, T, Q or H;

X_{10} is V, T, I, Y, L or D; and

X_{11} is S, F, A or L.

In some embodiments described herein, the antibody specifically binding CCL17 comprises the VH of SEQ ID NOs: 45, 46, 47 or 48.

In some embodiments described herein, the antibody specifically binding CCL17 comprises the VL of SEQ ID NOs: 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65 or 66.

In some embodiments described herein, the antibody specifically binding CCL17 comprises the VH comprises the amino acid sequence of SEQ ID NOs: 45, 46 or 47.

In some embodiments described herein, the antibody specifically binding CCL17 comprises the VL comprises the amino acid sequence of SEQ ID NOs: 50, 51, 52, 55, 56, 57, 59, 60 or 62.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the HCDR1, HCDR2, HCDR3, LCDR1, LCDR2 and LCDR3 sequences of

SEQ ID NOs: 4, 5, 6, 7, 19 and 27, respectively;

SEQ ID NOs: 4, 5, 6, 8, 20 and 28, respectively;

SEQ ID NOs: 4, 5, 6, 9, 21 and 29, respectively;

SEQ ID NOs: 4, 5, 6, 10, 22 and 30, respectively;

SEQ ID NOs: 4, 5, 6, 11, 23 and 31, respectively;

SEQ ID NOs: 4, 5, 6, 12, 24 and 32, respectively;

SEQ ID NOs: 4, 5, 6, 13, 21 and 33, respectively;

SEQ ID NOs: 4, 5, 6, 14, 20 and 34, respectively;

SEQ ID NOs: 4, 5, 6, 15, 25 and 35, respectively;

SEQ ID NOs: 4, 5, 6, 16, 21 and 36, respectively;

SEQ ID NOs: 4, 5, 6, 17, 25 and 37, respectively;
SEQ ID NOs: 4, 5, 6, 18, 26 and 38, respectively;
SEQ ID NOs: 4, 5, 6, 8, 39 and 28, respectively;
SEQ ID NOs: 4, 5, 6, 8, 24 and 28, respectively;
SEQ ID NOs: 4, 5, 6, 8, 22 and 28, respectively;
SEQ ID NOs: 4, 5, 6, 8, 40 and 28, respectively;
SEQ ID NOs: 4, 5, 6, 8, 26 and 28, respectively;
SEQ ID NOs: 4, 5, 6, 8, 41 and 28, respectively;
SEQ ID NOs: 4, 5, 42, 8, 24 and 28, respectively;
SEQ ID NOs: 4, 5, 43, 8, 24 and 28, respectively;
or
SEQ ID NOs: 4, 5, 44, 8, 24 and 28, respectively.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises

the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 58, 59, 60, 61, 62, 63, 64, 65 or 66;

the VH and the VL of SEQ ID NOs: 46 and 62, respectively;

the VH and the VL of SEQ ID NOs: 47 and 62, respectively; or

the VH and the VL of SEQ ID NOs: 48 and 62, respectively.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises

the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 50, 51, 52, 55, 56, 57, 59 or 60;

the VH and the VL of SEQ ID NOs: 46 and 62, respectively; or

the VH and the VL of SEQ ID NOs: 47 and 62, respectively.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 50.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 51.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 52.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 55.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 56.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 57.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 59.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises VH of SEQ ID NO: 45 and the VL of SEQ ID NOs: 60.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the

antibody comprises the VH of SEQ ID NO: 46 and the VL of SEQ ID NOs: 62.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH of SEQ ID NO: 47 and the VL of SEQ ID NOs: 62.

Another embodiment of the invention described herein is an isolated antibody specifically binding CCL17, wherein the antibody comprises the VH comprising the amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the VH of SEQ ID NO: 46 and the VL comprising the amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the VL of SEQ ID NO: 62.

Such exemplary antibodies are antibodies shown in Table 9.

Antibodies whose heavy chain CDR, light chain CDR, VH or VL amino acid sequences differ insubstantially from those shown in Tables 3, 4, 6, 7 and 9 are encompassed within the scope of the invention. Typically, this involves one or more conservative amino acid substitutions with an amino acid having similar charge, hydrophobic, or stereo chemical characteristics in the antigen-binding site or in the framework without adversely altering the properties of the antibody. Conservative substitutions may also be made to improve antibody properties, for example stability or affinity. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or 15 amino acid substitutions can be made to the VH or VL sequence. For example, a “conservative amino acid substitution” may involve a substitution of a native amino acid residue with a nonnative residue such that there is little or no effect on the polarity or charge of the amino acid residue at that position. Furthermore, any native residue in the polypeptide may also be substituted with

alanine, as has been previously described for alanine scanning mutagenesis (MacLennan *et al* (1998) *Act Physiol. Scand. Suppl.* 643:55-67; Sasaki *et al* (1998) *Adv. Biopsy's.* 35:1-24). Desired amino acid substitutions can be determined by those skilled in the art at the time such substitutions are desired. For example, amino acid substitutions can be used to identify important residues of the molecule sequence, or to increase or decrease the affinity of the molecules described herein. The following eight groups contain amino acids that are conservative amino acid substitutions for one another: 1) Alanine (A), Glycine (G); 2) Aspartic acid (D), Glutamic acid (E); 3) Asparagine (N), Glutamine (Q); 4) Arginine (R), Lysine (K); 5) Isoleucine (I), Leucine (L), Methionine (M), Valine (V); 6) Phenylalanine (F), Tyrosine (Y), Tryptophan (W); 7) Serine (S), Threonine (T); and 8) Cysteine (C), Methionine (M) (see, e.g., Creighton, Proteins (1984)).

Amino acid substitutions can be done for example by PCR mutagenesis (US Pat. No. 4,683,195). Libraries of variants can be generated using well known methods, for example using random (NNK) or non-random codons, for example DVK codons, which encode 11 amino acids (Ala, Cys, Asp, Glu, Gly, Lys, Asn, Arg, Ser, Tyr, Trp) and screening the libraries for variants with desired properties.

Although the embodiments illustrated in the Examples comprise pairs of variable regions, one from a heavy chain and one from a light chain, a skilled artisan will recognize that alternative embodiments may comprise single heavy or light chain variable regions. The single variable region can be used to screen for variable domains capable of forming a two-domain specific antigen-binding fragment capable of, for example, binding to human CCL17 having the sequence of SEQ ID NO: 1. The screening may be accomplished by phage display screening methods using for example hierarchical dual

combinatorial approach disclosed in Int. Pat. Publ. No. WO1992/01047. In this approach, an individual colony containing either a H or L chain clone is used to infect a complete library of clones encoding the other chain (L or H), and the resulting two-chain specific antigen-binding domain is selected in accordance with phage display techniques as described. Therefore, the individual VH and VL polypeptide chains are useful in identifying additional antibodies specifically binding human CCL17 having the sequence of SEQ ID NO: 1 using the methods disclosed in Int. Pat. Publ. No. WO1992/01047.

Antibodies of the invention described herein may be made using a variety of technologies for generating monoclonal antibodies. For example, the hybridoma method of Kohler and Milstein, *Nature* 256:495, 1975 can be used. In the hybridoma method, a mouse or other host animal, such as a hamster, rat or monkey, is immunized with human CCL17 and/or cyno CCL17 protein or fragments of these proteins, such as an extracellular portion of human CCL17, followed by fusion of spleen cells from immunized animals with myeloma cells using standard methods to form hybridoma cells (Gooding, Monoclonal Antibodies: Principles and Practice, pp.59-103 (Academic Press, 1986)). Colonies arising from single immortalized hybridoma cells are screened for production of antibodies with desired properties, such as specificity of binding, cross-reactivity or lack thereof, and affinity for the antigen.

Various host animals can be used to produce antibodies against human CCL17. For example, Balb/c mice may be used to generate mouse anti-human CCL17 antibodies. The antibodies made in Blab/c mice and other non-human animals can be humanized using various technologies to generate more human-like sequences. Exemplary humanization techniques including selection of human acceptor frameworks are known to skilled

in the art and include CDR grafting (U.S. Pat. No. 5,225,539), SDR grafting (U.S. Pat. No. 6,818,749), Resurfacing (Palin, *Mol Immunol* 28:489-499, 1991), Specificity Determining Residues Resurfacing (U.S. Pat. Publ. No. 2010/0261620), human-adaptation (or human framework adaptation) (U.S. Pat. Publ. No. US2009/0118127), Super humanization (U.S. Pat. No. 7,709, 226) and guided selection (Osborn *et al., Methods* 36:61-68, 2005; U.S. Pat. No. 5,565,332).

Humanized antibodies can be further optimized to improve their selectivity or affinity to a desired antigen by incorporating altered framework support residues to preserve binding affinity (back mutations) by techniques such as those disclosed as described in Int. Pat. Publ. No. WO1990/007861 and in Int. Pat. Publ. No. WO1992/22653.

Transgenic mice carrying human immunoglobulin loci in their genome can be used to generate human antibodies against a target protein, and are described in for example Int. Pat. Publ. No. WO1990/04036, U.S. Pat. No. 6,150,584, Int. Pat. Publ. No. WO1999/45962, Int. Pat. Publ. No. WO2002/066630, Int. Pat. Publ. No. WO2002/43478, Loner *et al., Nature* 368:856-9, 1994; Green *et al., Nature Genet.* 7:13-21, 1994; Green & Jakobovits *Exp Med* 188:483-95, 1998; Lonberg and Huszar *Int Rev Immunol* 13:65-93, 1995; Bruggemann *et al., Eur J Immunol* 21:1323-1326, 1991; Fishwild *et al., Nat Biotechnol* 14:845-851, 1996; Mendez *et al., Nat Genet* 15:146-156, 1997; Green, *J Immunol Methods* 231:11-23, 1999; Yang *et al., Cancer Res* 59:1236-1243, 1999; Brüggemann and Taussig *Curr Opin Biotechnol* 8:455-458, 1997; Int. Pat. Publ. No. WO2002/043478). The endogenous immunoglobulin loci in such mice may be disrupted or deleted, and at least one complete or partial human immunoglobulin locus may be inserted into the mouse genome using homologous or non-homologous recombination, using transchromosomes, or using minigenes.

Companies such as Regeneron (http://_www_regeneron_com), Harbour Antibodies (http://_www_harbourantibodies_com), Open Monoclonal Technology, Inc. (OMT) (http://_www_omtinc_net), KyMab (http://_www_kymab_com), Trianni (http://_www.trianni_com) and Ablexis (http://_www_ablexis_com) can be engaged to provide human antibodies directed against a selected antigen using technology as described above.

Human antibodies can be selected from a phage display library, where the phage is engineered to express human immunoglobulins or portions thereof such as Fabs, single chain antibodies (scFv), or unpaired or paired antibody variable regions (Knappik *et al.*, *J Mol Biol* 296:57-86, 2000; Krebs *et al.*, *J Immunol Meth* 254:67-84, 2001; Vaughan *et al.*, *Nature Biotechnology* 14:309-314, 1996; Sheets *et al.*, *PITAS (USA)* 95:6157-6162, 1998; Hoogenboom and Winter, *J Mol Biol* 227:381, 1991; Marks *et al.*, *J Mol Biol* 222:581, 1991). The antibodies of the invention may be isolated for example from phage display library expressing antibody heavy and light chain variable regions as fusion proteins with bacteriophage pIX coat protein as described in Shi *et al.*, *J Mol Biol* 397:385-96, 2010 and Int. Pat. Publ. No. WO2009/085462). The antibody libraries are screened for binding to human CCL17 extracellular domain and the obtained positive clones are further characterized, the Fabs isolated from the clone lysates, and expressed as full length IgGs. Such phage display methods for isolating human antibodies are established in the art. See for example: U.S. Patent Nos. 5,223,409; 5,403,484; and 5,571,698 to Ladner *et al.*; U.S. Patent Nos. 5,427,908 and 5, 580,717 to Dower *et al.*; U.S. Patent Nos. 5,969,108 and 6,172,197 to McCafferty *et al.*; and U.S. Patent Nos. 5,885,793; 6,521,404; 6,544,731; 6,555,313; 6,582,915 and 6,593,081 to Griffiths *et al.*

Preparation of immunogenic antigens and monoclonal antibody production can be performed using any suitable technique, such as recombinant protein production. The immunogenic antigens can be administered to an animal in the form of purified protein, or protein mixtures including whole cells or cell or tissue extracts, or the antigen can be formed *de novo* in the animal's body from nucleic acids encoding said antigen or a portion thereof.

The antibodies of the invention described herein may be human or humanized.

The antibodies of the invention described herein may be synthetic or recombinant.

The antibodies of the invention described herein may be of IgA, IgD, IgE, IgG or IgM type. The antibodies of the invention described herein may be of IgG1, IgG2, IgG3, IgG4 isotype.

Immune effector properties of the antibodies of the invention may be enhanced or silenced through Fc modifications by techniques known to those skilled in the art. For example, Fc effector functions such as C1q binding, complement dependent cytotoxicity (CDC), antibody-dependent cell-mediated cytotoxicity (ADCC), phagocytosis, down regulation of cell surface receptors (e.g., B cell receptor; BCR), etc. can be modulated by modifying residues in the Fc responsible for these activities. Pharmacokinetic properties may also be enhanced by mutating residues in the Fc domain that extend antibody half-life. Exemplary Fc modifications are IgG4 S228P/L234A/L235A, IgG2 M252Y/S254T/T256E (Dall'Acqua *et al.*, *J Biol Chem* 281:23514-24, 2006; or IgG2 V234A/G237A/P238S, V234A/G237A/H268Q, H268A/V309L/A330S/P331 or V234A/G237A/P238S/H268A/V309L/A330S/P331S on IgG2 (Intl. Pat. Publ. No. WO2011/066501), or those described in US. Pat. No. 6,737,056 (numbering according to the EU numbering).

In some embodiments described herein, the antibody specifically binding human CCL17 comprises a substitution in an Fc region.

In some embodiments described herein, the substitution comprises V234A, G237A, P238S, H268A, V309L, A330S or P331S substitution on IgG2, or S228P, L234A or L235A substitution on IgG4, wherein residue numbering is according to the EU Index.

Additionally, antibodies of the invention described herein can be post-translationally modified by processes such as glycosylation, isomerization, deglycosylation or non-naturally occurring covalent modification such as the addition of polyethylene glycol moieties (pegylation) and lipidation. Such modifications may occur *in vivo* or *in vitro*. For example, the antibodies of the invention can be conjugated to polyethylene glycol (PEGylated) to improve their pharmacokinetic profiles. Conjugation can be carried out by techniques known to those skilled in the art. Conjugation of therapeutic antibodies with PEG has been shown to enhance pharmacodynamics while not interfering with function (Knight *et al., Plateles* 15:409-418, 2004; Leong *et al., Cytokine* 16:106-119, 2001; Yang *et al., Protein Eng* 16:761-770, 2003).

Antibodies or fragments thereof of the invention described herein may be modified to improve stability, selectivity, cross-reactivity, affinity, immunogenicity or other desirable biological or biophysical property are within the scope of the invention. Stability of an antibody is influenced by a number of factors, including (1) core packing of individual domains that affects their intrinsic stability, (2) protein/protein interface interactions that have impact upon the HC and LC pairing, (3) burial of polar and charged residues, (4) H-bonding network for polar and charged residues; and (5) surface charge and polar residue

distribution among other intra- and inter-molecular forces (Worn and Pluckthun, *J Mol Biol* 305:989-1010, 2001). Potential structure destabilizing residues may be identified based upon the crystal structure of the antibody or by molecular modeling in certain cases, and the effect of the residues on antibody stability can be tested by generating and evaluating variants harboring mutations in the identified residues. One of the ways to increase antibody stability is to raise the thermal transition midpoint (T_m) as measured by differential scanning calorimetry (DSC). In general, the protein T_m is correlated with its stability and inversely correlated with its susceptibility to unfolding and denaturation in solution and the degradation processes that depend on the tendency of the protein to unfold (Remmele *et al., Pharm Res* 15:200-208, 1997). A number of studies have found correlation between the ranking of the physical stability of formulations measured as thermal stability by DSC and physical stability measured by other methods (Bedu-Addo *et al., Pharm Res* 21:1353-1361, 2004; Gupta and Kaisheva, *AAPS PharSci*, 5E8, 2003; Maa and Hsu, *Int J Pharm* 140:155-168, 1996; Remmele *et al., Pharm Res* 15:200-208, 1997; Zhang *et al., J Pharm Sci* 93:3076-3089, 2004). Formulation studies suggest that a Fab Tm has implication for long-term physical stability of a corresponding mAb. Differences in amino acids in either framework or within the CDRs could have significant effects on the thermal stability of the Fab domain (Yasui *et al., FEBS Lett* 353:143-146, 1994).

CCL17 antibodies of the invention described herein can be engineered into bispecific antibodies which are also encompassed within the scope of the invention. The VL and/or the VH regions of the antibodies of the invention can be engineered using published methods into single chain bispecific antibodies as structures such as TandAb® designs

(Int. Pat. Publ. No. WO1999/57150; U.S. Pat. Publ. No. US2011/0206672) or into bispecific scFVs as structures such as those disclosed in U.S. Pat. No. 5,869,620; Int. Pat. Publ. No. WO1995/15388, 1nt. Pat. Publ. No. WO1997/14719 or Int. Pat. Publ. No WO2011/036460.

The VL and/or the VH regions of the antibodies of the invention described herein can be engineered into bispecific full length antibodies, where each antibody arm binds a distinct antigen or epitope. Such bispecific antibodies are typically made by modulating the CH3 interactions between the two antibodies heavy chains to form bispecific antibodies using technologies such as those described in U.S. Pat. No. 7,695,936; Int. Pat. Publ. No. WO2004/111233; U.S. Pat. Publ. No. US2010/0015133; U.S. Pat. Publ. No. US2007/0287170; Int. Pat. Publ. No. WO2008/119353; U.S. Pat. Publ. No. US2009/0182127; U.S. Pat. Publ. No. US2010/0286374; U.S. Pat. Publ. No. US2011/0123532; Int. Pat. Publ. No. WO2011/131746; Int. Pat. Publ. No. WO2011/143545; or U.S. Pat. Publ. No. US2012/0149876. Additional bispecific structures into which the VL and/or the VH regions of the antibodies of the invention can be incorporated are for example Dual Variable Domain Immunoglobulins (Int. Pat. Publ. No. WO2009/134776), or structures that include various dimerization domains to connect the two antibody arms with different specificity, such as leucine zipper or collagen dimerization domains (Int. Pat. Publ. No. WO2012/022811, U.S. Pat. No. 5,932,448; U.S. Pat. No. 6,833,441).

Another embodiment of the invention is an isolated polynucleotide encoding any of the antibody heavy chain variable regions or the antibody light chain variable regions of the invention. Certain exemplary polynucleotides are disclosed herein, however, other polynucleotides which, given the degeneracy of the genetic code or codon preferences in a given expression system, encode the antibodies of the

invention are also within the scope of the invention. The polynucleotide sequences encoding a VH or a VL or a fragment thereof of the antibody of the invention can be operably linked to one or more regulatory elements, such as a promoter and enhancer, that allow expression of the nucleotide sequence in the intended host cell. The polynucleotide may be a cDNA.

Another embodiment of the invention is a vector comprising the polynucleotide of the invention. Such vectors may be plasmid vectors, viral vectors, vectors for baculovirus expression, transposon based vectors or any other vector suitable for introduction of the polynucleotide of the invention into a given organism or genetic background by any means. For example, polynucleotides encoding light and heavy chain variable regions of the antibodies of the invention, optionally linked to constant regions, are inserted into expression vectors. The light and heavy chains can be cloned in the same or different expression vectors. The DNA segments encoding immunoglobulin chains are operably linked to control sequences in the expression vector(s) that ensure the expression of immunoglobulin polypeptides. Such control sequences include signal sequences, promoters (e.g. naturally associated or heterologous promoters), enhancer elements, and transcription termination sequences, and are chosen to be compatible with the host cell chosen to express the antibody. Once the vector has been incorporated into the appropriate host, the host is maintained under conditions suitable for high level expression of the proteins encoded by the incorporated polynucleotides.

Suitable expression vectors are typically replicable in the host organisms either as episomes or as an integral part of the host chromosomal DNA. Commonly, expression vectors contain selection markers such as ampicillin-resistance, hygromycin-resistance, tetracycline resistance, kanamycin

resistance or neomycin resistance to permit detection of those cells transformed with the desired DNA sequences.

Suitable promoter and enhancer elements are known in the art. For expression in a bacterial cell, exemplary promoters include lacI, lacZ, T3, T7, gpt, lambda P and trc. For expression in a eukaryotic cell, exemplary promoters include light and/or heavy chain immunoglobulin gene promoter and enhancer elements; cytomegalovirus immediate early promoter; herpes simplex virus thymidine kinase promoter; early and late SV40 promoters; promoter present in long terminal repeats from a retrovirus; mouse metallothionein-I promoter; and various art-known tissue specific promoters. For expression in a yeast cell, an exemplary promoter is constitutive promoter such as an ADH1 promoter, a PGK1 promoter, an ENO promoter, a PYK1 promoter and the like; or a regulatable promoter such as a GAL1 promoter, a GAL10 promoter, an ADH2 promoter, a PH05 promoter, a CUP1 promoter, a GAL7 promoter, a MET25 promoter, a MET3 promoter, a CYC1 promoter, a HIS3 promoter, an ADH1 promoter, a PGK promoter, a GAPDH promoter, an ADC1 promoter, a TRP1 promoter, a URA3 promoter, a LEU2 promoter, an ENO promoter, a TP1 promoter, and AOX1 (e.g., for use in Pichia). Selection of the appropriate vector and promoter is well within the level of ordinary skill in the art.

Large numbers of suitable vectors and promoters are known to those of skill in the art; many are commercially available for generating a subject recombinant constructs. The following vectors are provided by way of example. Bacterial: pBs, phagescript, PsiX174, pBluescript SK, pBs KS, pNH8a, pNH16a, pNH18a, pNH46a (Stratagene, La Jolla, Calif., USA); pTrc99A, pKK223-3, pKK233-3, pDR540, and pRIT5 (Pharmacia, Uppsala, Sweden). Eukaryotic: pWLneo, pSV2cat, pOG44, PXR1, pSG (Stratagene) pSVK3, pBPV, pMSG and pSVL (Pharmacia).

Another embodiment of the invention is a host cell comprising the vector of the invention. The term "host cell" refers to a cell into which a vector has been introduced. It is understood that the term host cell is intended to refer not only to the particular subject cell but to the progeny of such a cell. Because certain modifications may occur in succeeding generations due to either mutation or environmental influences, such progeny may not be identical to the parent cell, but are still included within the scope of the term "host cell" as used herein. Such host cells may be eukaryotic cells, prokaryotic cells, plant cells or archeal cells.

Escherichia coli, bacilli, such as Bacillus subtilis, and other enterobacteriaceae, such as Salmonella, Serratia, and various Pseudomonas species are examples of prokaryotic host cells. Other microbes, such as yeast, are also useful for expression. Saccharomyces (e.g., S. cerevisiae) and Pichia are examples of suitable yeast host cells. Exemplary eukaryotic cells may be of mammalian, insect, avian or other animal origins. Mammalian eukaryotic cells include immortalized cell lines such as hybridomas or myeloma cell lines such as SP2/0 (American Type Culture Collection (ATCC), Manassas, VA, CRL-1581), NS0 (European Collection of Cell Cultures (ECACC), Salisbury, Wiltshire, UK, ECACC No. 85110503), FO (ATCC CRL-1646) and Ag653 (ATCC CRL-1580) murine cell lines. An exemplary human myeloma cell line is U266 (ATTC CRL-TIB-196). Other useful cell lines include those derived from Chinese Hamster Ovary (CHO) cells such as CHO-K1SV (Lonza Biologics, Walkersville, MD), CHO-K1 (ATCC CRL-61) or DG44.

Another embodiment of the invention is a method of producing an antibody of the invention comprising culturing the host cell of the invention and recovering the antibody produced by the host cell. Methods of making antibodies and

purifying them are well known in the art. Once synthesized (either chemically or recombinantly), the whole antibodies, their dimers, individual light and heavy chains, or other antibody fragments such as VH or VL, can be purified according to standard procedures of the art, including ammonium sulfate precipitation, affinity columns, column chromatography, high performance liquid chromatography (HPLC) purification, gel electrophoresis, and the like (see generally Scopes, Protein Purification (Springer- Verlag, N.Y., (1982)). A subject antibody can be substantially pure, e.g., at least about 80% to 85% pure, at least about 85% to 90% pure, at least about 90% to 95% pure, or at least about 98% to 99%, or more, pure, e.g., free from contaminants such as cell debris, macromolecules other than a subject antibody, etc.

The polynucleotides encoding certain VH or VL sequences of the invention are incorporated into vectors using standard molecular biology methods. Host cell transformation, culture, antibody expression and purification are done using well known methods.

Methods of Treatment

Antibodies specifically binding human CCL17 may be suitable for treating or preventing a spectrum of CCL17-mediated conditions.

The term "CCL17-mediated condition" as used herein encompasses all diseases and medical conditions in which CCL17 plays a role, whether directly or indirectly, in the disease or medical condition, including the causation, development, progress, persistence or pathology of the disease or condition.

The term "CCL17-mediated inflammatory condition" as used herein refers to an inflammatory condition resulting at least partially from CCL17 biological activity. Exemplary

CCL17-mediated inflammatory conditions are asthma and allergies.

The methods of the invention may be used to treat an animal patient belonging to any classification. Examples of such animals include mammals such as humans, rodents, dogs, cats and farm animals. For example, the antibodies of the invention are useful in the prophylaxis and treatment of CCL17-mediated conditions, such as asthma and respiratory allergic diseases such as allergic asthma, allergic rhinitis, chronic obstructive pulmonary disease (COPD), idiopathic pulmonary fibrosis (IPF), hypersensitivity lung diseases and the like, allergic diseases such as systemic anaphylaxis or hypersensitivity responses, drug allergies, allergic bronchopulmonary aspergillosis (ABPA), insect sting allergies and food allergies, inflammatory bowel diseases such as Crohn's disease, ulcerative colitis, ileitis and enteritis, vaginitis, psoriasis and inflammatory dermatoses such as dermatitis, eczema, atopic dermatitis, allergic contact dermatitis, urticaria and pruritus, vasculitis, spondyloarthropathies, scleroderma, autoimmune diseases, such as arthritis (including rheumatoid and psoriatic), multiple sclerosis, systemic lupus erythematosus, type I diabetes, glomerulonephritis, and the like, graft rejection (including allograft rejection and graft-v-host disease), and other diseases in which undesired inflammatory responses are to be inhibited, such as atherosclerosis, myositis, T-cell mediated neurodegenerative diseases, multiple sclerosis, encephalitis, meningitis, hepatitis, nephritis, sepsis, sarcoidosis, allergic conjunctivitis, otitis, Castleman's disease, sinusitis, LPS-induced endotoxic shock, Behcet's syndrome and gout,

The antibodies of the invention described herein and are also useful in the preparation of a medicament for such

treatment, wherein the medicament is prepared for administration in dosages defined herein.

The methods and uses of the present may be intended for use in animals and patients that have, or are at risk for developing any disease or condition associated with CCL17 expression or biological activity or in which CCL17 plays a biological role.

By not wishing to be bound by any theory, the antibodies of the invention may provide their efficacious effect in various inflammatory diseases by direct inhibition of Th2 cell recruitment and therefore simultaneous inhibition of multiple Th2 cytokines. The antibodies of the invention may provide an improved safety profile in comparison to anti-CCR4 antibodies by selectively blocking CCL17 only. The antibodies will not interact with platelets, which express CCR4. In addition, the antibodies will not block the beneficial innate immune effects of CCL22 on CCR4 (Matsukawa *et al., I. Immunol* 164:5382-8, 2000).

"Inflammatory condition" as used herein refers to acute or chronic localized or systemic responses to harmful stimuli, such as pathogens, damaged cells, physical injury or irritants, that are mediated in part by the activity of cytokines, chemokines, or inflammatory cells (*e.g.*, neutrophils, monocytes, lymphocytes, macrophages, mast cells, dendritic cells, neutrophils) and is characterized in most instances by pain, redness, swelling, and impairment of tissue function.

Inflammatory pulmonary condition is an example of a CCL17-mediated inflammatory condition. Exemplary inflammatory pulmonary conditions include infection-induced pulmonary conditions including those associated with viral, bacterial, fungal, parasite or prion infections; allergen-induced pulmonary conditions; pollutant-induced pulmonary conditions such as asbestosis, silicosis, or berylliosis;

gastric aspiration-induced pulmonary conditions, immune dysregulation, inflammatory conditions with genetic predisposition such as cystic fibrosis, and physical trauma-induced pulmonary conditions, such as ventilator injury. These inflammatory conditions also include asthma, emphysema, bronchitis, chronic obstructive pulmonary disease (COPD), sarcoidosis, histiocytosis, lymphangiomyomatosis, acute lung injury, acute respiratory distress syndrome, chronic lung disease, bronchopulmonary dysplasia, community-acquired pneumonia, nosocomial pneumonia, ventilator -associated pneumonia, sepsis, viral pneumonia, influenza infection, parainfluenza infection, rotavirus infection, human metapneumovirus infection, respiratory syncitial virus infection and *Aspergillus* or other fungal infections. Exemplary infection-associated inflammatory diseases may include viral or bacterial pneumonia, including severe pneumonia, cystic fibrosis, bronchitis, airway exacerbations and acute respiratory distress syndrome (ARDS). Such infection-associated conditions may involve multiple infections such as a primary viral infection and a secondary bacterial infection.

Asthma is an inflammatory disease of the lung that is characterized by airway hyperresponsiveness ("AHR"), bronchoconstriction, wheezing, eosinophilic or neutrophilic inflammation, mucus hypersecretion, subepithelial fibrosis, and elevated IgE levels. Patients with asthma experience "exacerbations", a worsening of symptoms, most commonly due to microbial infections of the respiratory tract (*e.g.* rhinovirus, influenza virus, Haemophilus influenza, etc.). Asthmatic attacks can be triggered by environmental factors (*e.g.* ascarids, insects, animals (*e.g.*, cats, dogs, rabbits, mice, rats, hamsters, guinea pigs and birds), fungi, air pollutants (*e.g.*, tobacco smoke), irritant gases, fumes, vapors, aerosols, chemicals, pollen, exercise, or cold air.

Apart from asthma, several chronic inflammatory diseases affecting the lung are characterized by neutrophil infiltration to the airways, for example chronic obstructive pulmonary disease (COPD), bacterial pneumonia and cystic fibrosis (Linden *et al., Eur Respir J* 15:973-7, 2000; Rahman *et al., Clin Immunol* 115:268-76, 2005), and diseases such as COPD, allergic rhinitis, and cystic fibrosis are characterized by airway hyperresponsiveness (Fahy and O'Byrne *Am J Respir Crit Care Med* 163:822-3, 2001).

In allergic asthma, the presence of high levels of allergen-specific IgE is a reflection of an aberrant Th2 cell immune response to commonly inhaled environmental allergens. Allergens are presented to T cells by dendritic cells (DCs) that continuously sample incoming foreign antigens. Upon proper activation by DCs, allergen-specific lymphocytes that are present in diseased airways produce Th2 cytokines interleukin (IL)-4, IL-5 and IL-13 that furthermore control leukocyte extravasation, goblet cell hyperplasia and bronchial hyper-reactivity (BHR). CCL17 produced by DCs induce the selective migration of Th2 cells but not Th1 cells through triggering CCR4. In murine models of asthma, that treatment with anti-CCL17 antibodies reduced the number of CD4+ T cells and eosinophils in bronchoalveolar lavage (BAL) fluid, the production of Th2 cytokines and airway hyper-responsiveness after allergen challenge, suggesting that CCL17 neutralization is a feasible strategy for inhibiting allergic inflammation in humans.

Commonly used animal models for asthma and airway inflammation include the ovalbumin challenge model, methacholine sensitization models and sensitization with *Aspergillus fumigatus* (Hessel *et al., Eur J Pharmacol* 293:401-12, 1995). Inhibition of cytokine and chemokine production from cultured human bronchial epithelial cells, bronchial fibroblasts or airway smooth muscle cells can also

be used as *in vitro* models. The administration of antibodies of the invention to any of these models can be used to evaluate ther efficacy to ameliorate symptoms and alter the course of asthma, airway inflammation, COPD and the like.

Atopic dermatitis is an example of a CCL17-mediated inflammatory condition.

One aspect of the invention is a method of treating a CCL17-mediated disease, comprising administering to a subject in need thereof the antibody of the invention for a time sufficient to treat the CCL17-mediated disease.

In some embodiments described herein, the CCL17-mediated disease is an inflammatory disease.

In some embodiments described herein, the inflammatory disease is asthma, ulcerative colitis (UC), atopic dermatitis (AD) or idiopathic pulmonary fibrosis (IPF).

One embodiment of the invention is a method of treating asthma, comprising administering to a subject an antibody of the invention described herein for a time sufficient to treat asthma.

One embodiment of the invention is a method of treating ulcerative colitis, comprising administering to a subject an antibody of the invention described herein for a time sufficient to treat ulcerative colitis.

One embodiment of the invention is a method of treating atopic dermatitis, comprising administering to a subject an antibody of the invention described herein for a time sufficient to treat atopic dermatitis.

One embodiment of the invention is a method of treating idiopathic pulmonary fibrosis, comprising administering to a subject an antibody of the invention described herein for a time sufficient to treat idiopathic pulmonary fibrosis.

Administration/Pharmaceutical Compositions

The invention provides for pharmaceutical compositions comprising the antibodies specifically binding CCL17 of the invention of the invention and a pharmaceutically acceptable carrier. For therapeutic use, the antibodies specifically binding CCL17 of the invention may be prepared as pharmaceutical compositions containing an effective amount of the domain, molecule or antibody as an active ingredient in a pharmaceutically acceptable carrier. The term "carrier" refers to a diluent, adjuvant, excipient, or vehicle with which the active compound is administered. Such vehicles may be liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin, such as peanut oil, soybean oil, mineral oil, sesame oil and the like. For example, 0.4% saline and 0.3% glycine can be used. These solutions are sterile and generally free of particulate matter. They may be sterilized by conventional, well-known sterilization techniques (*e.g.*, filtration). The compositions may contain pharmaceutically acceptable auxiliary substances as required to approximate physiological conditions such as pH adjusting and buffering agents, stabilizing, thickening, lubricating and coloring agents, etc. The concentration of the molecules or antibodies of the invention described herein in such pharmaceutical formulation may vary widely, *i.e.*, from less than about 0.5%, usually at or at least about 1% to as much as 15 or 20% by weight and will be selected primarily based on required dose, fluid volumes, viscosities, etc., according to the particular mode of administration selected. Suitable vehicles and formulations, inclusive of other human proteins, e.g., human serum albumin, are described, for example, in e.g. Remington: The Science and Practice of Pharmacy, 21st Edition, Troy, D.B. ed., Lipincott Williams and Wilkins, Philadelphia, PA 2006, Part 5, Pharmaceutical Manufacturing pp 691-1092, See especially pp. 958-989.

The mode of administration for therapeutic use of the antibodies specifically binding CCL17 of the invention described herein may be any suitable route that delivers the agent to the host, such as parenteral administration, e.g., intradermal, intramuscular, intraperitoneal, intravenous or subcutaneous, pulmonary; transmucosal (oral, intranasal, intravaginal, rectal); using a formulation in a tablet, capsule, solution, powder, gel, particle; and contained in a syringe, an implanted device, osmotic pump, cartridge, micropump; or other means appreciated by the skilled artisan, as well known in the art. Site specific administration may be achieved by for example intrarticular, intrabronchial, intraabdominal, intracapsular, intracartilaginous, intracavitary, intracelial, intracerebellar, intracerebroventricular, intracolic, intracervical, intragastric, intrahepatic, intracardial, intraosteal, intrapelvic, intrapericardiac, intraperitoneal, intrapleural, intraprostatic, intrapulmonary, intrarectal, intrarenal, intraretinal, intraspinal, intrasynovial, intrathoracic, intrauterine, intravascular, intravesical, intralesional, vaginal, rectal, buccal, sublingual, intranasal, or transdermal delivery.

Thus, a pharmaceutical composition of the invention described herein for intramuscular injection may be prepared to contain 1 ml sterile buffered water, and between about 1 ng to about 100 mg/kg, *e.g.* about 50 ng to about 30 mg/kg or more preferably, about 5 mg to about 25 mg/kg, of the antibodies specifically binding CCL17 of the invention.

The dose given to a patient having a CCL17-mediated condition is sufficient to alleviate symptoms or treat the CCL17-mediated condition ("therapeutically effective amount") and is sometimes 0.1 to 10 mg/kg body weight, for example 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 mg/kg, but may even higher, for example 15, 20, 30, 40, 50, 60, 70, 80, 90 or 100 mg/kg. A

fixed unit dose may also be given, for example, 50, 100, 200, 500 or 1000 mg, or the dose may be based on the patient's surface area, e.g., 400, 300, 250, 200, or 10 mg/m^2. Usually between 1 and 8 doses, (e.g., 1, 2, 3, 4, 5, 6, 7 or 8) are administered, but 10, 12, 20 or more doses may be given. Administration of the antibodies specifically binding CCL17 of the invention described herein may be repeated after one day, two days, three days, four days, five days, six days, one week, two weeks, three weeks, one month, five weeks, six weeks, seven weeks, two months, three months, four months, five months, six months or longer. Repeated courses of treatment are also possible, as is chronic administration. The repeated administration may be at the same dose or at a different dose.

The dosage of the CCL17 antibodies of the invention described herein that will be effective in the treatment of inflammatory diseases such as asthma can be determined by administering the CCL17 antibodies to relevant animal models well known in the art and as described herein.

In vitro assays can optionally be employed to help identify optimal dosage ranges. Selection of a particular effective dose can be determined (*e.g.*, via clinical trials) by those skilled in the art based upon the consideration of several factors. Such factors include the disease to be treated or prevented, the symptoms involved, the patient's body mass, the patient's immune status and other factors known by the skilled artisan. The precise dose to be employed in the formulation will also depend on the route of administration, and the severity of disease, and should be decided according to the judgment of the practitioner and each patient's circumstances. Effective doses can be extrapolated from dose-response curves derived from *in vitro* or animal model test systems. The antibodies of the

invention may be tested for their efficacy and effective dosage using any of the models described herein.

For example, a pharmaceutical composition comprising the antibodies specifically binding CCL17 of the invention described herein for intravenous infusion may be made up to contain about 200 ml of sterile Ringer's solution, and about 8 mg to about 2400 mg, about 400 mg to about 1600 mg, or about 400 mg to about 800 mg of the antibodies specifically binding CCL17 of the invention for administration to a 80 kg patient. Methods for preparing parenterally administrable compositions are well known and are described in more detail in, for example, "Remington's Pharmaceutical Science", 15th ed., Mack Publishing Company, Easton, PA.

The antibodies specifically binding CCL17 of the invention described herein may be lyophilized for storage and reconstituted in a suitable carrier prior to use. This technique has been shown to be effective with conventional protein preparations and art-known lyophilization and reconstitution techniques can be employed.

The antibodies specifically binding CCL17 of the invention described herein may be administered in combination with a second therapeutic agent simultaneously, sequentially or separately.

The present invention will now be described with reference to the following specific, non-limiting examples.

Example 1.Generation of CCL17 neutralizing antibodies

Human CCL17 binding Fabs were selected from *de novo* pIX phage display libraries described in Shi *et al.*, J. Mol. Biol. 397:385-396, 2010; Int. Pat. Publ. No. WO2009/085462; U.S. Pat. Publ. No. US2010/0021477; U.S. Pat. Publ. No. US2012/0108795. Briefly, the libraries were generated by

diversifying human scaffolds where germline VH genes IGHV1-69*01, IGHV3-23*01, and IGHV5-51*01 were recombined with the human IGHJ-4 minigene *via* the H3 loop, and human germline VL kappa genes O12 (IGKV1-39*01), L6 (IGKV3-11*01), A27 (IGKV3-20*01), and B3 (IGKV4-1*01) were recombined with the IGKJ-1 minigene to assemble complete VH and VL domains. The positions in the heavy and light chain variable regions around H1, H2, L1, L2 and L3 loops corresponding to positions identified to be frequently in contact with protein and peptide antigens were chosen for diversification. Sequence diversity at selected positions was limited to residues occurring at each position in the IGHV or IGLV germline gene families of the respective IGHV or IGLV genes. Diversity at the H3 loop was generated by utilizing short to mid-sized synthetic loops of lengths 7-14 amino acids. The amino acid distribution at H3 was designed to mimic the observed variation of amino acids in human antibodies. Library design is detailed in Shi *et al.*, J Mol Biol 397:385-96, 2010. The scaffolds utilized to generate libraries were named according to their human VH and VL germline gene origin. The three heavy chain libraries were combined with the four germline light chains or germline light chain libraries to generate 24 unique VH:VL combinations for screening. All 24 VH:VL library combinations were utilized in phage panning experiments against human CCL17.

The libraries were panned using human CCL17 of SEQ ID NO: 1. Briefly, human CCL17 was biotinylated using standard methods and the biotinylated human CCL17 (Bt-huCCL17) was captured on streptavidin-coated magnetic beads (Dynal, M280), and the Fab-pIX phage libraries were added to the beads. Bt-huCCL17 concentrations used were 100 nM for rounds 1 and 2 and 10 mM for rounds 3 and 4). Screening was done by ELISA for Fab binding to human CCL17 protein. For panning, the bt-huCCL17 coated magnetic beads were washed and blocked with

PBST-M (BPS with 0.05% Tween-20 and 3% non-fat dry milk). Blocked phage from the libraries were added to the beads and rotated at room temperature for round 1. Beads were washed and then incubated in a culture of log phase E. coli, (MC1061F') cells and the infected E coli were grown on LB agar plates overnight at 37°C. The next morning cultures were scraped from the plates in 2mL 2xYT (20% glycerol) per plate, 50 µL of bacterial suspension was added to 50mL 2xYT (Carb) and grown at 37°C shaking for up to 2 hours. Helper phage was added to mid-log phase cultures and the cultures were incubated at 37°C for 30 minutes. Kanamycin and IPTG were added to each culture to final concentrations of 35 µg/mL and 1mM, respectively, and grown overnight at 30°C shaking. The amplified phage from the bacterial media was precipitated using PEG/NaCl and re-suspended in 1 mL PBS. 200 µL was used for the next round of panning.

After three rounds of panning, phagemid DNA was isolated from the infected MC1061F' cells and digested with restriction enzymes to remove the sequence encoding pIX, and the linearized plasmid DNA was excised and purified from agarose gels. This DNA was then self-ligated with T4 DNA ligase. The ligated DNA was electroporated into MC1061F' cells and plated onto LB (Carb/Glucose) agar plates. Colonies from this electroporation were picked for the ELISA screen and assessment of Fab expression. The Fabs contain an in-frame His tag at the C-terminus of the heavy chain. From the initial screen, 24 Fabs were partially purified via the C-terminal His tag using standard methods and characterized further.

The Fabs were characterized for their binding to human CCL17 (SEQ ID NO: 1), cyno CCL17 (SEQ ID NO: 2) and cyno CCL22 (SEQ ID NO: 3) in an ELISA assay. Briefly, Maxisorp 96 well plates were coated with 1µg/ml Goat anti-human Kappa (Southern Biotech). Semi-purified Fab was added to each

plate. Biotinylated huCCL17, cCCL17 or cCCL22 was added to each Fab-captured well. Proteins bound to the captured Fabs were detected using Streptavidin:HRP. Five Fabs (F21, F24, F34, F43 and F44) that bound to both human and cyno CCL17 but not cyno CCL22 were selected for affinity maturation.

Example 2.Affinity maturation of anti- CCL17 antibodies

Five Fabs were selected for affinity maturation based on their initial characterization profile. The Fabs were affinity-matured by diversifying the light chains using the in-line maturation technology desribed in Shi et al. (Shi *et al., J Mol Biol* 397:385-396, 2010) and keeping the heavy chain invariant. The heavy chain in the Fabs was either VH3-23 or VH5-51. F24 affinity maturation libraries produced improved CCL17 binders.

Briefly, F24 was affinity-matured using the B3 light chain library. The B3 library diversification sheme is shown in Table 2. The positions are indicated as Kabat numbering.

Table 2.

Residue position (Kabat)	Germline residue	Library compositions
27d	Y	SYHFA
30	K	KTNE
32	Y	YFHNWDAS
50	W	YWSRDYA
91	Y	YSHA
92	Y	YNDSHIFK
93	S	SNTDGHR
94	T	TYLVFAS
96	L	WYFLIR

The VH regions of the Fabs were cloned into the LC library phagemid resulting in a complete re-diversification of the LC for each Fab. VH regions were isolated by restriction digestion of DNA minipreps using NcoI and ApaI. The VH regions were gel isolated and ligated into similarly digested LC library DNA. Ligations were purified and transformed into MC1061F' cells. Cells were grown in 2xYT (Carb) until log phase growth (OD_{600nm} ≈ 0.6) was achieved. Helper phage was added and the cultures were incubated at 37°C for 30 minutes. Kanamycin and IPTG were added to each culture to final concentrations of 35ug/mL and 1mM, respectively, and grown overnight at 30°C shaking. The phage from the bacterial media was precipitated using PEG/NaCl and re-suspended in PBS.

For affinity maturation panning, Bt-CCL17 was captured on 50 µl of SA-coated magnetic beads. Antigen concentrations were 100nM for round 1, 10nM for round 2, and 10 nM for round 3. Beads were subjected to 6 washes with PBST and one wash with PBS, followed by E. coli infection as described above. Isolation of Fab expression plasmids and expression of Fabs was done as described.

Affinity-matured Fabs were screened in an ELISA assay for binding to huCCL17 (SEQ ID NO: 1), cCCL17 (SEQ ID NO: 2) and cCCL22 (SEQ ID NO: 3) as described above for binding to huCCL17. Identified clones were sequenced, converted to full IgG1 antibodies and their binding to huCCL17, cCCL17 and cCCL22 was confirmed using MSD-SEA.

CDR sequences of the parent and affinity-matured antibodies are shown in Table 3 and Table 4 for heavy chain and light chain CDRs, respectively.

Table 3.

mAb ID	HDCR1	HCDR2	HCDR3

	sequence	SEQ ID NO:	sequence	SEQ ID NO:	sequence	SEQ ID NO:
C17F24 (parent)	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B234	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B235	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B236	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B237	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B238	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B239	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B240	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B241	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B242	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B243	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B244	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6

Table 4.

mAb ID	LCDR1		LCDR2		LCDR3	
	sequence	SEQ ID NO:	sequence	SEQ ID NO:	sequence	SEQ ID NO:
C17F24 (parent)	KSSQSVLYSSNNKNYLA	7	WASTRES	19	QQYYSTPLT	27
C17B234	KSSQSVLLSFDNINKLA	8	NASTRES	20	QQFYSVPST	28
C17B235	KSSQSVLYSFYNFNALA	9	HASTRES	21	QQFYATPFT	29
C17B236	KSSQSVLLSPWNSNQLA	10	GASTRES	22	QQYYLIPST	30
C17B237	KSSQSVLTSYNNSNYLA	11	LASTRES	23	QQYLSPPST	31
C17B238	KSSQSVLISAFNQNPLA	12	DASTRES	24	QQYQFIPFT	32
C17B239	KSSQSVLSSFTNTNTLA	13	HASTRES	21	QQYLIYPST	33
C17B240	KSSQSVLYSHVNYNALA	14	NASTRES	20	QQYYTLPAT	34
C17B241	KSSQSVLNSFTNNNALA	15	EASTRES	25	QQTNSIPLT	35
C17B242	KSSQSVLFSHDNLNTLA	16	HASTRES	21	QQYYAVPQT	36
C17B243	KSSQSVLNSFDNKNDLA	17	EASTRES	25	QQHWQTPLT	37
C17B244	KSSQSVLSSITNVNDLA	18	TASTRES	26	QQYYHDPFT	38

Example 3. Binding of affinity-matured anti-CCL17 antibodies to human and cyno CCL17

Antibodies were assessed for their binding to human CCL17 and cyno CCL17 using solution equilibrium affinity (SEA). The procedure for these experiments was similar to that used by Haenel et al (Haenel *et al., Anal Biochem*

339:182-184, 2005). To prepare the antigen-antibody complexes, human CCL17 or cyno CCL17 was serially diluted in Tris-Based Saline buffer containing 0.05% Tween-20, TBST, (Thermo Scientific) at a 1:6 ratio starting at a concentration of 2,000,000 pM in 96-deep well polypropylene plates. Equal volumes of the anti-hCCL17 mAbs at 40 pM or 200 pM were added to each chemokine dilution to obtain mixtures containing the serial dilution of chemokines starting at a final concentration of 1μM and a constant concentration (20pM or 100pM) of anti-CCL17 antibody. The mixtures were prepared in duplicate and incubated at 4°C for 48 hours to reach equilibrium. The free antibody was detected using a SECTOR Imager 6000 (Meso Scale Discovery) instrument. The resulting binding curves were fitted to obtain the dissociation equilibrium constant (K_D) using the GraphPad Prism software (v 5.01) using a 1:1 binding model to perform nonlinear least-square regression analysis of the data. Table 5 shows affinities of the antibodies to human and cyno CCL17. The affinities ranged from about 2 pM to about 700 pM for human CCL17 and from about 200 pM to about 9500 pM to cyno CCL17. The generated antibodies bound human CCL17 with about 2- to about 150 fold higher affinities when compared to binding to cyno CCL17.

Table 5.

	Affinity (pM)		Fold binding human/cyno CCL17
mAb ID	human CCL17	cyno CCL17	
C17F24 (parent)	1000	ND*	
C17B234	2	230	115.0
C17B235	72	9497	131.9
C17B236	39	297	7.6
C17B237	657	3066	4.7
C17B238	115	1456	12.7
C17B239	92	630	6.8
C17B240	83	4596	55.4
C17B241	50	583	11.7

C17B242	167	384	2.3
C17B243	28	677	24.2
C17B244	33	565	17.1

*Not determined

Example 4. Optimization of CCL17 antibodies

C17B234 and C17B240 anti-CCL17 antibodies contained a potential N-linked glycosylation site at the beginning of the LCDR2 ("NAS"). The asparagine residue (N) at residue position 50 (Kabat numbering) of C17B234 was mutated to six different amino acids (A, D, G, S, T and I).

A potential aspartic acid isomerization motif, "DS" was identified in the HCDR3 in the parent C17F24 and all its affinity matured variants. To test the effect of substitutions at this position, the serine residue at position 100c (Kabat numbering) was mutated to A, T or S or the D at position 100b was mutated to E in the heavy chain of mAb C17B234. The resulting heavy chains were paired with the light chain of mAb C17B258.

The antibodies were expressed as IgG1 and their affinity to human and cyno CCL17 was measured. Table 6 and Table 7 shows the heavy and light chain CDR sequences of the optimized antibodies. Table 8 shows the affinity of the antibodies for human and cyno CCL17. Mutagenesis of N50 in the light chain resulted in improved binding of 2- to 100-fold.

Table 6.

	HCDR1		HCDR2		HCDR3	
mAb ID	Sequence	SEQ ID NO:	Sequence	SEQ ID NO:	Sequence	SEQ ID NO:
C17B257	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B258	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B260	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B262	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B263	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6

C17B264	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDSFDY	6
C17B293	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDAFDY	42
C17B294	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWDTFDY	43
C17B295	SYWIG	4	IIDPSDSDTRYSPSFQG	5	VGPADVWESFDY	44

Table 7.

mAb ID	LCDR1		LCDR2		LCDR3	
	Sequence	SEQ ID NO:	Sequence	SEQ ID NO:	Sequence	SEQ ID NO:
C17B257	KSSQSVLLSFDNINKLA	8	AASTRES	39	QQFYSVPST	28
C17B258	KSSQSVLLSFDNINKLA	8	DASTRES	24	QQFYSVPST	28
C17B260	KSSQSVLLSFDNINKLA	8	GASTRES	22	QQFYSVPST	28
C17B262	KSSQSVLLSFDNINKLA	8	SASTRES	40	QQFYSVPST	28
C17B263	KSSQSVLLSFDNINKLA	8	TASTRES	26	QQFYSVPST	28
C17B264	KSSQSVLLSFDNINKLA	8	IASTRES	41	QQFYSVPST	28
C17B293	KSSQSVLLSFDNINKLA	8	DASTRES	24	QQFYSVPST	28
C17B294	KSSQSVLLSFDNINKLA	8	DASTRES	24	QQFYSVPST	28
C17B295	KSSQSVLLSFDNINKLA	8	DASTRES	24	QQFYSVPST	28

Table 8.

mAb ID	Affinity (pM)		Fold binding human/cyno CCL17
	Human CCL17	Cyno CCL17	
c17B257	0.1	65.6	656.0
C17B258	0.1	41.6	416.0
C17B260	0.5	36.4	72.8
C17B262	0.3	55.5	185.0
C17B263	0.1	75.59	755.9
C17B264	0.4	71.83	179.6
C17B293	<0.1	39	
C17B294	1	22	22.0
C17B295	175	29892	170.8

A Tryptophan residue in HCDR3 at position 100a (Kabat numbering) in mAb of C17B236 was identified as a putative site for undesired post translational oxidation. This residue was mutated to 17 other amino acids (all except C and

M) in the Fab parent of C17B236, C17F319 which mAb is this. Kunkel's mutagenesis was performed with "NNK" or defined codon oligonucleotides to produce this panel. These Fabs were then screened using a ranking ELISA for binding to both bt-human and bt-cyno CCL17. Five variants (W → R, Y, F, T, I) showed some binding in a Fab binding ELISA (Table 5). The best three were converted to mAb (M17B288, C17B289, C17B290) for expression and MSD-SEA (Table 6). Most variants displayed reduced affinity to the human and cyno CCL17.

VH and VL sequences of the antibodies are shown in Table 9.

Table 9.

mAb	VH SEQ ID NO:	VL SEQ ID NO:
C17F24 (parent)	45	49
C17B234	45	50
C17B235	45	51
C17B236	45	52
C17B237	45	53
C17B238	45	54
C17B239	45	55
C17B240	45	56
C17B241	45	57
C17B242	45	58
C17B243	45	59
C17B244	45	60
C17B257	45	61
C17B258	45	62
C17B260	45	63
C17B262	45	64
C17B263	45	65
C17B264	45	66
C17B293	46	62

C17B294	47	62
C17B295	48	62

Example 6. Selection of constant regions

Select antibodies were cloned as IgG2 or IgG4 with following substitutions: IgG4 S228P/L234A/L235A or IgG2 V234A/G237A/P238S/H268A/V309L/A330S/P331S using standard methods. Table 10 shows the resulting antibodies

Table 10.

mAb name	isotype	Variable regions from mAb
C17B302	IgG2 V234A/G237A/P238S/H268A/V309L/A330S/P331S	C17B293
C17B311	IgG4 S228P/L234A/L235A	C17B293
C17B301	IgG2 V234A/G237A/P238S/H268A/V309L/A330S/P331S	C17B294
C17B312	IgG4 S228P/L234A/L235A	C17B294

Heavy and light chains of certain antibodies are shown below:

CB302 HC (SEQ ID NO: 67)
EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYS
PSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDAFDYWGQGTLVTVSSA
STKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGL
YSLSSVVTVTSSNFGTQTYTCNVDHKPSNTKVDKTVERKCCVECPPCPAPPAAASSVFLFP
PKPKDTLMISRTPEVTCVVVDVSAEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVVSV
LTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLT
CLVKGFYPSDIAVEWESNGQPENNYKTTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSV
MHEALHNHYTQKSLSLSPGK

CB302 LC (SEQ ID NO: 68)
DIVMTQSPDSLAVSLGERATINCKSSQSVLLSFDNINKLAWYQQKPGQPPKLLIYDASTRE
SGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQFYSVPSTFGQGTKVEIKRTVAAPSVF
IFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSLSS
TLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

CB301 HC (SEQ ID NO: 69)
EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYS
PSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDTFDYWGQGTLVTVSSA
STKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGL
YSLSSVVTVTSSNFGTQTYTCNVDHKPSNTKVDKTVERKCCVECPPCPAPPAAASSVFLFP
PKPKDTLMISRTPEVTCVVVDVSAEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFRVVSV
LTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKTKGQPREPQVYTLPPSREEMTKNQVSLT
CLVKGFYPSDIAVEWESNGQPENNYKTTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFSCSV
MHEALHNHYTQKSLSLSPGK

CB301 LC (SEQ ID NO: 70)
DIVMTQSPDSLAVSLGERATINCKSSQSVLLSFDNINKLAWYQQKPGQPPKLLIYDASTRE
SGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQFYSVPSTFGQGTKVEIKRTVAAPSVF
IFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSLSS
TLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

Example 7. Characterization of anti-CCL17 antibodies

Select anti-CCL17 antibodies were characterized in calcium flux, β-arrestin reporter assays and in chemotaxis assay to assess their ability to inhibit CCL17 biological activities.

Calcium flux assay. Calcium mobilization assay was used to test for ability of hybridoma mAbs to neutralize CCL17 signaling. CCRF-CEM cells (ATCC® CCL-119™) were

cultured in RPMI with GlutaMAX; 10% FBS; 10 mM Hepes, 1 mM Sodium Pyruvate, 4500 mg/L glucose, and 1500 mg/ml Sodium bicarbonate at 37°C incubator with 5% CO_2 saturation. Cells were labeled with dye using the Fluo-8 NW No Wash Calcium Assay Kit (#36315) from ABD Bioquest, Inc. Test antibodies and 10 ng/mL human CCL17 or 5 ng/mL cyno CCL17 were pre-incubated with the test antibodies and the mixture was added to the cells. Fluorescent signal was detected using FDSS 6000 (Hamamatsu, Bridgewater, NJ) to using 490 nm excitation and 525 nm emission.

β-Arrestin Reporter Assay. β-arrestin assay was used to assess the ability of the anti-CCL17 antibodies to neutralize CCL17 function. Assay was performed using the PathHunter eXpress β-arrestin assay (DiscoveRx). Briefly, ability of anti-CCL17 antibodies to inhibit CCL17-induced β-arresting recruitment was assessed in Hek293 cells co-expressing CCR4 fused in frame with the small enzyme fragment ProLink™ and a fusion protein of β-Arrestin and the N-terminal deletion mutant of β-gal (called enzyme acceptor or EA). Anti-CCL17 antibodies at various concentrations (0.15 nM – 1 µM) were combined with 20 nM CCL17 and the mixture was incubated at 37°C for 20-30 minutes prior to adding the antibody-CCL17 complex to the cells. The mixture was then applied to the cells and incubated at 37°C (95% O_2/5% CO_2) for 90 minutes. 55 µl of detection reagent was added per well and incubated for 60 min at room temperature. Samples were read on a standard luminescence plate reader, and IC_{50} values were calculated.

Chemotaxis assay: Chemotaxis assay was used to demonstrate that the anti-CCL17 antibodies inhibit CCL17 function. The migration of the HSC-F cells (HSC-F cells were obtained through the NIH Nonhuman Primate Reagent Resource) or CCRF-CEM cells (ATCC® CCL-119™) was assessed using a 96-

well chemotaxis chamber using a 5µm polycarbonate filter according to protocol described in Imai et al. 1997; Imai et al. 1999 . Briefly, the lower chambers were filled with 320 µl RPMI/BSA 0.1% and 1nM of the human or cyno CCL17 without or with different concentrations of the antibodies (0.125, 0.25, 0.5 1 and 10 µg/ml) and then were carefully overlaid with the polycarbonate membrane. Cells were washed with PBS and suspended in RPMI/BSA 0.1% at $0.5x10^6$ cells/ml, and the cell suspension was added to the upper chambers. The chambers were incubated for 60 min in a 5% CO_2-humidified incubator at 37°C, and cells migrating across the membrane into the lower chamber were determined using The Cell Titer-Glo Luminescence Cell Viability.

Table 11 shows the IC50 values for the calcium flux assay. The data is an average of three independent experiments. Each mAb completely neutralized the calcium flux induced by human or cyno CCL17 using either 10 ng/ml (1.25nM) human CCL17 or 5 ng/ml (0.625 nM) cyno CCL17 and as shown in Table 11, IC_{50} values were roughly equivalent for each of the antibodies against both human and cyno protein.

Table 11.

mAb	IC_{50} (nM)	
	Human CCL17	Cyno CCL17
C17B302	0.593	0.238
C17B311	0.553	0.239
C17B318	0.275	0.237
C17B319	0.753	0.289
C17B234	0.421	0.369
C17B235	0.558	0.919
C17B236	0.385	0.349
C17B237	0.882	0.549
C17B238	0.387	0.348
C17B239	0.427	0.430
C17B240	0.405	0.308
C17B241	0.456	0.339

C17B242	0.483	0.340
C17B243	0.231	0.310
C17B244		0.311

Table 12 shows the IC_{50} values for the β-arrestin assay. The data is an average of three independent experiments. All of the mAbs were able to completely inhibit human or cyno CCL17-induced β-arrestin recruitment at 20 nM and dose-dependently inhibit β-arrestin recruitment induced by human or cyno CCL17 with equivalent potency.

Table 12.

	Human CCL17		Cyno CCL17	
	IC_{50} (nM)	STD	IC_{50} (nM)	STD
C17B302	13.94	9.56	13.412	6.403
C17B311	10.65	2.89	10.324	2.569
C17B318	11.006	2.886	12.141	2.294
C17B319	14.225	4.133	17.51	6.605
C17B234	8.42	5.525	5.391	0.0431
C17B236	6.98	3.33	9.502	0.073

Figure 1 and Figure 2 show the inhibition of chemotaxis with select antibodies in human and cyno cells, respectively. All antibodies tested inhibited both human CCL17-induced CCRF-CEM cell chemotaxis at a level of inhibition of about 50% at an antibody concentration of 0.5 μg/ml. C17B302 and C17B311 inhibited cyno HSC-F cell chemotaxis induced by cyno CCL17 at a level of inhibition of about 50% at antibody concentration of 0.5 μg/ml.

Example 8. Epitope mapping of anti-CCL17 antibody C17B236

The binding epitope of antibody C17B236 (VH: SEQ ID NO: 45; VL: SEQ ID NO: 52) was determined by X-ray crystallography.

Human CCL17 was expressed in *E. coli*, isolated from inclusion bodies and refolded. The Fab fragment of mAb C17B236 was expressed in HEK293F cells. The CCL17: C17B236 complex was prepared by mixing at a molar ratio of 1.6:1 with an excess of CCL17. The complex was then purified by size exclusion chromatography. The complex was crystallized by the vapor-diffusion method from solution containing 20% PEG 3350 and 0.2 M K/Na tartrate. The X-ray diffraction data were collected to 1.9 Å resolution. The structure was determined by molecular replacement and refined to an R-factor of 18.0%.

C17B236 epitope is conformational and spans 3 segments of the CCL17 molecule, namely two loops (residues 21-23 and 44-45) and the C-terminal helix (residues 60-68). The key interactions involve basic residues Arg22 and Lys23 of CCL17 and a cluster of acidic residues in HCDR2 including Asp52, Asp55 and Asp57. In addition to these electrostatic interactions, van-der-Waals contacts in the center of the epitope occur between Trp33 and Trp105 of VH and Arg22 of CCL17. Given the number of contacts, the key residue of the epitope is Arg22, which stacks against Trp33 of VH and makes numerous contacts to HCDR3. The paratope and the epitope residues are shown in Figure 7.

The paratope (antibody residues involved in binding CCL17) includes 18 residues that belong to 5 out of 6 CDRs (all except LCDR2).

The C17B236 epitope is on the opposite side of the CCL17 monomer from its dimerization surface. C17B236 thus does not block dimerization of CCL17. The neutralization

effect of C17B236 results from the competition with CCR4 for the overlapping epitopes.

5

Sequences:

SEQ ID NO	Type	Species	Description	Sequence
1	PRT	Homo sapiens	CCL17	argtnvgreccleyfkga iplrklktwyqtsedcsr daivfvtvqgraicsdpn nkrvknavkylqslers
2	PRT	Cyno	CCL17	margtnvgrecclkyfkg aiplrklktwyqtsedcs rdaivfvtvqnkaicsdp ndkkvkkalkylqslers
3	PRT	cyno	CCL22	gpyganmedsvccrdyvr yrmplrvvkhfywtsdsc prpgvvlltsrdkeicad prvpwvkmilnklsq
4	PRT	Artificial sequence	HCDR1 fo C17F24	SYWIG
5	PRT	Artificial sequence	HCDR2 of C17F24	IIDPSDSDTRYSPSFQG
6	PRT	Artificial sequence	HCDR3 of C17F24	VGPADVWDSFDY
7	PRT	Artificial sequence	LCDR1 of C17F24 (parent)	KSSQSVLYSSNNKNYLA
8	PRT	Artificial sequence	LCDR1 of C17B234	KSSQSVLLSFDNINKLA
9	PRT	Artificial sequence	LCDR1 fo C17B235	KSSQSVLYSFYNFNALA

10	PRT	Artificial sequence	LCDR1 of C17B236	KSSQSVLLSPWNSNQLA
11	PRT	Artificial sequence	LCDR1 of C17B237	KSSQSVLTSYNNSNYLA
12	PRT	Artificial sequence	LCDR1 of C17B238	KSSQSVLISAFNQNPLA
13	PRT	Artificial sequence	LCDR1 of C17B239	KSSQSVLSSFTNTNTLA
14	PRT	Artificial sequence	LCDR1 of C17B240	KSSQSVLYSHVNYNALA
15	PRT	Artificial sequence	LCDR1 of C17B241	KSSQSVLNSFTNNNALA
16	PRT	Artificial sequence	LCDR1 of C17B242	KSSQSVLFSHDNLNTLA
17	PRT	Artificial sequence	LCDR1 of C17B243	KSSQSVLNSFDNKNDLA
18	PRT	Artificial sequence	LCDR1 of C17B244	KSSQSVLSSITNVNDLA
19	PRT	Artificial sequence	LCDR2 fo C17F24 (parent)	WASTRES
20	PRT	Artificial sequence	LCDR2 of C17B234	NASTRES
21	PRT	Artificial sequence	LCDR2 fo C17B235	HASTRES
22	PRT	Artificial sequence	LCDR2 of C17B236	GASTRES
23	PRT	Artificial sequence	LCDR2 fo C17B237	LASTRES
24	PRT	Artificial sequence	LCDR2 of C17B238	DASTRES

25	PRT	Artificial sequence	LCDR2 of C17B241	EASTRES
26	PRT	Artificial sequence	LCDR2 of C17B244	TASTRES
27	PRT	Artificial sequence	LCDR3 of C17F24 (parent)	QQYYSTPLT
28	PRT	Artificial sequence	LCDR3 of C17B234	QQFYSVPST
29	PRT	Artificial sequence	LCDR3 of C17B235	QQFYATPFT
30	PRT	Artificial sequence	LCDR3 of C17B236	QQYYLIPST
31	PRT	Artificial sequence	LCDR3 of C17B237	QQYLSPPST
32	PRT	Artificial sequence	LCDR3 of C17B238	QQYQFIPFT
33	PRT	Artificial sequence	LCDR3 of C17B239	QQYLIYPST
34	PRT	Artificial sequence	LCDR3 fo C17B240	QQYYTLPAT
35	PRT	Artificial sequence	LCDR3 of C17B241	QQTNSIPLT
36	PRT	Artificial sequence	LCDR3 of C17B242	QQYYAVPQT
37	PRT	Artificial sequence	LCDR3 of C17B243	QQHWQTPLT

38	PRT	Artificial sequence	LCDR3 of C17B244	QQYYHDPFT
39	PRT		LCDR2 of C17B257	AASTRES
40	PRT		LCDR2 of C17B262	SASTRES
41	PRT		LCDR2 fo C17B264	IASTRES
42	PRT		HCDR3 of C17B293	VGPADVWDAFDY
43	PRT		HCDR3 of C17B294	VGPADVWDTFDY
44	*PRT*		*HCDR3 of C17B295*	*VGPADVWESFDY*
45	PRT	Homo sapiens	VH of C17F24, C17B234, C17B235, C17B236, C17B237, C17B238, C17B239, C17B240,	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYSPSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDSFDYWGQGTLVTVSS

			C17B241, C17B242, C17B243, C17B244, C17B257, C17B258, C17B260, C17B262, C17B266, C17B264	
46	PRT	Homo sapiens	VH of C17M293	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYSPSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDAFDYWGQGTLVTVSS
47	PRT	Homo sapiens	VH of C17B294	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYSPSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVGPADVWDTFDYWGQGTLVTVSS
48	PRT	Homo sapiens	VH of C17B295	EVQLVQSGAEVKKPGESLKISCKGSGYSFTSYWIGWVRQMPGKGLEWMGIIDPSDSDTRYSPSFQGQVTISADKSISTAYLQWSSLKASDTAMYYCARVG

				PADVWESFDYWGQGTLVTVSS
49	PRT	Homo sapiens	VL of C17F24 (parent)	DIVMTQSPDSLAVSLGERATINCKSSQSVLYSSNNKNYLAWYQQKPGQPPKLLIYWASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQYYSTPLTFGQGTKVEIK
50	PRT	Homo sapiens	VL of C17B234	DIVMTQSPDSLAVSLGERATINCKSSQSVLLSFDNINKLAWYQQKPGQPPKLLIYNASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQFYSVPSTFGQGTKVEIK
51	PRT	Homo sapiens	VL of C17B235	DIVMTQSPDSLAVSLGERATINCKSSQSVLYSFYNFNALAWYQQKPGQPPKLLIYHASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQFYATPFTFGQGTKVEIK
52	PRT	Homo sapiens	VL of C17B236	DIVMTQSPDSLAVSLGERATINCKSSQSVLLSPWNSNQLAWYQQKPGQPPKLLIYGASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQYYLIPSTFGQGTKVEIK
53	PRT	Homo sapiens	VL of C17B237	DIVMTQSPDSLAVSLGERATINCKSSQSVLTSYNNSNYLAWYQQKPGQPPKLLIYLASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQYLSPPSTFGQGTKVEIK
54	PRT	Homo sapiens	VL of C17B238	DIVMTQSPDSLAVSLGERATINCKSSQSVLISAFNQNPLAWYQQKPGQPPKLLIYDASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQYQFIPFTFGQGTKVEIK
55	PRT	Homo sapiens	VL of C17B239	DIVMTQSPDSLAVSLGERATINCKSSQSVLSSFTNTNTLAWYQQKPGQPPKLLIYHASTRESGVPDRFSGSGSGTDFTLTISSLQAEDVAVYYCQQYLIYPSTFGQGTKVEIK
56	PRT	Homo sapiens	VL of C17B240	DIVMTQSPDSLAVSLGERATINCKSSQSVLYSHVNYNALAWYQQKPGQPPKLLIYNASTR

				ESGVPDRFSGSGSGTDFTLTI SSLQAEDVAVYYCQQYYTLP ATFGQGTKVEIK
57	PRT	Homo sapiens	VL of C17B241	DIVMTQSPDSLAVSLGERATI NCKSSQSVLNSFTNNNALA WYQQKPGQPPKLLIYEASTR ESGVPDRFSGSGSGTDFTLTI SSLQAEDVAVYYCQQTNSIP LTFGQGTKVEIK
58	PRT	Homo sapiens	VL of C17B242	DIVMTQSPDSLAVSLGERATI NCKSSQSVLFSHDNLNTLA WYQQKPGQPPKLLIYHASTR ESGVPDRFSGSGSGTDFTLTI SSLQAEDVAVYYCQQYYAVP QTFGQGTKVEIK
59	PRT	Homo sapiens	VL of C17B243	DIVMTQSPDSLAVSLGERATI NCKSSQSVLNSFDNKNDLA WYQQKPGQPPKLLIYEASTR ESGVPDRFSGSGSGTDFTLTI SSLQAEDVAVYYCQQHWQT PLTFGQGTKVEIK
60	PRT	Homo sapiens	VL of C17B244	DIVMTQSPDSLAVSLGERATIN CKSSQSVLSSITNVNDLAWYQQ KPGQPPKLLIYTASTRESGVPD RFSGSGSGTDFTLTISSLQAED VAVYYCQQYYHDPFTFGQGTKV EIK
61	PRT	Homo sapiens	VL of C17B257	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYAASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK
62	PRT	Homo sapiens	VL of C17B258	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYDASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK
63	PRT	Homo sapiens	VL of C17B260	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYGASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK

64	PRT	Homo sapiens	VL of C17B262	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYSASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK
65	PRT	Homo sapiens	VL of C17B263	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYTASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK
66	PRT	Homo sapiens	VL of C17B264	DIVMTQSPDSLAVSLGERATI NCKSSQSVLLSFDNINKLAW YQQKPGQPPKLLIYIASTRES GVPDRFSGSGSGTDFTLTISS LQAEDVAVYYCQQFYSVPST FGQGTKVEIK
67	PRT	Homo sapiens	CB302 HC	EVQLVQSGAEVKKPGESL KISCKGSGYSFTSYWIGW VRQMPGKGLEWMGIIDPS DSDTRYSPSFQGQVTISA DKSISTAYLQWSSLKASD TAMYYCARVGPADVWDAF DYWGQGTLVTVSSASTKG PSVFPLAPCSRSTSESTA ALGCLVKDYFPEPVTVSW NSGALTSGVHTFPAVLQS SGLYSLSSVVTVTSSNFG TQTYTCNVDHKPSNTKVD KTVERKCCVECPPCPAPP AAASSVFLFPPKPKDTLM ISRTPEVTCVVVDVSAED PEVQFNWYVDGVEVHNAK TKPREEQFNSTFRVVSVL TVLHQDWLNGKEYKCKVS NKGLPSSIEKTISKTKGQ PREPQVYTLPPSREEMTK

				NQVSLTCLVKGFYPSDIA VEWESNGQPENNYKTTPP MLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMHEAL HNHYTQKSLSLSPGK
68	PRT	Homo sapiens	CB302 LC	DIVMTQSPDSLAVSLGER ATINCKSSQSVLLSFDNI NKLAWYQQKPGQPPKLLI YDASTRESGVPDRFSGSG SGTDFTLTISSLQAEDVA VYYCQQFYSVPSTFGQGT KVEIKRTVAAPSVFIFPP SDEQLKSGTASVVCLLNN FYPREAKVQWKVDNALQS GNSQESVTEQDSKDSTYS LSSTLTLSKADYEKHKVY ACEVTHQGLSSPVTKSFN RGEC
69	PRT	Homo sapiens	CB301 HC	EVQLVQSGAEVKKPGESL KISCKGSGYSFTSYWIGW VRQMPGKGLEWMGIIDPS DSDTRYSPSFQGQVTISA DKSISTAYLQWSSLKASD TAMYYCARVGPADVWDTF DYWGQGTLVTVSSASTKG PSVFPLAPCSRSTSESTA ALGCLVKDYFPEPVTVSW NSGALTSGVHTFPAVLQS SGLYSLSSVVTVTSSNFG TQTYTCNVDHKPSNTKVD KTVERKCCVECPPCPAPP

				AAASSVFLFPPKPKDTLM ISRTPEVTCVVVDVSAED PEVQFNWYVDGVEVHNAK TKPREEQFNSTFRVVSVL TVLHQDWLNGKEYKCKVS NKGLPSSIEKTISKTKGQ PREPQVYTLPPSREEMTK NQVSLTCLVKGFYPSDIA VEWESNGQPENNYKTTPP MLDSDGSFFLYSKLTVDK SRWQQGNVFSCSVMHEAL HNHYTQKSLSLSPGK
70	PRT	Homo sapiens	CB301 LC	DIVMTQSPDSLAVSLGER ATINCKSSQSVLLSFDNI NKLAWYQQKPGQPPKLLI YDASTRESGVPDRFSGSG SGTDFTLTISSLQAEDVA VYYCQQFYSVPSTFGQGT KVEIKRTVAAPSVFIFPP SDEQLKSGTASVVCLLNN FYPREAKVQWKVDNALQS GNSQESVTEQDSKDSTYS LSSTLTLSKADYEKHKVY ACEVTHQGLSSPVTKSFN RGEC

CLAIMS

1. An isolated antibody specifically binding human CCL17 comprising a heavy chain variable region (VH), a light chain variable region (VL), wherein the VH comprises heavy chain complementarity determining regions (HCDR) 1 (HCDR1), 2 (HCDR2) and 3 (HCDR3) and the VL comprises light chain complementarity determining regions (LCDR) 1 (LCDR1), 2 (LCDR2) and 3 (LCDR3), wherein the HCDR1, HCDR2, HCDR3, LCDR1, LCDR2, and LCDR3 comprise the amino acid sequences of:
   a) SEQ ID NOs: 4, 5, 6, 8, 20 and 28, respectively;
   b) SEQ ID NOs: 4, 5, 6, 9, 21 and 29, respectively;
   c) SEQ ID NOs: 4, 5, 6, 10, 22 and 30, respectively;
   d) SEQ ID NOs: 4, 5, 6, 13, 21 and 33, respectively;
   e) SEQ ID NOs: 4, 5, 6, 14, 20 and 34, respectively;
   f) SEQ ID NOs: 4, 5, 6, 15, 25 and 35, respectively;
   g) SEQ ID NOs: 4, 5, 6, 17, 25 and 37, respectively;
   h) SEQ ID NOs: 4, 5, 6, 18, 26 and 38, respectively;
   i) SEQ ID NOs: 4, 5, 42, 8, 24 and 28, respectively; or
   j) SEQ ID NOs: 4, 5, 43, 8, 24 and 28, respectively.
2. The antibody of claim 1, wherein the HCDR1, HCDR2, HCDR3, LCDR1, LCDR2, and LCDR3 comprise the amino acid sequences of SEQ ID NOs: 4, 5, 42, 8, 24, and 28, respectively.
3. The antibody of claim 1 or 2, wherein the VH comprises an amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, or 99% identical to the amino acid sequence of SEQ ID NO: 46 and the VL comprises an amino acid sequence at least 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98% or 99% identical to the amino acid sequence of SEQ ID NO: 62.
4. The antibody of any one of claims 1-3, wherein the VH comprises the amino acid sequence of SEQ ID NO: 45, 46, or 47.
5. The antibody of any one of claims 1-4, wherein the VL comprises the amino acid sequence of SEQ ID NO: 50, 51, 52, 55, 56, 57, 59, 60, or 62.

6. The antibody of any one of claims 1-5, wherein the VH and VL comprise the amino acid sequences of:
   a) SEQ ID NOs: 45 and 50, respectively;
   b) SEQ ID NOs: 45 and 51, respectively;
   c) SEQ ID NOs: 45 and 52, respectively;
   d) SEQ ID NOs: 45 and 55, respectively;
   e) SEQ ID NOs: 45 and 56, respectively;
   f) SEQ ID NOs: 45 and 57, respectively;
   g) SEQ ID NOs: 45 and 59, respectively;
   h) SEQ ID NOs: 45 and 60, respectively;
   i) SEQ ID NOs: 46 and 62, respectively; or
   j) SEQ ID NOs: 47 and 62, respectively.
7. The antibody of any one of claims 1-6, wherein the VH and VL comprise the amino acid sequences of SEQ ID NOs: 46 and 62, respectively.
8. The antibody of any one of claims 1-7, wherein the antibody binds human CCL17 at least within CCL17 amino acid residues 21-23, 44-45 and 60-68 of SEQ ID NO: 1.
9. The antibody of claim 8, wherein the antibody binds human CCL17 at least at residues R22 and K23 of SEQ ID NO: 1.
10. The antibody of any one of claims 1-9, wherein the antibody blocks CCL17/CCR4 interaction.
11. The antibody of any one of claims 1-10, wherein the antibody binds human CCL17 with an affinity constant (K_D) of about $1x10^{-10}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing 0.05% Tween-20 after co-incubation of the antibody and human CCL17 for 48 hours at 4°C.
12. The antibody of claim 11, wherein the antibody binds human CCL17 with the K_D of about $5x10^{-12}$ M or less.
13. The antibody of any one of claims 1-12, wherein the antibody binds *Macaca fascicularis* (cyno) CCL17 with an affinity constant (K_D) of about $1x10^{-8}$ M or less, when the K_D is measured using solution equilibrium affinity in tris-based saline buffer containing

0.05% Tween-20 after co-incubation of the antibody and cyno CCL17 for 48 hours at 4°C.

14. The antibody of any one of claims 1-13, wherein the antibody inhibits 10 ng/ml human CCL17-induced calcium mobilization in CCRF-CEM cells measured using Fluo-8 NW with an IC_{50} value of about $1x10^{-9}$ M or less.

15. The antibody of claims 1-14, wherein the antibody is human or humanized.

16. The antibody of claim 15, wherein the antibody is of IgG1, IgG2, IgG3, or IgG4 isotype.

17. The antibody of claim 16, wherein the antibody comprises a substitution in an Fc region.

18. The antibody of claim 17, wherein the substitution comprises V234A, G237A, P238S, H268A, V309L, A330S or P331S substitution on IgG2, or S228P, L234A or L235A substitution on IgG4, wherein residue numbering is according to the EU Index.

19. The antibody of claim 18, wherein the substitution comprises V234A/G237A/P238S/H268A/V309L/A330S/P331S substitution on IgG2 or S228P/L234A/L235A substitution on IgG4, wherein residue numbering is according to the EU Index.

20. A pharmaceutical composition comprising the antibody of claims 1-19 and a pharmaceutically accepted carrier.

21. An isolated polynucleotide encoding the VH and/or VL of the antibody of any one of the claims 1-19.

22. A vector comprising the polynucleotide of claim 21.

23. A host cell comprising the vector of claim 22.

24. A method of producing an antibody, comprising culturing the host cell of claim 23 in conditions that the antibody is produced.

25. The use of the antibody of claims 1-19 in the manufacture of a medicament for the treatment of a CCL17-mediated disease.

26. The use of claim 25, wherein the CCL17-mediated disease is an inflammatory disease.

27. The use of claim 26, wherein the inflammatory disease is asthma, ulcerative colitis (UC), atopic dermatitis (AD) or idiopathic pulmonary fibrosis (IPF).
28. The use of the antibody of claims 1-19 in the manufacture of a medicament for the therapeutic and/or prophylactic treatment of asthma or airway hyper-reactivity.
29. The antibody of claims 1-19 for use in therapy.
30. The antibody of claims 1-19 for use in the treatment of a CCL17-mediated disease.
31. The antibody for use according to claim 30, wherein the CCL17-mediated disease is an inflammatory disease, asthma, ulcerative colitis (UC), atopic dermatitis (AD) or idiopathic pulmonary fibrosis (IPF).
32. The antibody for use according to claim 31, wherein the CCL17-mediated disease is asthma.