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COMPOUNDS AND METHODS TARGETING INTERLEUKIN-34

The present invention relates to compounds, pharmaceutical compositions, and methods, which include antibodies directed against human interleukin-34 (IL-34), which are expected to be useful in the field of neuroinflammation and acute or chronic inflammatory diseases. In particular, the embodiments are expected to be useful in treatment and/or diagnostic applications relating to Alzheimer's Disease, as well as other tauopathies.

Alzheimer's disease (AD), a leading cause of dementia, develops in one percent of the population between the ages 65 and 69, and increases to 40-50% in those 95 years and older. AD patients exhibit telltale clinical symptoms that include cognitive impairment and deficits in memory function. In these patients, the presence of AD is confirmed by heavy senile plaque burden and neurofibrillary tangles (NFT) found in the cerebral cortex upon post-mortem histopathological examination. The mature senile plaques consist of extracellular β -amyloid peptides derived from enzymatic processing of amyloid precursor protein and intracellular neurofibrillary tangles (NFT), which are derived from filaments of hyperphosphorylated tau proteins. Aggregates of hyperphosphorylated tau, such as neurofibrillary tangles, are linked to the degree of cognitive impairment in Alzheimer's disease. In AD and various other tauopathies, tau aggregates appear in specific brain regions and patterns that are linked to disease risk, onset, and or progression, and these regions and patterns are known to skilled artisans.

Cytokines regulate normal homeostatic tissue functions, and dysregulation of these cytokine networks is associated with pathological conditions. The central nervous system (CNS), where few blood-borne immune cells circulate, seems to be particularly vulnerable to dysregulated cytokine networks. In neurodegenerative diseases, CNS-resident cells are the predominant producers of pro-inflammatory cytokines and can contribute to dysregulated cytokine networks and neuroinflammation. Damage to the CNS may involve recruitment of circulating immune cells resulting in an innate immune response consisting of resident microglia, peripherally derived monocytes, macrophages and dendritic cells. The activation states of microglia and macrophages are not strictly pro

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or anti-inflammatory and instead may have a spectrum of functional states. Microglia and/or peripherally derived monocytes and macrophages may acquire an anti-inflammatory phenotype, in which they remove debris and promote regeneration and homeostasis. Neuronal dysfunction or damage can also activate microglia to produce pro-inflammatory cytokines and recruit leukocytes from the bloodstream. In neurodegenerative conditions, such as Alzheimer's disease (AD), microglia activation is a frequent finding and reflects the tissue response to accumulation of extracellular beta-amyloid plaques and hyperphosphorylated tau aggregates. Neuroinflammation is an important component of neurodegenerative diseases and is characterized by elevated production of pro-inflammatory cytokines by CNS cells (Becher, B., Spath, S. & Goverman, J. *Cytokine networks in neuroinflammation*. Nat Rev Immunol 17, 49–59 (2017)). Neuroinflammation and microgliosis are believed to be mechanisms underlying neurodegenerative diseases such as plaque accumulation in Alzheimer's disease, and neuronal death and dysfunction in Parkinson's disease and Huntington's disease.

Microgliosis involves the abnormal proliferation and/or hypertrophy of microglia in response to inflammatory signals. Broadly, IL-34 acts as a potent and pleiotropic cytokine in the regulation of inflammatory and immune processes and is a key regulatory cytokine for the growth of CNS-resident microglia in normal tissue homeostasis. IL-34 is expressed by neurons in the cortex, the anterior olfactory nucleus and the hippocampus. IL-34 is closely related to colony-stimulating factor 1 (CSF1; also known as M-CSF), and both cytokines bind the CSF1 receptor. IL-34 is a secreted homodimeric cytokine that acts as one of two activating ligands for CSF1R, and triggers receptor autophosphorylation and dimerization with subsequent activation of multiple signaling pathways (See, for example, *Structural basis for the dual recognition of helical cytokines IL-34 and CSF-1 by CSF-1R*. Structure 20, 676–687, and Felix J, De Munck S, Verstraete K, Meuris L, Callewaert N, Elegheert J. et al.). Human and mouse IL-34 polypeptides are disclosed for example in US Patent No. 9,770,486. IL-34 is a protein of 242 amino acids in humans (SEQ ID NO: 41), and 235 amino acids in mouse (SEQ ID NO: 42).

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Anti-IL-34 antibodies have been described in the art, and for example, WO 2016/196679 recites various anti-IL-34 antibodies and potential uses thereof. However, to date, no antibody targeting IL-34 has been approved for therapeutic use.

Thus, there remains an unmet need for alternative and/or improved anti-IL-34 antibodies, pharmaceutical compositions thereof, and methods of using the same for therapeutic and/or in diagnostic applications relating to immune-mediated diseases involving IL-34, and/or diseases treatable with an anti-IL-34 antibody, such as neuroinflammatory disorders, and/or Alzheimer's Disease. Further, there remains an unmet need for alternative and/or improved anti-IL-34 antibodies which have a combination of particularly advantageous properties over prior art anti-IL-34 antibodies, in view of at least one or more properties from the following: 1) desirable association and dissociation rates, 2) potency in neutralization of human IL-34 to achieve an anti-neuroinflammatory response and *in vivo* efficacy, 3) sufficiently potent as a monotherapy for the treatment and/or prevention of immune-mediated and/or inflammatory disorders; 4) a sustained duration of action; 5) sufficiently limited induction of undesirable cytokine release, 6) acceptably low immunogenicity (i.e., sufficiently non-immunogenic in humans); 7) avoidance of untoward immunocompromise; and/or 8) desirable *in vivo* stability, physical and chemical stability including, but not limited to, thermal stability, solubility, low self-association, and pharmacokinetic characteristics which are acceptable for development and/or use in the treatment of inflammatory or neuroinflammatory disorders, for example AD.

Summary of Invention:

Embodiments of the present invention provide novel anti-human IL-34 and anti-murine IL-34 antibodies. According to some embodiments, the present invention provides antibodies which comprise a light chain variable region (LCVR) and a heavy chain variable region (HCVR), wherein the LCVR comprises complementarity determining regions (CDRs) LCDR1, LCDR2 and LCDR3 and the HCVR comprises CDRs HCDR1, HCDR2 and HCDR3 are selected from the groupings of CDR combinations provided in

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Table 1. The sequence identifiers used herein are listed in Table 1, and the sequences are provided in the amino acid and nucleotide sequence listing provided herein.

Table 1: Amino Acid and Nucleotide Sequences

	Antibody 1	Antibody 2	Antibody 3
SEQ ID HC	1	13	19
SEQ ID LC	2	2	20
SEQID HCVR	3	14	21
SEQID LCVR	4	4	22
SEQID HCDR1	5	15	23
SEQID HCDR2	6	16	24
SEQID HCDR3	7	17	25
SEQID LCDR1	8	8	26
SEQID LCDR2	9	9	27
SEQID LCDR3	10	10	28
SEQ ID: DNA HC	11	18	29
SEQ ID DNA LC	12	12	30

5 Accordingly, embodiments of the present invention also provide antibodies comprising a LCVR and a HCVR selected from:

- a. the LCVR having the amino acid sequence of SEQ ID NO: 4 and the HCVR having the amino acid sequence of SEQ ID NO: 3;
- b. the LCVR having the amino acid sequence of SEQ ID NO: 4 and the HCVR having the amino acid sequence of SEQ ID NO: 14;
- c. the LCVR having the amino acid sequence of SEQ ID NO: 22 and the HCVR having the amino acid sequence of SEQ ID NO: 21.

10 According to other embodiments, the present invention also provides antibodies comprising a combination of LCVR and HCVR as described above in a-c, with a hinge
15 region and Fc region selected from SEQ ID NO: 51 and SEQ ID NO: 52.

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According to other embodiments, the present invention also provides antibodies comprising a LC and a HC selected from, or having amino acid sequences with at least 95% homology to the amino acid sequences of:

- a. the LC having the amino acid sequence of SEQ ID NO: 2 and the HC having the amino acid sequence of SEQ ID NO: 1;
- b. the LC having the amino acid sequence of SEQ ID NO: 2 and the HC having the amino acid sequence of SEQ ID NO: 13; and
- c. the LC having the amino acid sequence of SEQ ID NO: 20 and the HC having the amino acid sequence of SEQ ID NO: 19.

As used herein “Antibody 1” refers to an antibody having the HCDR1 amino acid sequence of SEQ ID NO: 5, the HCDR2 amino acid sequence of SEQ ID NO: 6, the HCDR3 amino acid sequence of SEQ ID NO: 7, the LCDR1 amino acid sequence of SEQ ID NO: 8, the LCDR2 amino acid sequence of SEQ ID NO: 9, the LCDR3 amino acid sequence of SEQ ID NO: 10, the HCVR amino acid sequence of SEQ ID NO: 3, the LCVR amino acid sequence of SEQ ID NO: 4, the HC amino acid sequence of SEQ ID NO: 1, the LC amino acid sequence of SEQ ID NO: 2, the HC DNA sequence of SEQ ID NO: 11, and the LC DNA sequence of SEQ ID NO: 12. The framework and CDR sequences in each of the antibodies for which sequences are set forth herein are annotated using annotation rules in agreement with the method of North, *et al.*, *J. Mol. Biol.* 2011: 406: 228-256 unless otherwise specified.

As used herein “Antibody 2” refers to an antibody having the HCDR1 amino acid sequence of SEQ ID NO: 15, the HCDR2 amino acid sequence of SEQ ID NO: 16, the HCDR3 amino acid sequence of SEQ ID NO: 17, the LCDR1 amino acid sequence of SEQ ID NO: 8, the LCDR2 amino acid sequence of SEQ ID NO: 9, the LCDR3 amino acid sequence of SEQ ID NO: 10, the HCVR amino acid sequence of SEQ ID NO: 14, the LCVR amino acid sequence of SEQ ID NO: 4, the HC amino acid sequence of SEQ ID NO: 13, the LC amino acid sequence of SEQ ID NO: 2, the HC DNA sequence of SEQ ID NO: 18, and the LC DNA sequence of SEQ ID NO: 12. The framework and CDR sequences in each of the antibodies for which sequences are set forth herein are

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annotated using annotation rules in agreement with the method of North, *et al.* *J. Mol. Biol.* 2011: 406: 228-256 unless otherwise specified.

As used herein "Antibody 3" refers to an antibody having the HCDR1 amino acid sequence of SEQ ID NO: 23, the HCDR2 amino acid sequence of SEQ ID NO: 24, the HCDR3 amino acid sequence of SEQ ID NO: 25, the LCDR1 amino acid sequence of SEQ ID NO: 26, the LCDR2 amino acid sequence of SEQ ID NO: 27, the LCDR3 amino acid sequence of SEQ ID NO: 28, the HCVR amino acid sequence of SEQ ID NO: 21, the LCVR amino acid sequence of SEQ ID NO: 22, the HC amino acid sequence of SEQ ID NO: 19, the LC amino acid sequence of SEQ ID NO: 20, the HC DNA sequence of SEQ ID NO: 29, and the LC DNA sequence of SEQ ID NO: 30. The framework and CDR sequences in each of the antibodies for which sequences are set forth herein are annotated using annotation rules in agreement with the method of North, *et al.* *J. Mol. Biol.* 2011: 406: 228-256 unless otherwise specified.

The carboxy-terminal portion of each HC defines a constant region primarily responsible for effector functions, and in some embodiments of the present invention the antibodies have one or more modifications in the constant region of each HC that reduce effector functions. Preferably, embodiments of the present invention are IgG4 antibodies, and thus contain an IgG4 Fc region, or an Fc region derived from human IgG4, e.g., a modified IgG4 Fc region.

According to some embodiments, modifications in the constant region of both HCs which reduce effector functions, and amino acid substitutions are introduced into the IgG4 hinge and Fc regions. Thus, some embodiments have modifications in the constant region of both HCs which include the amino acid alanine at both residues 230 and 231 (exemplified in HC of Antibody 1, HC of Antibody 2, and SEQ ID NO: 52, respectively), and further modifications in the constant region of both HCs promoting stability, including the amino acid proline at residue 224 (exemplified in HC of Antibody 1, HC of Antibody 2, and for example in SEQ ID NO: 51), and the deletion of the amino acid lysine at residue 443 (exemplified HC of SEQ ID NO.1).

The antibodies of the present invention are believed to have a combination of particularly advantageous properties over prior art anti-IL-34 antibodies, including but

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not limited to, one or more of the following properties: 1) desirable association and dissociation rates, 2) potency in neutralization of human IL-34 to achieve an anti-neuroinflammatory response and *in vivo* efficacy, 3) sufficiently potent as a monotherapy for the treatment and/or prevention of immune-mediated and/or inflammatory disorders; 5 4) a sustained duration of action; 5) sufficiently limited induction of undesirable cytokine release, 6) acceptably low immunogenicity (i.e., sufficiently non-immunogenic in humans); 7) avoidance of untoward immunocompromise; and/or 8) desirable *in vivo* stability, physical and chemical stability including, but not limited to, thermal stability, solubility, low self-association, and pharmacokinetic characteristics which are acceptable 10 for development and/or use in the treatment of inflammatory or neuroinflammatory disorders, for example AD.

Embodiments of the present invention provide a significant advance over the prior art by providing compositions and methods useful in the prevention, downregulation, or amelioration of inflammatory and/or neuroinflammatory related disorders, through IL-34 15 neutralization, using a pharmacologically advantageous anti-human IL-34 antibody as provided in the embodiments described herein. Anti-human IL-34 antibodies of the present invention are capable of improving immune and/or inflammatory pathology, or restoring immune homeostasis, preferably, through inhibition of the innate arm of the immune response, and/or abrogation of microgliosis or other monocyte/macrophage 20 lineage cellular activation and or proliferation, thereby directly modifying underlying disease pathology. The use of such antibodies clinically may lead to durable long-term improvement of the disease(s) being treated.

Further, there is a need for diagnostic anti-human IL-34 antibodies that are specific for human IL-34, and possess improved binding affinity, and demonstrate 25 enhanced sensitivity in human IL-34 determinations, and improved enzyme-linked immunosorbent assay (ELISA) assay conditions that result in minimal interference and broad dilutional linearity. According to some aspects of the present invention, anti-human IL-34 antibodies, including human IL-34 neutralizing antibodies, are provided which bind human IL-34 given by SEQ ID NO: 41. Interleukin 34 (IL-34; also known as 30 uncharacterized protein C16orf77) is secreted as a homodimer consisting of 39 kDa

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monomers. It belongs to no known cytokine family. Human IL-34 is synthesized as a 242 amino acid (AA) precursor that contains a 20 AA signal sequence, and results in a 222 AA mature chain. As used herein IL-34 refers to the mature chain. The mature chain contains one potential site of N-linked glycosylation. Human IL-34 is 71% identical to mouse IL-34 on the amino acid level. IL-34 is expressed in various tissues, including the heart, brain, liver, kidney, spleen, thymus, testes, ovary, small intestine, prostate, and colon, and is most abundant in the spleen. “h IL-34” or “human IL-34” when used herein in reference to an IL-34 polypeptide, unless otherwise stated, refers to wild-type human IL-34, and preferably has the amino acid sequence set forth in SEQ ID NO: 41, which is mature IL-34 having the leader sequence removed. (See, for example, Lin et.al., Science (2008) Vol. 320, Issue 5877, pp. 807-811).

An exemplary human IL-34 (including the 20 AA signal peptide sequence which is removed to yield the mature polypeptide) is:

MPRGFTWLRYLGI FLGVALGNEPLEMWPLTQNEECTVTGFLRDKLQYRS
RLQYMKHYFPI NYKISVPYEGVFRIANVTRLQRAQVSERELRYLWVLVSLSATES
VQDVLLEGHP SWKYLQEVETLLLNVQQGLTDVEVSPKVESVLSLLNAPGPNLKL
VRPKALLDNCFRVMELLYCSCCKQSSVLNWQDCEVPSPQSCSPEPSLQYAATQL
YPPPPWSPSSPPHSTGSRPVRAQGEGLLP

(SEQ ID NO: 41, see NCBI Ref. Seq. No. NP_689669.2, March 1, 2018).

According to some aspects of the present invention, anti-murine IL-34 antibodies, including murine IL-34 neutralizing antibodies, are provided which bind human IL-34 given by SEQ ID NO. 42. An exemplary murine IL-34 (including the 20 AA signal peptide sequence which is removed to yield the mature polypeptide) is:

MPWGLAWLYCLGILLDVALGNENLEIWTLTQDKECDLTGYLRGKLQYK
NRLQYMKHYFPIN YRIAVPYEGVLRVANITRLQKAHVSERELRYLWVLVSLNAT
ESVMDVLLEGHP SWKYLQEVQTLLENVQRSLMDVEIGPHVEAVLSLLSTPGLSL
KLVRPKALLDNCFRVMELLYCSCCKQSPILKWQDCELPRLHPHSPGSLMQCTAT
NVYPLSRQTPTSLPGSPSSSHGSLP

(SEQ ID NO: 42, see NCBI Ref. Seq. No. NP_001128572.1, March 1, 2018).

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As used herein, “human anti-IL34 antibody” or “anti-human IL-34 antibody” refers to an antibody that binds to human IL-34, and when administered *in vitro* or *in vivo*, results in an IL-34 activity-neutralizing and/or blocking response, such as at least one significantly lessened desired activity, for example a desired reduction in IL-34 signaling as evidenced by a change in an IL-34 responsive molecular or cellular endpoint. For instance, microglia number, density, or phenotype in the CNS, is an example of an IL-34 responsive molecular or cellular effect. As used herein, the terms “signaling” and “signal transduction” and “IL-34-mediated”, as they relate to IL-34, refer to cellular and/or intercellular responses which result from the activity of IL-34.

The term “antibody,” as used herein, refers to an immunoglobulin molecule that binds an antigen. Embodiments of an antibody include a monoclonal antibody, polyclonal antibody, human antibody, humanized antibody, chimeric antibody or conjugated antibody. The antibodies can be of any class (e.g., IgG, IgE, IgM, IgD, IgA) and any subclass (e.g., IgG1, IgG2, IgG3, IgG4). An exemplary antibody is an immunoglobulin G (IgG) type antibody comprised of four polypeptide chains: two heavy chains (HC) and two light chains (LC) that are cross-linked via inter-chain disulfide bonds. LCs are classified as kappa or lambda, which are each characterized by a specific constant region. Embodiments of the present invention may comprise an IgG1 or IgG4 antibody, and further comprise kappa light chains or lambda light chains. Preferably antibodies of the present invention comprise light chain constant regions which are kappa constant regions.

HCs are classified as gamma, mu, alpha, delta, or epsilon, and define the isotype of an antibody as IgG, IgM, IgA, IgD, or IgE, respectively. The amino-terminal portion of each of the four polypeptide chains includes a variable region of about 100-125 or more amino acids primarily responsible for antigen recognition. The carboxyl-terminal portion of each of the four polypeptide chains contains a constant region primarily responsible for effector functions. Each heavy chain is comprised of a heavy chain variable region (VH) and a heavy chain constant region. The constant region of the heavy chains contains CH1, CH2, and CH3 domains. CH1 comes after the HCVR; the CH1 and HCVR form the heavy chain portion of an antigen-binding (Fab) fragment, which is the part of an antibody that binds antigen(s). CH2 comes after the hinge region and before CH3. CH3

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comes after CH2 and is at the carboxy-terminal end of the heavy chain. The constant region of the light chains contains one domain, CL. CL comes after the LCVR; the CL and LCVR form the light chain portion of a Fab.

The antibodies of the present invention include IgG HCs which can be further
5 divided into subclasses, e.g., IgG1, IgG2, IgG3, IgG4, and embodiments of the present invention may include one or more modifications in the constant region of each HC, for example that enhance or reduce effector function. The term "Fc region" as used herein refers to a region of an antibody, which comprises the CH2 and CH3 domains of the antibody heavy chain. Optionally, the Fc region may include a portion of the hinge
10 region or the entire hinge region of the antibody heavy chain. IgG1 is known to induce antibody-dependent cell cytotoxicity (ADCC) and complement-dependent cytotoxicity (CDC), and Fc mutations described herein may reduce aggregation, reduce or enhance ADCC or CDC activities, (or other functions), and/or modify the pharmacokinetics of the antibodies. Embodiments of anti-human IL-34 antibodies described herein have reduced
15 binding to the FcγR and C1q receptors, thereby reducing or eliminating the cytotoxicity which may be induced by antibodies with wild type IgG Fc regions. Thus, according to some embodiments, mutations are introduced in the Fc region at positions as described herein. Patient safety can be improved with sufficiently reduced or eliminated effector functions of such anti-human IL-34 antibodies comprising a modified Fc region, and in
20 combination with other properties described herein, provide therapeutic agents with an improved profile of useful activities while avoiding undesirable activities.

When expressed in certain biological systems, antibodies are glycosylated in the Fc region. Typically, glycosylation occurs in the Fc region of the antibody at a highly conserved N-glycosylation site. N-glycans typically attach to asparagine. Antibodies may
25 be glycosylated at other positions as well. Antibodies of the present invention are monoclonal antibodies. Monoclonal antibodies are antibodies derived from a single copy or clone including, for example, any eukaryotic, prokaryotic or phage clone, and not defined by the method by which it is produced. Monoclonal antibodies can be produced, for example, by hybridoma technologies, recombinant technologies, phage display
30 technologies, synthetic technologies, e.g., CDR-grafting, or combinations of such or other

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technologies known in the art. The present invention contemplates the antibodies of the present invention are human or humanized antibodies. In the context of monoclonal antibodies, the terms “human” and “humanized” are well-known to those of ordinary skill in the art (Weiner LJ, J. Immunother. 2006; 29: 1-9; Mallbris L, et al., J. Clin. Aesthet.

5 Dermatol. 2016; 9: 13-15). Exemplary embodiments of antibodies of the present invention also include antibody fragments or antigen-binding fragments, which comprise at least a portion of an antibody retaining the ability to specifically interact with an antigen such as Fab, Fab', F(ab')₂, Fv fragments, scFv antibody fragments, disulfide-linked Fvs (sdFv), a Fd fragment and linear antibodies.

10 The amino terminal portion of each LC and HC includes a variable region of about 100-120 amino acids primarily responsible for antigen recognition via the CDRs contained therein. The VH and VL regions can be further subdivided into regions of hyper-variability, termed complementarity determining regions (CDRs), interspersed with regions that are more conserved, termed framework regions (FR). The CDRs are exposed
15 on the surface of the protein and are important regions of the antibody for antigen binding specificity. Each VH and VL is composed of three CDRs and four FRs, arranged from amino-terminus to carboxyl-terminus in the following order: FR1, CDR1, FR2, CDR2, FR3, CDR3, FR4. Herein, the three CDRs of the heavy chain are referred to as “HCDR1, HCDR2, and HCDR3” and the three CDRs of the light chain are referred to as “LCDR1,
20 LCDR2 and LCDR3”. The CDRs contain most of the residues that form specific interactions with the antigen. The functional ability of an antibody to bind a specific antigen is largely influenced by the six CDRs. Assignment of amino acid residues to the CDRs may be done according to the well-known schemes, including those described in Kabat (Kabat et al., “Sequences of Proteins of Immunological Interest,” National
25 Institutes of Health, Bethesda, Md. (1991)), Chothia (Chothia et al., “Canonical structures for the hypervariable regions of immunoglobulins”, Journal of Molecular Biology, 196, 901-917 (1987); Al-Lazikani et al., “Standard conformations for the canonical structures of immunoglobulins”, Journal of Molecular Biology, 273, 927-948 (1997)), North (North et al., “A New Clustering of Antibody CDR Loop Conformations”, Journal of Molecular

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Biology, 406, 228-256 (2011)), or IMGT (the international ImMunoGeneTics database available on at www.imgt.org; see Lefranc et al., Nucleic Acids Res. 1999; 27:209-212).

For the purposes of the present invention, and except where specified otherwise, the North CDR definitions are used for the anti-IL-34 antibodies described herein, and assignment of amino acids to CDR domains within the LCVR and HCVR regions. Below is table of CDR sequences for Antibody 1 based on North definitions. The skilled artisan can also apply alternative definitions of Kabat, Chothia, and/or IMGT, to specify CDR's according to those conventions for Antibodies of the present invention including Antibodies 1-3 in Table 1.

Exemplary CDRs of Antibody 1 (or Antibodies of the present disclosure)						
Ab	HCDR1	HCDR2	HCDR3	LCDR1	LCDR2	LCDR3
North	AASGFTFSSY ATS (SEQ ID NO: 5)	AISHSGRSTY YADSVKG (SEQ ID NO: 6)	ARGRSSLDLT (SEQ ID NO: 7)	RASQSISS AYLA (SEQ ID NO: 8)	YASSIRPT (SEQ ID NO: 9)	SQYGDSLS (SEQ ID NO: 10)

Antibody embodiments of the present invention possess a combination of several pharmacologically useful and important activities, and in one respect are capable of binding with high affinity to human IL-34 and high specificity for human IL-34, as well as other useful properties. The terms "bind" and "binds" as used herein are intended to mean, unless indicated otherwise, the ability of a protein or molecule to form attractive interactions with another protein or molecule, which results in proximity of the two proteins or molecules as determined by common methods known in the art. The phrase "specifically binds", as used herein in reference to the affinity of an anti-IL-34 antibody for human IL-34, is intended to mean, unless indicated otherwise, a K_D of preferably less than about 1×10^{-11} M, even more preferably, between about 1×10^{-11} M and about 1×10^{-12} M, as determined by common methods known in the art, including by use of a SPR biosensor, and/or MSD, essentially as described herein. The phrase "specifically binds" also indicates the relative affinity of an anti-IL-34 antibody for human IL-34, as

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compared to other antigens, wherein the affinity for human IL-34 results in a specific recognition of human IL-34.

Antibody embodiments of the present invention may be expressed and produced by a variety of techniques known in the art from constructs comprising sequences of the present embodiments. The terms “nucleic acid” or “polynucleotide”, as used
5 interchangeably herein, refer to polymers of nucleotides, including single-stranded and / or double-stranded nucleotide-containing molecules, such as DNA, cDNA and RNA molecules, incorporating native, modified, and/or analogs of, nucleotides. Polynucleotides of the present disclosure may also include substrates incorporated
10 therein, for example, by DNA or RNA polymerase or a synthetic reaction. A DNA molecule of the present invention is a DNA molecule that comprises a non-naturally occurring polynucleotide sequence encoding a polypeptide having the amino acid sequence of at least one of the polypeptides in an antibody of the present invention (e.g., heavy chain, light chain, variable heavy chain, and variable light chain).

15 An isolated DNA encoding a HCVR or LCVR region can be converted to a full-length heavy chain gene by operably linking the respective HCVR or LCVR-encoding DNA to another DNA molecule encoding heavy or light chain constant regions, to form a heavy or light chain respectively. The sequences of human, as well as other mammalian, heavy chain constant region genes are known in the art. DNA fragments encompassing
20 these regions can be obtained, *e.g.*, by standard PCR amplification.

The polynucleotides of the present invention can be expressed in a host cell after the sequences have been operably linked to an expression control sequence. The 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 will
25 contain selection markers, *e.g.*, tetracycline, neomycin, and dihydrofolate reductase, to permit detection of those cells transformed with the desired DNA sequences. The vectors containing the polynucleotide sequences of interest (*e.g.*, the polynucleotides encoding the polypeptides of the antibody and expression control sequences) can be transferred into the host cell by well-known methods, which vary depending on the type of cellular host.

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The antibodies of the present invention can readily be produced in mammalian cells, non-limiting examples of which includes CHO, NS0, HEK293 or COS cells. The host cells are cultured using techniques well known in the art. Mammalian expression of antibodies typically results in glycosylation. Glycosylation of antibodies is typically
5 either N-linked or O-linked. N-linked glycosylation refers to the attachment of a carbohydrate moiety to the side chain of an asparagine residue. O-linked glycosylation refers to the attachment of a sugar, for example N-acetylgalactosamine, galactose, or xylose to a hydroxyamino acid. Typically, glycosylation occurs in the Fc region of the antibody at a highly conserved N-glycosylation site (e.g., position 297 in IgG1, according
10 to IMGT or EU Index numbering). Glycosylation sites can be modified to alter glycosylation (e.g., blocking or reducing glycosylation or altering the amino acid sequence to produce additional or diverse glycosylation).

Mammalian expression of antibodies from IgG subclasses can result in clipping of C-terminal amino acids from one or both heavy chains; for example, one or two C-
15 terminal amino acids can be removed for IgG1 antibodies. For IgG1 antibodies, if a C-terminal lysine is present, then it may be truncated or clipped off from the heavy chain during expression. Additionally, a penultimate glycine may also be truncated or clipped off from the heavy chain as well.

Mammalian expression of antibodies can also result in the modification of N-
20 terminal amino acids. For example, where the N-terminal most amino acid of a heavy chain or light chain is a glutamine, it may be modified into pyro-glutamic acid.

An antibody of the present invention, or a pharmaceutical composition comprising the same, may be administered by parenteral routes, non-limiting examples of which are subcutaneous administration and intravenous administration. An antibody of the present
25 invention may be administered to a patient with pharmaceutically acceptable carriers, diluents, or excipients in single or multiple doses. Pharmaceutical compositions of the present invention can be prepared by methods well known in the art (e.g., Remington: The Science and Practice of Pharmacy, 22nd ed. (2012), A. Loyd et al., Pharmaceutical Press) and comprise an antibody, as disclosed herein, and one or more pharmaceutically
30 acceptable carriers, diluents, or excipients.

Uses of antibody embodiments of the present invention:

According to some embodiments, the anti-IL-34 antibodies of the present invention are useful in the treatment of immune-mediated diseases. As used herein, the
5 term “immune-mediated disease” or “inflammatory disease or disorder” are used interchangeably and refer to undesirable conditions that arise from an inappropriate, or excessive immune responses in which IL-34 inhibition results in more homeostatic and less pathological responses. The term “immune-mediated disease” or “inflammatory
10 disorder” is meant to include such conditions, whether they be mediated by microglia or macrophage cellular immune responses, or those of similar tissue-resident cell types, such as histiocytes, Kupffer cells, alveolar macrophages, intestinal macrophages, macrophage-like synoviocytes, or Langerhans cells. Exemplary diseases contemplated to be treated by the antibodies of the invention described herein include Alzheimer’s Disease; a
15 Tauopathy disease; Sjogren’s syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD).

In some more specific embodiments, the immune-mediated disease is Alzheimer’s Disease (AD). According to other embodiments of the present invention, the anti-IL-34 antibodies are useful in diagnostic applications for immune-mediated diseases. In some
20 embodiments, the immune-mediated diseases are at least one of AD; Sjogren’s syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD).

The present invention further provides pharmaceutical compositions comprising an anti-IL-34 antibody of the present invention and one or more pharmaceutically
25 acceptable carriers, diluents or excipients. Further, the present invention provides a method of treating an immune-mediated disease, such as AD; Sjogren’s syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD), comprising administering to a patient in need thereof a pharmaceutical composition of the present
30 invention.

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In addition, the present invention provides a method of treating immune-mediated diseases. More particularly, the present invention provides a method of treating immune-mediated diseases, including AD; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD), comprising administering to a patient in need thereof an effective amount of an anti-IL-34 antibody of the present invention.

The present invention also provides an anti-IL-34 antibody of the present invention for use in therapy. More particularly, the present invention provides an anti-IL-34 antibody of the present invention for use in treatment of immune-mediated diseases including AD; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD).

In certain embodiments, the present invention provides the use of an anti-IL-34 antibody of the present invention in the manufacture of a medicament for the treatment of one or more immune-mediated diseases including AD; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD).

Antibodies of the present invention are useful in the identification of immune-mediated disorders wherein IL-34 may contribute to the etiopathogenesis of the disorder. In further embodiments, the present invention provides a method of treating an immune-mediated disease in a patient. Such methods comprise the steps of contacting a patient sample with an anti-IL-34 antibody and detecting binding between human IL-34 in the patient sample and the antibody; and diagnosing the patient as having; at risk for; in need of treatment for; and/or at risk of symptoms relating to an immune-mediated disease when the presence of IL-34 in the patient sample is detected as above a reference value observed in non-diseased individuals (See for example Xie, H.H., et al. *Elevated Serum Interleukin-34 Level in Patients with Systemic Lupus Erythematosus Is Associated with Disease Activity*. Sci Rep 8, 3462 (2018). According to some more specific embodiments of the methods of treating provided herein, such methods further include the steps of determining the reference value including the further steps of contacting a control

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standard with a first antibody which binds the same first epitope region of IL-34 as used in contacting the patient sample; contacting the control standard with a second antibody having a detectable label and which binds the same second epitope region of IL-34 as used in contacting the patient sample; and detecting a signal provided by the detectable signal. In some specific embodiments, the anti-IL-34 antibody comprises a combination of LC and HC CDRs provided in Table 1. In further embodiments, the second antibody comprises a combination of LCVR and HCVR provided in Table 1. According to some embodiments, the reference value is approximately 10-30pg/mL, for example from CNS tissue lysates. In certain embodiments, the immune-mediated disease is one of AD; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty liver disease (NAFLD). In some embodiments, the patient sample is one of CSF, blood, serum, a tissue lysate, or plasma. According to some embodiments, the method further includes the steps of contacting the patient sample with a second anti-IL-34 antibody which binds a second epitope region of IL-34, and has a detectable label, and detecting a signal provided by the detectable signal. In further embodiments, the second antibody comprises a combination of LC and HC CDRs provided in Table 1. In further embodiments, the second antibody comprises a combination of LCVR and HCVR provided in Table 1. According to certain embodiments, the first and second anti-IL-34 antibodies do not bind together.

According to some embodiments, the present invention provides a method of detecting IL-34 in a patient sample comprising the steps of contacting the patient sample with a first antibody which binds a first epitope region of IL-34; contacting the patient sample with a second antibody which binds a second epitope region of IL-34 and has a detectable label; and detecting a signal provided by said detectable label. In some embodiments, the patient sample is one of blood, serum, a tissue lysate or plasma. According to some more specific embodiments, the first epitope region of IL-34 partially overlaps with the second epitope region of IL-34. Further, in some embodiments, said steps of contacting with the first and second antibodies occurs simultaneously. In some specific embodiments, the first antibody comprises a combination of LC and HC CDRs

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provided in Table 1. In further embodiments, the first antibody comprises a combination of LCVR and HCVR provided in Table 1.

According to some embodiments of the present invention, a method of quantifying IL-34 in a patient sample is provided. Such method includes the steps of contacting the patient sample with a first antibody which binds a first epitope region of IL-34; contacting the patient sample with a second antibody which binds a second epitope region of IL-34 and said has a detectable label; and detecting the signal provided by said detectable label; contacting a control standard with a first antibody which binds the same first epitope region of IL-34 (as used in contacting the patient sample); contacting the control standard with a second antibody which binds the same second epitope region of IL-34 (as used in contacting the patient sample) and having a detectable label; and detecting a signal provided by said detectable signal. In some embodiments, the patient sample is one of blood, serum or plasma, or a tissue lysate. According to some more specific embodiments, the first epitope region of IL-34 partially overlaps with the second epitope region of IL-34. Further, in some embodiments, said steps of contacting with the first and second antibodies occurs simultaneously. In some specific embodiments, the first antibody comprises a combination of LC and HC CDRs provided in Table 1. In further embodiments, the first antibody comprises a combination of LCVR and HCVR provided in Table 1. In some specific embodiments, the second antibody comprises a combination of LC and HC CDRs provided in Table 1. In further embodiments, the second antibody comprises a combination of LCVR and HCVR provided in Table 1.

According to some embodiments, a method of diagnosing an immune-mediated disease is provided. Such method comprises the steps of contacting a patient sample with an anti-IL-34 antibody and detecting binding between IL-34 in the patient sample and the antibody. According to some specific embodiments, the method of diagnosing includes diagnosing the patient as having; at risk for; in need of treatment for; and/or at risk of symptoms relating to an immune-mediated disease when the presence of IL-34 in the patient sample is detected as above a reference value. According to some more specific embodiments, such methods further include the steps of determining the reference value including the steps of contacting a control standard with a first antibody which binds the

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same first epitope region of IL-34 as used in contacting the patient sample; contacting the control standard with a second antibody having a detectable label and which binds the same second epitope region of IL-34 as used in contacting the patient sample; and detecting a signal provided by the detectable signal. In some embodiments, the first
5 antibody comprises a combination of LC and HC CDRs provided in Tables 1. Some embodiments of the method of diagnosing an immune-mediated disease, provided herein, further includes the steps of contacting the patient sample with a second anti-IL-34 antibody which binds a second epitope region of IL-34 and has a detectable label; and detecting a signal provided by the detectable label. In some specific embodiments, the
10 anti-IL-34 antibody comprises a combination of LC and HC CDRs provided in Table 1. In further embodiments, the antibody comprises a combination of LCVR and HCVR provided in Table 1. According to specific embodiments, the first epitope region of IL-34 partially overlaps with the second epitope region of IL-34. According to certain embodiments, the first and second antibodies do not bin together. According to further
15 embodiments, the reference value is approximately a range from 10-30 pg/mL from CNS tissue lysates, and/ or as determined by the skilled artisan for the appropriate reference group and sample source. In further embodiments, the immune-mediated disease is one of AD; a tauopathy; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-alcoholic fatty
20 liver disease (NAFLD).

In an embodiment the present invention provides a method of determining the human IL-34 level in a bodily fluid comprising: (a) contacting the bodily fluid with an anti-human IL-34 diagnostic monoclonal antibody, or antigen-binding fragment thereof, that specifically binds to human IL-34 consisting of the amino acid sequence as in SEQ
25 ID NO: 41, the antibody, or antigen-binding fragment thereof, comprising: light chain complementarity determining regions LCDR1, LCDR2, and LCDR3 comprising the amino acid sequences (SEQ ID NO: 8), (SEQ ID NO: 9), and (SEQ ID NO: 10), respectively, and heavy chain complementarity determining regions HCDR1, HCDR2, and HCDR3 comprising the amino acid sequences (SEQ ID NO: 15), (SEQ ID NO: 16),
30 and (SEQ ID NO: 17), respectively; (b) optionally, removing any non-specifically bound

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monoclonal antibody or, antigen-binding fragment thereof; and (c) detecting and/or quantifying the amount of monoclonal antibody, or antigen-binding fragment thereof, which is specifically bound to human IL-34. Preferably, wherein said bodily fluid is blood, serum or plasma, or cerebrospinal fluid, and said contacting occurs ex vivo.

5 Tauopathy diseases include but are not limited to, Alzheimer's disease (AD), Pick's disease (PiD), progressive supranuclear palsy (PSP), corticobasal degeneration (CBD), argyrophilic grain disease, Down's Syndrome, chronic traumatic encephalopathy (CTE), traumatic brain injury (TBI), frontotemporal dementia with Parkinsonism linked to chromosome 17 (FTDP-17), Parkinsonism-dementia complex of Guam, Niemann-Pick
10 disease type C, myotonic dystrophy (*See Li, C., Götz, J. Tau-based therapies in neurodegeneration: opportunities and challenges. Nat Rev Drug Discov 16, 863–883 (2017).*).

 In embodiments of the invention a patient is a human who has been diagnosed as having a medical risk, condition or disorder, such as one of the diseases or disorders
15 described herein, in need of treatment with an antibody described herein. In those instances where the disorders which can be treated by the methods of the present invention are known by established and accepted classifications, such as Alzheimer's Disease; a tauopathy disease; Sjogren's syndrome (SS); Rheumatoid arthritis (RA); inflammatory bowel disease (IBD), atopic dermatitis, kidney disease, sepsis, and/or non-
20 alcoholic fatty liver disease (NAFLD), their classifications can be found in various well-known medical texts. For example, at present, the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), provides a diagnostic tool for identifying certain disorders described herein. Also, the International Classification of Diseases, Tenth Revision (ICD-10), provides classifications for certain disorders
25 described herein. The skilled artisan will recognize that there are alternative nomenclatures, nosologies, and classification systems for diseases and disorders described herein, including those as described in the DSM-5 and ICD-10, and that terminology and classification systems evolve with medical scientific progress.

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The term "treating" (or "treat" or "treatment") refers to slowing, interrupting, arresting, alleviating, stopping, reducing, or reversing the progression or severity of an existing symptom, disorder, condition, or disease.

As used herein, the term "innate immunity" includes the arm of the immune
5 response which, in contrast to the adaptive arm of the immune response, is required to initiate and maintain an adaptive immune response (antibody and T cell responses).

"Effective amount" means the amount of an anti-human IL-34 antibody of the present invention, or a pharmaceutical composition comprising such an antibody, that will elicit the biological or medical response of or desired therapeutic effect on a tissue,
10 system, or human, that is being sought by the treating health professional. As used herein, the term "effective response" of a patient or a patient's responsiveness to treatment refers to the clinical or therapeutic benefit imparted to a patient upon administration an antibody of the present disclosure. An effective amount of the antibody may vary according to factors such as the disease state, age, sex, and weight of the individual, and the ability of
15 the antibody to elicit a desired response in the individual. An effective amount is also one in which any toxic or detrimental effect of the antibody is outweighed by the therapeutically beneficial effects. Such benefit includes any one or more of: a decreased level of inflammation or immune activation, stabilized immune-mediated disease or disorder; or improving signs or symptoms of an immune-mediated disorder.
20 Alternatively, such benefit includes any one or more of the following: an increased immune tolerance of transplanted organs; stabilized autoimmune disease or disorder; or improving signs or symptoms of an autoimmune disorder.

A potential advantage of methods disclosed herein is the possibility of producing marked and/or prolonged relief in a patient suffering from an immune-mediated disorder,
25 or neuroinflammatory disorder, with an acceptable safety profile including acceptable tolerability, toxicities and/or adverse events, so that the patient benefits from the treatment method overall. The efficacy of the treatment of the present disclosure can be measured by various endpoints that are commonly used in evaluating treatments for various immune-mediated disorders. Other approaches to determining efficacy of any
30 particular therapy of the present invention can be optionally employed, including, for

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example, immune cell activation markers, measures of inflammation, cell-cycle dependent biomarker measurement and visualization, and/or measurement of response through various inflammation or immune or tissue specific biomarker assessments.

An effective amount can be readily determined by one skilled in the art, using
5 known techniques, and by observing results obtained under analogous circumstances. An effective amount of an anti-human IL-34 antibody of the present invention may be administered in a single dose or in multiple doses. Furthermore, an effective amount of an antibody of the invention may be administered in multiple doses of amounts that would be less than an effective amount if not administered more than once. In determining the
10 effective amount for a patient, a number of factors are considered by the attending medical practitioner, including, but not limited to: the patient's size (e.g., weight or mass), body surface area, age, and general health; the specific disease or disorder involved; the degree of, or involvement, or the severity of the disease or disorder; the response of the individual patient; the particular compound administered; the mode of
15 administration; the bioavailability characteristics of the preparation administered; the dose regimen selected; the use of concomitant medication; and other relevant circumstances known to medical practitioners.

A weekly, every two week, monthly, or quarterly parenteral (including, but not limited to, subcutaneous, intramuscular, and/or intravenous) dose can be from about 0.5
20 mg/kg to about 50 mg/kg.

A weekly, every two week, monthly, or quarterly parenteral (including, but not limited to, subcutaneous, intramuscular, and/or intravenous) dose can be from about 0.5 mg/kg to about 10 mg/kg, from about 1 mg/kg to about 10 mg/kg, from about 2 mg/kg to about 10 mg/kg, from about 3 mg/kg to about 10 mg/kg, from about 4 mg/kg to about 10
25 mg/kg, from about 5 mg/kg to about 10 mg/kg, from about 6 mg/kg to about 10 mg/kg, from about 7 mg/kg to about 10 mg/kg from about 8 mg/kg to about 10 mg/kg, from about 1 mg/kg to about 8 mg/kg, from about 2 mg/kg to about 8 mg/kg, from about 3 mg/kg to about 8 mg/kg, from about 4 mg/kg to about 8 mg/kg, from about 5 mg/kg to about 8 mg/kg, from about 6 mg/kg to about 8 mg/kg, from about 1 mg/kg to about 6
30 mg/kg, from about 2 mg/kg to about 6 mg/kg, from about 3 mg/kg to about 6 mg/kg, from

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about 4 mg/kg to about 6 mg/kg, from about 5 mg/kg to about 6 mg/kg, from about 1 mg/kg to about 5 mg/kg, from about 2 mg/kg to about 5 mg/kg, from about 3 mg/kg to about 5 mg/kg, from about 4 mg/kg to about 5 mg/kg, from about 1 mg/kg to about 4 mg/kg, from about 2 mg/kg to about 4 mg/kg, from about 3 mg/kg to about 4 mg/kg, from about 3.5 mg/kg to about 5 mg/kg, or about 4 mg/kg to about 5 mg/kg.

A weekly, every two weeks, monthly, or quarterly parenteral (including, but not limited to, subcutaneous, intramuscular, and/or intravenous) dose can be, for example, from about 50 mg to about 500 mg, from about 75 mg to about 500 mg, from about 100 mg to about 500 mg, from about 125 mg to about 500 mg, from about 250 mg to about 500 mg, from about 300 mg to about 500 mg, from about 350 mg to about 500 mg, from about 400 mg to about 500 mg, from about 450 mg to about 500 mg, from about 50 mg to about 400 mg, from about 75 mg to about 400 mg, from about 100 mg to about 400 mg, from about 125 mg to about 400 mg, from about 250 mg to about 400 mg, from about 300 mg to about 400 mg, from about 350 mg to about 400 mg, from about 50 mg to about 300 mg, from about 75 mg to about 300 mg, from about 100 mg to about 300 mg, from about 125 mg to about 300 mg, from about 150 mg to about 300 mg, from about 175 mg to about 300 mg, from about 200 mg to about 300 mg, from about 250 mg to about 300 mg, from about 50 mg to about 250 mg, from about 75 mg to about 250 mg, from about 100 mg to about 250 mg, from about 125 mg to about 250 mg, from about 150 mg to about 250 mg, from about 175 mg to about 250 mg, from about 200 mg to about 250 mg, from about 75 mg to about 250 mg, from about 50 mg to about 200 mg, from about 75 mg to about 200 mg, from about 100 mg to about 200 mg, from about 125 mg to about 200 mg, from about 150 mg to about 200 mg, from about 175 mg to about 200 mg, from about 50 mg to about 175 mg, from about 75 mg to about 175 mg, from about 100 mg to about 175 mg, from about 125 mg to about 175 mg, or from about 150 mg to about 175 mg.

However, doses below or above the doses mentioned herein are also envisioned, especially considering dosage considerations known to those skilled in the art and/or described herein. Progress of the patient being treated may be monitored by periodic assessment, and the dose adjusted accordingly if necessary.

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A potential advantage of methods disclosed herein is the possibility of producing marked and/or prolonged relief in a patient suffering from an immune-mediated disorder, or neuroinflammatory disorder, with an acceptable safety profile including acceptable tolerability, toxicities and/or adverse events, so that the patient benefits from the treatment method overall, and more particularly the antibodies of the present invention will provide effective treatment while avoiding clinically undesirable immunosuppression and/or immune associated adverse events such as “cytokine storm” or significant cytokine release. Antibodies of the present invention may be useful for the treatment of cytokine storm, or otherwise adverse cytokine release. As used herein, “significant cytokine release” refers to a significant increase in measurable cytokines that can be detected by methods known to persons of ordinary skill. For example, significant cytokine release may be detected in human blood samples by ELISA, wherein cytokine levels from unstimulated blood are compared to cytokine levels with blood incubated with antibody. In some such studies, for example, a significant cytokine release may be detected if the levels of IL-6, or IL-8, or IFN- γ are at least three-fold higher in blood incubated with antibody compared to levels in unstimulated blood. Preferably, treatment of an immune-mediated disorder as described in the embodiments herein will occur wherein the patient will not experience significant cytokine release.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 shows Antibody 1 neutralization of human IL-34 induced luciferase reporter activity in hCSF1R expressing 293 SRE cells.

FIGURE 2 shows the ability of Antibody 1 to neutralize the dimerization of CSF1R in the PathHunter eXpress Dimerization Assay.

FIGURE 3 shows the ability of Antibody 1 to inhibit ERK phosphorylation in NIH-3T3/CSF1R cells.

FIGURE 4 shows the ability of anti-IL34 antibodies to inhibit IL-34 induced expression of CD163 in human monocytes by flow cytometry.

EXAMPLES

The following examples are offered to illustrate, but not to limit, the claimed invention. The results of the following assays demonstrate that the exemplified

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monoclonal antibodies, and/or antigen-binding fragments thereof of the present invention bind and/or neutralize IL-34, and therefore may be used for treating immune-mediated and inflammatory diseases described herein.

5 **Example 1: Antibody Generation, Expression and Purification**

A panel of human anti-IL-34 antibodies is obtained using human antibody phage display libraries and screened to identify reagents that could be effective IL-34 neutralizing antibodies. Mutations are systematically introduced into individual complementarity determining regions (CDRs) of each antibody and the resulting libraries
10 are subjected to multiple rounds of selection with decreasing concentrations of antigen and/or increasing periods of dissociation, in order to isolate clones with improved affinities. The sequences of individual variants are determined and used to construct a combinatorial library which is subjected to an additional round of selection with increased stringency to identify additive or synergistic mutational pairings between the individual
15 CDR regions. Individual combinatorial clones are sequenced, and binding characteristics are determined. In order to further increase the affinity to IL-34, these combinatorial clones are subjected to additional rounds of single and combinatorial mutagenesis. This screening can be conducted against human or mouse IL-34 to increase affinity against a selected species (for example Antibody 1 for human IL-34, and Antibody 3 for mouse IL-
20 34). Selected antibodies can also be mutagenized to fix post-translational modifications such as methionine oxidation, while retaining binding affinity to IL-34. Additionally, framework (FW) substitutions can be made to the antibody to revert these FW1 sequences to their germline state in order to reduce potential immunogenicity risk.

Engineered and/or optimized anti-IL-34 antibodies referred to herein as Antibody
25 1, Antibody 2, and/or Antibody 3 are obtained, having the amino acid sequences of the variable regions of the heavy chain and light chain, and the complete heavy chain and light chain amino acid sequences, and the nucleotide sequences encoding the same, as listed below in the section entitled "Listing of Amino Acid and Nucleotide Sequences". The SEQ ID NO's corresponding to these fragments are shown below in Table 1, as well
30 as the light chain and heavy chain CDR amino acid sequences.

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The exemplified anti-IL-34 antibodies of the present invention can be expressed and purified essentially as follows. An appropriate host cell, such as HEK 293, NS0 or CHO, can be either transiently or stably transfected with an expression system for secreting antibodies using an optimal predetermined HC:LC vector ratio (such as 1:3 or 1:2) or a single vector system encoding both the HC and the LC. Clarified media, into which the antibody has been secreted, is purified using any of many commonly-used techniques. For example, the medium may be applied to a Protein A or G column, for instance a MabSelect® column (GE Healthcare), or KappaSelect column (GE Healthcare) for Fab fragment, that has been equilibrated with a compatible buffer, such as phosphate buffered saline (pH 7.4). The column may be washed to remove nonspecific binding components. The bound antibody may be eluted, for example, by pH gradient (such as 20 mM Tris buffer, pH 7.0 to 10 mM sodium citrate buffer, pH 3.0, or phosphate buffered saline pH 7.4 to 100 mM glycine buffer, pH 3.0). Antibody fractions may be detected, such as by SDS-PAGE, and then may be pooled. The bound antibody is eluted, for example, by pH gradient (such as 0.1 M sodium phosphate buffer pH 6.8 to 0.1 M sodium citrate buffer pH 2.5). Antibody fractions are detected, such as by SDS-PAGE, and then are pooled. Further purification is optional, depending on the intended use. The antibody may be concentrated and/or sterile filtered using common techniques. Soluble aggregate and multimers may be effectively removed by common techniques, including size exclusion, hydrophobic interaction, or ion exchange, multimodal, or hydroxyapatite chromatography. The purity of the antibody after these chromatography steps is greater than 99%. The product may be immediately frozen at -70 °C, or may be lyophilized, or preserved in 4 °C for immediate use. Amino acid SEQ ID NOs for exemplified human antibodies of the present invention are shown below in Table 1.

The expression plasmid contains cDNA versions of the LC and HC genes for Antibody 1 (for example, a DNA sequence of SEQ ID NO:12 encoding a HC of exemplified Antibody 1 presented in Table 1, and a DNA sequence encoding a LC amino acid sequence according to Table 1, for example, a DNA sequence of SEQ ID NO:13 encoding a LC of exemplified Antibody 1 presented in Table 1); and are expressed from a commonly-used and suitable construct for this purpose, such as one based on human

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cytomegalovirus major immediate early promoters. The LC and HC genes are flanked by inverted terminal repeat (ITR) sequences recognized by a transposase enzyme. The parent cell line is co-transfected with the expression plasmid and a transposase mRNA which enables transient expression of the transposase enzyme, to promote stable integration of the Antibody 1 gene expression cassette into the genomic DNA.

The selected bulk culture is subjected to single-cell cloning using Fluorescence-Activated Cell Sorting (FACS) technology. The clonally-derived cell lines are expanded and screened for Antibody 1 production. A clonally-derived cell line is selected and established. This cell line is generated without any animal component-containing materials and used for production.

Clarified medium, into which the antibody is secreted, is applied to a Protein A affinity column that is equilibrated with a compatible buffer, such as phosphate buffered saline (pH 7.4) or 20mM Tris with 150mM sodium chloride (pH 8.0). The column is washed with 1M NaCl to remove nonspecific binding components. Bound antibody is eluted, for example, with sodium citrate at pH (approx.) 3.5 and fractions are neutralized with 1M Tris buffer. Antibody fractions are detected, such as by SDS-PAGE or analytical size-exclusion, and then pooled. Soluble aggregate and multimers may be effectively removed by common techniques, including size exclusion, hydrophobic interaction, ion exchange, or hydroxyapatite chromatography. An exemplified anti-IL-34 antibody of the present invention is concentrated and/or sterile filtered using common techniques. The purity of an exemplified antibody after these chromatography steps is greater than 95%. An exemplified anti-IL-34 antibody of the present invention may be immediately frozen at -70 °C or stored at 4 °C for several months.

Example 2: Characterization of the anti-IL-34 antibodies

Binding Affinity to Human IL-34

Binding affinity of anti-IL-34 monoclonal antibodies of the present invention to human IL-34 including the leader sequence, or mature human IL-34, may be determined by methods known in the art. Except where noted, all reagents and materials may be purchased from Meso Scale Discovery (MSD®), and measurements may be performed at

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37 °C. Human and mouse IL-34 can be made and purified using IMAC and size exclusion chromatography or purchased from commercial suppliers. Human CSF1R Fc fusion protein (Exemplified compound D) is also made, purified by MabSelect™ SuRe™ (GE Healthcare), and further polished by size exclusion chromatography.

5 Briefly, usually a 2-fold or 3-fold dilution series of human, cyno or mouse IL-34 is prepared from a starting concentration of 40, or 50 or 60 or 80 or 100 or 120 nM to 100fM; and each series includes an IL-34 blank control. Samples are prepared in 3% (w/v) Blocker A solution (MSD®, #R93AA-1) and a fixed final concentration of 5-
10 50 pM of each exemplified antibody in Table 1 is added to each sample. An antibody only control is included. A volume of 50 µl of each protein-antibody sample is added to individual wells of a 96-well microtiter plate (Greiner, EK-20101). The plate is sealed with optical adhesive film (Thermo Fisher Scientific, #4311971) and incubated at 37 °C for 1-3 days to allow for sample equilibrium. On the day before analysis, each row of a 96-well MSD® Standard plate (MSD®, #L15XA) is coated with 30 µl of the corresponding
15 IL-34 (as used in the titration series) at a concentration of 1 µg/ml in phosphate buffered saline (PBS). On the day of the experiment, the MSD® Standard plate is washed three times with 150 µl PBST (PBS with 0.05% Tween) and blocked with 150µl of 3% Blocker A solution for 60 min at room temperature with shaking at 300 rpm on a MaxQ 4450 benchtop shaker (Thermo Fisher Scientific). Following three washes with PBST, 50 µl of
20 each protein-antibody sample (prepared and incubated as described above) is added to the MSD® Standard plate and incubated for 150 seconds at 37 °C with shaking at 300 rpm. Following three times wash with PBST, 50 µl of 1 µg/ml SULFO-TAG labeled detection antibody prepared in 1% (w/v) Blocker A solution is added to the MSD® Standard plate and the plate is incubated at 37 °C for 150 seconds with shaking at 300 rpm. The plate is
25 washed three more times with PBST followed by the addition of 150 µl/well of 1X Read buffer (MSD®, #R92TC-2). The MSD® Standard plate is read using a MESO Quickplex SQ 120/1300 instrument (Meso Scale Discovery). Data analysis is done using GraphPad Prism 8 (Version 8.0.0 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com) and binding affinity (K_D) is determined using GraphPad Prism 8's

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integrated Four Parameter Logistic Curve Model. Results are provided in Table 2, 3 and 4.

Table 2: Binding affinity (K_D) of antibody-human IL-34 complexes at 37°C

Antibody	Binding Affinity, K_D (pM, 37 °C, Mean $\pm$ STDEV, n = 5)
	Antigen (mature Human IL-34)
Exemplified Antibody 1	59 $\pm$ 7
Exemplified Antibody 2	54 $\pm$ 7
Exemplified compound D (hCSF1R-Fc)	56 $\pm$ 12

5 **Table 3: Binding affinity (K_D) of antibody-cyno IL-34 complexes at 37°C**

Antibody	Binding Affinity, K_D (pM, 37 °C, Mean $\pm$ STDEV, n = 5)
	Antigen (Cyno IL-34)
Exemplified Antibody 1	108 $\pm$ 25
Exemplified Antibody 2	152 $\pm$ 31

Table 4: Binding affinity (K_D) of antibody-mouse IL34 complexes at 37°C

Antibody	Binding Affinity, K_D (pM, 37 °C)
	Antigen (Mouse IL-34)
Exemplified Antibody 3	16

10

IL-34 binds to human CSF1R at approximately 50-100 pM affinity, necessitating a high-affinity antibody for effective neutralization of this cytokine in the CNS. Blocking IL-34 is believed to provide a useful means for disease modification while avoiding safety concerns associated with some existing immunomodulatory therapies. Therefore, neutralizing IL-34-mediated signaling represents a therapeutic approach for the management of neuroinflammation, microgliosis and neurodegenerative diseases, such as Alzheimer's Disease and other tauopathies and inflammatory diseases.

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The results in Tables 2, 3, and 4 show that Antibodies 1, 2, and 3 possess high affinity for IL-34, and in particular, Antibody 1 and Antibody 2 show affinity for human IL-34 comparable to hCSF1R-Fc. Therefore, the Antibodies of the present invention possess binding properties that enable them to effectively neutralize IL-34 *in vivo*.

5

Physicochemical attributes:

With respect to therapeutic antibody product attributes, including Chemical Stability, Photostability, 3X Slow Freeze/Thaw, Solubility, Antibody 1 exhibits a desirable combination of physicochemical attributes for use as a human therapeutic agent.

10

Stability sample preparation

To prepare stability samples, the aqueous antibody solution is dialyzed overnight at 4 °C into PBS, or 10 mM histidine/280 mM mannitol, pH 6 (H6M) or 10mM histidine/150 mM NaCl, pH 6 (H6N), or 10 mM histidine/17% sucrose, pH 6.0 (H6S). Polysorbate-80 is added to final stability sample at 0.05% ("T") when required. The formulated Antibody 1 is further concentrated to the desired concentration using an Amicon spin concentrator. Abbreviations: 4wk = 4-week; H6MT = 10 mM histidine/280 mM mannitol/0.05% polysorbate, pH 6.0; H6ST = 10 mM histidine/17% sucrose, 0.05% polysorbate, pH 6.0.

15

Chemical stability

Antibody 1 demonstrates an acceptable rating for four weeks (4wk) chemical stability hotspot check at 5 mg/ml in PBS. After four weeks of storage at 35 °C in PBS and compared to time 0 control, Antibody 1 shows 0.26 % aggregate growth, as measured by analytical size exclusion chromatography (aSEC). Hotspots are checked by LC-MS (liquid chromatography-mass spectrometry) peptide mapping. The following degradation/hotspots changes are reported in PBS at 35 °C when compared to 4wk/4 °C sample: isomerization of D104 (0.1%); cleavage of G93/D94/S95 (0.8%). Total change of CDR degradation was 0.9%.

25

High concentration stability temperature hold

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Antibody 1 demonstrates an acceptable rating for the 4wk high concentration stability at 100 mg/ml in H6MT. After 4wk storage at 35 °C and compared to time 0 control, there is 1.0 % aggregate growth, as measured by aSEC, and 0.9% increase in low molecular weight fragments under non-reducing conditions as determined by CE-SDS (capillary electrophoresis sodium dodecyl sulfate). Hotspots are checked by LC-MS peptide mapping. The change of following degradation/hotspots are reported in H6MT after 4wk incubation at 35 °C and compared to the control of 4wk incubation at 5 °C: deamidation of Q91 (0.1%); isomerization of D104 (0.1%); cleavage of G93/D94/S95 (0.5%). Total change of CDR degradation was 0.7%.

Solubility

Antibody 1 demonstrates an acceptable rating based on solubility assessment. The antibody achieves 150 mg/ml in both H6M and H6N formulations with no visible precipitation or phase separation observed after 3 days of storage at 5° C followed by one week of storage at -5 °C.

Photostability

Antibody 1 demonstrates an acceptable rating for photostability. Antibody in H6MT at 100 mg/ml is exposed to UV/VIS light (20% ICH guidelines) and compared to dark control sample. Chemical degradation is assessed by LC-MS peptide mapping. Total change in CDR hotspots analysis is 0.1%. Growth of cleavage was observed at residues G93/D94/S95 of light chain was 0.1%. Upon exposure to UV/VIS, the aggregate growth is 3.6 % as determined by aSEC.

High concentration slow freeze/thaw stability

Physical stability of Antibody 1 is assessed in slow freeze-thaw and demonstrates an acceptable rating when formulated in H6ST. After 3X slow freeze-thaw cycles in a shelf lyophilizer (VirTis SP Scientific), Antibody 1 shows 0.1% aggregate increase in H6ST determined by aSEC when compared to time 0 control.

Example 3: *In vitro* functional characterization of the anti-human IL-34 antibodies**Neutralization of IL-34 *in vitro***

Antibodies of the present invention are tested for the ability to neutralize IL-34
5 binding and/or activity. Neutralization of IL-34 binding and/or activity by antibodies of
the present invention may be assessed by one or more IL-34/CSF1R receptor binding
assay formats, as well as IL-34 cell-based activity assays, for example, as described
below.

Screening for neutralizing antibodies of IL-34/ CSF1R binding may initially be
10 done through an enzymatic assay. Such assays can use recombinantly expressed CSF1R
extracellular domain proteins capable of binding to IL-34. These proteins can be bound to
an ELISA plate in order to capture soluble IL-34. IL-34 can then be detected through
either biotinylation of the antigen and detection via a streptavidin/neutravidin conjugated
peroxidase or phosphatase enzyme. Alternatively, another detection technique may be
15 used, such as an antibody that detects a his-tagged version of IL-34. Such neutralization
assays involve pre-incubation of the antibody being assessed with the labeled IL-34 (for
example, for 1 hour) before addition to the binding assay (as well as control samples in
which no antibody targeting IL-34 is involved). Concentrations of labeled IL-34 near the
50% binding level (EC_{50}) may be used, as well as varying concentrations (for example, in
20 assessing a dose response of the antibody such as from about 100 micromolar down to
about 1 picomolar). Antibody inhibition assessed for a range allows determination of
potency (IC_{50}).

Inhibition of IL-34 induced responses *in vitro*

25 Neutralization of IL-34 activity by antibodies of the present invention may be
assessed by one or more of the IL-34 cell-based assays, for example, as described below.
The ability of antibodies of the present invention to neutralize human IL-34 induced
luciferase reporter activity can be assessed in NIH-3T3 hCSF1R AP1, or 293 hCSF1R
SRE cells, transfected with cDNAs to express human CSF1R, mouse CSF1R or
30 cynomolgus CSF1R (human CSF1R (accession: NP_001275634.1); mouse CSF1R

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(accession: NM_001037859.2) and cyno CSF1R (accession: NC_022277). (The terms “cyno”, “cynomolgus” or “cynomolgus monkey” are used interchangeably, herein.) For example, 293/SRE cells stably overexpressing human CSF1R (hCSF1R) are dissociated in 0.05% trypsin-PBS and plated at 70,000 cells per 100 ml in tissue culture-treated 96 well plates. The following day, growth media is removed, and cells starved with DMEM-F12 (Dulbecco's Modified Eagle Medium: Nutrient Mixture F-12) supplemented with heat-inactivated 1% FBS (fetal bovine serum). 24hr-post starve, cells are treated with 100ng/ml human IL-34 or cyno IL-34 and multiple concentrations of either hCSF1R-Fc or Antibody 1 for 6hr. Following incubation, cells are lysed with 50ul Promega™ Glo™ Lysis Buffer (Promega™ E266A) for 5min with gentle agitation. 50ml of BrightGlo™ luminescence reagent (Promega™ E2620) is added and incubated on lysed cells for 2 min. Luminescence is read on Perkin Elmer Wallac 1420 Victor2™ Microplate Reader. The reduction in relative fluorescence units (RFUs) shown in Table 5, and Figure 1, reflects the ability of Antibody 1 to neutralize IL-34 and reduce luciferase activity. The half maximum inhibitory concentration (IC₅₀) value for Antibody 1 is 385 pM for neutralization of hIL-34 (Figure 1), and 654 pM for cyno IL-34. Human CSF1R-Fc is used as a positive control in this assay and inhibits luciferase activity with an IC₅₀ of 560 pM.

Table 5: Antibody 1 neutralization of human IL-34 induced luciferase reporter activity in hCSF1R expressing 293 SRE cells.

	hCSF1R-Fc		Antibody 1	
Concentration [nM]	Average RLU	Standard deviation	Average RLU	Standard deviation
133	1216	93.3	1180	18.4
26.6	995	153.4	1047.5	202.9
5.32	962	33.2	1117.5	38.9
1.064	2209	292.7	1494	70.7
0.213	7342.5	1282.0	7157.5	557.9
0.043	8472.5	727.6	7993	229.1
0.009	8185	459.6	8377.5	463.2
0.002	8253	365.6	8200.5	526.8
	IC50 [nM]	95% CI [nM]	IC50 [nM]	95% CI [nM]

	0.5598	0.4047 to 0.7743	0.3852	0.3364 to 0.4412
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Table 5 and Figure 1 show that Antibody 1 can effectively neutralize human IL-34 induced luciferase reporter activity in the above 293 hCSF1R cell-based assay (IC₅₀ 0.3852 nM), and demonstrate potency at least comparable to or better than hCSF1R-Fc in this assay. These data support the ability of Antibody 1 to neutralize human IL-34 mediated signaling and treat diseases in which IL-34 mediated signaling contributes to etiopathogenesis.

Ability of Antibody 1 to neutralize the dimerization of the CSF1R in the PathHunter® eXpress Dimerization Assay:

Human IL-34 neutralization can further be assessed by plating U2OS CSF1R/CSF1R cells (Path Hunter® eXpress Dimerization Assay, DiscoverX) in 96-well plates to assess the ability of anti-IL-34 antibodies to inhibit the dimerization of CSF1R. These assays utilize Enzyme Fragment Complementation (EFC) technology, where the b-galactosidase (b-gal) enzyme is split into two fragments, ProLink (PK) and Enzyme Acceptor (EA). Independently these fragments have no b-gal activity; however, when forced to complement through protein-protein interactions, they form an active b-gal enzyme. The PathHunter® eXpress Dimerization assay detects ligand-induced dimerization of two subunits of the CSF1R receptor-dimer pair. The cells have been engineered to co-express one CSF1R receptor subunit fused to Enzyme Donor (ED), and a second CSF1R dimer partner fused to Enzyme Acceptor (EA). Binding of human IL-34 to one receptor subunit induces it to interact with its dimer partner, forcing complementation of the two enzyme fragments. This results in the formation of a functional enzyme that hydrolyzes a substrate to generate a chemiluminescent signal. The reduction in relative fluorescence units (RFUs) shown in Table 6, and/or Figure 2, reflects the ability of Antibody 1 to neutralize human IL-34 and reduce chemiluminescence. The half maximum inhibitory concentration (IC₅₀) value for Antibody 1 is 226 pM. Human CSF1R-Fc is used as a positive control in this assay and inhibits luciferase activity with an IC₅₀ of 353 pM. The data in Table 6 and Figure 2 support the ability of the Antibody 1 to block the interaction of human IL-34 with CSF1R, thereby inhibiting the dimerization

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of CSF1R in this assay. This data supports the use of the antibodies of the present invention to neutralize human IL-34.

Table 6: Ability of Antibody 1 to neutralize the dimerization of the CSF1R in the PathHunter® eXpress Dimerization Assay.

hCSF1R-Fc			Antibody 1		
Con [nM]	Avg RLU	Stdev	Con [nM]	Avg RLU	Stdev
0.012	99405	5235.4	0.014	96495.5	3039.8
0.037	99090	1195.0	0.043	94760	1656.0
0.112	85642.5	832.3	0.128	81315.5	4488.0
0.335	68380	427.1	0.384	44394	91.9
1.004	40124	2375.9	1.151	29459.5	9280.7
3.011	29109	2643.2	3.453	27611.5	5296.9
9.033	26071.5	1119.4	10.360	28085.5	1103.8
27.100	34622.5	10704.9	31.080	27261	916.4
81.301	27529.5	3655.0	93.240	28438	1299.7
243.902	32958	973.0	279.720	29827	319.6
IC50 [nM] 95% CI [nM] 0.2595 to 0.4629			IC50 [nM] 95% CI [nM] 0.1936 to 0.2630		

Ability of anti-IL-34 Antibodies to inhibit ERK phosphorylation in NIH-3T3/CSF1R cells.

Alternatively, IL-34 neutralization can be determined by plating NIH-3T3/CSF1R cells in 96 well plates to assess the ability of anti-IL-34 antibodies to inhibit extracellular-

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signal-regulated kinase (ERK) phosphorylation. In this assay, cells are plated on day 1 in DMEM supplemented with 10% FBS and incubated overnight at 37°C. On day 2, medium is removed, cells are washed in serum-free DMEM and incubated for an additional 24-hour period in serum-free DMEM. On the third day, medium is removed and 1 µg/ml IL-34 is added to the cells for 5 minutes in the presence or absence of anti-IL-34 antibody. Phospho/Total ERK 1/2 is assessed by the Whole Cell Lysate Kit (Meso Scale Discovery, cat#K15107D-3). The reduction in relative fluorescence units (RLUs) shown in Table 7 and/or Figure 3 reflects the ability of Antibody 3 to neutralize IL-34 and reduce chemiluminescence. The half maximum inhibitory concentration (IC₅₀) value for Antibody 3 is 16 nM. Human CSF1R-Fc was used as a positive control in this assay and inhibited luciferase activity with an IC₅₀ of 63 nM.

Table 7: Ability of Antibody 3 to inhibit ERK phosphorylation in NIH-3T3/CSF1R cells.

CSF1R			Antibody 3		
Conc(nM)	RLU	Stdev	Conc(nM)	RLU	Stdev
0	0.20982427	0.00490388	0	0.20982427	0.00490388
0.19	0.22678655	0.00463113	0.21	0.21266665	0.01065081
1	0.22612366	0.00094345	1.067	0.21877016	0.01222609
4.87	0.1696282	0.01027709	5.33	0.16963485	0.01577903
24.37	0.13803397	0.01444251	26.27	0.11909114	0.00324742
121.84	0.08925054	0.0052968	133.33	0.07254438	0.00527854
609.19	0.03167946	0.00344925	666.67	0.05997649	0.01118308
	IC₅₀(nM)	63.2		IC₅₀(nM)	15.7

15 Ability of anti-IL34 antibodies to inhibit IL-34 induced expression of CD163 in human monocytes by flow cytometry:

IL-34 neutralization can also be assessed by measuring the expression of the cell surface antigen CD163 in human monocytes after treatment with IL-34 by flow cytometry (See for example, Boulakirba, S., *et al. IL-34 and CSF-1 display an equivalent*

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macrophage differentiation ability but a different polarization potential. Sci Rep **8**, 256 (2018). CD14-positive monocytes are treated with IL-34 for 72 hrs and CD163 expression is assessed by flow cytometry after staining with antibodies for CD163. In the experiments described in Figure 4, a right shift in the number of cells expressing CD163 indicates that IL-34 treatment increases the expression of this antigen in monocytes. The increase in CD163 expression is inhibited by the addition of Antibody 3. An isotype matched IgG4 antibody is used as a negative control in this experiment.

The inhibition by Antibody 3 of CD163 expression in human monocytes, in response to IL-34, demonstrates the ability of the antibodies of the present invention to modulate monocyte/macrophage number and/or phenotypic differentiation responses to IL-34, and supports the use of the present antibodies to treat immune-mediated diseases, such as neuroinflammation and other inflammatory conditions (See, e.g., Lelios, I. et al. *Emerging roles of IL-34 in health and disease*, J Exp Med (2020) 217 (3): e20190290).

15 **Example 4: *In vivo* functional characterization of the anti-IL-34 antibodies**

Ability of Antibody 3 to reduce microglial cell number in dorsal cortex and hippocampus of mice

The ability of anti-IL-34 antibodies of the present invention to reduce microglial cell number is examined using a mouse model. Briefly, FBV female mice (Envigo, 6-8 weeks old) are administered a subcutaneous dose of 50 mg/kg of an Antibody 3, or an isotype matched IgG control antibody. At different times post antibody administration (1, 3, 7 and 14 days), animals are euthanized with CO₂ and the brain is perfused with saline. Following perfusion, brain tissue is collected, dorsal cortex and hippocampus are dissected under a microscope and flash frozen in liquid nitrogen. mRNA is prepared from dorsal cortex and hippocampus and used to assess the impact of anti-IL34 antibody or control antibody treatment on the expression of microglia markers Iba-1 and CD11b by TaqMan. Changes in mRNA expression are normalized versus an internal GAPDH mRNA control and presented as FOLD changes. Expression of Iba-1 and CD11b mRNA is routinely used as a surrogate marker for microglial cell number, and reduction in the

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expression of these markers is commonly accepted to reflect a reduction in brain microglia. Expression of mRNAs for two of the receptors for IL-34, CSF1R and PTP zeta, and both CSF1R ligands (IL-34 and CSF-1), are also assessed following administration of Antibody 3. Results are provided in Table 8 (A-Hippocampus, and B-
5 Cortex):

Table 8: Effect of Antibody 3 on mRNA expression of microglia markers

8A Hippocampus								
	1 Day		3 Days		7 Days		14 days	
	FOLD	SEM	FOLD	SEM	FOLD	SEM	FOLD	SEM
Iba1	1.16	0.15	0.91	0.06	0.50	0.02	0.74	0.04
CD11b	0.85	0.06	0.49	0.03	0.74	0.03	0.64	0.04
CSF-1R	1.01	0.06	0.78	0.04	0.52	0.02	0.79	0.04
PTPRz	1.01	0.00	0.98	0.00	1.00	0.00	1.00	0.00
CSF-1	1.01	0.03	0.79	0.05	1.11	0.05	1.03	0.05
IL-34	1.01	0.00	0.99	0.00	0.99	0.00	0.98	0.00

8B Cortex								
	1 Day		3 Days		7 Days		14 days	
	FOLD	SEM	FOLD	SEM	FOLD	SEM	FOLD	SEM
Iba1	1.09	0.06	0.67	0.04	0.82	0.03	0.88	0.04
CD11b	0.99	0.08	0.69	0.05	0.59	0.02	0.70	0.06
CSF1R	0.97	0.02	0.59	0.03	0.79	0.02	0.80	0.03
PTPRz	1.01	0.00	0.98	0.00	1.00	0.00	1.00	0.00
CSF1	1.22	0.10	1.02	0.06	0.69	0.04	0.90	0.07
IL34	1.01	0.00	0.99	0.00	0.99	0.00	0.98	0.00

10 **Ability of Antibody 3 to reduce microglial cell number in a mouse model of Alzheimer's Disease (Tg4510 mouse):**

The ability of anti-IL-34 antibodies of the present invention to reduce microglial cell number in a mouse model of Alzheimer's Disease (Tg4510 mouse) is also examined. The Tg4510 mouse is a model of tauopathy characterized by the overexpression of the
15 P301L mutant form of human Tau in the forebrain. These mice are used for studying the formation of neurofibrillary tangles as a model for Alzheimer's disease, neurodegenerative tauopathies and frontotemporal dementia, and they exhibit an age-

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dependent and region-specific progression of neuropathology associated with cognitive impairment. Briefly, 8-week-old female Tg4510 mice are administered biweekly doses of 5, 15 and 50 mg/kg of an anti-IL-34 antibody, or an isotype-matched IgG control, for 9 consecutive weeks. At the end of the dosing period, animals are euthanized and perfused with PBS. Following perfusion, brain tissue is collected and both hemispheres are separated via a midsagittal section and from each hemisphere, dorsal cortex and hippocampus are dissected under a microscope and flash frozen in liquid nitrogen. To assess the effect of anti-IL-34 antibodies on the expression of microglia markers, mRNA is prepared from hippocampus, and the expression of CD11b, Iba-1, and CSF1R are analyzed by real time PCR, as shown in Table 9 for hippocampus.

Table 9: Effect of Antibody 3 on the expression of microglia markers (mRNA from hippocampus, CD11b, Iba-1, and CSF1R, analyzed by real time PCR)

	CD11b		Iba1		CSF1R	
	FOLD	SEM	FOLD	SEM	FOLD	SEM
Control	1.00	0.03	1.00	0.07	1.00	0.07
Antibody 3, 5mpk	0.87	0.02	0.89	0.04	0.76	0.03
Antibody 3, 15mpk	0.61	0.02	0.78	0.03	0.63	0.03
Antibody 3, 50mpk	0.36	0.01	0.65	0.02	0.45	0.02

15 Ability of anti-IL34 antibodies to reduce phosphorylated Tau in Tg4510 mice:

To assess whether anti-IL-34 antibodies can reduce phospho-Tau, one of the pathological forms of Tau associated with Alzheimer's Disease, protein lysates are prepared from the cortex of animals treated with anti-IL-34 antibody or IgG control antibody. Briefly, anti-phospho Tau antibodies (AT8) are used to coat the wells of a 96-well plate and incubated for 24 hrs at 4°C. The following day, plates are washed with 0.05% Tween/PBS, blocked with SynBlock™ buffer (ImmunoChemistry Technology) and incubated with cortex lysates for 24 hrs at 4 °C followed by the addition of a biotinylated Tau detection antibody (CP27) and streptavidin-horseradish peroxidase

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conjugate. As shown in Table 9, treatment with anti-IL-34 antibodies reduced phosphorylated Tau in the cortex of Tg4510 mice.

Table 9: FDT248: AT8 Tau ELISA P1 Cortex (µg/mg protein)

	mIgG1 Control 50 mg/kg	Antibody 3, 50 mg/kg	Antibody 3, 15 mg/kg	Antibody 3, 5 mg/kg
Number of Values	18	17	18	18
Mean	997.4	492.6	531.1	890.8
Standard Deviation	645.4	281.7	604.1	539.5
Standard Error of the mean	152.1	68.3	142.4	127.2
percent change from control		-51%	-17%	-11%

Listing of Amino Acid and Nucleotide Sequences

Heavy Chain of Antibody 1 (SEQ ID NO: 1)

EVQLLESGGGLVQPGGSLRLSCAASGFTFSSYATSWVRQAPGKGLEWVSAISHSG
 5 RSTYYADSVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDTWGQ
 GTLVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTS
 GVHTFPAVLQSSGLYSLSSVVTVPSSSLGTQTYTCNV DHKPSNTKVDKR VESKYG
 PPCPPCPAPEAAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWY
 VDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSI
 10 EKTISKAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQP
 ENNYKTTTPVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSL
 SLSLG

Light Chain of Antibody 1; LC of Antibody 2 (SEQ ID NO: 2)

15 EIVLTQSPGTLSPGERATLSCRASQSISSAYLAWYQQKPGQAPRLLIYASSIRPT
 GIPDRFSGSGSGTDFTLTISP LEPEDFAVYYCSQYGDSL SFGGGTKVEIKRTVAAPS
 VFIFPPSDEQLKSGTASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDS
 KDSTYSLSSLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNRGEC

20 HCVR of Antibody 1 (SEQ ID NO: 3)

EVQLLESGGGLVQPGGSLRLSCAASGFTFSSYATSWVRQAPGKGLEWVSAISHSG
 RSTYYADSVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDTWGQ
 GTLVTVSS

25 LCVR of Antibody 1; LCVR of Antibody 2 (SEQ ID NO: 4)

EIVLTQSPGTLSPGERATLSCRASQSISSAYLAWYQQKPGQAPRLLIYASSIRPT
 GIPDRFSGSGSGTDFTLTISP LEPEDFAVYYCSQYGDSL SFGGGTKVEIK

HCDR1 of Antibody 1 (SEQ ID NO: 5)

30 AASGFTFSSYATS

HCDR2 of Antibody 1 (SEQ ID NO: 6)

AISHSGRSTYYADSVKG

35 HCDR3 of Antibody 1 (SEQ ID NO: 7)

ARGRSSLD

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LCDR1 of Antibody 1 and Antibody 2 (SEQ ID NO: 8)

RASQSISSAYLA

LCDR2 of Antibody 1 and Antibody 2 (SEQ ID NO: 9)

5 YASSIRPT

LCDR3 of Antibody 1 and Antibody 2 (SEQ ID NO: 10)

SQYGDLSL

10 DNA Encoding the Heavy Chain of Antibody 1 (SEQ ID NO: 11)

gaagttcaattgctggagtcagggggaggattgggtccaacccggcggatcccttcggctgtcatgtgctgcttctggatttaccttc
tctagctacgctacctcctgggtaagacaggccccaggttaaggggctggagtgggtgtcagcaataagtcactccgggcgatct
acatattatgctgattccgtcaaggacgtttcactataagccgggataatagcaagaacactctgtatctgcaaatgaactctcttc
gggcagaggacaccgctgtttactattgcgctcggggtcgaagctccctcgacacatgggggcagggtacattggtcaccgtat
15 cctcagcctccaccaaggggcccatcggtcttccgctagcgccctgctccaggagcacctccgagagcacagccgcctggg
ctgcctgggtcaaggactacttccccgaaccgggtgacgggtgctgtggaactcaggcgccctgaccagcggtgcacaccttc
cggctgtctctacagtcctcaggactctactccctcagcagcgtgggtgacctgacctccagcagcttgggcacgaagacctaca
cctgcaacgtagatcacaagcccagcaacaccaaggtggacaagagagttgagtcacaatatggtccccatgccaccctgc
ccagcacctgaggccgcccggggaccatcagttcttctgttcccccaaaaccaaggacactctcatgtctccggaccttc
20 gaggtcacgtgcgtgggtggacgtgagccaggaagaccccaggtccagttcaactgggtacgtggatggcgtggaggtgc
ataatgccaaagacaaagccgcccggaggagcagttcaacagcagctaccgtgtgtgcagcgtcctaccgtctgaccaggga
ctggctgaacggcaaggagtacaagtgcaaggtctccaacaaggcctcccgtcctccatcgagaaaaccatctccaaagcca
aagggcagccccgagagccacaggtgtacacctgcccccatccaggaggagatgaccaagaaccaggtcagctgacct
gcctgggtcaaaggcttctaccccagcgacatcgccgtggagtgggaaagcaatgggcagccggagaaactacaagaccac
25 gcctcccgtgctggactccgacggtccttcttctctacagcaggctaacctggacaagagcaggtggcaggagggggaatg
tcttctcatgctccgtgatgcatgaggctctgcacaaccactacacacagaagagcctctccctgtctctgggt

DNA Encoding the Light Chain of Antibody 1 (SEQ ID NO: 12)

gaaatgctactgacccaaagcccagggactttgagttgtcccttggggaaagagcaaccctctcatgtcgtgcaagtcaaagta
30 tatccagtgcatacttcttggtatcagcaaaagcctgggtcaagcaccaaggctgcttattatgcctcatctattagacctacaggt
atccctgaccgattctccggaagtggcagtgaggactgatttcacacttacaatttccccctggaacctgaagactttgccgtatatt
attgttcacagtatggcgactcacttagtttcggggcgggcacaagggtgaaataaagcgactgtggctgcaccatctgtcttc
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gtacagtggaagggtgataacgccctccaatcggttaactcccaggagagtgacagagcaggacagcaaggacagcacct
35 acagcctcagcagaccctgacgctgagcaaaagcagactacgagaacacaaagtctacgcctgcgaagtcacccatcaggg
cctgagctcggccgtcacaagagcttcaacaggggagagtgct

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Heavy Chain of Antibody 2 (SEQ ID NO:13)

EVQLLESGGGLVQPGGSLRLSCAASGFTFFSYAHSWVRQAPGKGLEWVSAISHS
GRSTYYADAVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDTWG
QGT LVT VSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALT
5 SGVHTFPAVLQSSGLYSLSSVTVPSSSLGKTYTCNV DHKPSNTKVDKRVESKY
GPPCPPCPAPEAAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNW
YVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPS
SIEKTISKAKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQ
PENNYKTTTPVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSV MHEALHNHYTQKS
10 LSLSLG

HCVR of Antibody 2 (SEQ ID NO: 14)

EVQLLESGGGLVQPGGSLRLSCAASGFTFFSYAHSWVRQAPGKGLEWVSAISHS
GRSTYYADAVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDTWG
15 QGT LVT VSS

HCDR1 of Antibody 2 (SEQ ID NO: 15)

AASGFTFFSYAHS

HCDR2 of Antibody 2 (SEQ ID NO: 16)

AISHSGRSTYYADAVKG

HCDR3 of Antibody 2 (SEQ ID NO: 17)

ARGRSSLDT

25

DNA Encoding the Heavy Chain of Antibody 2 (SEQ ID NO: 18)

gaagttcaattgctggagtcagggggaggattgggtccaaccggcgccgatccctcggctgtcatgtgctgcttctggatttaccttc
ttcagctacgctcattcctgggtaagacaggccccaggtgaaggggctggagtggtgtcagcaataagtcactccggcgatct
acatattatgctgatgctgtcaaaaggacgtttcactataagccgggataatagcaagaacactctgtatctgcaaatgaactctcttc
30 gggcagaggacaccgctgtttactattgcgctcgggggtcgaagtcctcgacacatgggggcagggtacattggtcaccgtat
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cctgcaacgtagatcacaagcccagcaacaccaaggtggacaagagagttgagtcacaatatggtcccccatgccaccctgc
35 ccagcacctgaggcgccgggggaccatcagttctctgttcccccaaaacccaaggacactctcatgatctccggaccttc
gaggtcacgtgcgtggtggtggacgtgagccaggaagaccccgaggtccagttcaactggtacgtggatggcgtggaggtgc
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ctggctgaacggcaaggagtacaagtgaaggtctccaacaagccctccgtcctccatcgagaaaaccatctccaagcca
aagggcagccccgagagccacaggtgtacacctgcccccatccaggaggagatgaccaagaaccaggtcagcctgacct

- 44 -

gcctggtaaaggcttctacccagcgacatcgccgtggagtgggaaagcaatgggcagccggagaacaactacaagaccac
gcctcccgtgctggactccgacggctccttctctctacagcaggctaaccgtggacaagagcaggtggcaggagggaatg
tcttctcatgctccgtgatgcatgaggctctgcacaaccactacacacagaagagcctcctctctctgggt

5 **Heavy Chain of Antibody 3 (SEQ ID NO: 19)**

EVQLLESGGGLVQPGGSLRLSCAASGFTFSYYAMSWVRQAPGKGLEWVSAISHR
GGSTLYADSVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDGWG
QGTMTVTVSSAKTTPPSVYPLAPGSAAQTNSMVTLGCLVKGYFPEPVTVTWNSGS
LSSGVHTFPAVLQSDLYTLSSSVTVPSSTWPSETVTCNVAHPASSTKVDKKIVPRD
10 CGCKPCICTVPEVSSVFIFPPKPKDVLITITLTPKVTCTVVDISKDDPEVQFSWFVDD
VEVHTAQTQPREEQFNSTFRSVSELPIMHQDWLNGKEFKCRVNSAAFPAPIEKTIS
KTKGRPKAPQVYTIPPPKEQMAKDKVSLTCMITDFFPEDITVEWQWNGQPAENY
KNTQPIMDTDGSYFVYSKLVQKSNWEAGNTFTCSVLHEGLHNHHTTEKSLSHSP
GK

15

Light Chain of Antibody 3 (SEQ ID NO: 20)

EIVLTQSPGILSLSPGERASLSCRASTSVSSAYLAWYQQKPGQAPRLLIYASSHRPL
GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYGDSL SFGGGTKVEIKRADAAP
TVSIFPPSSEQLTSGGASVVCFLNFPYKPDINVKWKIDGSERQNGVLNSWTDQDS
20 KDSTYSMSSTLTTLTKDEYERHNSYTCEATHKTSTSPIVKSFNRNEC

HCVR of Antibody 3 (SEQ ID NO: 21)

EVQLLESGGGLVQPGGSLRLSCAASGFTFSYYAMSWVRQAPGKGLEWVSAISHR
GGSTLYADSVKGRFTISRDN SKNTLYLQMNSLRAEDTAVYYCARGRSSLDGWG
25 QGTMTVTVSSAKTTPPSVYPLAPGSAAQTNSMVTLGCLVKGYFPEPVTVTWNSGS
LSSGVHTFPAVLQSDLYTLSSSVTVPSSTWPSETVTCNVAHPASSTKVDKKIVPRD
CGCKPCICTVPEVSSVFIFPPKPKDVLITITLTPKVTCTVVDISKDDPEVQFSWFVDD
VEVHTAQTQPREEQFNSTFRSVSELPIMHQDWLNGKEFKCRVNSAAFPAPIEKTIS
KTKGRPKAPQVYTIPPPKEQMAKDKVSLTCMITDFFPEDITVEWQWNGQPAENY
30 KNTQPIMDTDGSYFVYSKLVQKSNWEAGNTFTCSVLHEGLHNHHTTEKSLSHSP
GK

LCVR of Antibody 3 (SEQ ID NO: 22)

EIVLTQSPGILSLSPGERASLSCRASTSVSSAYLAWYQQKPGQAPRLLIYASSHRPL
35 GIPDRFSGSGSGTDFTLTISRLEPEDFAVYYCQQYGDSL SFGGGTKVEIKRADAAP
TVSIFPPSSEQLTSGGASVVCFLNFPYKPDINVKWKIDGSERQNGVLNSWTDQDS
KDSTYSMSSTLTTLTKDEYERHNSYTCEATHKTSTSPIVKSFNRNEC

HCDR1 of Antibody 3 (SEQ ID NO: 23)

40 AASGFTFSYYAMS

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HCDR2 of Antibody 3 (SEQ ID NO: 24)

AISHRGGSTLYADSVKG

5 **HCDR3 of Antibody 3 (SEQ ID NO: 25)**

ARGRSSLDG

LCDR1 of Antibody 3 (SEQ ID NO: 26)

RASTSVSSAYLA

10

LCDR2 of Antibody 3 (SEQ ID NO: 27)

YASSHRPL

LCDR3 of Antibody 3 (SEQ ID NO: 28)

15 QQYGDSLS

DNA Encoding the Heavy Chain of Antibody 3 (SEQ ID NO:29)

gaagtccaactcttggagagcgggtggaggtctggttcagcctggcggttcactgcccgttagctgtgccgctagtggcttcacttt
cagttattatgccatgtctctgggtacgccaggccccaggcaagggtctggaatgggtgtctgccattcccacagggggcggtc
20 acattgtacgctgacagtgttaaaggacgggttactataagcagggataaactcaaaaaacacattgtatctccagatgaactcctg
cgggcagaagacaccgctgtgtattattgtgctcggggctcgctcctccctcgatggctgggggcaagggaacctgggtcactgta
agctccgcaaaaacgacacccccatctgtctatccgctcgcacctggatctgccgccagaccaacagcatgggtgacctggg
ctgtctggtgaagggtacttccctgagcctgtgacagtgcctggaacagcggctctgtctagcggcgtgcacacattccctg
ccgtgctgcagagcgacctgtacacctgagcagcagcgtgacctgacctagcagcacatggcctagcagacctgacatg
25 caacgtggcccaccctgcctcttctaccaaggtggacaagaagatcggtcccagagactgaggctgcaagccttgcacatgcac
cgtgcctgaggtgagcagcgtgtcatcttcccacccaagccaaggacgtgctcaccatcacctcaccccaagggtcacgtg
tgtgtggttagacatcagcaaggatgatccgagggtccagttcagctggtttgtagatgatgtggaggtgcacacagctcagacg
caacccgggaggagcagttcaacagcacttccgctcagtcagtgaaactcccatcgcaccaggactggctcaatggcaag
gagttcaaatgcagggtcaacagtgcagcttccctgccccatcgagaaaacctcctcaaaaacaaaggcagaccgaaggc
30 tccacaggtgtacacattccacctccaaggagcagatggccaaggataaagtcagctgacctgcatgataacagacttctt
cctgaagacattactgtggagtggcagtggaatgggcagccagcggagaactacaagaacactcagcccatcatggacacag
atggctcttactctgtctacagcaagctcaatgtgcagaagagcaactgggaggcaggaaatacttccactgctctgtgttacatg
agggcctgcacaaccaccatactgagaagagcctctcccactctcctgtaaatagtatttaaatgagtttaa

35 **DNA Encoding the Light Chain of Antibody 3 (SEQ ID NO:30)**

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gagatagtagtaccacaaagtccgggtatattgtccctcagccctggcggaacgagccagccttagctgtcgggctccaccagt
 gtgtcaagcgctacttggcctggtaccaaaaaaccaggccaagcgctcgactcctgatatatgcctcctcccaccggccc
 ctggaatcccgacagattttccgggtcaggctcaggtacagattttaccctcactatatcccgactggagcccaggacttcgca
 gtatattactccagcagtatggtgactccctctccttggcggggtactaagggtgaaatcaagcgggctgatgcggcgccca
 5 ctgtatccatcttcccaccatccagtgagcagttaacatctggaggtgctagcgtcgtgtgcttctgaacaacttctacccaaaga
 catcaatgtcaagtgaagattgatggcagtgaaacgacaaaatggcgtcctgaacagttggactgatcaggacagcaaagaca
 gcacctacagcatgagcagcaccctcacgttgaccaaggacgagtatgaacgacataacagctatacctgtgaggccactcac
 aagacatcaactcaccattgtcaagagcttcaacaggaatgagtg

10 **Human IL-34 (SEQ ID NO: 41)**

NEPLEMWPLTQNEECTVTGFLRDKLQYRSRLQYMKHYFPINYKISVPYEGVFRIA
 NVTRLQRAQVSERELRYLWVLVSLSATESVQDVLLEGHPSPWKYLQEVETLLNV
 QQGLTDVEVSPKVESVLSLLNAPGPNLKLVRPKALLDNCFRVMELLYCSCCKQS
 SVLNWQDCEVPSPQSCSPEPSLQYAATQLYPPPPWSPSSPPHSTGSRVPVRAQGE

15 GLLP

Murine IL-34 (SEQ ID NO: 42)

NENLEIWTLTQDKECDLTGYLRGKLQYKNRLQYMKHYFPINYRIAPYEGVLRV
 ANITRLQKAHVSERELRYLWVLVSLNATESVMDVLLEGHPSPWKYLQEVQTLLN
 20 VQRSLMDVEIGPHVEAVLSLLSTPGLSLKLVRPKALLDNCFRVMELLYCSCCKQS
 PILKWQDCELPRLHPHSPGSLMQCTATNVYPLSRQTPTSLPGSPSSSHGSLP

IgG4PAA hinge region (SEQ ID NO: 51)

ESKYGPPCPPCP

25

IgG4PAA Fc region (SEQ ID NO: 52)

APEAAGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNWYVDGVEV
 HNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISK
 AKGQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYK
 30 TTPPVLDSDGSFFLYSRLTVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLGLG