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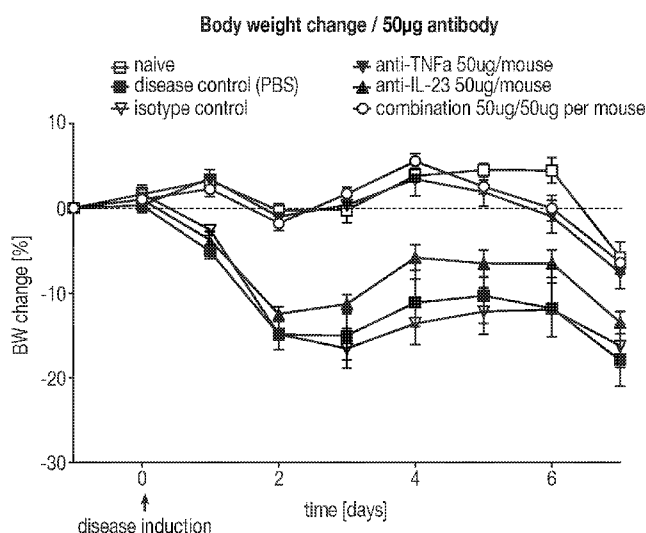


FIG. 1A

(57) Abstract: A method of treating inflammatory bowel disorders, such as ulcerative colitis, comprises administering an IL-23 inhibitor, such as an anti-IL-23p19 antibody (e.g., guselkumab) and a TNF- $\alpha$  inhibitor, such as an anti-TNF- $\alpha$  antibody (e.g., golimumab).



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## **METHOD OF TREATING INFLAMMATORY BOWEL DISEASE WITH A COMBINATION THERAPY OF ANTIBODIES TO IL-23 AND TNF ALPHA**

### **Reference To Sequence Listing Submitted Electronically**

This application contains a sequence listing, which is submitted electronically via EFS-Web as an ASCII formatted sequence listing with a file name “JBI6091WOPCT1SEQLIST.TXT” and a creation date of May 20, 2020 and having a size of 18 kb. The sequence listing submitted via EFS-Web is part of the specification and is herein incorporated by reference in its entirety.

### **Background**

Inflammatory bowel diseases (IBD), including Crohn’s disease (CD) and ulcerative colitis (UC), are characterized by idiopathic intestinal inflammation, disruption of the epithelial barrier, and microbial dysbiosis. While the use of biologic agents, such as anti-TNF $\alpha$  antibody therapies, has revolutionized the clinical management of IBD, many patients do not achieve a clinical response with induction therapy and biologic therapies used as monotherapies have short term remission rates <20%. (2)

The role of IL-23 in promoting intestinal inflammation has been demonstrated in several mouse models where attenuated colitis was exhibited in mice treated with neutralizing anti-IL-23p19 antibodies or in mice with a genetic deletion of the p19 subunit of IL-23. (1, 3-5) Genome-wide association studies (GWAS) have identified polymorphisms in the IL-23 receptor gene (IL23R) associated with both risk and protection for IBD. (6) In patients with moderate to severe Crohn’s disease, two anti-IL-23 agents, risankizumab (BI 655066) and brazikumab (MEDI2070, AMG-139), have recently reported Phase 2 results demonstrating efficacy. While there may be a role for anti-IL-23 therapies in the treatment of IBD, it is anticipated that a population of patients may not fully respond to IL-23 alone as observed with anti-TNF $\alpha$  therapies.

There is a need for improved treatment of IBD, particularly of patients that do not respond to therapies based on either an anti-TNF $\alpha$  antibody or an anti-IL-23 antibody alone.

### **Summary of the Invention**

One aspect of the invention is a method of treating an inflammatory bowel disease in a patient (subject). The method comprises administering a first co-therapeutically effective amount of an IL-23 inhibitor and administering a second co-therapeutically effective amount of a TNF- $\alpha$  inhibitor. The method is effective to treat the inflammatory bowel disease, and the first and second co-therapeutically effective amounts are the same or different.

In some embodiments, the inflammatory bowel disease is ulcerative colitis (UC). In some embodiments, the inflammatory bowel disease is Crohn's disease. In some embodiments, the inflammatory bowel disease is indeterminate colitis. In some embodiments, the subject was previously treated with a TNF- $\alpha$  inhibitor alone and the inflammatory bowel disease did not undergo remission after the previous treatment. In some embodiments, the subject was previously treated with IL-23 inhibitor alone and the inflammatory bowel disease did not undergo remission after the previous treatment.

In various embodiments, the IL-23 inhibitor comprises a pharmaceutical composition of an anti-IL-23p19 antibody (also referred to herein as anti-p19 or anti-IL-23) or an antigen-binding fragment thereof. In various embodiments, the TNF- $\alpha$  inhibitor comprises a pharmaceutical composition of an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof. In some embodiments, the anti-IL-23p19 antibody comprises a human antibody or a humanized antibody. In some embodiments, the anti-TNF- $\alpha$  antibody comprises a human antibody or a humanized antibody.

In some embodiments, the IL-23 inhibitor comprises the guselkumab antibody (also referred to as CNTO1959) (marketed by Janssen Biotech, Inc. as Tremfya®) or an antigen-binding fragment thereof comprising the guselkumab CDR sequences of: (i) the heavy chain CDR amino acid sequences of SEQ ID NO: 1 (CDRH1), SEQ ID NO: 2 (CDRH2), and SEQ ID NO: 3 (CDRH3); and (ii) the light chain CDR amino acid sequences of SEQ ID NO: 4 (CDRL1), SEQ ID NO: 5 (CDRL2), and SEQ ID NO: 6 (CDRL3) at 100 mg/mL; 7.9% (w/v) sucrose, 4.0mM Histidine, 6.9 mM L-Histidine monohydrochloride monohydrate; 0.053% (w/v) Polysorbate 80 of the pharmaceutical composition; wherein the diluent is water at standard state.

Another aspect of the method of the invention comprises administering a pharmaceutical composition comprising an isolated anti-IL-23 specific antibody having the guselkumab heavy chain variable region amino acid sequence of SEQ ID NO: 7 and the guselkumab light chain

variable region amino acid sequence of SEQ ID NO: 8 at 100 mg/mL; 7.9% (w/v) sucrose, 4.0mM Histidine, 6.9 mM L-Histidine monohydrochloride monohydrate; 0.053% (w/v) Polysorbate 80 of the pharmaceutical composition; wherein the diluent is water at standard state.

A further aspect of the method of the invention comprises administering a pharmaceutical composition comprising an isolated anti-IL-23 specific antibody having the guselkumab heavy chain amino acid sequence of SEQ ID NO: 9 and the guselkumab light chain amino acid sequence of SEQ ID NO: 10 at 100 mg/mL; 7.9% (w/v) sucrose, 4.0mM Histidine, 6.9 mM L-Histidine monohydrochloride monohydrate; 0.053% (w/v) Polysorbate 80 of the pharmaceutical composition; wherein the diluent is water at standard state.

The guselkumab sequences are as follows:

| SEQ ID NO: | Description | Sequence   |
|------------|-------------|--|
| 1          | HCDR1       | NYWIG  |
| 2          | HCDR2       | IIDPSNSYTR YSPSFQG   |
| 3          | HCDR3       | WYYKPFDV   |
| 4          | LCDR1       | TGSSSNIGSG YDVH  |
| 5          | LCDR2       | GNSKRPS  |
| 6          | LCDR3       | ASWTDGLSLV V   |
| 7          | VH          | EVQLVQSGAE VKKPGESLKI SCKGSGYSFS NYWIGWVRQM<br>PGKGLEWMGI<br>IDPSNSYTRY SPSFQGQVTI SADKSISTAY LQWSSLKASD<br>TAMYYCARWY<br>YKPFDVWGQG TLVTVSS |
| 8          | VL          | QSVLTQPPSV SGAPGQRVTI SCTGSSSNIG SGYDVHWYQQ<br>LPGTAPKLLI<br>YGNSKRPSGV PDRFSGSKSG TSASLAITGL QSEDEADYYC<br>ASWTDGLSLV<br>VFGGGTKLTV L       |

|    |             |  |
|----|-------------|--|
| 9  | Heavy Chain | EVQLVQSGAE VKKPGESLKI SCKGSGYSFS NYWIGWVRQM<br>PGKGLEWMGI IDPSNSYTRY<br>SPSFQGQVTI SADKSISTAY LQWSSLKASD<br>TAMYYCARWY YKPFDVWGQG TLVTVSSAST<br>KGPSVFPLAP SSKSTSGGTA ALGCLVKDYF PEPVTVSWNS<br>GALTSGVHTF PAVLQSSGLY<br>SLSSVVTVPS SSLGTQTYIC NVNHKPSNTK VDKKVEPKSC<br>DKTHTCPPCP APELLGGPSV<br>FLFPPKPKDT LMISRTPEVT CVVVDVSHED PEVKFNWYVD<br>GVEVHNAKTK PREEQYNSTY<br>RVVSVLTVLH QDWLNGKEYK CKVSNKALPA PIEKTISKAK<br>GQPREPQVYT LPPSRDELTK<br>NQVSLTCLVK GFYPSDIAVE WESNGQPENN YKTTTPVLDS<br>DGSFFLYSKL TVDKSRWQQG<br>NVFSCSVME ALHNHYTQKS LSLSPGK |
| 10 | Light Chain | QSVLTQPPSV SGAPGQRVTI SCTGSSSNIG SGYDVHWYQQ<br>LPGTAPKLLI YGNSKRPSGV<br>PDRFSGSKSG TSASLAITGL QSEDEADYYC ASWTDGLSLV<br>VFGGGTKLTV LGQPKAAPSV<br>TLFPPSSEEL QANKATLVCL ISDFYPGAVT VAWKADSSPV<br>KAGVETTTPS QQSNNKYAAS<br>SYLSLTPEQW KSHRSYSCQV THEGSTVEKT VAPTECS   |

In various embodiments, the TNF- $\alpha$  inhibitor comprises the golimumab antibody (marketed by Janssen Biotech, Inc. as Simponi®) or an antigen-binding fragment thereof comprising the sequences shown in SEQ ID NOS:

**Example anti-TNF- $\alpha$  antibody sequences - SIMPONI® (golimumab)**

CDRs determined by Kabat

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region heavy chain 1 (CDRH1): (SEQ ID NO:11)

SYAMH

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region heavy chain 2 (CDRH2): (SEQ ID NO:12)

FMSYDGSNKKYADSVKG

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region heavy chain 3 (CDRH3): (SEQ ID NO:13)

DRGIAAGGNYYYYGMDV

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region light chain 1 (CDRL1): (SEQ ID NO:14)

RASQSVYSYLA

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region light chain 2 (CDRL2): (SEQ ID NO:15)

DASNRAT

Amino acid sequence of anti-TNF- $\alpha$  antibody complementarity determining region light chain 3 (CDRL3): (SEQ ID NO:16)

QQRSNWPPFT

Amino acid sequence of anti-TNF- $\alpha$  antibody heavy chain variable region (CDRs underlined): (SEQ ID NO:17)

1 QVQLVESGGG VVQPGRSLRL SCAASGFIFS SYAMHWVRQA PGNGLEWVAF MSYDGSNKKY  
 61 ADSVKGRFTI SRDNSKNTLY LQMNSLRAED TAVYYCARDR GIAAGGNYYY YGMDVWGQGT  
 121 TVTVSS

Amino acid sequence of anti-TNF- $\alpha$  antibody light chain variable region (CDRs underlined): (SEQ ID NO:18)

1 EIVLTQSPAT LSLSPGERAT LSCRASQSVY SYLAWYQQKP GQAPRLLIYD ASNRATGIPA  
 61 RFGSGSGGTD FTLTISSLEP EDFAVYYCQQ RSNWPPFTFG PGTKVDIKRT V

Amino acid sequence of anti-TNF- $\alpha$  antibody heavy chain (CDRs underlined): (SEQ ID NO:19)

1 QVQLVESGGG VVQPGRSLRL SCAASGFIFS SYAMHWVRQA PGNGLEWVAF MSYDGSNKKY  
 61 ADSVKGRFTI SRDNSKNTLY LQMNSLRAED TAVYYCARDR GIAAGGNYYY YGMDVWGQGT  
 121 TVTVSSASTK GPSVFPLAPS SKSTSGGTAA LGCLVKDYFP EPVTVSWNSG ALTSGVHTFP  
 181 AVLQSSGLYS LSSVVTVPSS SLGTQTYICN VNHKPSNTKV DKKVEPKSCD KHTTCCPPCPA  
 241 PELLGGPSVF LFPPKPKDTL MISRTPEVTC VVVDVSHEDP EVKFNWYVDG VEVHNAKTKP  
 301 REEQYNSTYR VVSVLTVLHQ DWLNGKEYKC KVSNAKALPAP IEKTISKAKG QPREPQVYTL  
 361 PPSRDELTKN QVSLTCLVKG FYPSDIAVEW ESNGQPENNY KTTTPVLDSD GSFFLYSKLT  
 421 VDKSRWQQGN VFSCSVMHEA LHNHYTQKSL SLSPGK 456

Amino acid sequence of anti-TNF- $\alpha$  antibody light chain (CDRs underlined): (SEQ ID NO:20)

1 EIVLTQSPAT LSLSPGERAT LSCRASQSVY SYLAWYQQKP GQAPRLLIYD ASNRATGIPA  
 61 RFSGSGSGTD FTLTISSLEP EDFAVYYCQQ RSNWPPFTFG PGTKVDIKRT VAAPSVFIFP  
 121 PSDEQLKSGT ASVVCLLNNF YPREAKVQWK VDNALQSGNS QESVTEQDSK DSTYSLSTL  
 181 TLSKADYEKH KVYACEVTHQ GLSSPVTKSF NRGEC

In some embodiments, the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 1:2 to 2:1 (w/w). In some embodiments, the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 15:1 to 400:1 (w/w), or a range of from 2:1 to 14:1.

In some embodiments, the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody are administered simultaneously or on the same day for the initial dose and administration is staggered between the two antibodies by two or more weeks for subsequent doses. In some embodiments, the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody are administered sequentially. In some embodiments, the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody are administered within one day of one another.

In another aspect is provided a method of reducing inflammation of the colon in a subject who has inflammatory bowel disease. The method comprises administering a first co-inflammation reducing effective amount of an anti-IL-23p19 antibody and administering a second co-inflammation reducing effective amount of an anti-TNF $\alpha$  antibody. The method is effective to reduce inflammation of the colon of the subject to a level comparable to the colon of a normal patient. The first and second co-inflammation reducing effective amounts are the same or different.

In some embodiments, the inflammation is very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody. In some embodiments, the gland loss is very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody. In some embodiments, the erosion is very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody. In some embodiments, the mucosal thickness and hyperplasia are independently very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody. In some

embodiments, after administration of the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody, the histopathology of the colon is about identical (or identical) to that of normal tissue.

In another aspect is provided a method of both treating inflammatory bowel disease in a subject and reducing weight loss in the subject. The method comprises: (a) administering a first co-therapeutically and weight loss reducing effective amount of an anti-IL-23p19 antibody or an antigen-binding fragment thereof; and (b) administering a second co-therapeutically and weight loss reducing effective amount of an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof; wherein said first and second co-therapeutically and weight loss reducing effective amount are the same or different.

In another aspect is provided a method of treating inflammatory bowel disease in a human subject. The method comprises: (a) administering 0.0005 to 0.002 mg/kg of an anti-IL-23p19 antibody or an antigen-binding fragment thereof; and (b) administering 0.020 to 0.125 mg/kg of an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof.

In various embodiments, the method is effective to treat the inflammatory bowel disease. In some embodiments, the inflammatory bowel disease is ulcerative colitis. In some embodiments, the inflammatory bowel disease is Crohn's disease. In some embodiments, the inflammatory bowel disease is indeterminate colitis. In some embodiments, the method is effective to inhibit weight loss (e.g., weight loss associated with the inflammatory bowel disease.)

In another aspect is provided a method of preventing inflammation of the colon in a subject who has inflammatory bowel disease, the method comprising: (a) administering a first co-inflammation reducing effective amount of an IL-23 inhibitor; and (b) administering a second co-inflammation reducing effective amount of a TNF- $\alpha$  inhibitor. The method is effective to reduce inflammation of the colon of the subject to a level comparable to the colon of a normal patient. The first and second co-inflammation reducing effective amounts are the same or different.

In one embodiment, guselkumab is administered to UC patients in an initial intravenous dose of 200 mg, intravenous doses of 200 mg at weeks 4 and 8 and subsequent subcutaneous doses of 100 mg every 8 weeks; golimumab is administered in an initial subcutaneous dose of 200 mg and subsequent subcutaneous doses of 100 mg at weeks 2, 6 and 10. The UC patient will be evaluated by Mayo Score to determine clinical response or remission. Clinical response

measured at Week 12 is defined as a decrease from baseline in the Mayo score  $\geq 30\%$  and  $\geq 3$  points with either a decrease in rectal bleeding subscore (RBS)  $\geq 1$  or a RBS of 0 or 1. Clinical remission measured at Week 12 is defined as a Mayo score  $\leq 2$  with no individual subscore  $> 1$ . Additional measures of clinical response are used within the scope of the invention.

### **Brief Description of the Drawings**

Figures 1A and 1B show the results of a body weight loss analysis performed on mice after low dose (FIG. 1A at 50 $\mu$ g) and high dose (FIG. 1B at 500 $\mu$ g) anti-TNF- $\alpha$  and anti-IL-23p19 antibody treatment alone or in combination. Each line represents the group mean with error bars for standard error (n=9 antibody treatment; n=5 PBS control; n=3 naïve control) and is shown as percent change from day -1 (dotted line). Some error bars are within the size of the symbol and are not depicted. Disease was induced by administration of anti-CD40 antibody (BioXCell, Cat. No. BE0016-2, Agonist CD40 Ab clone FGK4.55, lot# 5345/0515).

Figures 2A and 2B show the results of a histopathology study performed on the colon of mice treated with low dose (FIG. 2B at 50 $\mu$ g/mouse) anti-TNF- $\alpha$  and/or anti-IL-23p19 antibody and high dose (FIG. 2B at 500 $\mu$ g/mouse) anti-TNF- $\alpha$  and/or anti-IL-23p19 antibody, respectively. Disease was induced by administration of anti-CD40 antibody.

Figure 3A shows humanized treatment signatures of anti-TNF $\alpha$  or anti-IL-23p19 monotherapy from the anti-CD40 model of murine colitis projected onto the Crohn's Evaluation of Response to Ustekinumab Anti-Interleukin-12/23 for Induction (CERTIFI) human IBD gene expression network. Figure 3A shows the overlap between genes present in the anti-TNF $\alpha$  and anti-IL-23p19 subnetworks as illustrated by a Venn diagram. Figure 3B illustrates the largest connected component of the shared anti-TNF $\alpha$  and anti-IL-23p19 subnetworks.

Figures 4A, 4B, 4C and 4D show the results of a body weight loss analysis performed on female RAG2<sup>-/-</sup> mice dosed ip with isotype control antibody (FIG. 4A), or anti-IL-23p19 antibody (FIG. 4B) at 50, 15, 5, 1.5, 0.5, 0.15 $\mu$ g/mouse, or an anti-TNF $\alpha$  antibody (FIG. 4C) at 150 and 15  $\mu$ g/mouse. Disease was induced by administration of anti-CD40 antibody. As shown in Figure 4D, statistics were generated comparing each group to the isotype control.

Figures 5A, 5B and 5C show the results of a histopathology study performed on the colon of female RAG2<sup>-/-</sup> mice dosed ip with isotype control antibody (FIG. 5A), anti-IL-23p19

antibody at 50, 15, 5, 1.5, 0.5, 0.15 µg/mouse (FIG. 5B), or an anti-TNF $\alpha$  antibody at 150 and 15 µg/mouse (FIG. 5C). Disease was induced by administration of anti-CD40 antibody.

Figures 6A, 6B, 6C and 6D show the results of a body weight loss analysis performed on mice dosed with control antibody (FIG. 6A), 500 µg/mouse anti-TNF $\alpha$  antibody alone (FIG. 6B), 1.5, 5, or 25 µg/mouse anti-IL-23p19 antibody alone (FIG. 6C), or a combination of 500 µg/mouse anti-TNF $\alpha$  antibody with 1.5, 5, or 25 µg/mouse anti-IL-23p19 antibody (FIG. 6D). Disease was induced by administration of anti-CD40 antibody. Figure 6E shows a compilation of the data from the different groups.

Figures 7A, 7B and 7C show the results of a histopathology study performed on the colon of mice dosed with 500 µg/mouse anti-TNF $\alpha$  antibody alone, mouse anti-IL-23p19 antibody alone, or a combination of 500 µg/mouse anti-TNF $\alpha$  antibody with mouse anti-IL-23p19 antibody at an anti-IL23p19 antibody concentration of: 1.5 µg (FIG 7A), 5 µg (FIG. 7B), or 25 µg (FIG. 7C). Disease was induced by administration of anti-CD40 antibody.

Figure 8 shows the results of a network analysis based on humanized colonic gene expression signatures of anti-TNF $\alpha$  (500µg) or high dose anti-IL-23p19 (25µg) monotherapies that were intersected with a gene expression signature from the combination therapy (500µg anti-TNF $\alpha$  with 1.5µg anti-IL-23p19). The analysis was performed to determine whether the molecular response to anti-TNF $\alpha$  and low dose anti-IL-23p19 antibody combination treatment was additive or unique compared with either therapy alone. A unique subnetwork was identified of about 200 genes; the subnetwork was enriched in fibroblasts and extracellular matrix organization, cell types and pathways involved in wound repair and mucosal healing.

## **Detailed Description**

### Definitions:

Unless defined otherwise, technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

As used herein, including the appended claims, the singular forms of words such as “a,” “an,” and “the,” include their corresponding plural references unless the context clearly dictates otherwise.

“About” means within an acceptable error range for the particular value as determined by one of ordinary skill in the art, which will depend in part on how the value is measured or determined, i.e., the limitations of the measurement system. Unless explicitly stated otherwise within the Examples or elsewhere in the Specification in the context of a particular assay, result or embodiment, “about” means within one standard deviation per the practice in the art, or a range of up to 5%, whichever is larger.

“Administration” and “treatment,” as it applies to an animal, human, experimental subject, cell, tissue, organ, or biological fluid, refers to contact of an exogenous pharmaceutical, therapeutic, diagnostic agent, or composition to the animal, human, subject, cell, tissue, organ, or biological fluid. “Administration” and “treatment” can refer, e.g., to therapeutic, pharmacokinetic, diagnostic, research, and experimental methods. Treatment of a cell encompasses contact of a reagent to the cell, as well as contact of a reagent to a fluid, where the fluid is in contact with the cell. “Administration” and “treatment” also means in vitro and ex vivo treatments, e.g., of a cell, by a reagent, diagnostic, binding composition, or by another cell. “Treatment,” as it applies to a human, veterinary, or research subject, refers to therapeutic treatment, prophylactic or preventative measures, to research and diagnostic applications. “Treatment” as it applies to a human, veterinary, or research subject, or cell, tissue, or organ, encompasses contact of an agent with animal subject, a cell, tissue, physiological compartment, or physiological fluid. “Treatment of a cell” also encompasses situations where the agent contacts a target, such as IL-23 receptor, e.g., in the fluid phase or colloidal phase, but also situations where the agonist or antagonist does not contact the cell or the receptor.

“Treat” or “treating” may also refer to administration of a therapeutic agent, such as a composition described herein, internally or externally to a patient in need of the therapeutic agent. Typically, the agent is administered in an amount effective to prevent or alleviate one or more disease symptoms, or one or more adverse effects of treatment with a different therapeutic agent, whether by preventing the development of, inducing the regression of, or inhibiting the progression of such symptom(s) or adverse effect(s) by any clinically measurable degree. The amount of a therapeutic agent that is effective to alleviate any particular disease symptom or adverse effect (also referred to as the “therapeutically effective amount”) may vary according to factors such as the disease state, age, and weight of the patient, the ability of the therapeutic

agent to elicit a desired response in the patient, the overall health of the patient, the method, route and dose of administration, and the severity of side effects.

An “inhibitor,” as used herein, is any agent that reduces the activity of a targeted molecule. Specifically, an antagonist of IL-23 or TNF- $\alpha$  is an agent that reduces the biological activity of IL-23 or TNF- $\alpha$ , for example by blocking binding of IL-23 or TNF- $\alpha$  to its receptor or otherwise reducing its activity (e.g. as measured in a bioassay).

As used herein, an “anti-IL-23 specific antibody,” “anti-IL-23 antibody,” “antibody portion,” or “antibody fragment” and/or “antibody variant” and the like include any protein or peptide containing molecule that comprises at least a portion of an immunoglobulin molecule, such as but not limited to, at least one complementarity determining region (CDR) of a heavy or light chain or a ligand binding portion thereof, a heavy chain or light chain variable region, a heavy chain or light chain constant region, a framework region, or any portion thereof, or at least one portion of an IL-23 receptor or binding protein, which can be incorporated into an antibody of the present invention. Such antibody optionally further affects a specific ligand, such as but not limited to, where such antibody modulates, decreases, increases, antagonizes, agonizes, mitigates, alleviates, blocks, inhibits, abrogates and/or interferes with at least one IL-23 activity or binding, or with IL-23 receptor activity or binding, in vitro, in situ and/or in vivo. As a non-limiting example, a suitable anti-IL-23 antibody, specified portion or variant of the present invention can bind at least one IL-23 molecule, or specified portions, variants or domains thereof. A suitable anti-IL-23 antibody, specified portion, or variant can also optionally affect at least one of IL-23 activity or function, such as but not limited to, RNA, DNA or protein synthesis, IL-23 release, IL-23 receptor signaling, membrane IL-23 cleavage, IL-23 activity, IL-23 production and/or synthesis.

The term “antibody” is further intended to encompass antibodies, digestion fragments, specified portions and variants thereof, including antibody mimetics or comprising portions of antibodies that mimic the structure and/or function of an antibody or specified fragment or portion thereof, including single chain antibodies and fragments thereof. Functional fragments include antigen-binding fragments that bind to a mammalian IL-23. For example, antibody fragments capable of binding to IL-23 or portions thereof, include, but are not limited to, Fab (e.g., by papain digestion), Fab' (e.g., by pepsin digestion and partial reduction) and F(ab')<sub>2</sub> (e.g., by pepsin digestion), facb (e.g., by plasmin digestion), pFc' (e.g., by pepsin or plasmin

digestion), Fd (e.g., by pepsin digestion, partial reduction and reaggregation), Fv or scFv (e.g., by molecular biology techniques) fragments.

Such fragments can be produced by enzymatic cleavage, synthetic or recombinant techniques, as known in the art and/or as described herein. Antibodies can also be produced in a variety of truncated forms using antibody genes in which one or more stop codons have been introduced upstream of the natural stop site. For example, a combination gene encoding a F(ab')<sub>2</sub> heavy chain portion can be designed to include DNA sequences encoding the CH1 domain and/or hinge region of the heavy chain. The various portions of antibodies can be joined together chemically by conventional techniques, or can be prepared as a contiguous protein using genetic engineering techniques.

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

“Human antibody” refers to an antibody having heavy and light chain variable regions in which both the framework and the antigen binding site are derived from sequences of human origin. If the antibody contains a constant region or a portion of the constant region, the constant region also is derived from sequences of human origin.

“Subject” or “patient” as used interchangeably includes any human or nonhuman animal. “Nonhuman animal” includes all vertebrates, e.g., mammals and non-mammals, such as nonhuman primates, sheep, dogs, cats, horses, cows, chickens, amphibians, reptiles, etc.

“Tumor necrosis factor,” “TNF” or “TNF- $\alpha$ ” refers to the well-known human tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ), a multifunctional pro-inflammatory cytokine. TNF- $\alpha$  triggers pro-inflammatory pathways that result in tissue injury, such as degradation of cartilage and bone, induction of adhesion molecules, induction of pro-coagulant activity on vascular endothelial cells, an increase in the adherence of neutrophils and lymphocytes, and stimulation of the release of platelet activating factor from macrophages, neutrophils and vascular endothelial cells.

TNF- $\alpha$  is found as a soluble protein as well as a precursor form called transmembrane TNF- $\alpha$  that is expressed as a cell surface type II polypeptide. Transmembrane TNF- $\alpha$  is processed by metalloproteinases such as TNF- $\alpha$ -converting enzyme (TACE) between residues

Ala76 and Va177, resulting in the release of the soluble form of TNF- $\alpha$  of 157 amino acid residues. Soluble TNF- $\alpha$  is a homotrimer of 17-kDa cleaved monomers. Transmembrane TNF- $\alpha$  also exists as a homotrimer of 26-kD uncleaved monomers.

In a first aspect is provided a method of treating an inflammatory bowel disease in a subject. The method comprises administering a first co-therapeutically effective amount of an IL-23 inhibitor and administering a second co-therapeutically effective amount of a TNF- $\alpha$  inhibitor. The method is effective to treat the inflammatory bowel disease, and the first and second co-therapeutically effective amounts are the same or different.

The combination of an anti-TNF $\alpha$  antibody and an anti-IL-23p19 antibody may provide a systemic impact as well as a local impact on the bowel or colon. The combination may provide a greater systemic impact than by treatment with either anti-TNF $\alpha$  antibody or an anti-IL-23p19 antibody alone. The combination can provide for superior anti-inflammatory activity in treating IBD in a human. An anti-IL-23p19 antibody can be highly efficacious in blocking the development of IBD (e.g., colitis and Crohn's disease), but not in blocking anti-CD40-induced body weight loss, while an anti-TNF $\alpha$  antibody can provide substantial protection against anti-CD40-induced body weight loss with some degree of protection against IBD. Each antibody, and the combination, may provide for a differential effect on local versus systemic inflammation.

Various anti-IL-23 antibodies may be used, such as any of the anti-IL-23 antibodies described in U.S. Patent No. 7,491,391, issued on Feb. 17, 2009, and U.S. Patent Publication No. 2018/0094052, published on April 5, 2018, both of which are incorporated by reference herein.

Various anti-TNF $\alpha$  antibodies may be used. For example, any of the anti-IL-23 antibodies described in U.S. Patent No. 7,250,165, issued on July 31, 2007, and U.S. Patent Publication No. 2017/0218092, published on Aug. 3, 2017, both of which are incorporated by reference herein, may be used.

Various host animals may be used to produce anti-TNF- $\alpha$  antibodies. For example, Balb/c mice may be used to generate mouse anti-human TNF- $\alpha$  antibodies. The antibodies made in Balb/c mice and other non-human animals may be humanized using various technologies to generate more human-like sequences.

Anti-IL-23 antibodies can optionally be characterized by high affinity binding to IL-23 and, optionally, having low toxicity. Anti-TNF $\alpha$  antibodies can optionally be characterized by high affinity binding to TNF $\alpha$  and, optionally, having low toxicity. In particular, an antibody,

specified fragment or variant of the antibody may be used in where the individual components, such as the variable region, constant region and framework, individually and/or collectively, optionally and preferably possess low immunogenicity. Low or acceptable immunogenicity and/or high affinity, as well as other suitable properties, can contribute to the therapeutic results achieved. "Low immunogenicity" is defined herein as raising significant HAHA, HACA or HAMA responses in less than about 75%, or preferably less than about 50% of the patients treated and/or raising low titers in the patient treated (less than about 300, preferably less than about 100 measured with a double antigen enzyme immunoassay) (Elliott et al., *Lancet* 344:1125-1127 (1994), entirely incorporated herein by reference). For the anti-IL-23 antibodies, "low immunogenicity" can also be defined as the incidence of titrable levels of antibodies to the anti-IL-23 antibody in patients treated with anti-IL-23 antibody as occurring in less than 25% of patients treated, preferably, in less than 10% of patients treated with the recommended dose for the recommended course of therapy during the treatment period. For the anti-TNF $\alpha$  antibodies, "low immunogenicity" can also be defined as the incidence of titratable levels of antibodies to the anti-TNF $\alpha$  antibody in patients treated with anti-TNF $\alpha$  antibody as occurring in less than 25% of patients treated, preferably, in less than 10% of patients treated with the recommended dose for the recommended course of therapy during the treatment period.

At least one anti-IL-23 antibody and anti-TNF $\alpha$  used in the methods described herein can be produced by a cell line, a mixed cell line, an immortalized cell or clonal population of immortalized cells, as well known in the art. See, e.g., Ausubel, et al., ed., *Current Protocols in Molecular Biology*, John Wiley & Sons, Inc., NY (1987-2001); Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor, N.Y. (1989); Harlow and Lane, *Antibodies, a Laboratory Manual*, Cold Spring Harbor, N.Y. (1989); Colligan, et al., eds., *Current Protocols in Immunology*, John Wiley & Sons, Inc., NY (1994-2001); Colligan et al., *Current Protocols in Protein Science*, John Wiley & Sons, NY (1997-2001), each entirely incorporated herein by reference herein.

An anti-IL-23 antibody and/or an anti-TNF- $\alpha$  antibody can also be generated by immunization of a transgenic animal (e.g., mouse, rat, hamster, non-human primate, and the like) capable of producing a repertoire of human antibodies, as described herein and/or as known in the art. Cells that produce a human anti-IL-23 antibody can be isolated from such animals and immortalized using suitable methods, such as the methods described herein.

The anti-IL-23 antibodies used in the methods described herein can also be prepared using at least one anti-IL-23 antibody encoding nucleic acid to provide transgenic animals or mammals, such as goats, cows, horses, sheep, rabbits, and the like, that produce such antibodies in their milk. The anti-TNF- $\alpha$  antibodies used in the methods described herein can also be prepared using at least one anti-TNF- $\alpha$  antibody encoding nucleic acid to provide transgenic animals or mammals, such as goats, cows, horses, sheep, rabbits, and the like, that produce such antibodies in their milk. Such animals can be provided using known methods. See, e.g., but not limited to, U.S. Patent Nos. 5,827,690; 5,849,992; 4,873,316; 5,849,992; 5,994,616; 5,565,362; 5,304,489, and the like, each of which is entirely incorporated herein by reference.

The anti-IL-23 antibodies can bind human IL-23 with a wide range of affinities ( $K_D$ ). In a preferred embodiment, a human mAb can optionally bind human IL-23 with high affinity. For example, a human mAb can bind human IL-23 with a  $K_D$  equal to or less than about  $10^{-7}$  M, such as but not limited to, 0.1-9.9 (or any range or value therein)  $\times 10^{-7}$ ,  $10^{-8}$ ,  $10^{-9}$ ,  $10^{-10}$ ,  $10^{-11}$ ,  $10^{-12}$ ,  $10^{-13}$  or any range or value therein.

The anti-TNF- $\alpha$  antibodies can bind human TNF- $\alpha$  with a wide range of affinities ( $K_D$ ). In a preferred embodiment, a human mAb can optionally bind human TNF- $\alpha$  with high affinity. For example, a human mAb can bind human TNF- $\alpha$  with a  $K_D$  equal to or less than about  $10^{-7}$  M, such as but not limited to, 0.1-9.9 (or any range or value therein)  $\times 10^{-7}$ ,  $10^{-8}$ ,  $10^{-9}$ ,  $10^{-10}$ ,  $10^{-11}$ ,  $10^{-12}$ ,  $10^{-13}$  or any range or value therein.

The anti-IL-23 antibodies may be an IgG1, IgG2, IgG3 or IgG4 isotype. The anti-TNF- $\alpha$  antibodies may be an IgG1, IgG2, IgG3 or IgG4 isotype.

Without wishing to be bound by theory, the benefits of combining an anti-IL-23p19 antibody with an anti-TNF $\alpha$  antibody can arise from distinct gene expression changes induced by each antibody. As described in the Example 1 and at least in Figures 2A and 2B, at doses where each antibody provided similar protection against colonic inflammation (Figure 2, 50 $\mu$ g anti-IL-23p19 and 500 $\mu$ g anti-TNF $\alpha$ ), distinct intestinal gene expression changes were observed in mice when blocking IL-23p19 compared to blocking TNF $\alpha$ . These gene expression changes may apply to human disease as well. Integration of 'humanized' murine anti-TNF $\alpha$  and anti-IL-23p19 gene signatures with a human intestinal biopsy gene network can allow for focus only on genes that were expressed and varied in human intestinal tissues. Additional context for the potential molecular impact of each antibody on human IBD can be obtained by generating

treatment subnetworks that included genes one step removed in the network (i.e. strongly correlated) from genes within each signature. Individual anti-TNF $\alpha$  and anti-IL-23p19 subnetworks show unique single antibody gene signatures, allowing for insight into the biology targeted by both mechanisms.

Effectiveness of treatment according to the methods described herein can be determined, for example, by assessing the degree of weight loss, nutrient absorption, and histopathological studies of tissue samples. Histopathological studies can include measurement of one or more of submucosal edema, inflammation, gland loss, erosion, mucosal thickness, and hyperplasia. Submucosal edema can be quantified by measuring thickness from the muscularis mucosa to the internal border of the outer muscle layer (e.g., in a nontangential area thought to best represent the severity of this change). Inflammation scoring can reflect the extent of macrophage, lymphocyte, and neutrophil infiltration into the colon. Gland loss of the crypt epithelium and remaining gland epithelium can be quantitated by assessing the percentage of the mucosa affected. Erosion reflects a loss of surface epithelium and can be scored by assessing the percentage of mucosa that is affected (e.g., by mucosal hemorrhage). Mucosal thickness can be assessed by measuring a non-tangential area of the section that best represents the overall mucosal thickness. Increased thickness reflects gland elongation and mucosal hyperplasia.

An overall histopathology score can be derived from measurements of one or more of submucosal edema, inflammation, gland loss, erosion, mucosal thickness, and hyperplasia. An exemplary scoring system for mice is described in Example 1. A similar system can be used for human and other mammalian subjects.

In some embodiments, the inflammatory bowel disease is colitis, e.g., ulcerative colitis. Colitis can involve irritation, swelling and other signs of inflammation of the colon. Sores and ulcers are present in ulcerative colitis.

In some embodiments, the inflammatory bowel disease is Crohn's disease. Crohn's disease may be confined to the colon, but may also be present in other tissues such as the small intestine. Crohn's disease can involve inflammation of the colon and small intestine. There may even be inflammation of the mouth, anus, skin, eyes, joints, and/or liver.

In some embodiments, the subject was previously treated with a TNF- $\alpha$  inhibitor alone and the inflammatory bowel disease did not undergo remission after the previous treatment. In some embodiments, the subject was previously treated with IL-23 inhibitor alone and the

inflammatory bowel disease did not undergo remission after the previous treatment. The methods described herein may be beneficial for subjects who did not respond to monotherapy treatments with either TNF- $\alpha$  inhibitor (e.g., an anti-TNF- $\alpha$  antibody) or IL-23 inhibitor (e.g., an anti-IL-23p19 antibody). Based on results described herein showing substantial improvement in histopathology of the colon when administering both an anti-TNF- $\alpha$  antibody and an anti-IL-23p19 antibody (as compared to either antibody alone), subjects may respond much better to the combination of a TNF- $\alpha$  inhibitor (e.g., an anti-IL-23p19 antibody) and an IL-23 inhibitor (e.g., an anti-IL-23p19 antibody).

In various embodiments, the IL-23 inhibitor comprises an anti-IL-23p19 antibody or an antigen-binding fragment thereof. These can bind to the p19 subunit of IL-23.

In various embodiments, the TNF- $\alpha$  inhibitor comprises an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof. In some embodiments, the anti-IL-23p19 antibody comprises a human antibody or a humanized antibody. In some embodiments, the anti-TNF- $\alpha$  antibody comprises a human antibody or a humanized antibody.

Anti-IL-23 antibodies and/or anti-TNF $\alpha$  antibodies can also be humanized or prepared as human antibodies engineered with retention of high affinity for the antigen and other favorable biological properties. Humanized (or human) antibodies can be optionally prepared by a process of analysis of the parental sequences and various conceptual humanized products using three-dimensional models of the parental and humanized sequences. Three-dimensional immunoglobulin models are commonly available and are familiar to those skilled in the art. Computer programs are available which illustrate and display probable three-dimensional conformational structures of selected candidate immunoglobulin sequences. Inspection of these displays permits analysis of the likely role of the residues in the functioning of the candidate immunoglobulin sequence, i.e., the analysis of residues that influence the ability of the candidate immunoglobulin to bind its antigen. In this way, framework (FR) residues can be selected and combined from the consensus and import sequences so that the desired antibody characteristic, such as increased affinity for the target antigen(s), is achieved.

Humanization or engineering of antibodies of the present invention can be performed using any known method, such as but not limited to those described in, Winter (Jones et al., Nature 321:522 (1986); Riechmann et al., Nature 332:323 (1988); Verhoeyen et al., Science 239:1534 (1988)), Sims et al., J. Immunol. 151: 2296 (1993); Chothia and Lesk, J. Mol. Biol.

196:901 (1987), Carter et al., Proc. Natl. Acad. Sci. U.S.A. 89:4285 (1992); Presta et al., J. Immunol. 151:2623 (1993), and U.S. Patent Nos: 5,723,323, 5,976,862, 5,824,514, 5,817,483, 5,814,476, 5,763,192, 5,723,323, 5,766,886, 5,714,352, 6,204,023, 6,180,370, 5,693,762, 5,530,101, 5,585,089, 5,225,539; 4,816,567, each entirely incorporated herein by reference.

In another aspect is provided a method of reducing inflammation of the colon in a subject who has inflammatory bowel disease. The method comprises administering a first co-inflammation reducing effective amount of an IL-23 inhibitor and administering a second co-inflammation reducing effective amount of a TNF- $\alpha$  inhibitor. The method is effective to reduce inflammation of the colon of the subject to a level comparable to the colon of a normal patient. The first and second co-inflammation reducing effective amounts are the same or different. Prevention or reduction of inflammation can be measured by histopathological analysis, degree of weight loss, and degree of inflammation.

In some embodiments, in a histopathology study of a tissue sample from the colon of the subject after administration of the IL-23 inhibitor and the TNF- $\alpha$  inhibitor, the inflammation score is very minimal or normal. Very minimal inflammation may reflect the presence of just one or two small foci, with mononuclear inflammatory cells (MNIC) likely background mucosal lymphoid aggregates.

In some embodiments, in a histopathology study of a tissue sample from the colon of the subject after administration of the IL-23 inhibitor and the TNF- $\alpha$  inhibitor, the gland loss score is very minimal or normal. Very minimal gland loss may involve only one or two small focal areas of gland loss.

In some embodiments, in a histopathology study of a tissue sample from the colon of the subject after administration of the IL-23 inhibitor and the TNF- $\alpha$  inhibitor, the erosion score is very minimal or normal. Very minimal erosion may involve only one or two small focal areas of mucosal erosion.

In some embodiments, in a histopathology study of a tissue sample from the colon of the subject after administration of the IL-23 inhibitor and the TNF- $\alpha$  inhibitor, the mucosal thickness and hyperplasia score are independently very minimal or normal. Very minimal mucosal thickness may involve less than a 25% increase in mucosal thickness as compared to the thickness of normal mucosal tissue.

In some embodiments, after administration of the IL-23 inhibitor and the TNF- $\alpha$  inhibitor, the histopathology of the colon is about identical (or identical) to that of normal tissue. The histopathology can be assessed by measuring one or more of submucosal edema, inflammation, gland loss, erosion, mucosal thickness, and hyperplasia. Any or all of these parameters may be measured and scored. An exemplary scoring system is described in Example 1.

In various embodiments, the IL-23 inhibitor is an anti-IL-23p19 antibody or an antigen-binding fragment thereof. Exemplary anti-IL-23p19 antibodies and fragments are described in U.S. Patent No. 7,491,391, issued on Feb. 17, 2009 and incorporated by reference herein in its entirety. In various embodiments, the TNF- $\alpha$  inhibitor is an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof.

In some embodiments, the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 1:2 to 2:1 (w/w). The ratio may be calculated from the dosage of one antibody in a patient in mg/kg and the dosage of the other antibody in the same patient in mg/kg. In some embodiments, the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 15:1 to 400:1 (w/w). The ratio may be calculated from the dosage of one antibody in a patient in mg/kg and the dosage of the other antibody in the same patient in mg/kg.

Administration to a subject (e.g., human patient) of anti-TNF $\alpha$  antibody and an anti-IL-23p19 antibody in a ratio of from 1:2 to 2:1 (w/w) can provide for enhanced treatment of IBD (e.g., colitis and Crohn's disease) in the subject. In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:2 to 1:1.8 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.9 to 1:1.7 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.8 to 1:1.6 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.7 to 1:1.5 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.6 to 1:1.4 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.5 to 1:1.3 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.4 to 1:1.2 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.3 to 1:1.1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.2 to 1:1

(w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1.1 to 1.1:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1:1 to 1.2:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.1:1 to 1.3:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.2:1 to 1.4:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.3:1 to 1.5:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.4:1 to 1.6:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.5:1 to 1.7:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.6:1 to 1.8:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.7:1 to 1.9:1 (w/w). In some embodiments, the ratio of anti-TNF $\alpha$  antibody to anti-IL-23p19 antibody is from 1.8:1 to 2:1 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is about 1:2, 1:1.8, 1:1.5, 1:1.2, 1:1, 1.2:1, 1.5:1, 1.8:1 or 2:1 (w/w).

A minimally active dose of an anti-IL-23p19 antibody can be administered to the subject (e.g., human patient) with a larger dose of anti-TNF $\alpha$  antibody to prevent development of inflammatory bowel disease (e.g., colitis and Crohn's disease). The ratio of the minimally active dose of anti-IL-23p19 to the ratio of the larger dose of anti-TNF $\alpha$  antibody can range from 1:400 to 1:15 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:400 to 1:350 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:370 to 1:320 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:350 to 1:300 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:300 to 1:250 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:280 to 1:230 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:250 to 1:200 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:220 to 1:170 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:170 to 1:120 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:150 to 1:100 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:120 to 1:80

(w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:100 to 1:60 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:80 to 1:40 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:60 to 1:30 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:50 to 1:25 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:40 to 1:20 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:35 to 1:15 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is about 1:400, 1:300, 1:200, 1:150, 1:100, 1:75, 1:50, 1:25, or 1:15 (w/w).

In some embodiments, the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 15:1 to 400:1 (w/w). In some embodiments, the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment thereof are administered simultaneously. In some embodiments, the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment thereof are administered sequentially. The a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment thereof may be administered within one hour, two hours, three hours, six hours, 12 hours, one day, two days, three days, or four days of one another.

In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-TNF- $\alpha$  antibody alone without significant remission of the inflammatory bowel disease. In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-IL-23p19 antibody alone without significant remission of the inflammatory bowel disease.

In another aspect is provided a method of treating inflammatory bowel disease in a human subject. The method comprises: (a) administering 0.0005 to 0.002 mg/kg of an anti-IL-23p19 antibody or an antigen-binding fragment thereof; and (b) administering 0.020 to 0.125 mg/kg of an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof. In various embodiments, the method is effective to treat the inflammatory bowel disease. In some

embodiments, the inflammatory bowel disease is colitis. In some embodiments, the inflammatory bowel disease is Crohn's disease. In some embodiments, the method is effective to inhibit weight loss (e.g., weight loss associated with the inflammatory bowel disease.)

The (a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the (b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment thereof may be administered simultaneously, sequentially, or within one day of one another.

In various embodiments, administration to a subject (e.g., human patient) of 0.020 to 0.125 mg/kg anti-TNF $\alpha$  antibody and 0.020 to 0.125 mg/kg of an anti-IL-23p19 antibody can provide for enhanced treatment of IBD (e.g., colitis and Crohn's disease) in the subject. Initial results from evaluating the combination of 50 $\mu$ g each anti-TNF $\alpha$  and anti-IL-23p19 in mice suggest that the combination provides enhanced protection against colitis versus single treatments at the same dose. See Example 1. In some embodiments, 0.020 to 0.040 mg/kg anti-TNF $\alpha$  antibody and 0.020 to 0.040 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.030 to 0.050 mg/kg anti-TNF $\alpha$  antibody and 0.030 to 0.050 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.040 to 0.060 mg/kg anti-TNF $\alpha$  antibody and 0.040 to 0.060 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.050 to 0.070 mg/kg anti-TNF $\alpha$  antibody and 0.050 to 0.070 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.060 to 0.080 mg/kg anti-TNF $\alpha$  antibody and 0.060 to 0.080 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.070 to 0.090 mg/kg anti-TNF $\alpha$  antibody and 0.070 to 0.090 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.080 to 0.100 mg/kg anti-TNF $\alpha$  antibody and 0.080 to 0.100 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.090 to 0.110 mg/kg anti-TNF $\alpha$  antibody and 0.090 to 0.110 mg/kg of an anti-IL-23p19 antibody are administered to a human subject. In some embodiments, 0.100 to 0.125 mg/kg anti-TNF $\alpha$  antibody and 0.100 to 0.125 mg/kg of an anti-IL-23p19 antibody are administered to a human subject.

In various embodiments, the anti-IL-23p19 antibody is administered to the subject (e.g., human patient) daily, every two days, every three days, every four days, every five days, every six days, or once every week. In various embodiments, the anti-TNF $\alpha$  antibody is administered to the subject (e.g., human patient) daily, every two days, every three days, every four days,

every five days, every six days, or once every week. In some embodiments, both the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody are administered daily, every two days, every three days, every four days, every five days, every six days, or once every week.

The anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody can be administered conjointly to the subject (e.g., human patient). Alternatively, the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody can be administered separately to the subject. If administered separately, the antibodies may be administered within three hours, six hours, twelve hours, one day, two days, three days, or four days of one another.

In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-TNF- $\alpha$  antibody alone without significant remission of the inflammatory bowel disease. In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-IL-23p19 antibody alone without significant remission of the inflammatory bowel disease.

In another aspect, a minimally active dose of an anti-IL-23p19 antibody can be administered with a larger dose of anti-TNF $\alpha$  antibody to prevent relapse of inflammatory bowel disease (e.g., ulcerative colitis, indeterminate colitis and/or Crohn's disease) when the subject is in remission from inflammatory bowel disease. The ratio of the minimally active dose of anti-IL-23p19 to the ratio of the larger dose of anti-TNF $\alpha$  antibody can range from 1:400 to 1:15 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:400 to 1:350 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:370 to 1:320 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:350 to 1:300 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:300 to 1:250 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:280 to 1:230 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:250 to 1:200 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:220 to 1:170 (w/w). In some embodiments, the ratio of anti-IL-23p19

antibody to anti-TNF $\alpha$  antibody is from 1:170 to 1:120 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:150 to 1:100 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:120 to 1:80 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:100 to 1:60 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:80 to 1:40 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:60 to 1:30 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:50 to 1:25 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:40 to 1:20 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is from 1:35 to 1:15 (w/w). In some embodiments, the ratio of anti-IL-23p19 antibody to anti-TNF $\alpha$  antibody is about 1:400, 1:300, 1:200, 1:150, 1:100, 1:75, 1:50, 1:25, or 1:15 (w/w).

In various embodiments, the anti-IL-23p19 antibody is administered daily, every two days, every three days, every four days, every five days, every six days, or once every week. In various embodiments, the anti-TNF $\alpha$  antibody is administered daily, every two days, every three days, every four days, every five days, every six days, or once every week. In some embodiments, both the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody are administered daily, every two days, every three days, every four days, every five days, every six days, or once every week.

The anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody can be administered conjointly. Alternatively, the anti-IL-23p19 antibody and the anti-TNF $\alpha$  antibody can be administered separately.

Combining anti-TNF $\alpha$  antibody (500  $\mu$ g/mouse) treatment with minimally active doses of anti-IL-23p19 antibody can provide superior efficacy in preventing development of colitis when compared to either single antibody treatment at these doses. See, e.g., Example 5. An analysis of colonic gene signatures of this combination therapy versus anti-TNF $\alpha$  or anti-IL-23p19 monotherapy identified a unique set of genes modulated by combination therapy enriched in fibroblasts and extracellular matrix organization, cell types and pathways involved in wound repair. This novel finding indicates that a combination treatment of antibodies against TNF $\alpha$  and IL-23p19 can provide for superior efficacy in treating colitis and inflammatory bowel syndrome.

Further, a combination treatment of antibodies against TNF $\alpha$  and IL-23p19 may have synergistic effects due to modulation of specific gene networks implicated in mucosal healing.

The data in Example 5 demonstrates that combination treatment with antibodies against TNF $\alpha$  and IL-23p19 can provide superior protection against colitis, as compared to treatment with either antibody as monotherapy. The colitis may be acute colitis. Without wishing to be bound by theory, transcriptomics and gene network analyses identified both overlapping and distinct molecular effects for each monotherapy and revealed a unique set of genes influenced by the combination treatment that are implicated in wound repair processes. Taken together, these findings suggest that combination therapy with anti-TNF $\alpha$  and anti-IL-23p19 antibodies can provide a synergistic impact on alleviating intestinal inflammation. The synergistic impact may arise through the targeting of common inflammatory pathways. The synergistic impact may arise from treatment of distinct cell types implicated in IBD pathogenesis with an impact on genes involved in tissue restoration.

In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-TNF- $\alpha$  antibody alone without significant remission of the inflammatory bowel disease. In some embodiments, the combination of the a) anti-IL-23p19 antibody or the antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or the antigen-binding fragment is effective to treat a subject who was previously treated with an anti-IL-23p19 antibody alone without significant remission of the inflammatory bowel disease.

### Formulations

Each of the anti-TNF $\alpha$  and anti-IL-23 (e.g., anti-IL-23p19) antibodies may be present in stable formulations. The stable formulations may comprise a phosphate buffer with saline or a chosen salt, as well as preserved solutions and formulations containing a preservative as well as multi-use preserved formulations suitable for pharmaceutical or veterinary use, comprising an anti-IL-23 (e.g., anti-IL-23p19) antibody in a pharmaceutically acceptable formulation. Preserved formulations may contain at least one known preservative or optionally selected from the group consisting of at least one phenol, m-cresol, p-cresol, o-cresol, chlorocresol, benzyl alcohol, phenylmercuric nitrite, phenoxyethanol, formaldehyde, chlorobutanol, magnesium

chloride (e.g., hexahydrate), alkylparaben (methyl, ethyl, propyl, butyl and the like), benzalkonium chloride, benzethonium chloride, sodium dehydroacetate and thimerosal, polymers, or mixtures thereof in an aqueous diluent. Any suitable concentration or mixture can be used, such as about 0.0015%, or any range, value, or fraction therein. Non-limiting examples include, without preservative, about 0.1-2% m-cresol (e.g., 0.2, 0.3, 0.4, 0.5, 0.9, 1.0%), about 0.1-3% benzyl alcohol (e.g., 0.5, 0.9, 1.1, 1.5, 1.9, 2.0, 2.5%), about 0.001-0.5% thimerosal (e.g., 0.005, 0.01), about 0.001-2.0% phenol (e.g., 0.05, 0.25, 0.28, 0.5, 0.9, 1.0%), 0.0005-1.0% alkylparaben(s) (e.g., 0.00075, 0.0009, 0.001, 0.002, 0.005, 0.0075, 0.009, 0.01, 0.02, 0.05, 0.075, 0.09, 0.1, 0.2, 0.3, 0.5, 0.75, 0.9, 1.0%), and the like.

The aqueous diluent may further comprise a pharmaceutically acceptable preservative. Preferred preservatives include those selected from the group consisting of phenol, m-cresol, p-cresol, o-cresol, chlorocresol, benzyl alcohol, alkylparaben (methyl, ethyl, propyl, butyl and the like), benzalkonium chloride, benzethonium chloride, sodium dehydroacetate and thimerosal, or mixtures thereof. The concentration of preservative used in the formulation is a concentration sufficient to yield an anti-microbial effect. Such concentrations are dependent on the preservative selected and are readily determined by the skilled artisan.

Other excipients, e.g., isotonicity agents, buffers, antioxidants, and preservative enhancers, can be added to the diluent. An isotonicity agent, such as glycerin, is commonly used at known concentrations. A physiologically tolerated buffer is preferably added to provide improved pH control. The formulations can cover a wide range of pHs, such as from about pH 4 to about pH 10, and preferred ranges from about pH 5 to about pH 9, and a most preferred range of about 6.0 to about 8.0. Preferably, the formulations of the present invention have a pH between about 6.8 and about 7.8. Preferred buffers include phosphate buffers, most preferably, sodium phosphate, particularly, phosphate buffered saline (PBS).

Other additives, such as a pharmaceutically acceptable solubilizers like Tween 20 (polyoxyethylene (20) sorbitan monolaurate), Tween 40 (polyoxyethylene (20) sorbitan monopalmitate), Tween 80 (polyoxyethylene (20) sorbitan monooleate), Pluronic F68 (polyoxyethylene polyoxypropylene block copolymers), and PEG (polyethylene glycol) or non-ionic surfactants, such as polysorbate 20 or 80 or poloxamer 184 or 188, Pluronic® polyols, other block co-polymers, and chelators, such as EDTA and EGTA, can be added to the formulations or compositions to reduce aggregation. These additives may be useful if a pump or plastic container

is used to administer the formulation. The presence of pharmaceutically acceptable surfactant can reduce any propensity for an antibody to aggregate.

The formulations of the present invention can be prepared by a process that comprises mixing at least one anti-IL-23 antibody or anti-TNF $\alpha$  antibody with a selected buffer. The buffer can be a phosphate buffer containing saline or a chosen salt. Mixing the at least one anti-IL-23 antibody and buffer in an aqueous diluent is carried out using conventional dissolution and mixing procedures. To prepare a suitable formulation, for example, a measured amount of at least one antibody in water or buffer is combined with the desired buffering agent in water in quantities sufficient to provide the protein and buffer at the desired concentrations. Variations of this process would be recognized by one of ordinary skill in the art. For example, the order the components are added, whether additional additives are used, the temperature and pH at which the formulation is prepared, are all factors that can be optimized for the concentration and means of administration used.

Stable or preserved formulations comprising one or both of anti-IL-23 antibody and anti-TNF $\alpha$  antibody can be provided to patients as clear solutions or as dual vials comprising a vial of lyophilized at least one antibody that is reconstituted with a second vial containing a preservative or buffer and excipients in an aqueous diluent. Either a single solution vial or dual vial requiring reconstitution can be reused multiple times and can suffice for a single or multiple cycles of patient treatment and thus provides a more convenient treatment regimen than currently available.

For parenteral administration, the anti-IL-23 antibody or anti-TNF $\alpha$  antibody can be formulated as a solution, suspension, emulsion, particle, powder, or lyophilized powder in association, or separately provided, with a pharmaceutically acceptable parenteral vehicle. Examples of such vehicles are water, saline, Ringer's solution, dextrose solution, and about 1-10% human serum albumin. Liposomes and nonaqueous vehicles, such as fixed oils, can also be used. The vehicle or lyophilized powder can contain additives that maintain isotonicity (e.g., sodium chloride, mannitol) and chemical stability (e.g., buffers and preservatives). The formulation is sterilized by known or suitable techniques.

Suitable pharmaceutical carriers are described in the most recent edition of Remington's Pharmaceutical Sciences, A. Osol, a standard reference text in this field.

Many known and developed modes can be used according to the present invention for administering pharmaceutically effective amounts of at least one anti-IL-23 antibody or anti-TNF $\alpha$  antibody. While pulmonary administration is used in the following description, other modes of administration can be used according to the present invention with suitable results. IL-23p19 antibodies of the present invention can be delivered in a carrier, as a solution, emulsion, colloid, or suspension, or as a dry powder, using any of a variety of devices and methods suitable for administration by inhalation or other modes described here within or known in the art.

Formulations for parenteral administration may comprise a common excipient. Exemplary common excipients include, but are not limited to, sterile water or saline, polyalkylene glycols, such as polyethylene glycol, oils of vegetable origin, hydrogenated naphthalenes and the like. Aqueous or oily suspensions for injection can be prepared by using an appropriate emulsifier or humidifier and a suspending agent, according to known methods. Agents for injection can be a non-toxic, non-orally administrable diluting agent, such as aqueous solution, a sterile injectable solution or suspension in a solvent. As the usable vehicle or solvent, water, Ringer's solution, isotonic saline, etc. are allowed; as an ordinary solvent or suspending solvent, sterile involatile oil can be used. For these purposes, any kind of involatile oil and fatty acid can be used, including natural or synthetic or semisynthetic fatty oils or fatty acids; natural or synthetic or semisynthetic mono- or di- or tri-glycerides.

Formulations for oral administration may include the co-administration of adjuvants (e.g., resorcinols and nonionic surfactants, such as polyoxyethylene oleyl ether and n-hexadecylpolyethylene ether) to increase artificially the permeability of the intestinal walls, as well as the co-administration of enzymatic inhibitors (e.g., pancreatic trypsin inhibitors, diisopropylfluorophosphate (DFF) and trasyolol) to inhibit enzymatic degradation. Formulations for delivery of hydrophilic agents including proteins and antibodies and a combination of at least two surfactants intended for oral, buccal, mucosal, nasal, pulmonary, vaginal transmembrane, or rectal administration are taught in U.S. Patent No. 6,309,663. The active constituent compound of the solid-type dosage form for oral administration can be mixed with at least one additive, including sucrose, lactose, cellulose, mannitol, trehalose, raffinose, maltitol, dextran, starches, agar, arginates, chitins, chitosans, pectins, gum tragacanth, gum arabic, gelatin, collagen, casein, albumin, synthetic or semisynthetic polymer, and glyceride. These dosage forms can also contain other type(s) of additives, e.g., inactive diluting agent, lubricant, such as magnesium stearate,

paraben, preserving agent, such as sorbic acid, ascorbic acid,  $\alpha$ -tocopherol, antioxidant such as cysteine, disintegrator, binder, thickener, buffering agent, sweetening agent, flavoring agent, perfuming agent, etc.

It can be desirable to deliver the compounds of the present invention to the subject over prolonged periods of time, for example, for periods of one week to one year from a single administration. Various slow release, depot or implant dosage forms can be utilized. For example, a dosage form can contain a pharmaceutically acceptable non-toxic salt of the compounds that has a low degree of solubility in body fluids, for example, (a) an acid addition salt with a polybasic acid, such as phosphoric acid, sulfuric acid, citric acid, tartaric acid, tannic acid, pamoic acid, alginic acid, polyglutamic acid, naphthalene mono- or di-sulfonic acids, polygalacturonic acid, and the like; (b) a salt with a polyvalent metal cation, such as zinc, calcium, bismuth, barium, magnesium, aluminum, copper, cobalt, nickel, cadmium and the like, or with an organic cation formed from e.g., N,N'-dibenzyl-ethylenediamine or ethylenediamine; or (c) combinations of (a) and (b), e.g., a zinc tannate salt. Additionally, the compounds of the present invention or, preferably, a relatively insoluble salt, such as those just described, can be formulated in a gel, for example, an aluminum monostearate gel with, e.g., sesame oil, suitable for injection. Particularly preferred salts are zinc salts, zinc tannate salts, pamoate salts, and the like.

### **Examples**

The present invention is also described and demonstrated by way of the following examples. However, the use of these and other examples anywhere in the specification is illustrative only and in no way limits the scope and meaning of the invention or of any exemplified term. Likewise, the invention is not limited to any particular preferred embodiments described here. Indeed, many modifications and variations of the invention may be apparent to those skilled in the art upon reading this specification, and such variations can be made without departing from the invention in spirit or in scope. The invention is therefore to be limited only by the terms of the appended claims along with the full scope of equivalents to which those claims are entitled.

#### **Example 1: Dose range determination for single treatments with antibody against TNF $\alpha$ or IL-23p19 and combination studies in the CD40 antibody-induced colitis model**

Three separate studies were conducted. In all three studies, animals were randomized by weight, assigned to treatment groups and labeled by a specific number from 1-10 for each group. Vehicle (PBS) and mAb treatments were administered as a single intraperitoneal (ip) injection one day before (day -1) disease was induced by injecting 0.2mg CD40 agonist antibody in 0.2ml PBS per animal ip (day 0).

Naïve control mice were not treated and were kept in a separate cage until termination at day 7. Observations for clinical signs of disease were conducted daily. Body weights were measured and recorded daily from day -1 until termination at day 7. At study termination (day 7), the animals were euthanized by CO<sub>2</sub> overdose and colon tissues removed and processed accordingly for histological analysis.

Following euthanasia, the colon, defined as the intestinal segment between cecum and rectum, was excised and flushed with ice cold PBS to remove fecal content. One centimeter of the proximal colon was placed in histology cassettes and submerged into a fixative solution (10% Neutral Buffered Formalin, NBF). After 24 hours the cassettes were removed from the fixative and transferred to 70% ethanol and stored refrigerated until processing. The remaining colon tissue was divided into three equal parts; the first third snap frozen in liquid nitrogen for PK analysis, the second third snap frozen in liquid nitrogen for cytokine analysis, and the last third (distal, close to rectum) stored in 1ml RNAlater (Ambion™) on ice until all animals had been euthanized and tissues removed accordingly and then frozen for RNA extraction and gene expression analysis. All frozen samples were stored at -80°C until further processing.

In all three studies, animals were randomized by weight, assigned to treatment groups and labeled by a specific number from 1-10 for each group. Vehicle (PBS) and mAb treatments were administered as a single intraperitoneal (ip) injection one day before (day -1) disease was induced by injecting 0.2mg CD40 agonist antibody in 0.2ml PBS per animal ip (day 0). Naïve control mice were not treated and were kept in a separate cage until termination at day 7. Observations for clinical signs of disease were conducted daily. Body weights were measured and recorded daily from day -1 until termination at day 7. The animals were euthanized at day 7 by CO<sub>2</sub> overdose and colon tissues removed and processed accordingly for histological analysis.

In the first study (Study 1), anti-TNF $\alpha$  or anti-IL-23p19 mAbs were evaluated in a CD40 colitis model. These antibodies were evaluated individually at doses of 500 $\mu$ g or 50 $\mu$ g per

mouse, or in combination (i.e., 500 µg + 500 µg/mouse each or 50 + 50 µg/mouse each). The protocol is summarized in Table 1 below.

**Table 1: Evaluation of single antibody treatment against TNF $\alpha$  and IL-23p19 versus combination (at equal high and low doses) in the CD40 colitis model / Study 1, ELN: Immunopharmacology WC-2018-00034**

| Test article             | Route | Dose                          | Number of animals |
|--------------------------|-------|-------------------------------|-------------------|
| Naïve                    |       | None                          | 3                 |
| Vehicle (PBS)            | ip    | 10 ml/kg, day -1              | 5                 |
| CNTO 6601                | ip    | 1000 µg/mouse, day -1         | 9                 |
| CNTO 5048                | ip    | 50 µg/mouse, day -1           | 9                 |
| CNTO 5048                | ip    | 500 µg/mouse, day -1          | 9                 |
| CNTO 3723                | ip    | 50 µg/mouse, day -1           | 9                 |
| CNTO 3723                | ip    | 500 µg/mouse, day -1          | 9                 |
| CNTO 3723 +<br>CNTO 5048 | ip    | 50 + 50 µg/mouse,<br>day -1   | 10                |
| CNTO 3723 +<br>CNTO 5048 | ip    | 500 + 500 µg/mouse,<br>day -1 | 10                |

CNTO 3723 is a murine anti-IL-23p19 monoclonal antibody (neutralizing IL-23p19 mAb). CNTO 5048 is a murine anti-TNF $\alpha$  monoclonal antibody (neutralizing TNF $\alpha$  mAb). CNTO 6601 refers to the isotype control used throughout the experiments. CNTO 6601 does not specifically bind to either TNF $\alpha$  or IL-23p19.

Anti-inflammatory activity of anti-TNF $\alpha$  and anti-IL-23p19 antibody treatment, alone or in combination, was assessed in the anti-CD40 antibody induced colitis model. Ligation of the co-stimulatory receptor CD40 via an agonist antibody causes an acute innate systemic and colonic inflammatory response in lymphopenic (T and B cell-deficient) RAG2<sup>-/-</sup> mice where the inflammatory response in the colon peaks around day 7, followed by resolution (ELN Immunopharmacology WC-2015-00008). IL-23 drives local colonic inflammation in this model.

While the expression of TNF $\alpha$  controls manifestations of systemic disease (e.g., body weight loss), TNF $\alpha$  has only modest effects on colitis development. (1) The inventors sought to investigate the distinct molecular impact of anti-TNF $\alpha$  versus anti-IL-23p19 antibody treatment

on intestinal gene expression and determine whether combination treatment of anti-TNF $\alpha$  and anti-IL-23p19 exhibited enhanced efficacy over either monotherapy. At day -1, RAG2<sup>-/-</sup> mice were dosed once ip with 0.5mg or 0.05mg anti-TNF $\alpha$  antibody (CNTO5048), 0.5mg or 0.05mg anti-IL-23p19 antibody (CNTO3732), a combination of both antibodies (0.5mg or 0.05mg each), 1.0mg isotype control antibody (CNTO6601), or 10ml/kg PBS. (The RAG2<sup>-/-</sup> mice used in all examples herein are 8-10 week old female mice sourced from Taconic Farms.) One day later, at day 0, all animals were challenged ip with anti-CD40 antibody (0.2mg) to induce inflammation.

Body weight loss analysis was performed after low dose (50 $\mu$ g) and high dose (500 $\mu$ g) antibody treatment. Body weight was monitored from day -1, when the mice were injected with antibody or PBS, until termination on day 7.

The data are shown in Figures 1A and 1B. Each line represents the group mean with error bars for standard error (n=9 antibody treatment; n=5 PBS control; n=3 naïve control) and is shown as percent change from day -1 (dotted line). Some error bars are within the size of the symbol and are not depicted. Figure 1A shows the low dose (50 $\mu$ g/mouse) and Figure 1B shows the high dose antibody treatment (500 $\mu$ g/mouse). Statistical significance of differences in body weight loss between antibody treatment groups and the isotype control group as comparator were analyzed by 2-way ANOVA with Dunnett's multiple comparison test and P-values for each time point are shown in the table. P-values indicating significance are highlighted in bold/italic. ELN: Immunopharmacology WC-2018-00034, Immunopharmacology WC-2018-00033.

The CD40 mAb-induced colitis model is characterized by a biphasic weight loss with an initial rapid body weight loss within 24-48 hours after the CD40-agonist antibody dosing followed by recovery and a second weight loss phase at days 5-7. Single treatment with anti-IL-23p19 antibody (0.5mg and 0.05mg) did not protect mice from the initial rapid body weight loss but promoted a faster recovery after day 2 with an overall dose-dependent partial protection against body weight loss during the second phase of the disease, as shown in Figures 1A and 1B.

In contrast, single treatments with anti-TNF $\alpha$  antibody (0.5mg and 0.05mg) completely protected mice from body weight loss during the entire duration of the study for both doses. Similar to the single antibody treatments against TNF $\alpha$ , the combination treatment resulted in complete protection from body weight loss at both doses (Figures 1A and 1B). No adverse effects were observed for the low-dose or high-dose combination treatments of anti-TNF $\alpha$ /IL-23p19.

At termination (day 7), colon histopathology scores were determined for low and high dose antibody treatment groups. The proximal colon sections were stained with H&E and examined for histopathological changes by a blinded pathologist using a severity score from 0-20 according to the following protocol.

For proximal colons, two (2) pieces were cut and embedded in paraffin. Sections (5 µm) were cut and stained with hematoxylin & eosin (H&E). The two colon segments from each animal were evaluated for histopathology individually and average values per animal were used in group analysis. For each H&E stained section, submucosal edema was quantitated by measuring the thickness from the muscularis mucosa to the internal border of the outer muscle layer in a nontangential area thought to best represent the severity of this change.

The Inflammation Score reflected the extent of macrophage, lymphocyte, and neutrophil (PMN) infiltrate. A severity score was assigned according to the following criteria:

0 = Normal;

0.5 = Very Minimal; one or two small foci, mononuclear inflammatory cells (MNIC) likely background mucosal lymphoid aggregates. However, if aggregates are Peyer's patches, then they are not scored as abnormal

1 = Minimal, larger focal area with MNIC and neutrophils or minimal diffuse, no separation of glands, may be mostly in areas of submucosal edema or mesentery

2 = Mild, diffuse mild, or multifocal affecting 11–25% of mucosa with minor focal or multifocal gland separation, no separation in most areas

3 = Moderate, 26–50% of mucosa affected with minimal to mild focal or multifocal separation of glands by inflammatory cell infiltrate, milder in remaining areas of mucosa with some areas having no gland separation by inflammation

4 = Marked, 51–75% of mucosa affected with mild to moderate separation of glands by inflammatory cell infiltrate, minimal to mild in remaining areas of mucosa but all glands have some separation by infiltrate

5 = Severe, 76–100% of mucosa affected with moderate to marked areas of gland separation by inflammatory cell infiltrate, mild to moderate in remaining areas of mucosa

A gland loss score was determined. Crypt epithelial and remaining gland epithelial loss is scored based on the approximate percent of the mucosa that was affected as follows:

0 = None

0.5 = Very Minimal, 1 or 2 small focal areas of gland loss or mucosal erosion

1 = Minimal, 1–10% of the mucosa affected

- 2 = Mild, 11–25% of the mucosa affected
- 3 = Moderate, 26–50% of the mucosa affected
- 4 = Marked, 51–75% of the mucosa affected
- 5 = Severe, 76–100% of the mucosa affected

An erosion score was determined. The loss of surface epithelium was scored based on the approximate percent of the mucosa that was affected as follows. This is generally associated with mucosal hemorrhage (reflective of the bleeding seen clinically and at necropsy):

- 0 = None
- 0.5 = Very Minimal, 1 or 2 small focal areas of gland loss or mucosal erosion
- 1 = Minimal, 1–10% of the mucosa affected
- 2 = Mild, 11–25% of the mucosa affected
- 3 = Moderate, 26–50% of the mucosa affected
- 4 = Marked, 51–75% of the mucosa affected
- 5 = Severe, 76–100% of the mucosa affected

A mucosal thickness and hyperplasia score was determined. Mucosal thickness was measured in a non-tangential area of the section that best represents the overall mucosal thickness. This parameter is indicative of gland elongation and mucosal hyperplasia. A hyperplasia score is derived from the measurement as follows:

- 0 =  $\leq 200$   $\mu\text{m}$  = normal
- 0.5 = 201–250  $\mu\text{m}$  = very minimal
- 1 = 251–350  $\mu\text{m}$  = minimal
- 2 = 351–450  $\mu\text{m}$  = mild
- 3 = 451–550  $\mu\text{m}$  = moderate
- 4 = 551–650  $\mu\text{m}$  = marked
- 5 =  $>650$   $\mu\text{m}$  = severe

The histopathology score is a sum of inflammation, gland loss, erosion, and hyperplasia scores. The range is from 0 to 20. The histopathology scores are shown in Figures 2A and 2B. In these figures, each bar represents the group mean with standard error. No histopathological findings were observed in naïve animals. Figure 2A shows the results for low dose antibody (50 $\mu\text{g}$ /mouse). Figure 2B depicts the results for the high dose treatment group (500 $\mu\text{g}$ /mouse).

Differences between treatment groups and respective vehicle and isotype controls were analyzed for significance by One-way ANOVA and Sidak's multiple comparisons test. ELN: Immunopharmacology WC-2018-00034, Immunopharmacology WC-2018-00033.

In the proximal colon, treatment with isotype antibody (1000µg/mouse) showed a trend toward reduced histopathology when compared to the disease control (PBS), but this did not reach statistical significance. Monotreatment with anti-TNFα antibody significantly reduced colon inflammation at the high dose (500µg, Figure 2B) when compared to isotype control, but not at the low dose (50µg, Figure 2A).

A single dose of anti-IL-23p19 antibody was highly efficacious at the high dose (500µg, Figure 2B), completely preventing the development of colitis. At the low dose (50µg, Figure 2A), the monotreatment significantly reduced histopathology compared to the isotype group but did not completely prevent colitis. The high dose combination of both antibodies (500µg anti-TNFα + 500µg anti-IL-23p19/mouse, Figure 2B) completely prevented colitis in the disease model, similar to the high dose of a single anti-IL-23p19 treatment.

The low dose combination treatment (50µg anti-TNFα + 50µg anti-IL-23p19/mouse, Figure 2A) was significantly more efficacious than the single anti-TNFα treatment and showed a trend for improved protection compared to monotreatment against IL-23p19, indicating potential superior efficacy for the combination.

### **Example 2: Anti-TNFα and anti-IL-23p19 treatments impact unique genes in the intestine**

The anti-TNFα and anti-IL-23p19 treatments show differential effects on readouts of systemic and local inflammation. In this example, an assessment was made whether the treatments of Example 1 above had distinct molecular effects on intestinal gene expression. To generate intestinal gene signatures, mRNA was isolated from the distal colon and submitted for microarray analysis.

For RNA extraction, tissue samples were thawed on ice and transferred into new tubes containing 900 µl of Qiazol (Qiagen) and one metal bead, followed by lysis using the TissueLyser II for disruption and homogenization of the tissue by running it 1min at a frequency of 30 S<sup>-1</sup>. 180 µl of chloroform were added to each sample, vortexed for 30 seconds, incubated for two minutes at room temperature, and centrifuged at 14,000 rpm for 15 minutes at 4°C to separate the mix into an organic and an aqueous phase. 150 µl of the aqueous phase was used for

RNA extraction using the RNeasy 96 well plate kit (Qiagen) including an on-column DNase digestion step all according to the manufacturer's protocols. Quality and quantity of the isolated RNA was determined by Nanodrop at a Nanodrop 8000 instrument (ThermoScientific) and by LabChip GX (DNA 5K/RNA/CZE Chip for use with GXTouch/GXII Touch HT) on Caliper instrument (Life Science) according to the manufacturer's protocols. For Caliper analysis the colon RNA aliquots were diluted 1:4 with molecular grade water.

The following exclusion criteria were used to determine which samples would be accepted for gene expression analysis by microarray. Nanodrop absorbance 260/280 (protein amount to nucleic acid) should be  $>1.8$ . Nanodrop absorbance 260/230 (salt amount to nucleic acid) should be close to 2. If nanodrop absorbance 260/230 was less than 1.5, then repurification was performed. Caliper RIN (RNA integrity number) should be 5-10. If less than 5, the accuracy of microarray analysis may be affected. RNA was shipped to BioStorage Technologies (Indianapolis, IN) for microarray analysis.

Differential gene expression analysis was performed by comparing the effect of anti-TNF $\alpha$  or anti-IL-23p19 to that of isotype control treatment. Because treatment with either the 50ug anti-IL-23p19 or 500ug anti-TNF $\alpha$  doses resulted in similar levels of reduction in histological inflammation (Figure 2), the inventors chose these colonic gene expression signatures for further evaluation to mitigate potential confounding effects of differential cellular infiltrates gene expression.

Murine gene signatures for each treatment were evaluated for overlap and enrichment in biological pathways (Enrichr: <http://amp.pharm.mssm.edu/Enrichr/>). The overlap of the individual gene signatures generated from anti-TNF $\alpha$  or anti-IL-23p19 treatment was relatively small, with only 11% of genes shared between the signatures, and did not show any specific pathway enrichment. The gene signature for anti-TNF $\alpha$  treatment (267 genes, FDR  $< 0.05$ , FC  $> 1.2$ ) was enriched in metabolic pathways and cytokine-cytokine receptor interactions while the anti-IL-23p19 gene signature (765 genes, FDR  $< 0.05$ , FC  $> 1.2$ ) was enriched in circadian rhythm and p53 signaling.

**Example 3: Anti-TNF $\alpha$  and anti-IL-23p19 single antibody treatments impact overlapping and distinct portions of human IBD networks**

In collaboration with the Mount Sinai School of Medicine (New York, NY), a predictive Bayesian network model was generated for integrating transcriptional and genetic data derived from intestinal biopsy samples from the Crohn's disease CERTIFI clinical trial (847 IBD biopsies, 28 non-IBD control biopsies; 7,796 gene nodes). (7, 10) This type of molecular integrative network provides a data-driven framework for studying gene-gene interactions in the context of disease. To translate the anti-TNF $\alpha$  and anti-IL-23p19 monotherapy gene signatures generated in murine colitis models to clinical disease, murine gene signatures were integrated with a human IBD patient gene network. As stated above, the 50 $\mu$ g anti-IL-23p19 and 500 $\mu$ g anti-TNF $\alpha$  doses were selected for evaluation based on their similar impact on histological inflammation.

To bridge the murine model data to the human IBD network, a 'humanized' version of each treatment gene signature was first generated by mapping the murine genes to their human orthologues (767 genes for anti-IL-23p19 and 274 genes for anti-TNF $\alpha$ ). The murine genes were mapped to their human orthologs using NCBI HomoloGene (<https://www.ncbi.nlm.nih.gov/homologene>) database (Build 68, 04/14/2014). Each NCBI Gene Id for each murine gene profiled was matched to all corresponding human members of the same cluster of putative orthologs.

A database term was considered significant if its one-sided Fisher's Exact test E-value (Bonferroni corrected p-value) was less than 0.05.

A hypergeometric test was performed in Excel (HYPGEOM.DIST function) to determine the enrichment of IBD GWAS loci genes in gene subnetworks. The gene list used for IBD GWAS loci enrichment was derived from Jostins et al, *Nature* 2012(8) and Liu et al, *Nature Genetics* 2015(9).

Using these humanized gene signatures, the enrichment analysis of the individual treatment signatures was extended to human pathways. The gene signature for anti-TNF $\alpha$  treatment was enriched in cellular response to stress and lipids, reactive oxygen species metabolism, inflammatory response genes and genes upregulated in patient biopsies. The anti-IL-23p19 treatment signature was enriched in cellular metabolism, regulation of proliferation and genes down-regulated in IBD patient biopsies.

Next, these humanized gene signatures were mapped onto the CERTIFI Bayesian network and generated treatment subnetworks using a web-based network visualization tool. Gene lists were generated as tab delimited text files and imported. Gene lists were applied to the T26 Pan-Intestine Bayesian Network (CERTIFI network(7)) and genes within the network and their first neighbors (genes within 1 step of a selected gene, either incoming or outgoing) were used to create a subnetwork.

These treatment subnetworks contain genes modified by anti-TNF $\alpha$  or anti-IL-23p19 treatment in the mouse model that are reflected in human IBD tissue and their immediate neighboring genes in the network. Thus, enrichment analysis of these subnetworks may provide insights into the biological pathways targeted by each therapeutic in the context of human disease tissue.

Figures 3A and 3B show humanized treatment signatures of anti-TNF $\alpha$  or anti-IL-23p19 monotherapy from the anti-CD40 model of murine colitis projected onto the CERTIFI human IBD gene expression network. First neighbors of genes within the human IBD network were extracted to produce treatment subnetworks. The overlap between genes present in the anti-TNF $\alpha$  and anti-IL-23p19 subnetworks is illustrated by the Venn diagram in the center. The largest connected component of the shared subnetwork of anti-TNF $\alpha$  and anti-IL-23p19 is shown in Fig. 3B.

While no specific biology was enriched in analysis of the intersection of the original gene signatures, focused analysis of the largest connected component of the network neighborhood shared by both anti-TNF $\alpha$  and anti-IL-23p19 revealed enrichment in genes dysregulated in IBD patient tissues as well as IBD GWAS loci genes, suggesting that efficacy of these distinct mechanisms could be mediated, in part, through targeting of shared core inflammatory pathways. The intersection of these two therapeutic subnetworks was significantly enriched in IBD GWAS loci genes ( $p = 0.001$ ) and genes up-regulated in IBD patient tissue (multiple signatures; top signature E-value  $7.25e-27$ ) (Figure 3). The unique portion of the anti-TNF subnetwork was highly enriched in neutrophil and CD11b<sup>+</sup> macrophage gene signatures (E-values  $8.28e-10$  and  $2.41e-06$ , respectively) while the unique portion of the anti-IL-23p19 subnetwork was highly enriched for colonic epithelial cells (E-value  $1.27e-32$ ), consistent with the role of IL-23 in promoting the expression of cytokines, such as IL-17A and IL-22, that impact epithelial cell biology. The relative enrichment in myeloid cells and epithelial cells in the anti-TNF $\alpha$  and anti-

IL-23p19 unique regions of the network, respectively, raised an additional hypothesis that combination therapy with both antibodies could provide benefit by targeting distinct cell types involved in IBD pathogenesis. Remarkably similar results were observed when performing the same type of network analyses using gene signatures derived from anti-TNF $\alpha$  or anti-IL-23p19 therapeutic treatments in an orthogonal murine model of intestinal inflammation, the T cell transfer model of colitis (ELN: jperrigo-2016-00002). Taken together, these network analyses suggest that the anti-TNF $\alpha$  and anti-IL-23p19 mechanisms of action are distinct, but converge on the molecular drivers of intestinal inflammation.

**Example 4: Expanded dose range analysis for anti-TNF $\alpha$  and anti-IL-23p19 antibody treatments in anti-CD40 antibody induced colitis (Study 2)**

To enable further evaluation of the effects of combination therapy, an extended dose response study in the CD40-antibody induced colitis model was conducted to determine the minimal effective dose for each antibody. One day before disease induction with anti-CD40 agonistic antibody, female RAG2<sup>-/-</sup> mice were dosed ip with anti-IL-23p19 antibody (CNTO 3723 at 50, 15, 5, 1.5, 0.5, 0.15 $\mu$ g/mouse), anti-TNF $\alpha$  antibody (CNTO 5048 at 150 and 15  $\mu$ g/mouse) or isotype control (50  $\mu$ g/mouse). The protocol is summarized in Table 2 below.

**Table 2: Evaluation of lower dose range for single antibody against TNF $\alpha$  and IL-23p19 in the CD40 colitis model / Study 2, ELN: Immunopharmacology WC-2016-00038**

| Test article  | Route | Dose                       | Number of animals |
|---------------|-------|----------------------------|-------------------|
| Naïve         |       | None                       | 5                 |
| Vehicle (PBS) | ip    | 10 ml/kg, day -1           | 5                 |
| CNTO 6601     | ip    | 50 $\mu$ g/mouse, day -1   | 10                |
| CNTO 3723     | ip    | 50 $\mu$ g/mouse, day -1   | 10                |
| CNTO 3723     | ip    | 15 $\mu$ g/mouse, day -1   | 10                |
| CNTO 3723     | ip    | 5 $\mu$ g/mouse, day -1    | 10                |
| CNTO 3723     | ip    | 1.5 $\mu$ g/mouse, day -1  | 10                |
| CNTO 3723     | ip    | 0.5 $\mu$ g/mouse, day -1  | 10                |
| CNTO 3723     | ip    | 0.15 $\mu$ g/mouse, day -1 | 10                |
| CNTO 5048     | ip    | 150 $\mu$ g/mouse, day -1  | 10                |
| CNTO 5048     | ip    | 15 $\mu$ g/mouse, day -1   | 10                |

Body weight was monitored from day -1, when the mice were injected with antibody or PBS, until termination on day 7. The data is shown in Figures 4A-4D. Each line represents the group mean with standard error (n=10 antibody treatment; n=5 PBS control; n=3 naïve control) and is shown as percent change from day -1 (dotted line). The significance of differences to the isotype control group was analyzed for each treatment group by 2-way ANOVA with Dunnett's multiple comparison test and the resulting p-values for each study day are shown in the table. P-values indicating significant differences are highlighted in bold/italic. ELN:

Immunopharmacology WC-2016-00038, Immunopharmacology WC-2018-00033.

A partially significant increase in body weight loss was observed in the isotype control group when compared to vehicle control. Treatment with anti-IL-23p19 antibody showed partial dose-dependent protection against body weight loss starting at day 2 at the two highest doses (15, 50  $\mu\text{g}/\text{mouse}$ ). Only at the lowest dose of anti-IL-23p19 antibody (0.15 $\mu\text{g}/\text{mouse}$ ), no protection from body weight loss was observed, as shown in Figure 4B. Treatment with anti-TNF $\alpha$  antibody completely protected against the body weight loss at the higher dose (150  $\mu\text{g}/\text{mouse}$ ), but at the lower dose (15  $\mu\text{g}/\text{mouse}$ ), only a partial protection was noted. See Figure 4C.

A histopathology analysis of the proximal colon was performed as follows, after single antibody treatments for dose range determination. At termination (day 7), proximal colon sections were removed, flushed, fixed and then stained with H&E. The stained samples were examined for histopathological changes by a blinded pathologist using a severity score from 0-20 using the protocol in Example 1 above. The data is shown in Figures 5A-C. No histopathological findings were observed in naïve animals. Differences between antibody treatment groups and respective isotype controls were analyzed for significance by a one-way ANOVA-Sidak's multiple comparisons test. The line depicts the group median. ELN: Immunopharmacology WC-2016-00038, Immunopharmacology WC-2018-00033.

Colon histopathology demonstrated dose-dependent protection from colitis by anti-IL-23p19 antibody treatment, as shown in Figure 5B. At the 50 $\mu\text{g}/\text{mouse}$  dose, anti-IL-23p19 antibody treatment provided near complete protection. Partial protection was detected at antibody doses of 15 $\mu\text{g}$  and 5 $\mu\text{g}$ , and no protection was observed at doses of 1.5 $\mu\text{g}$  and lower. In contrast, no significant treatment effects were detected for the two dose levels of anti-TNF $\alpha$  antibody (150, 15  $\mu\text{g}$ ) on colon histopathology. See Figure 5C. These results confirm that blocking IL-23 signaling is highly efficacious against colitis in this model. Inhibition of TNF $\alpha$ ,

although efficacious against systemic inflammation (as measured by the amelioration of body weight loss), only offers moderate protection against colitis in this model.

**Example 5: Determination of anti-inflammatory activity of a combination of fixed dose anti-TNF $\alpha$  antibody and varying doses of anti-IL-23p19 antibody in the CD40 colitis model (Study 3)**

A combination study was performed in the CD40 colitis model using a fixed dose of anti-TNF $\alpha$  antibody (500 $\mu$ g/mouse) in combination with varying doses of anti-IL-23p19 antibody (1.5, 5, 25  $\mu$ g/mouse). Corresponding single doses of anti-IL-23p19 antibody were also included. The protocol is summarized in Table 3 below.

**Table 3: Evaluation of single high dose TNF $\alpha$  antibody treatment and low doses of IL-23p19 alone versus in combination in the CD40 colitis model / Study 3, ELN: Immunopharmacology WC-2016-00066**

| Test article          | Route | Dose                          | Number of animals |
|-----------------------|-------|-------------------------------|-------------------|
| Naïve                 |       | None                          | 5                 |
| Vehicle (PBS)         | ip    | 10 ml/kg, day -1              | 10                |
| CNTO 6601             | ip    | 525 $\mu$ g/mouse, day -1     | 10                |
| CNTO 5048             | ip    | 500 $\mu$ g/mouse, day -1     | 10                |
| CNTO 3723             | ip    | 1.5 $\mu$ g/mouse, day -1     | 10                |
| CNTO 3723             | ip    | 5 $\mu$ g/mouse, day -1       | 10                |
| CNTO 3723             | ip    | 25 $\mu$ g/mouse, day -1      | 10                |
| CNTO 3723 + CNTO 5048 | ip    | 1.5+500 $\mu$ g/mouse, day -1 | 10                |
| CNTO 3723 + CNTO 5048 | ip    | 5+500 $\mu$ g/mouse, day -1   | 10                |
| CNTO 3723 + CNTO 5048 | ip    | 25+500 $\mu$ g/mouse, day -1  | 10                |

An assay of body weight loss after single and combination treatment with high dose anti-TNF $\alpha$  and low dose anti-IL-23p19 antibody was undertaken as follows.

Body weight was monitored from day -1, when the mice were injected with antibody (isotype control: 525 $\mu$ g; anti-TNF $\alpha$ : 500 $\mu$ g; anti-IL-23p19: 25, 5, 1.5 $\mu$ g) or PBS (10ml/kg), until

termination on day 7. The data are shown in Figure 6. Each line represents the group mean (n=10 antibody treatment and vehicle; n=5 naïve control) and is shown as percent change from day -1 (dotted line). The significance of differences to isotype control group was analyzed by for each treatment group by 2-way ANOVA with Dunnett's multiple comparison test. P-values for each study day are shown in the table and highlighted in bold/italic if they indicate significance. ELN: Immunopharmacology WC-2016-00066, Immunopharmacology WC-2018-00033.

Consistent with previous studies, high dose anti-TNF $\alpha$  antibody completely protected against body weight loss, as shown in Figure 6B. In contrast, monotherapy with anti-IL-23p19 antibody, at all doses, provided partial protection from body weight loss, particularly during the late phase of anti-CD40 antibody induced disease. See Figure 6C. The combination of anti-TNF $\alpha$  antibody and anti-IL-23p19 antibody provided no additional detectable benefit on inhibition of weight loss as compared to the monotherapy (Figure 6D). Without wishing to be bound by theory, this effect may be due to the robust efficacy of monotherapy of anti-TNF $\alpha$  antibody on this parameter.

Histopathology analysis for proximal colon was performed after single and combination antibody treatments with high dose anti-TNF $\alpha$  and low dose anti-IL-23p19 antibody. At termination (day 7), proximal colon tissue samples were removed, flushed, fixed and then stained with H&E and examined for histopathological changes by a blinded pathologist using a severity score from 0-20, as described in Example 1 above. The data are shown in Figures 7A-7C. No histopathological findings were observed in naïve animals. Differences between antibody treatment groups and respective isotype controls were analyzed for significance by One-way ANOVA-Sidak's multiple comparisons test. The line depicts the group median. ELN: Immunopharmacology WC-2016-00066, Immunopharmacology WC-2018-00033.

As shown in Figures 7A-7C, anti-TNF $\alpha$  antibody (500 $\mu$ g/mouse) did not offer significant protection against colon histopathology as compared to the isotype control. The anti-IL-23p19 antibody (1.5, 5 and 25 $\mu$ g/mouse) treatment demonstrated dose-dependent protection from colitis, with no protection seen at the lowest dose (1.5  $\mu$ g/mouse). Partial protection from colitis was observed with the two higher doses (5 and 25  $\mu$ g/mouse).

Due to the low amount of antibody used for anti-IL-23p19, the statistical significance for the single anti-IL23p19 treatments were calculated against the vehicle control, but not against the high dose (525 $\mu$ g/mouse) isotype control. All combination treatments showed significant

protection from colon inflammation compared with single anti-TNF $\alpha$  treatment. See Figures 7A-7C. Of note, in the case of the lowest combination dose evaluated (500 $\mu$ g/mouse TNF $\alpha$  + 1.5 $\mu$ g/mouse anti-IL-23p19), both monotherapy treatments failed to provide any protection from colonic histopathology but showed significant improvement in histopathology when given in combination. See Figure 7A. It was unexpected that the relatively small amount of anti-IL-23p19 antibody in combination with anti-TNF $\alpha$  antibody (e.g., as a ratio of 1:333 (w/w)) provided such a substantial improvement in colon histopathology. It was also unexpected that the colon histopathology score observed in the group receiving 500 $\mu$ g/mouse TNF $\alpha$  + 1.5 $\mu$ g/mouse anti-IL-23p19 is not statistically different from that observed in the isotype control group. These results indicate that a combination treatment of fixed high dose TNF $\alpha$  mAb and a sub-optimal low dose of IL-23p19 provides superior protection compared to the monotherapies against the two cytokines.

**Example 5: Combination anti-TNF $\alpha$  and anti-IL-23p19 treatment impacts a unique subnetwork enriched in wound healing pathways**

The molecular impact of combination therapy with anti-TNF $\alpha$  and anti-IL-23p19 antibodies versus monotherapy was determined. Humanized colonic gene expression signatures of anti-TNF $\alpha$  (500 $\mu$ g) or high dose anti-IL-23p19 (25 $\mu$ g) monotherapies were intersected with a gene expression signature from the combination therapy (500 $\mu$ g anti-TNF $\alpha$ /1.5 $\mu$ g anti-IL-23p19) to determine whether the molecular response to anti-TNF $\alpha$  and low dose anti-IL-23p19 antibody combination treatment was additive or unique compared with either therapy alone.

The 25 $\mu$ g dose of anti-IL-23p19 treatment was selected for comparison so as to compare the effect of combination treatment of anti-TNF $\alpha$  with a sub-optimal dose of anti-IL-23p19 to that of a monotherapy dose of anti-IL-23p19 that had efficacy in the model.

As in Study 1, humanized colonic gene signatures were generated for each single and combination therapy treatment group for evaluating signature overlap, generating treatment subnetworks and performing enrichment analyses. The data is shown in Figure 8, left panel. Two hundred twenty genes were found to be uniquely differentially-regulated after combination therapy (500 $\mu$ g anti-TNF $\alpha$ /1.5 $\mu$ g anti-IL-23p19) versus either monotherapy (500 $\mu$ g anti-TNF $\alpha$  or 25 $\mu$ g anti-IL-23p19). These genes were projected onto the CERTIFI intestinal Bayesian

network. The largest connected component of the resulting induced 1-step subnetwork was subjected to enrichment analysis, with results shown in Figure 8, right panel. A network analysis of these 220 genes identified a unique subnetwork (shown in Figure 8) for the combination treatment that was enriched in fibroblasts and extracellular matrix organization, cell types and pathways involved in wound repair and mucosal healing. Thus, anti-TNF $\alpha$  and anti-IL-23p19 therapies may provide added benefit when used in combination by targeting both shared and unique disease relevant pathways.

### **Example 6: Clinical Study of anti-TNF $\alpha$ and anti-IL-23p19 treatment in UC**

A Phase 2a Randomized, Double-blind, Active-controlled, Parallel-group, Multicenter, Proof-of-concept Clinical Study to Evaluate the Efficacy and Safety of Combination Therapy With Guselkumab and Golimumab in Participants With Moderately to Severely Active Ulcerative Colitis

Guselkumab (CNTO 1959 or TREMFYA<sup>®</sup>) is a fully human immunoglobulin G1 lambda monoclonal antibody (mAb) that binds to the p19 subunit of human interleukin (IL)-23 with high specificity and affinity. The binding of guselkumab to IL-23 blocks the binding of extracellular IL-23 to the cell surface IL-23 receptor, inhibiting IL-23-specific intracellular signaling and subsequent activation and cytokine production. Guselkumab is currently approved in the United States, European Union, Canada, and several other countries for the treatment of moderate to severe plaque psoriasis. In addition, guselkumab is also being evaluated in psoriatic arthritis (PsA) and Crohn's disease globally.

Golimumab (CNTO 148 or SIMPONI<sup>®</sup>) is a fully human anti-tumor necrosis factor alpha (TNF $\alpha$ ) mAb that binds to TNF $\alpha$  with high affinity. This interaction prevents the binding of TNF $\alpha$  to its receptors, thereby inhibiting the biological activity of TNF $\alpha$ . Golimumab is approved for treatment of moderately to severely active ulcerative colitis (UC) in over 90 countries worldwide. Additionally, golimumab is approved for 1 or more of the following indications around the world: rheumatoid arthritis (RA), PsA, ankylosing spondylitis (AS), nonradiographic axial spondyloarthritis (nr-Axial SpA), and polyarticular juvenile idiopathic arthritis (pJIA).

## OBJECTIVES AND ENDPOINTS

This study will consist of 2 distinct phases: a 12-week combination comparison phase followed by a 26-week monotherapy phase.

### Objectives

#### Primary Objectives

##### *Combination Comparison Phase*

- To evaluate the clinical efficacy of combination therapy with guselkumab and golimumab in participants with moderately to severely active UC.
- To evaluate the safety of combination therapy with guselkumab and golimumab in participants with moderately to severely active UC.

#### Secondary Objectives

##### *Combination Comparison Phase*

- To evaluate the effect of combination therapy with guselkumab and golimumab on endoscopic improvement.
- To evaluate the impact of combination therapy with guselkumab and golimumab on disease-specific health-related quality of life (HRQOL), including fatigue.
- To evaluate the efficacy of combination therapy with guselkumab and golimumab by negative response signature status at baseline.
- To evaluate the pharmacokinetics (PK), immunogenicity, and pharmacodynamics (PD) of combination therapy with guselkumab and golimumab, including changes in C-reactive protein (CRP), fecal calprotectin, and other PD biomarkers.

##### *Monotherapy Phase*

- To evaluate the clinical efficacy of combination therapy followed by guselkumab monotherapy.
- To evaluate the safety of combination therapy followed by guselkumab monotherapy.
- To evaluate the effect of combination therapy followed by guselkumab monotherapy on endoscopic improvement.
- To evaluate the impact of combination therapy followed by guselkumab monotherapy on disease-specific HRQOL, including fatigue.
- To evaluate the efficacy of combination therapy followed by guselkumab monotherapy by negative response signature status at baseline.
- To evaluate the PK, immunogenicity, and PD of combination therapy followed by guselkumab monotherapy, including changes in CRP, fecal calprotectin, and other PD biomarkers.

**Exploratory Objectives**

- To explore the effect of combination therapy on patient-reported outcome (PRO) instruments (e.g., Bristol Stool Form Scale [BSFS] and Patient's Global Impression of Change [PGIC] of Severity of UC).

**Endpoints****Primary Endpoint**

- Clinical response at Week 12, defined as a decrease from baseline in the Mayo score  $\geq 30\%$  and  $\geq 3$  points with either a decrease in rectal bleeding subscore (RBS)  $\geq 1$  or a RBS of 0 or 1.

**Major Secondary Endpoint**

- Clinical remission at Week 12, defined as a Mayo score  $\leq 2$  with no individual subscore  $> 1$ .

Note: Other remission definitions may be considered and will be fully described in the Statistical Analysis Plan (SAP).

**Hypothesis**

Combination therapy with guselkumab and golimumab will result in a rate of clinical response at Week 12 that is superior to both monotherapy arms.

**OVERALL DESIGN**

This is a Phase 2a, randomized, double-blind, active-controlled, parallel-group, multicenter, interventional proof-of-concept (POC) clinical study designed to evaluate the efficacy and safety of combination therapy with guselkumab and golimumab in adults with moderately to severely active UC. The target population is men or women 18 to 65 years old with moderately to severely active UC, as defined by a Mayo score of 6 to 12, inclusive, at baseline, including an endoscopy subscore  $\geq 2$  as obtained during the central review of the video endoscopy. Participants must be naïve to TNF antagonists and have failed or not tolerated conventional therapy with oral or intravenous (IV) corticosteroids or immunomodulators (6-mercaptopurine [6-MP] or azathioprine [AZA]).

Immunomodulators (6-MP, AZA, and methotrexate [MTX]) must be discontinued for at least 2 weeks before the first dose of study intervention. For participants who are receiving oral corticosteroids at baseline, the investigator must begin tapering the daily dose of corticosteroids at Week 6. All participants will be evaluated for clinical worsening of UC throughout the study. In general, doses of concomitant therapies for UC should remain stable through Week 38 (except for oral corticosteroid tapering beginning at Week 6), and concomitant therapies for UC should not be

initiated unless considered medically necessary by the investigator. Initiation of prohibited therapies will result in discontinuation of study intervention.

Endoscopy with central read is planned for screening/baseline, Week 12, and Week 38. Consenting participants will have an additional endoscopy at Week 4, which will also be assessed by a central reader. Efficacy, PK and PD parameters, biomarkers, and safety will be assessed according to the Schedule of Activities (SoA). A pharmacogenomic blood sample will be collected from participants who consent to this component of the protocol (where local regulations permit). Participation in pharmacogenomic research is optional.

An interim analysis is planned to inform future clinical development. Database locks (DBLs) are planned at Weeks 12 and 38, and a final DBL is planned after all participants complete the safety follow-up visit. An independent Data Monitoring Committee (DMC) will be commissioned for this study.

#### **NUMBER OF PARTICIPANTS**

A target of 210 participants will be enrolled in this study with 70 participants planned per intervention group.

#### **INTERVENTION GROUPS AND DURATION**

This study will consist of 2 distinct phases: a 12-week combination comparison phase followed by a 26-week monotherapy phase. At Week 0, a target of 210 participants will be randomized in a 1:1:1 ratio to either combination therapy with guselkumab and golimumab, guselkumab monotherapy, or golimumab monotherapy, stratified by the concomitant use of corticosteroids at baseline (Y/N). Participants randomized to combination therapy will receive guselkumab monotherapy after Week 12. Participants randomized to a monotherapy group will continue on their originally randomized monotherapy after Week 12. The combination therapy arm will employ the same dose regimens of guselkumab and golimumab being used in the respective monotherapy intervention groups to facilitate scientific interpretation of the results. The following is a description of the 3 intervention groups:

- **Combination therapy:** guselkumab 200 mg IV and golimumab 200 mg subcutaneous (SC) at Week 0; golimumab 100 mg SC at Weeks 2, 6, and 10; guselkumab 200 mg IV at Weeks 4 and 8 followed by guselkumab 100 mg SC q8w

- **Guselkumab monotherapy:** guselkumab 200 mg IV at Weeks 0, 4, and 8 followed by guselkumab 100 mg SC q8w
- **Golimumab monotherapy:** golimumab 200 mg SC injection at Week 0, followed by golimumab 100 mg at Week 2 and then golimumab 100 mg every 4 weeks (q4w)

In addition, placebo administrations (IV or SC) will be given, as appropriate, to maintain the blind throughout the duration of the study.

Overall participant duration will be up to 58 weeks total (screening: up to 8 weeks; treatment duration: 38 weeks [12 weeks for the combination comparison phase; 26 weeks for the monotherapy phase]; safety follow-up: approximately 16 weeks after the last administration of study intervention at Week 34). The end of the study will be defined as when the last participant completes his or her final safety follow-up visit.

#### **EFFICACY EVALUATIONS (endpoints)**

Efficacy evaluations will include the following:

- Mayo score and Partial Mayo score
- Ulcerative Colitis Endoscopic Index of Severity (UCEIS)
- Inflammatory PD markers including CRP and fecal calprotectin
- Patient-reported outcome measures to assess HRQOL outcomes and fatigue (ie, Inflammatory Bowel Disease Questionnaire [IBDQ], Patient-Reported Outcomes Measurement Information System [PROMIS]-29, and PROMIS Fatigue 7-item Short Form [7a])
- Exploratory patient-reported symptom measures including BSFS and PGIC of Severity of UC

#### **OTHER EFFICACY EVALUATIONS (endpoints)**

Efficacy evaluations will include the following:

##### **Combination Comparison Phase (i.e., through Week 12)**

- Endoscopic healing at Week 12 (Mayo endoscopic subscore of 0 or 1).
- Normalization of endoscopic appearance of the mucosa (Mayo endoscopic subscore of 0).
- Histologic healing at Week 12.
- Mucosal healing at Week 12 (Composite Mayo endoscopic healing and histologic healing).
- Change from baseline in the total score of the Inflammatory Bowel Disease Questionnaire (IBDQ) at Weeks 6 and 12.
- A >20-point improvement in the IBDQ score at Weeks 6 and 12.
- Change from baseline in the 7 domains and the abdominal pain numerical rating scale of Patient-Reported Outcomes Measurement Information System (PROMIS)-29 at Weeks 6 and 12.

- Fatigue response at Weeks 6 and 12 (based on the PROMIS Fatigue Short Form 7a; to be defined in the SAP).
- Clinical response, clinical remission, and endoscopic healing at Week 12 by negative response signature status at baseline.
- Change from baseline in the Mayo score at Week 12.
- Change from baseline in the partial Mayo score through Week 12.
- Change from baseline in CRP through Week 12.
- Change from baseline in fecal calprotectin concentration through Week 12.
- Normalization of CRP concentration at Week 12 among participants with abnormal CRP concentration at baseline.
- Normalization of fecal calprotectin concentration at Week 12 among participants with abnormal fecal calprotectin concentration at baseline.
- Ulcerative Colitis Endoscopic Index of Severity (UCEIS) score at Weeks 0 and 12 by the level of Mayo endoscopy score at the corresponding visit.
- Change from baseline in the UCEIS score at Week 12.
- UCEIS score  $\leq 4$  at Week 12.
- UC-related emergency department visits, hospitalizations, and surgeries through Week 12.

**Monotherapy Phase (i.e., after Week 12)**

- Clinical remission at Week 38.
- Clinical response at Week 38.
- Maintenance of clinical response at Week 38 among participants who achieved clinical response at Week 12.
- Endoscopic healing at Week 38.
- Normalization of endoscopic appearance of the mucosa at Week 38.
- Histologic healing at Week 38.
- Mucosal healing at Week 38.
- Clinical remission and not receiving concomitant corticosteroids at Week 38.
- Maintenance of clinical remission at Week 38 among participants who achieved clinical remission at Week 12.
- Change from baseline in the total score of the IBDQ at Weeks 24 and 38.
- A >20-point improvement in the IBDQ score at Weeks 24 and 38.
- Change from baseline in the 7 domains and the abdominal pain numerical rating scale of PROMIS-29 at Weeks 24 and 38.
- Fatigue response at Weeks 24 and 38.

- Clinical response, clinical remission, and endoscopic healing at Week 38 by negative response signature status at baseline.
- Change from baseline in the Mayo score at Week 38.
- Change from baseline in the partial Mayo score through Week 38.
- Change from baseline in CRP through Week 38.
- Change from baseline in fecal calprotectin concentration through Week 38.
- Normalization of CRP concentration at Week 38 among participants with abnormal CRP concentration at baseline.
- Normalization of fecal calprotectin concentration at Week 38 among participants with abnormal fecal calprotectin concentration at baseline.
- UCEIS score at Week 38 by the level of Mayo endoscopy score at Week 38.
- Change from baseline in the UCEIS score at Week 38.
- UCEIS score  $\leq 4$  at Week 38.
- UC-related emergency department visits, hospitalizations, and surgeries through Week 38.

#### **Exploratory Endpoints**

- BSFS score over time.
- The distribution of the PGIC of Severity of UC over time.

#### **PHARMACOKINETIC AND IMMUNOGENICITY EVALUATIONS**

Serum samples will be analyzed to determine concentrations of guselkumab and golimumab and detection of anti-guselkumab and anti-golimumab antibodies, respectively, using validated, specific, and sensitive immunoassay methods by or under the supervision of the sponsor.

#### **PHARMACODYNAMIC AND BIOMARKER EVALUATIONS**

Biomarker assessments will be made to examine the biologic response to treatment and to identify biomarkers that are relevant to guselkumab and/or golimumab in the treatment of UC. Assessments will include the evaluation of relevant biomarkers in serum, stool, whole blood, and mucosal biopsy samples (RNA [ribonucleic acid], histology, and single cell isolation).

## **PHARMACOGENOMIC (DNA) EVALUATIONS**

A pharmacogenomic whole blood sample of approximately 5 mL will be collected (where local regulations permit) for genetic analyses as specified in the SoA. Only participants who sign the consent form to participate in the genetic assessment will have whole blood deoxyribonucleic acid (DNA) samples collected. Participation in the pharmacogenomic sub-study is optional.

## **SAFETY EVALUATIONS**

Safety evaluations conducted at each study visit will include the assessment of adverse events (AEs, at the visit and those occurring between evaluation visits), a tuberculosis (TB) evaluation and other infection assessment, clinical laboratory blood tests (hematology and chemistry), vital signs, suicidality assessment, concomitant medication review, observations for injection-site reactions, AEs temporally associated with infusion, and/or hypersensitivity reactions.

## **STATISTICAL METHODS**

### **Sample Size Determination**

A sample size of 210 participants (70 per intervention group) was determined by the power to detect a significant difference in the proportion of participants in clinical response at Week 12 (primary endpoint) between the combination therapy and both monotherapies using a 1-sided chi-square test with 0.1 significance level for each comparison. The study is sized such that the combination therapy has approximately 80% power based on simulations to achieve both comparisons to monotherapy for the primary endpoint. The proportion of participants in clinical response at Week 12 is assumed to be 75% for the combination therapy, which is based on the additive effect from both monotherapies (20% improvement from each monotherapy relative to a historical placebo response of 35%).

### **Efficacy Analyses**

All randomized participants who receive at least 1 dose of study intervention will be included in the efficacy analyses. Participants will be analyzed according to the treatment group to which they were randomized regardless of the treatment they received.

For testing of the primary endpoint, the efficacy of combination therapy versus each monotherapy will be compared. For both statistical comparisons of the primary endpoint, a Cochran-Mantel-Haenszel (CMH) chi-square test stratified by concomitant use of corticosteroids at baseline (Y/N) will be used. The testing will be done simultaneously at the 1-sided 0.1 level of significance for each comparison. The study will be considered positive if the combination therapy group is significantly different from both monotherapy groups for the primary endpoint.

If both tests of the primary endpoint are positive, a CMH chi-square test (1-sided) stratified by concomitant use of corticosteroids at baseline (Y/N) will be used to compare the efficacy of the combination therapy to each monotherapy for the major secondary endpoint. The testing will be done simultaneously at the 1-sided 0.1 level of significance for each comparison.

Analyses for other efficacy endpoints will be performed with no adjustments made for multiple comparisons and nominal p-values will be provided.

### **Safety Analyses**

Safety data, including but not limited to, AEs, serious adverse events (SAEs), infections, serious infections, changes in laboratory assessments, and changes in vital signs will be summarized. Treatment-emergent AEs will be summarized by treatment group and Medical Dictionary for Regulatory Activities (MedDRA) system organ class and preferred terms.

### **Other Analyses**

#### ***Pharmacokinetic Analyses***

Serum guselkumab and golimumab concentrations over time will be summarized for each treatment group over time using descriptive statistics.

Population PK modeling may be conducted when appropriate. If these population PK analyses are conducted, the results of these analyses will be presented in a separate report.

#### ***Immunogenicity Analyses***

The incidence of antibodies to guselkumab and to golimumab will be summarized for all participants who receive at least 1 dose of guselkumab or golimumab and have appropriate samples

for detection of antibodies to guselkumab and to golimumab (i.e., participants with at least 1 sample obtained after their first dose of guselkumab or golimumab, respectively).

#### ***Pharmacokinetic/Pharmacodynamic Analyses***

The relationship between serum concentrations of guselkumab and golimumab and the efficacy measures and/or relevant biomarker(s) may be explored graphically when appropriate. Additional analysis may be conducted if deemed necessary.

#### ***Biomarkers Analyses***

Changes in serum protein analytes, fecal biomarkers, and biopsy and whole blood RNA obtained over time will be summarized by treatment group. Associations between baseline levels and changes from baseline in select markers and response to treatment will be explored. Biomarker analyses will be summarized in a separate technical report.

#### ***Pharmacogenomic Analyses***

Genetic (DNA) analyses will be conducted only in participants who sign the consent form to participate in the pharmacogenomic sub-study. These analyses are considered exploratory and will be summarized in a separate technical report.

The present application describes a number of examples and embodiments of the invention. Nevertheless, it must be borne in mind that various modifications of the described examples and embodiments can be developed, while not departing from the scope and the essence of the invention in principle. With this in mind, other embodiments are included in the scope of the items listed below. At that, all the numerical ranges described herein include all the sub ranges contained therein, as well as any individual values within the scope of these ranges. All publications, patents and patent applications mentioned in this description are hereby incorporated by reference.

The invention can be described with reference to the following numbered embodiments:

1. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use in the treatment of an inflammatory disease in a patient, wherein the inhibitors are in co-therapeutically effective amounts and the patient shows a clinical response.
2. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to embodiment 1, wherein the inflammatory disease is an inflammatory bowel disease and the patient shows a clinical response based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.
3. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the IL-23 inhibitor comprises an anti-IL-23p19 antibody or an antigen-binding fragment thereof and the TNF- $\alpha$  inhibitor comprises an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof.
4. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the inflammatory bowel disease is Crohn's disease.
5. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the inflammatory bowel disease is ulcerative colitis (UC) or indeterminate colitis.
6. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the inflammatory bowel disease is moderately to severely active ulcerative colitis (UC).
7. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the patient was previously treated with a TNF- $\alpha$  inhibitor alone and wherein the UC did not undergo remission after the previous treatment.
8. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the patient was previously treated with an IL-23 inhibitor alone and wherein the UC did not undergo remission after the previous treatment.
9. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the anti-IL-23p19 antibody comprises: a) heavy chain complementarity

determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) a heavy chain variable region amino acid sequence of SEQ ID NO:7 and a light chain variable region amino acid sequence of SEQ ID NO: 8; or c) a heavy chain amino acid sequence of SEQ ID NO:9 and a light chain amino acid sequence of SEQ ID NO:10.

10. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the anti-TNF $\alpha$  antibody comprises: a) heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and light chain CDR amino acid sequences of SEQ ID NOS: 14-16; b) a heavy chain variable region amino acid sequence of SEQ ID NO:17 and a light chain variable region amino acid sequence of SEQ ID NO:18; or c) a heavy chain amino acid sequence of SEQ ID NO:19 and a light chain amino acid sequence of SEQ ID NO:20.

11. An IL-23 inhibitor and a TNF- $\alpha$  inhibitor for use according to any one of the preceding embodiments, wherein the anti-IL-23p19 antibody comprises: a) heavy chain complementarity determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) a heavy chain variable region amino acid sequence of SEQ ID NO:7 and a light chain variable region amino acid sequence of SEQ ID NO: 8; or c) a heavy chain amino acid sequence of SEQ ID NO:9 and a light chain amino acid sequence of SEQ ID NO:10, and the anti-TNF $\alpha$  antibody comprises: a) heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and light chain CDR amino acid sequences of SEQ ID NOS: 14-16; b) a heavy chain variable region amino acid sequence of SEQ ID NO:17 and a light chain variable region amino acid sequence of SEQ ID NO:18; or c) a heavy chain amino acid sequence of SEQ ID NO:19 and a light chain amino acid sequence of SEQ ID NO:20.

12. An anti-IL-23 antibody or fragment thereof and an anti-TNF- $\alpha$  antibody or fragment thereof for use in the treatment of ulcerative colitis in a patient, wherein the anti-IL-23p19 antibody comprises (i) the heavy chain complementarity determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6, (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8, or (iii) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO:10; and the anti-TNF- $\alpha$  antibody comprises (i) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and

the light chain CDR amino acid sequences of SEQ ID NOS: 14-16, (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18, or (iii) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20, wherein the antibodies are in co-therapeutically effective amounts and the use is effective to treat ulcerative colitis and the patient shows a clinical response based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.

13. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 12, wherein the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 1:2 to 2:1 (w/w).

14. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiments 12 or 13, wherein the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 15:1 to 400:1 (w/w).

15. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 12-14, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered simultaneously.

16. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 12-14, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered sequentially.

17. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 12-14 and 16, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered within one day of one another.

18. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 12-17, wherein the anti-IL-23p19 antibody is administered in an initial intravenous dose of 200 mg, intravenous doses of 200 mg at weeks 4 and 8 and subsequent subcutaneous doses of 100 mg every 8 weeks and the anti-TNF- $\alpha$  antibody is administered in an initial subcutaneous dose of 200 mg and subsequent subcutaneous doses of 100 mg at weeks 2, 6 and 10.

19. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 12-18, wherein the patient shows a clinical remission based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.
20. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 19, wherein the clinical endpoint is measured about 12 weeks after initial treatment.
21. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiments 19 or 20, wherein the clinical endpoint is based on the Mayo Score.
22. An anti-IL-23 antibody or fragment thereof and an anti-TNF- $\alpha$  antibody or fragment thereof for use in, reducing inflammation of the colon in a patient with inflammatory bowel disease, wherein the antibodies are in co-therapeutically effective amounts and the use is effective to reduce inflammation of the colon of the patient to a level comparable to the colon of a normal subject.
23. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 22, wherein the inflammation is very minimal or normal in a tissue sample from the colon of the patient after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
24. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 22, wherein gland loss is very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
25. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 22, wherein erosion is very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
26. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 22, wherein mucosal thickness and hyperplasia are independently very minimal or normal in a tissue sample from the colon of the subject after administration of the anti-IL-23p19 antibody or

antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.

27. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to embodiment 22, wherein after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof, histopathology of the colon is identical to that of normal tissue.

28. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-27, wherein the anti-IL-23p19 antibody or antigen-binding fragment thereof comprises: a) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or c) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO: 10; and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof comprises d) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; e) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or f) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

29. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-28, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 1:2 to 2:1 (w/w).

30. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-28, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 15:1 to 400:1 (w/w).

31. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-30, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered simultaneously.

32. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-30, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered sequentially.
33. An anti-IL-23 antibody and an anti-TNF- $\alpha$  antibody for use according to any of embodiments 22-30, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered within one day of one another.
34. An anti-IL-23 antibody or fragment thereof and an anti-TNF- $\alpha$  antibody or fragment thereof for use in treating inflammatory bowel disease in a patient and reducing weight loss in the patient.
35. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to embodiment 34, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 15:1 to 400:1 (w/w).
36. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to embodiments 34 or 35, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered simultaneously.
37. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to embodiments 34 or 35, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered sequentially.
38. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to any of embodiments 34, 35 or 37, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered within one day of one another.

39. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to any of embodiments 34-38, wherein the anti-IL-23p19 antibody or antigen-binding fragment thereof comprises: a) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or c) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO: 10; and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof comprises d) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; e) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or f) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

40. An anti-IL-23 antibody or fragment thereof and an anti-TNF- $\alpha$  antibody or fragment thereof for use in treating moderately to severely active ulcerative colitis in a human patient, wherein the anti-IL-23p19 antibody or an antigen-binding fragment thereof is administered at 0.0005 to 0.002 mg/kg and comprises the sequences of (i) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or (iii) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO:10 and the anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof is administered at 0.020 to 0.125 mg/kg and comprises the sequences of (iv) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; (v) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or (vi) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

41. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to embodiment 40, wherein the use is effective to treat the ulcerative colitis.

42. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to embodiments 40 or 41, wherein the patient shows a clinical remission based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.

43. An anti-IL-23 antibody or antigen-binding fragment thereof and an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof for use according to any of embodiments 40-42, wherein the anti-IL-23p19 antibody is in an aqueous solution in a pharmaceutical composition at 100 mg/mL; 7.9% (w/v) sucrose, 4.0mM Histidine, 6.9 mM L-Histidine monohydrochloride monohydrate; 0.053% (w/v) Polysorbate 80 of the composition, and the anti-TNF- $\alpha$  antibody is in an aqueous solution in a pharmaceutical composition at 100 mg/mL; 4.1% (w/v) sorbitol, 5.6 mM L-Histidine and L-Histidine monohydrochloride monohydrate; 0.015% (w/v) Polysorbate 80 of the composition.

Claims:

1. A method of treating an inflammatory disease in a patient, the method comprising:
  - a) administering a first co-therapeutically effective amount of an IL-23 inhibitor; and
  - b) administering a second co-therapeutically effective amount of a TNF- $\alpha$  inhibitor,wherein the method is effective to treat the inflammatory disease and the patient shows a clinical response.
2. The method of claim 1, wherein the inflammatory disease is an inflammatory bowel disease and the patient shows a clinical response based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.
3. The method of claim 2, wherein the IL-23 inhibitor comprises an anti-IL-23p19 antibody or an antigen-binding fragment thereof and the TNF- $\alpha$  inhibitor comprises an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof.
4. The method of claim 3, wherein the inflammatory bowel disease is Crohn's disease.
5. The method of claim 3, wherein the inflammatory bowel disease is ulcerative colitis (UC) or indeterminate colitis.
6. The method of claim 5, wherein the inflammatory bowel disease is moderately to severely active ulcerative colitis (UC).
7. The method of claim 6, wherein the patient was previously treated with a TNF- $\alpha$  inhibitor alone and wherein the UC did not undergo remission after the previous treatment.
8. The method of claim 6, wherein the patient was previously treated with an IL-23 inhibitor alone and wherein the UC did not undergo remission after the previous treatment.

9. The method of claim 6, wherein the anti-IL-23p19 antibody comprises: a) heavy chain complementarity determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) a heavy chain variable region amino acid sequence of SEQ ID NO:7 and a light chain variable region amino acid sequence of SEQ ID NO: 8; or c) a heavy chain amino acid sequence of SEQ ID NO:9 and a light chain amino acid sequence of SEQ ID NO:10.

10. The method of claim 6, wherein the anti-TNF $\alpha$  antibody comprises: a) heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and light chain CDR amino acid sequences of SEQ ID NOS: 14-16; b) a heavy chain variable region amino acid sequence of SEQ ID NO:17 and a light chain variable region amino acid sequence of SEQ ID NO:18; or c) a heavy chain amino acid sequence of SEQ ID NO:19 and a light chain amino acid sequence of SEQ ID NO:20.

11. The method of claim 6, wherein the anti-IL-23p19 antibody comprises: a) heavy chain complementarity determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) a heavy chain variable region amino acid sequence of SEQ ID NO:7 and a light chain variable region amino acid sequence of SEQ ID NO: 8; or c) a heavy chain amino acid sequence of SEQ ID NO:9 and a light chain amino acid sequence of SEQ ID NO:10, and the anti-TNF $\alpha$  antibody comprises: a) heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and light chain CDR amino acid sequences of SEQ ID NOS: 14-16; b) a heavy chain variable region amino acid sequence of SEQ ID NO:17 and a light chain variable region amino acid sequence of SEQ ID NO:18; or c) a heavy chain amino acid sequence of SEQ ID NO:19 and a light chain amino acid sequence of SEQ ID NO:20.

12. A method of treating ulcerative colitis in a patient, the method comprising:

a) administering a first co-therapeutically effective amount of an anti-IL-23p19 antibody comprising (i) the heavy chain complementarity determining region (CDR) amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6, (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8, or (iii) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO:10; and

b) administering a second co-therapeutically effective amount of an anti-TNF- $\alpha$  antibody comprising (i) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS: 14-16, (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18, or (iii) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20, wherein the method is effective to treat ulcerative colitis and the patient shows a clinical response based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.

13. The method of claim 12, wherein the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 1:2 to 2:1 (w/w).

14. The method of claim 12, wherein the anti-TNF $\alpha$  antibody and the anti-IL-23p19 antibody are administered in a ratio of from 15:1 to 400:1 (w/w).

15. The method of claim 12, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered simultaneously.

16. The method of claim 12, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered sequentially.

17. The method of claim 12, wherein the anti-IL-23p19 antibody and the anti-TNF- $\alpha$  antibody are administered within one day of one another.

18. The method of claim 12, wherein the anti-IL-23p19 antibody is administered in an initial intravenous dose of 200 mg, intravenous doses of 200 mg at weeks 4 and 8 and subsequent subcutaneous doses of 100 mg every 8 weeks and the anti-TNF- $\alpha$  antibody is administered in an initial subcutaneous dose of 200 mg and subsequent subcutaneous doses of 100 mg at weeks 2, 6 and 10.

19. The method of claim 18, wherein the patient shows a clinical remission based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.
20. The method of claim 19, wherein the clinical endpoint is measured about 12 weeks after initial treatment.
21. The method of claim 19, wherein the clinical endpoint is based on the Mayo Score.
22. A method of reducing inflammation of the colon in a patient with inflammatory bowel disease, the method comprising
- a) administering a first co-therapeutically effective amount of an anti-IL-23p19 antibody antigen-binding fragment thereof; and
  - b) administering a second co-therapeutically effective amount of an anti-TNF- $\alpha$  antibody antigen-binding fragment thereof, wherein the method is effective to reduce inflammation of the colon of the patient to a level comparable to the colon of a normal subject.
23. The method of claim 22, wherein the inflammation is very minimal or normal in a tissue sample from the colon of the patient after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
24. The method of claim 22, wherein gland loss is very minimal or normal in a tissue sample from the colon of the patient after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
25. The method of claim 22, wherein erosion is very minimal or normal in a tissue sample from the colon of the patient after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.

26. The method of claim 22, wherein mucosal thickness and hyperplasia are independently very minimal or normal in a tissue sample from the colon of the patient after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.

27. The method of claim 22, wherein after administration of the anti-IL-23p19 antibody or antigen-binding fragment thereof and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof, histopathology of the colon is identical to that of normal tissue.

28. The method of claim 22, wherein the anti-IL-23p19 antibody or antigen-binding fragment thereof comprises: a) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or c) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO: 10; and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof comprises d) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; e) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or f) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

29. The method of claim 28, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 1:2 to 2:1 (w/w).

30. The method of claim 28, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 15:1 to 400:1 (w/w).

31. The method of claim 28, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered simultaneously.
32. The method of claim 28, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered sequentially.
33. The method claim 28, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered within one day of one another.
34. A method of treating inflammatory bowel disease in a patient and reducing weight loss in the patient, the method comprising
- a) administering a first co-therapeutically and weight reducing effective amount of an anti-IL-23p19 antibody or antigen-binding fragment thereof; and
  - b) administering a second co-therapeutically and weight reducing effective amount of an anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof.
35. The method of claim 34, wherein the anti-TNF $\alpha$  antibody or antigen-binding fragment thereof and the anti-IL-23p19 antibody or antigen-binding fragment thereof are administered in a ratio of from 15:1 to 400:1 (w/w).
36. The method of claim 34, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered simultaneously.
37. The method of claim 34, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered sequentially.

38. The method of claim 34, wherein the a) anti-IL-23p19 antibody or antigen-binding fragment thereof and the b) anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof are administered within one day of one another.

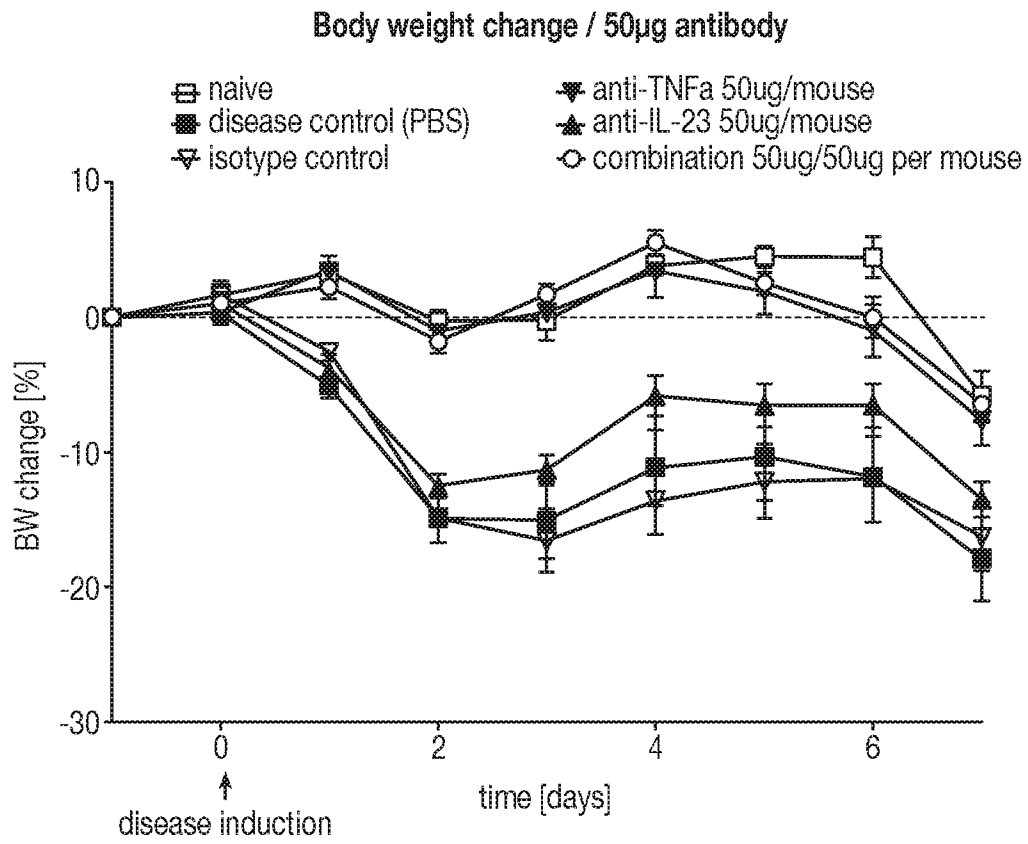
39. The method of claim 34, wherein the anti-IL-23p19 antibody or antigen-binding fragment thereof comprises: a) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; b) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or c) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO: 10; and the anti-TNF- $\alpha$  antibody or antigen-binding fragment thereof comprises d) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; e) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or f) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

40. A method of treating moderately to severely active ulcerative colitis in a human patient, the method comprising:

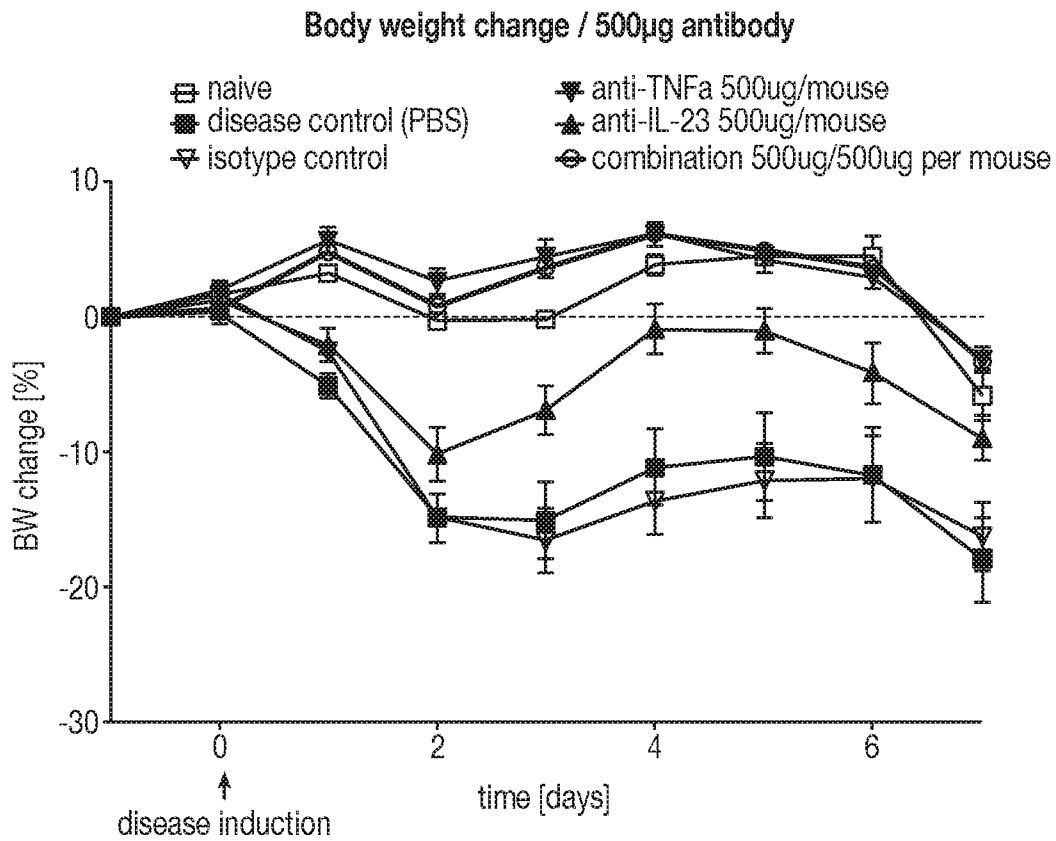
a) administering 0.0005 to 0.002 mg/kg of an anti-IL-23p19 antibody or an antigen-binding fragment thereof comprising the sequences of (i) the heavy chain CDR amino acid sequences of SEQ ID NOS:1-3 and the light chain CDR amino acid sequences of SEQ ID NOS: 4-6; (ii) the heavy chain variable region amino acid sequence of SEQ ID NO:7 and the light chain variable region amino acid sequence of SEQ ID NO: 8; or (iii) the heavy chain amino acid sequence of SEQ ID NO:9 and the light chain amino acid sequence of SEQ ID NO:10 and

b) administering 0.020 to 0.125 mg/kg of an anti-TNF- $\alpha$  antibody or an antigen-binding fragment thereof comprising the sequences of (iv) the heavy chain CDR amino acid sequences of SEQ ID NOS:11-13 and the light chain CDR amino acid sequences of SEQ ID NOS:14-16; (v) the heavy chain variable region amino acid sequence of SEQ ID NO:17 and the light chain variable region amino acid sequence of SEQ ID NO:18; or (vi) the heavy chain amino acid sequence of SEQ ID NO:19 and the light chain amino acid sequence of SEQ ID NO:20.

41. The method of claim 40, wherein the method is effective to treat the ulcerative colitis.
42. The method of claim 41, wherein the patient shows a clinical remission based on a clinical endpoint selected from the group consisting of Mayo score, partial Mayo score, Ulcerative Colitis Endoscopic Index of Severity (UCEIS), the markers CRP and/or fecal calprotectin and patient-reported outcome and symptom measures.
43. The method of claim 40, wherein the anti-IL-23p19 antibody is in an aqueous solution in a pharmaceutical composition at 100 mg/mL; 7.9% (w/v) sucrose, 4.0mM Histidine, 6.9 mM L-Histidine monohydrochloride monohydrate; 0.053% (w/v) Polysorbate 80 of the composition, and the anti-TNF- $\alpha$  antibody is in an aqueous solution in a pharmaceutical composition at 100 mg/mL; 4.1% (w/v) sorbitol, 5.6 mM L-Histidine and L-Histidine monohydrochloride monohydrate; 0.015% (w/v) Polysorbate 80 of the composition.

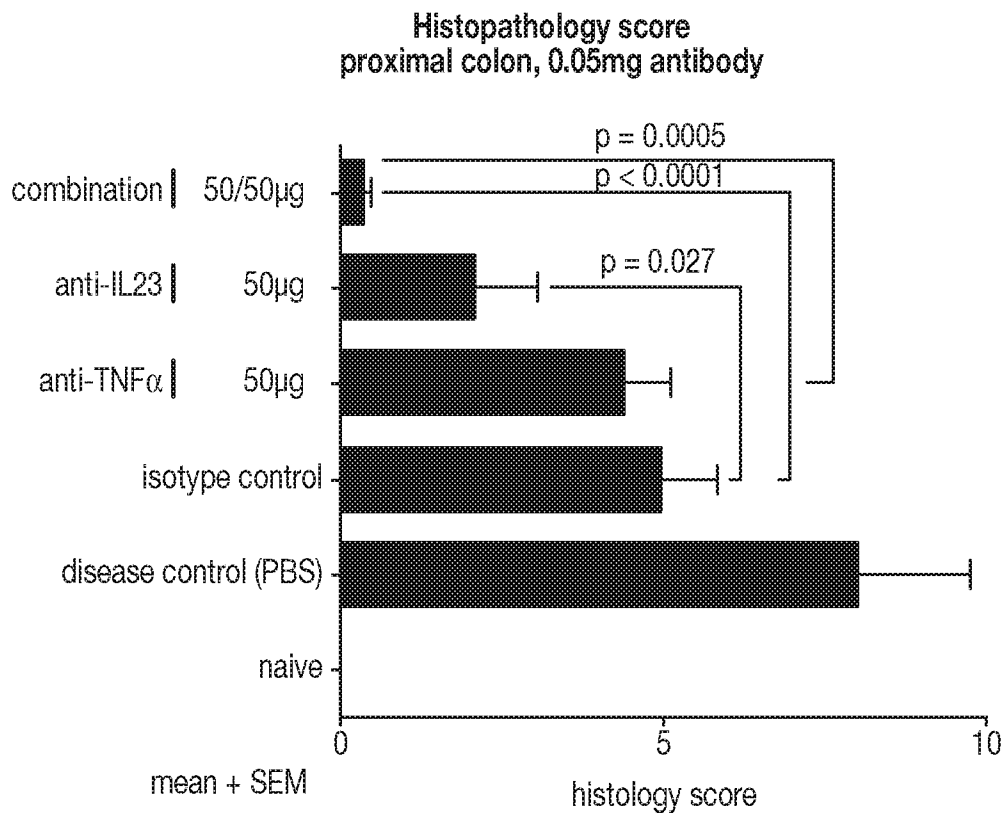


**FIG. 1A**

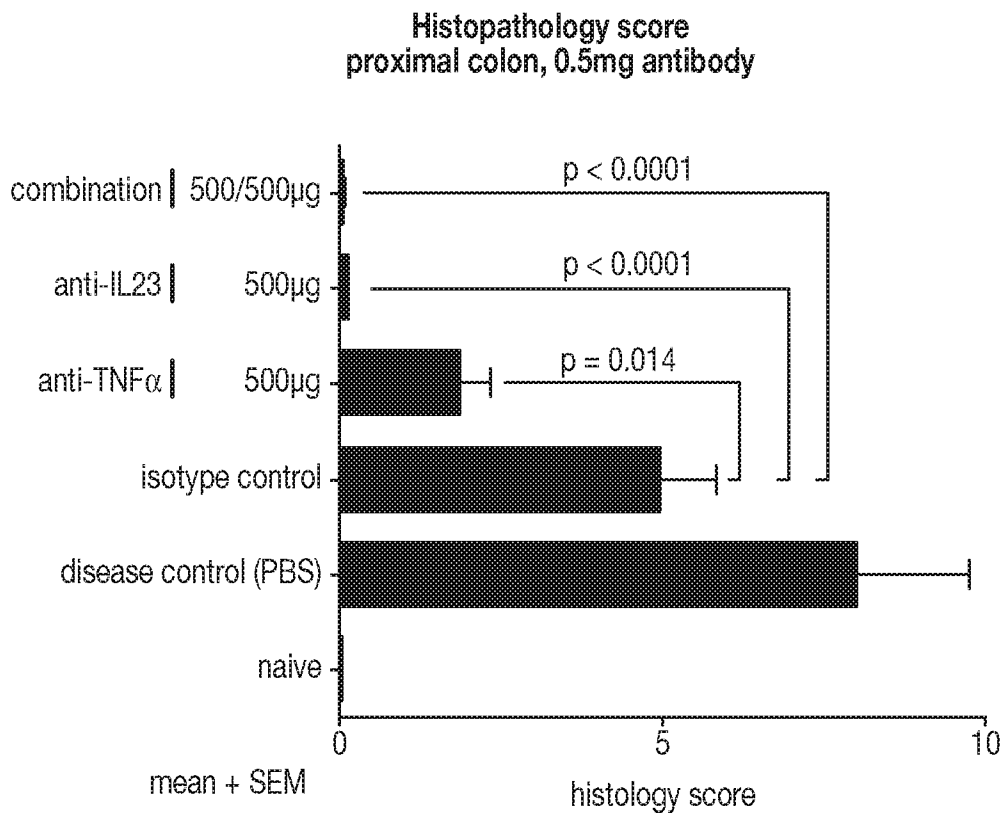


| mab treatment        | Day-1 | Day 0  | Day 1  | Day 2  | Day 3  | Day 4  | Day 5  | Day 6  | Day 7  |
|----------------------|-------|--------|--------|--------|--------|--------|--------|--------|--------|
| 50µg aTNFα           | 0.999 | 0.957  | 0.008  | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 500µg aTNFα          | 0.999 | 0.9998 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 50µg aIL-23          | 0.999 | 0.9979 | 0.6242 | 0.6242 | 0.0302 | 0.0003 | 0.0168 | 0.0219 | 0.5024 |
| 500µg aIL-23         | 0.999 | 0.9996 | 0.0633 | 0.0633 | 0.0001 | 0.0001 | 0.0001 | 0.0003 | 0.0009 |
| 50µg aTNFα + aIL-23  | 0.999 | 0.9995 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 500µg aTNFα + aIL-23 | 0.999 | 0.9694 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

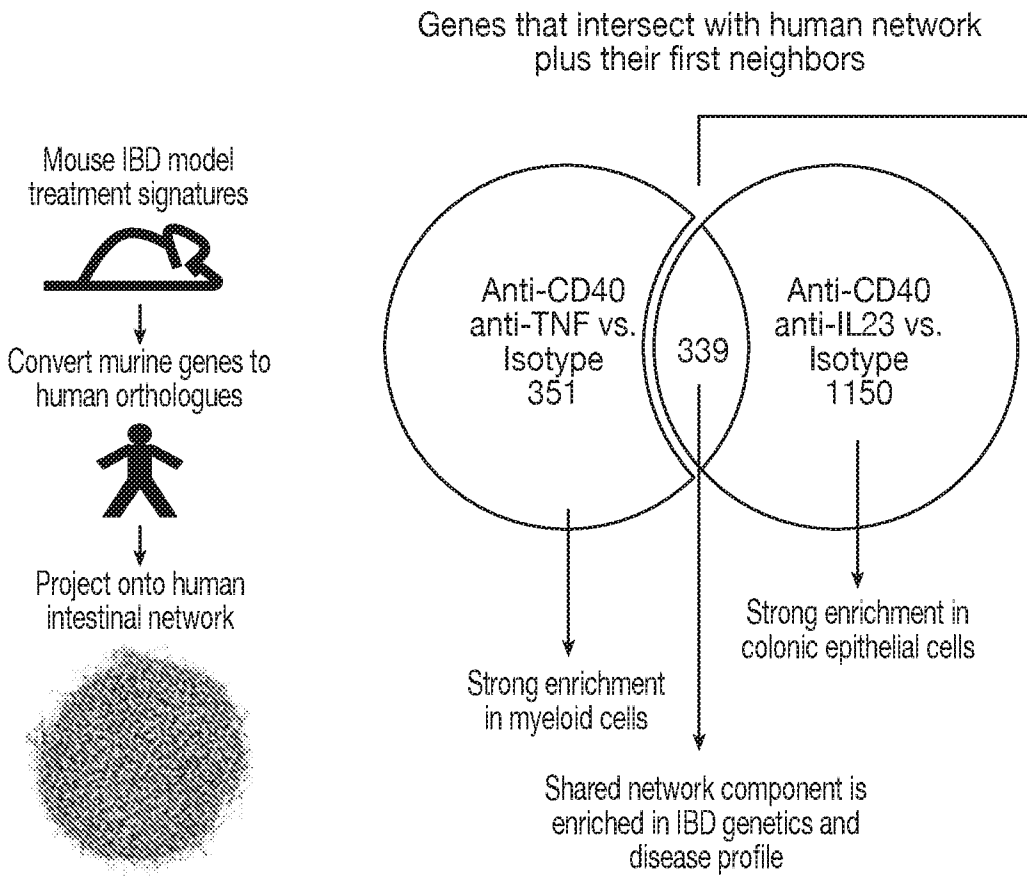
**FIG. 1B**



**FIG. 2A**

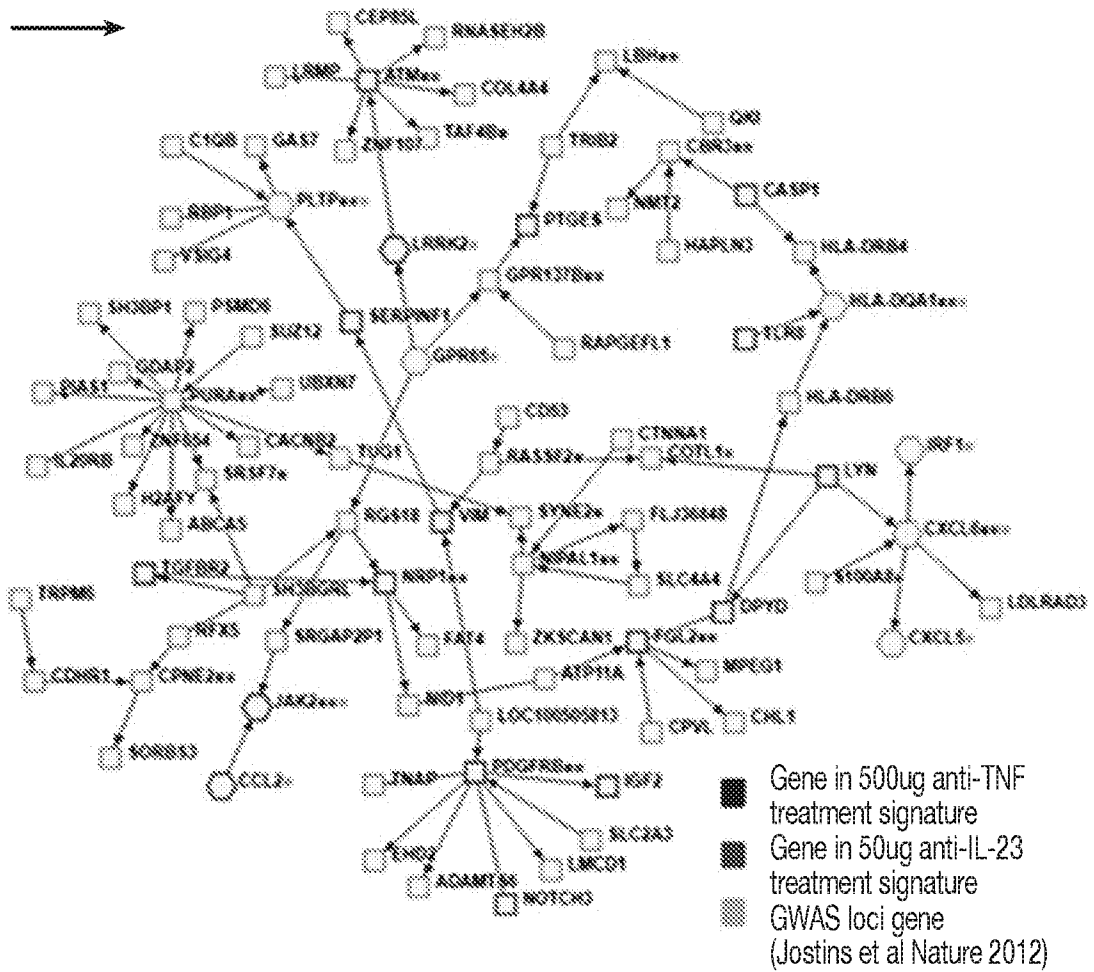


**FIG. 2B**

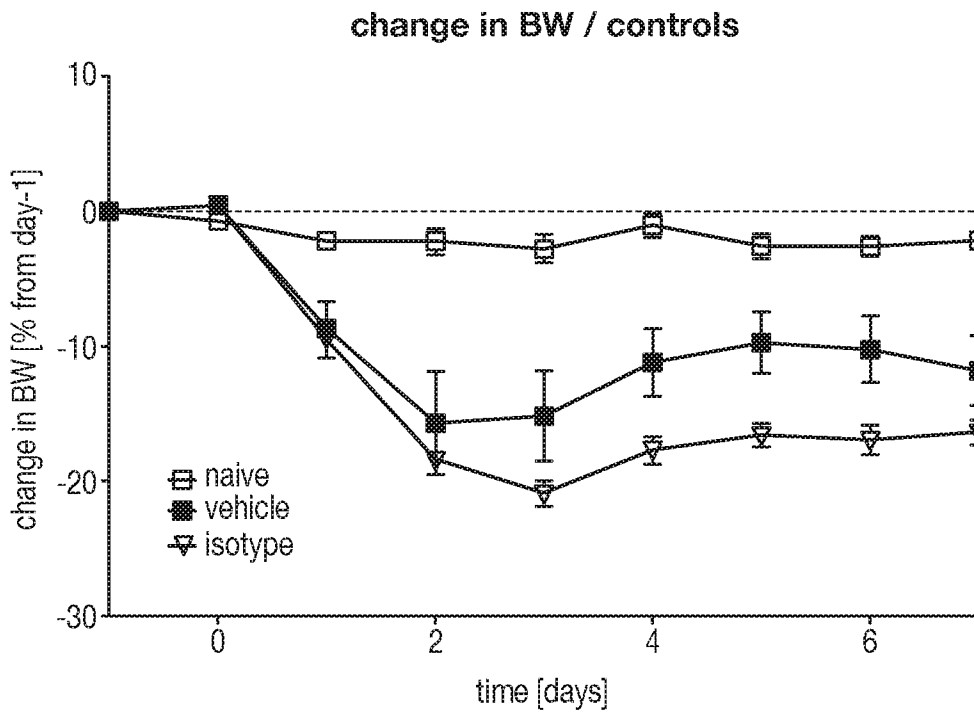


**FIG. 3A**

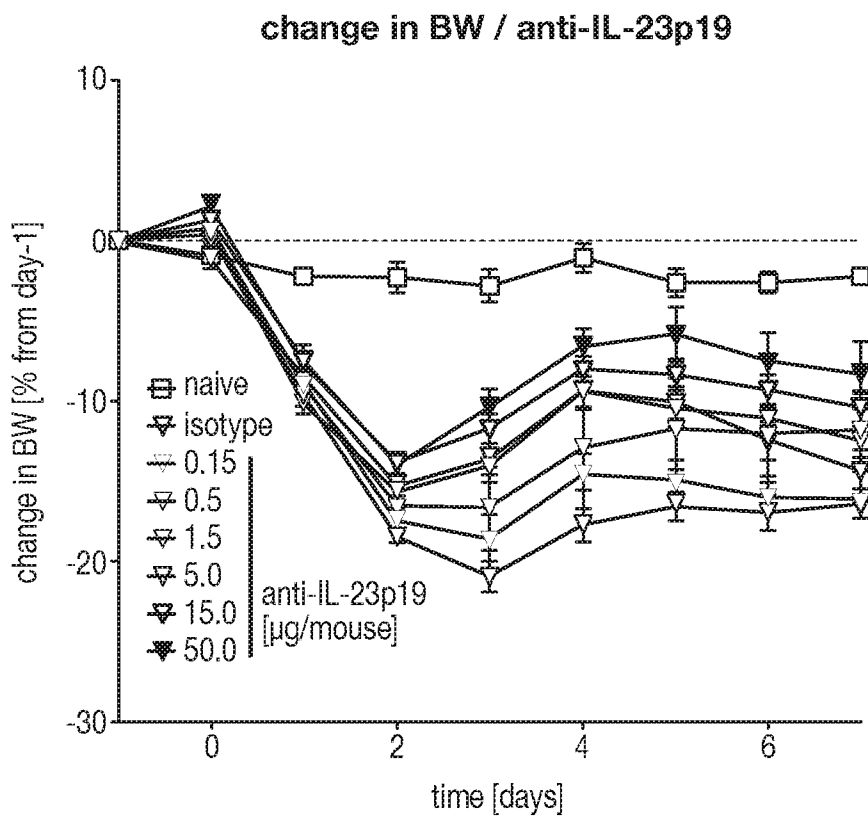
**Largest connected component of the shared anti-TNF and anti-IL-23 subnetworks**



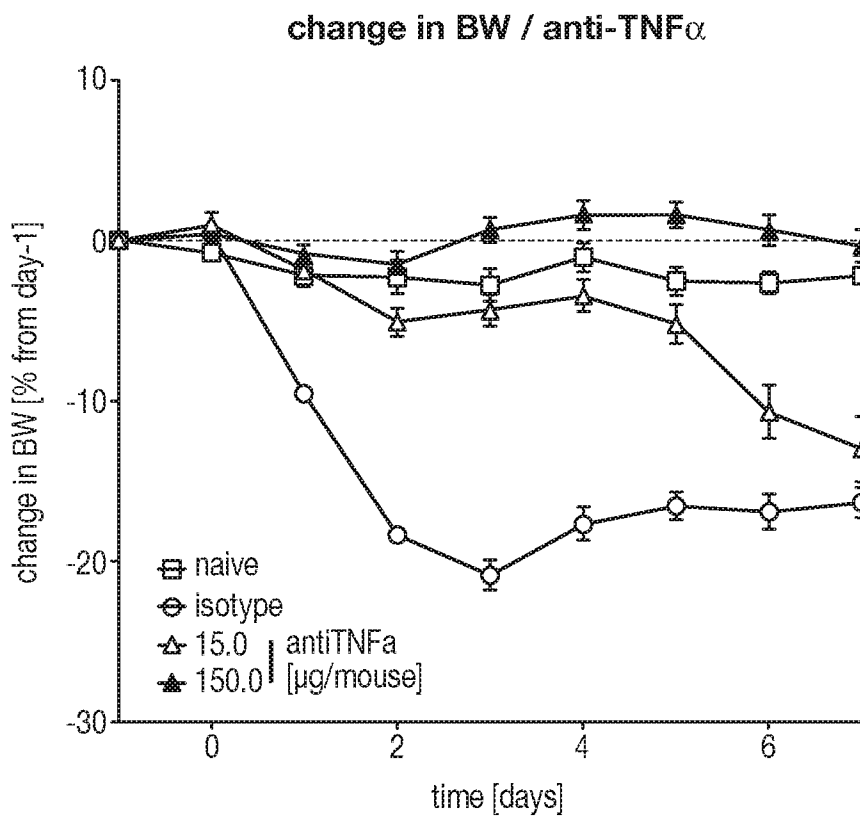
**FIG. 3B**



**FIG. 4A**



**FIG. 4B**



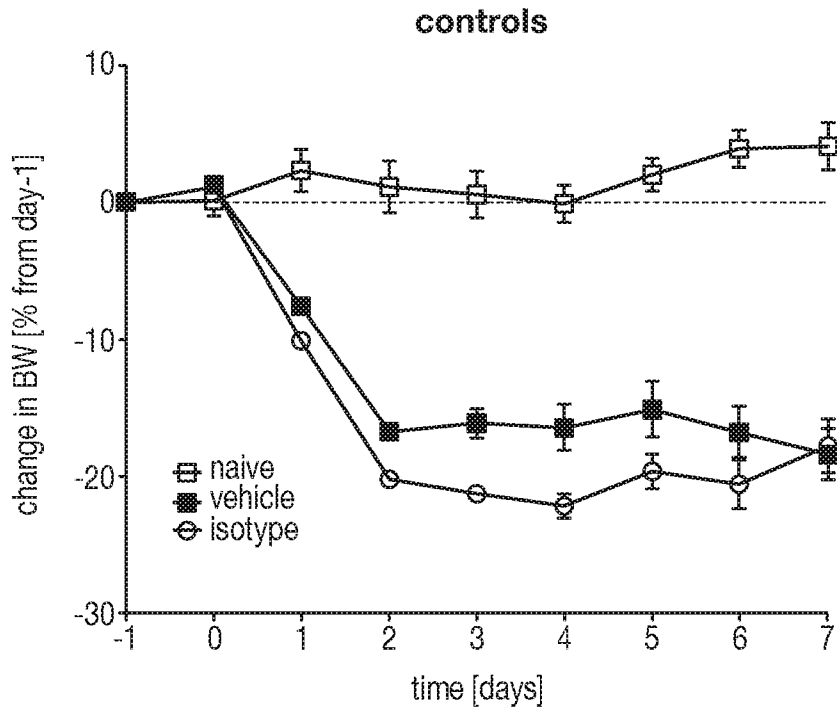
**FIG. 4C**

| mab treatment         | Day-1  | Day 0  | Day 1  | Day 2  | Day 3  | Day 4  | Day 5  | Day 6  | Day 7  |
|-----------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| vehicle<br>0.15mg     | 0.9999 | 0.9999 | 0.9994 | 0.6627 | 0.0286 | 0.0094 | 0.0053 | 0.0061 | 0.1302 |
| all-23<br>0.5µg allL- | 0.9999 | 0.9999 | 0.9995 | 0.9962 | 0.6460 | 0.2901 | 0.8859 | 0.9965 | 0.9997 |
| 23<br>1.5µg allL-     | 0.9999 | 0.9999 | 0.9994 | 0.8606 | 0.0733 | 0.0315 | 0.0262 | 0.0240 | 0.0488 |
| 23<br>5.0µg           | 0.9999 | 0.9295 | 0.9894 | 0.2940 | 0.0001 | 0.0001 | 0.0005 | 0.0400 | 0.7572 |
| all-23<br>15µg allL-  | 0.9999 | 0.9996 | 0.9995 | 0.2940 | 0.0002 | 0.0001 | 0.0013 | 0.0025 | 0.1064 |
| 23<br>50µg allL-      | 0.9999 | 0.9968 | 0.6920 | 0.0497 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| 23<br>15µg            | 0.9999 | 0.8692 | 0.8394 | 0.0294 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0021 |
| aTNFα<br>150µg        | 0.9999 | 0.9996 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0012 | 0.2255 |
| aTNFα                 | 0.9999 | 0.9999 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |

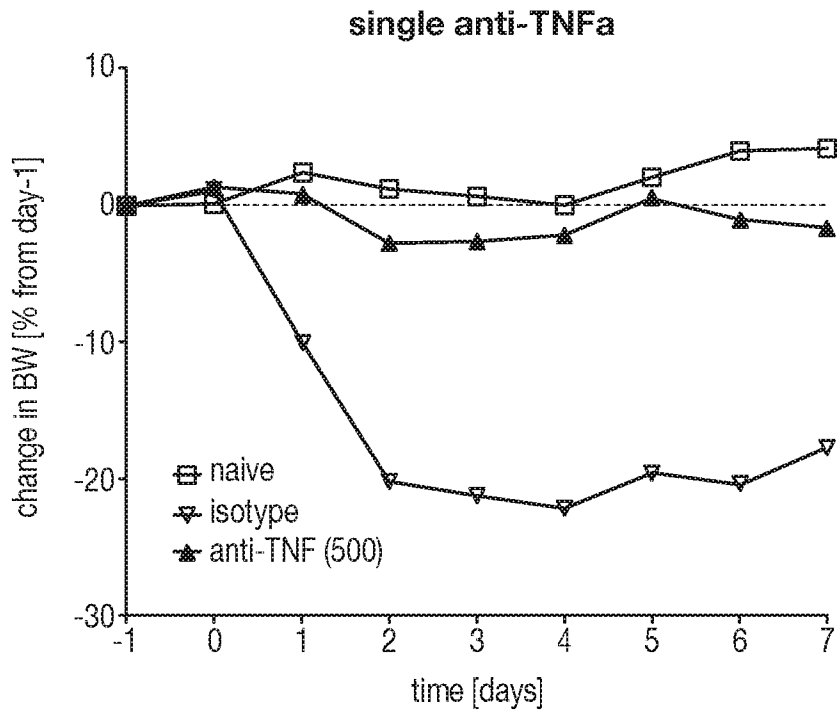
**FIG. 4D**



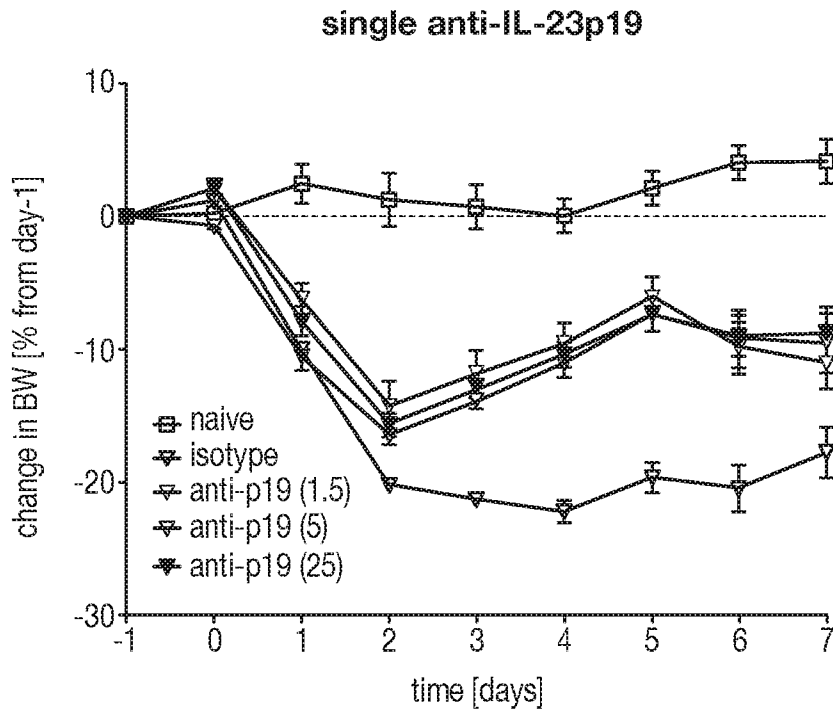




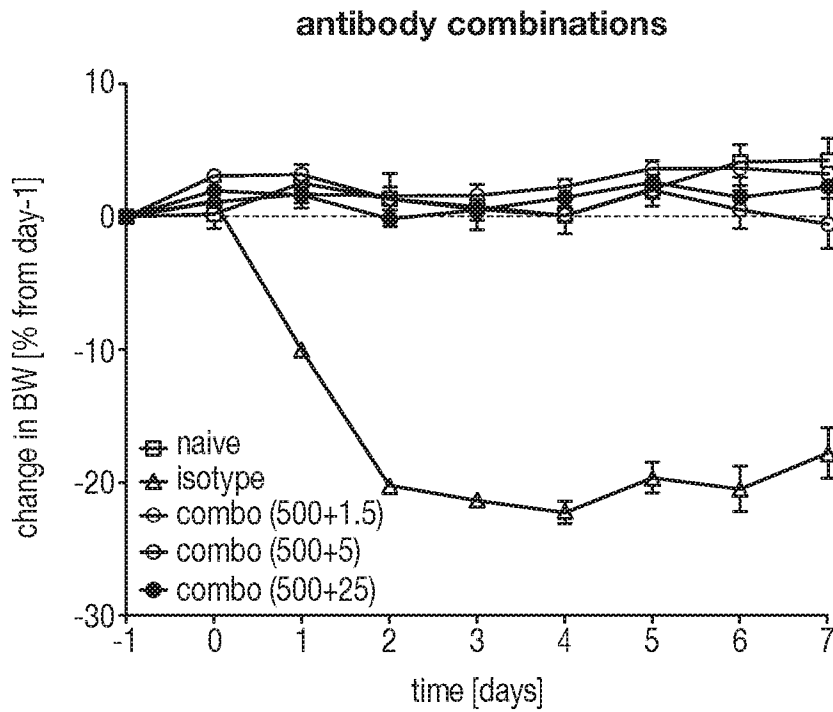
**FIG. 6A**



**FIG. 6B**



**FIG. 6C**



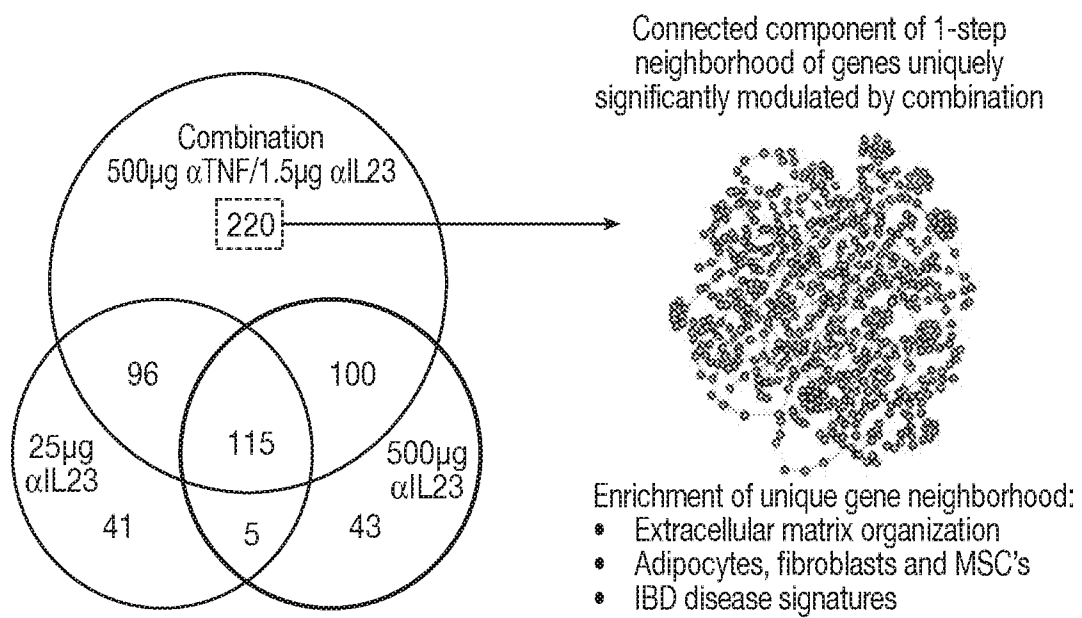
**FIG. 6D**

| mab<br>treatment  | time [days] |        |               |               |               | time [days]   |               |               |               |
|-------------------|-------------|--------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                   | Day-1       | Day 0  | Day 1         | Day 2         | Day 3         | Day 4         | Day 5         | Day 6         | Day 7         |
| PBS               | 0.9999      | 0.9999 | 0.5254        | 0.1832        | <b>0.0129</b> | <b>0.0034</b> | <b>0.0427</b> | 0.1373        | 0.9994        |
| 500µg<br>aTNFα    | 0.9999      | 0.9997 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 1.5µg allL-<br>23 | 0.9999      | 0.9938 | 0.1213        | <b>0.0021</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0004</b> |
| 5µg allL-<br>23   | 0.9999      | 0.8039 | 0.9995        | 0.1152        | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0009</b> |
| 25µg allL-<br>23  | 0.9999      | 0.9936 | 0.6811        | <b>0.0368</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 500µg<br>aTNFα+   | 0.9999      | 0.9999 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 1.5µg<br>allL-23  | 0.9999      | 0.8292 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 500µg<br>aTNFα+   | 0.9999      | 0.8292 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 5µg allL-<br>23   | 0.9999      | 0.9977 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 500µg<br>aTNFα+   | 0.9999      | 0.9977 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |
| 25µg allL-        | 0.9999      | 0.9977 | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> | <b>0.0001</b> |

**FIG. 6E**







**FIG. 8**

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB20/54859

| A. CLASSIFICATION OF SUBJECT MATTER  |  |  |
|--|--|--|
| IPC - A61P 1/04; C07K 16/24, 16/28; A61K 39/00, 39/395 (2020.01)   |  |  |
| CPC - A61P 1/04; C07K 16/241, 16/244, 16/2878, 16/24, 16/28; A61P 29/00, 1/00  |  |  |
| According to International Patent Classification (IPC) or to both national classification and IPC  |  |  |
| B. FIELDS SEARCHED   |  |  |
| Minimum documentation searched (classification system followed by classification symbols)<br>See Search History document   |  |  |
| Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>See Search History document   |  |  |
| Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br>See Search History document  |  |  |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT   |  |  |
| Category*  | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.  |
| X<br>--<br>Y<br>--<br>A  | WO 2011/070339 A1 (IMPERIAL INNOVATIONS LIMITED) 16 June 2011; page 1, line 3 to page 2, line 2; page 3, line 25 to page 4, line 2   | 1-4<br>-----<br>5-17, 22-43<br>-----<br>18-21                                  |
| Y  | US 2016/0122429 A1 (ELI LILLY AND COMPANY) 5 May 2016; abstract; paragraphs [0029], [0098]-[0100]  | 5-17, 22-43  |
| Y  | WO 2018/218215 A1 (THE JOHNS HOPKINS UNIVERSITY) 29 November 2018; paragraph [0153]  | 9, 11-17, 28-33, 37-43   |
| Y<br>--<br>A   | US 2009/0214528 A1 (DORAI, H et al.) 27 August 2009; paragraph [0115]  | 10-17, 28-33, 37-43<br>-----<br>18-21  |
| Y  | WO 2019/090329 A1 (JANSSEN BIOTECH, INC) 9 May 2019; page 4, 2nd-3rd paragraph   | 43<br>---<br>18-21   |
| Y  | ✓ (AUSTRALIAN GOVERNMENT, DEPARTMENT OF HEALTH, THERAPEUTIC GOODS ADMINISTRATION) Australian Public Assessment Report for golimumab (rmc). Product report (online). Commonwealth of Australia. 2014 [retrieved on 17 July 2020]. Retrieved from the Internet: <URL: <a href="https://www.tga.gov.au/auspar/auspar-golimumab-rmc-1">https://www.tga.gov.au/auspar/auspar-golimumab-rmc-1</a> >; page 11, 2nd-3rd paragraphs; page 12, 9th paragraph; page 36, 3rd paragraph | 43   |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.  |  |  |
| * Special categories of cited documents:<br>"A" document defining the general state of the art which is not considered to be of particular relevance<br>"D" document cited by the applicant in the international application<br>"E" earlier application or patent but published on or after the international filing date<br>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)<br>"O" document referring to an oral disclosure, use, exhibition or other means<br>"P" document published prior to the international filing date but later than the priority date claimed<br>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention<br>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone<br>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art<br>"&" document member of the same patent family |  |  |
| Date of the actual completion of the international search<br>6 August 2020 (06.08.2020)  |  | Date of mailing of the international search report<br><b>19 AUG 2020</b>       |
| Name and mailing address of the ISA/US<br>Mail Stop PCT, Attn: ISA/US, Commissioner for Patents<br>P.O. Box 1450, Alexandria, Virginia 22313-1450<br>Facsimile No. 571-273-8300  |  | Authorized officer<br>Shane Thomas<br>Telephone No. PCT Helpdesk: 571-272-4300 |

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB20/54859

**Box No. I** Nucleotide and/or amino acid sequence(s) (Continuation of item 1.c of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of a sequence listing:
- a.  forming part of the international application as filed:  
 in the form of an Annex C/ST.25 text file.  
 on paper or in the form of an image file.
- b.  furnished together with the international application under PCT Rule 13ter.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c.  furnished subsequent to the international filing date for the purposes of international search only:  
 in the form of an Annex C/ST.25 text file (Rule 13ter.1(a)).  
 on paper or in the form of an image file (Rule 13ter.1(b) and Administrative Instructions, Section 713).
2.  In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
3. Additional comments: