ANTI-CD40 ANTIBODIES AND THEIR USES

1. CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U. S. Provisional Application no. 62/342,417, filed May 27, 2016, the contents of which are incorporated herein in its entirety by reference thereto.

2. SEQUENCE LISTING

[0002] The instant application contains a Sequence Listing which has been submitted electronically in ASCII format and is hereby incorporated by reference in its entirety. Said ASCII copy, created on May 17, 2017, is named 381493-285WO_SL.txt and is 108,670 bytes in size.

3. TECHNICAL FIELD

[0003] The present application pertains to, among other things, novel anti-CD40 antibodies, compositions including the new antibodies, nucleic acids encoding the antibodies, and methods of making and using the same.

4. BACKGROUND

[0004] Cancer therapies comprise a wide range of therapeutic approaches, including surgery, radiation, and chemotherapy. While the various approaches allow a broad selection of treatments to be available to the medical practitioner to treat the cancer, existing therapeutics suffer from a number of disadvantages, such as a lack of selectivity of targeting cancer cells over normal, healthy cells, and the development of resistance by the cancer to the treatment.

[0005] Recent approaches based on targeted therapeutics, which interfere with cellular processes of cancer cells preferentially over normal cells, have led to chemotherapeutic regimens with fewer side effects as compared to non-targeted therapies such as radiation treatment.

[0006] Cancer immunotherapy, in particular the development of agents that activate T cells of the host's immune system to prevent the proliferation of or kill cancer cells, has emerged as a promising therapeutic approach to complement existing standards of care. *See*, *e.g.*, Miller, et al. Cancer Cell, 27, 439-449 (2015). Such immunotherapy approaches include the development of antibodies used to modulate the immune system to kill cancer cells. For example, anti-PD-1 blocking antibodies pembrolizumab (Keytruda®) and nivolumab (Opdivo®) have been approved in the US and the European Union to treat diseases such as unresectable or metastatic melanoma and metastatic non-

small cell lung cancer. Efforts to inhibit immunosuppressive proteins such as CTLA-4 have led to the development and clinical evaluation of anti-CTLA-4 antibodies, such as tremelimumab and ipilimumab (Yervoy®).

[0007] There remains a need for alternative approaches and additional cancer treatments to complement existing therapeutic standards of care.

5. SUMMARY

[0008] Human CD40 (SEQ ID NO:40) is a tumor necrosis factor (TNF) receptor superfamily member (TNF superfamily member 5) expressed on antigen-presenting cells such as B cells, dendritic cells (DC), and monocytes, and nonimmune cells, including certain types of tumor cells. When activated by human CD40 ligand (SEQ ID NO:41), human CD40 activates antigen-presenting cells and induces responses from both innate and adaptive immune systems. Agonistic CD40 agents can be used to induce the immune system to prevent proliferation of and/or kill tumor cells, and thus provide effective therapeutic treatment of solid tumors.

[0009] The present disclosure provides anti-CD40 antibodies and binding fragments thereof that specifically bind to human CD40 (SEQ ID NO:40). The amino acid sequences of exemplary CDRs, as well as the amino acid sequence of the V_H and V_L regions of the heavy and light chains of exemplary anti-CD40 antibodies are provided in the Detailed Description below.

[0009a] In one aspect, the present disclosure provides an anti-CD40 antibody or binding fragment which comprises (i) a V_H chain comprising three CDRs; and (ii) a V_L chain comprising three CDRs, wherein: V_H CDR#1 is GYSITSNYYWN (SEQ ID NO:8); V_H CDR#2 is YIRYDGSNNYNPSLKN (SEQ ID NO:18); V_H CDR#3 is LDY (SEQ ID NO:35); V_L CDR#1 is RSSQSLENTNGNTFLN (SEQ ID NO:58); V_L CDR#2 is RVSNRFS (SEQ ID NO:68); and V_L CDR#3 is LQVTHVPFT (SEQ ID NO:88).

[0009b] In another aspect, the present disclosure provides a pharmaceutical composition comprising an anti-CD40 antibody or binding fragment as described herein, and a pharmaceutically acceptable carrier.

[0010] The V_H and V_L chains of the anti-CD40 antibodies described herein afford an allosteric agonistic receptor response that can activate human CD40 in the presence or absence of CD40 ligand (CD40L), without competing with the CD40L-CD40 binding interaction. Moreover, the present anti-CD40 antibodies, by interacting with CD40, can enhance CD40L binding to CD40.

[0011] The anti-CD40 antibodies may include modifications and/or mutations that alter the properties of the antibodies, such as increase half-life, increase or decrease ADCC, or increase agonistic activity, as is known in the art.

[0012] Nucleic acids comprising nucleotide sequences encoding the anti-CD40 antibodies of the disclosure are provided herein, as are vectors comprising nucleic acids. Additionally, prokaryotic and eukaryotic host cells transformed with a vector comprising a nucleotide sequence encoding a disclosed anti-CD40 antibody are provided herein, as well as eukaryotic (such as mammalian) host cells engineered to express the nucleotide sequences. Methods of producing antibodies, by culturing host cells and recovering the antibodies are also provided, and discussed further in the Detailed Description below.

[0013] In another example, the present disclosure provides compositions including the anti-CD40 antibodies described herein. The compositions generally comprise one or more anti-CD40 antibody as described herein, and/or salts thereof, and one or more excipients, carriers or diluents.

[0014] The present disclosure provides methods of treating subjects, such as human subjects, diagnosed with a solid tumor with an anti-CD40 antibody. The method generally involves administering to the subject an amount of an anti-CD40 antibody described herein effective to provide therapeutic benefit. The subject may be diagnosed with any one of a number of solid tumors that may be newly diagnosed, relapsed, or relapsed and refractory. An anti-CD40 antibody is typically administered as an intravenous infusion or intratumoral injection at doses ranging from about 0.001 mg/kg to about 4 mg/kg. An anti-CD40 antibody is typically administered as an intravenous infusion or intratumoral injection twice a week, once a week, once every two weeks, once every three weeks, once every four weeks, once every five weeks, once every six weeks, once every seven weeks, or once every eight weeks.

[0015] The anti-CD40 antibodies may be administered as single therapeutic agents (monotherapy) or adjunctive to or with other therapeutic agents typically, but not necessarily, those used for the treatment of a solid tumor. Therapeutic agents typically will be used at their approved dose, route of administration, and frequency of administration, but may be used at lower dosages.

[0016] The anti-CD40 antibodies may be administered via a variety of routes or modes of administration, including but not limited to, intravenous infusion and/or injection, subcutaneous injection, and intratumoral injection. The amount administered will depend upon the route of administration, the dosing schedule, the type of cancer being treated, the stage of the cancer being treated, and other parameters such as the age and weight of the patient, as is well known in the art. Specific exemplary dosing schedules expected to provide therapeutic benefit are provided in the Detailed Description.

[0017] Based on data presented herein, it is expected that the anti-CD40 antibodies described herein will provide therapeutic benefit to subjects diagnosed with a solid tumor.

6. BRIEF DESCRIPTION OF THE FIGURES

[0018] FIG. 1 shows the amino acid sequences of human CD40 receptor (SEQ ID NO:40) and human CD40 ligand (SEQ ID NO:41).

[0019] FIGS. 2A-2G provide amino acid sequences for V_H and V_L of exemplary mouse and humanized anti-CD40 antibodies. FIG. 2A shows the V_H and V_L amino acid sequences for muAb1 through muAb3; FIG. 2B shows the V_H and V_L amino acid sequences for muAb4 through muAb7; FIG. 2C shows the V_H and V_L amino acid sequences for muAb8 through muAb10; FIG. 2D shows the V_H and V_L amino acid sequences for humanized antibodies of muAb6 and muAb8; FIG. 2E shows the V_H and V_L amino acid sequences for humanized antibodies of muAb8 and muAb9; FIG. 2F shows the V_H and V_L amino acid sequences for further humanized antibodies of muAb9; and FIG. 2G shows the V_H and V_L amino acid sequences for additional humanized antibodies of muAb9.

[0020] FIG. 3 provides the results of competition experiments on human CD40 between CD40L and exemplary anti-CD40 antibodies. Upper left shows exemplary anti-CD40 antibodies that compete with CD40L; upper right shows antibodies that do not significantly compete with CD40L; lower left shows antibodies that enhance CD40-CD40L interaction; lower right shows effects of anti-CD40 antibody huAb9 A2I and CP-870,893. Y-axis depicts optical density (OD) at 650 nm; x-axis depicts antibody dose ("Sample") in μg/mL.

[0021] FIG. 4 shows the binding of fluorochrome-conjugated human CD40 at a fixed concentration of 1 μg/mL on Jurkat cells expressing human CD40L in the presence of increasing amounts of antibody huAb9 A2I, CP-870,893, human IgG_1 ("huIgG1") isotype or human IgG_2 ("huIgG2") isotype. Y-axis depicts mean fluorescence intensity ("MFI") representing the binding; x-axis depicts antibody dose ("Sample") in μg/mL.

[0022] FIGS. 5A-5B show the effects of an antibody dose ("Sample") at 3 μg/mL or media only on NFκB signal from HEK293 blue CD40 NFκB reporter cells mixed with Jurkat D1.1 cells (1:1 ratio). Antibody huAb9 A2I, CP-870,893, human IgG_1 ("huIgG1") isotype or human IgG_2 ("huIgG2") isotype, or media only, was added to the individual sample. FIG. 5A depicts the NFκB signal in cultures containing CD40L negative ("CD40L-") Jurkat D1.1 cells. FIG. 5B depicts the NFκB signal in cultures containing CD40L positive ("CD40L+") Jurkat D1.1 cells. Y-axis depicts OD at 625 nm; x-axis depicts antibody or media only treatment ("Sample").

[0023] FIGS. 6A-6B show the binding of antibody doses ("Sample") in μg/mL of huAb9-5 with wild type huIgG$_1$, or with V273Y or V273E variant, or CP-870,893, in CHO cells expressing CD16F, CD16V, CD32a, CD32b, or CD64. FIG. 6A shows binding of an anti-CD40 antibody on CHO cells expressing CD16F (upper left), CD16V (upper right), CD32a (lower left), or CD32b (lower right). FIG. 6B shows binding of an anti-CD40 antibody on CHO cells expressing CD64. Y-axis depicts mean fluorescence intensity (MFI) representing the binding; x-axis depicts antibody dose ("Sample") in μg/mL.

[0024] FIG. 7 shows the antibody-dependent cell-mediated cytotoxicity (ADCC) of constant region variants V273E or V273Y for antibody huAb9-5 as compared with huAb9-5 with the wild type human IgG$_1$ in RL cells. Y-axis depicts percent cytotoxicity in RL cells; x-axis depicts antibody dose ("Sample") in μg/mL.

[0025] FIG. 8 shows the effect of antibody huAb6-1 (upper left), huAb9-5 (lower left), huAb8-1 (upper right) with wild type human IgG$_1$, or a constant region variant V273E or V273Y, on B cell proliferation. Lower right graph shows B cell proliferation effects of huAb9 A2I with human IgG$_1$ V273E variant or CP-870,893. Y-axis depicts B cell proliferation in counts per minute (CPM); x-axis depicts antibody dose ("Sample") in μg/mL.

[0026] FIG. 9 shows the effect of antibody huAb6-1 (upper left), huAb9-5 (lower left) and huAb8-1 (upper right) with wild type human IgG$_1$, or a constant region variant V273E or V273Y, on dendritic cell (DC) activation as measured by IL-12p70 production in pg/mL. Lower right graph shows DC activation of huAb9 A2I with human IgG$_1$ V273E variant or CP-870,893. Y-axis depicts IL-12p70 in pg/mL; x-axis depicts antibody dose ("Sample") in μg/mL.

[0027] FIG. 10 shows the effect of a V273Y variant of huAb6-1, huAb8-1, or huAb9-5 on DC and T-cell co-cultures as measured by interferon-gamma (IFN-γ) production in pg/mL.

[0028] FIG. 11 shows the effect of antibody huAb6-1 (upper), huAb9-5 (middle) or huAb9 A2I (lower) on tumor volume (mm^3) in a prophylactic PC3 mouse model.

[0029] FIG. 12 shows in vivo effects following intratumoral (IT) or intraperitoneal (IP) delivery of anti-CD40 antibody 1C10, or mIgG1 isotype, in a mouse model carrying bilaterally established CT26 syngeneic tumors. IT dosing was administered to one tumor at one flank, with no injection to the tumor at the other flank.

[0030] FIG. 13 shows effects on tumor volume (mm^3) following dosing two times a week of anti-CD40 antibody 1C10 at 0.6 mg/kg, an anti-PD-1 antibody at 10 mg/kg, or combination treatment of both 1C10 and the anti-PD-1 antibody in a CT26 mouse syngeneic model.

[0031] FIG. 14 shows ALT (upper left), TNFα ("TNFa", lower left), or IL-6 (lower right) levels 24 hours after dosing of anti-CD40 antibody 1C10 ("anti-CD40"), anti-PD-1 antibody ("anti-PD-1") or combination treatment ("anti-CD40 + anti-PD-1") in a CT26 mouse syngeneic model. Upper right graph shows spleen weight 4 days post-dosing.

7. DETAILED DESCRIPTION

[0032] The present disclosure concerns antibodies and fragments that specifically bind human CD40 (SEQ ID NO:40), compositions comprising the antibodies, polynucleotides encoding anti-CD40 antibodies, host cells capable of producing the antibodies, methods and compositions useful for making the antibodies and binding fragments, and various methods of using the same.

[0033] As will be appreciated by skilled artisans, antibodies are "modular" in nature. Throughout the disclosure, various specific embodiments of the various "modules" composing the antibodies are described. As specific non-limiting examples, various specific embodiments of V_H CDRs, V_H chains, V_L CDRs and V_L chains are described. It is intended that all of the specific embodiments may be combined with each other as though each specific combination were explicitly described individually.

7.1. Abbreviations

[0034] The antibodies, binding fragments, ADCs and polynucleotides described herein are, in many embodiments, described by way of their respective polypeptide or polynucleotide sequences. Unless indicated otherwise, polypeptide sequences are provided in N→C orientation; polynucleotide sequences in 5'→3' orientation. For polypeptide sequences, the conventional three or one-letter abbreviations for the genetically encoded amino acids may be used, as noted in TABLE 1, below.

TABLE 1
Encoded Amino Acid Abbreviations

Amino Acid	Three Letter Abbreviation	One-Letter Abbreviation
Alanine	Ala	A
Arginine	Arg	R
Asparagine	Asn	N

TABLE 1 Encoded Amino Acid Abbreviations		
Amino Acid	**Three Letter Abbreviation**	**One-Letter Abbreviation**
Aspartic acid	Asp	D
Cysteine	Cys	C
Glutamic acid	Glu	E
Glutamine	Gln	Q
Glycine	Gly	G
Histidine	His	H
Isoleucine	Ile	I
Leucine	Leu	L
Lysine	Lys	K
Methionine	Met	M
Phenylalanine	Phe	F
Proline	Pro	P
Serine	Ser	S
Threonine	Thr	T
Tryptophan	Trp	W
Tyrosine	Tyr	Y
Valine	Val	V

[0035] Certain sequences are defined by structural formulae specifying amino acid residues belonging to certain classes (*e.g.*, aliphatic, hydrophobic, *etc.*). The various classes to which the genetically encoded amino acids belong as used herein are noted in TABLE 2, below. Some amino acids may belong to more than one class. Cysteine, which contains a sulfhydryl group, and proline, which is conformationally constrained, are not assigned classes.

TABLE 2 Encoded Amino Acid Classes	
Class	**Amino Acids**
Aliphatic	A, I, L,V
Aromatic	F, Y, W
Non-Polar	M, A, I, L, V
Polar	N, Q, S, T
Basic	H, K, R
Acidic	D, E
Small	A, G

[0036] The abbreviations used for the various exemplary antibodies disclosed herein are provided in TABLE 3, below:

TABLE 3 Antibody Abbreviations					
Clone/Name	**Abbreviation**	**V_H Sequence (FIGS. 2A-2G)**		**V_L Sequence (FIGS. 2A-2G)**	
AD163.9.3	muAb1	muAb1 V_H	SEQ ID NO:101	muAb1 V_L	SEQ ID NO:151
AD166.4.4	muAb2	muAb2 V_H	SEQ ID NO:102	muAb2 V_L	SEQ ID NO:152
AD175.14.11	muAb3	muAb3 V_H	SEQ ID NO:103	muAb3 V_L	SEQ ID NO:153
AD163.10.7	muAb4	muAb4 V_H	SEQ ID NO:104	muAb4 V_L	SEQ ID NO:154
AD165.1.2	muAb5	muAb5 V_H	SEQ ID NO:105	muAb5 V_L	SEQ ID NO:155
AD163.162.1	muAb6	muAb6 V_H	SEQ ID NO:106	muAb6 V_L	SEQ ID NO:156
AD163.27.12	muAb7	muAb6 V_H	SEQ ID NO:106	muAb7 V_L	SEQ ID NO:157
AD163.7.2	muAb8	muAb8 V_H	SEQ ID NO:107	muAb8 V_L	SEQ ID NO:158
AD164.14.6	muAb9	muAb9 V_H	SEQ ID NO:108	muAb9 V_L	SEQ ID NO:159
AD164.76.3	muAb10	muAb10 V_H	SEQ ID NO:109	muAb10 V_L	SEQ ID NO:160

TABLE 3

Antibody Abbreviations

Clone/Name	Abbreviation	V_H Sequence (FIGS. 2A-2G)		V_L Sequence (FIGS. 2A-2G)	
Humanized muAb6 #1	huAb6-1	huAb6-1 V_H	SEQ ID NO:110	huAb6-1 V_L	SEQ ID NO:161
Humanized muAb6 #2	huAb6-2	huAb6-2 V_H	SEQ ID NO:111	huAb6-1 V_L	SEQ ID NO:161
Humanized muAb6 #3	huAb6-3	huAb6-3 V_H	SEQ ID NO:112	huAb6-1 V_L	SEQ ID NO:161
Humanized muAb8 #1	huAb8-1	huAb8-1 V_H	SEQ ID NO:113	huAb8-1 V_L	SEQ ID NO:162
Humanized muAb8 #2	huAb8-2	huAb8-2 V_H	SEQ ID NO:114	huAb8-1 V_L	SEQ ID NO:162
Humanized muAb8 #3	huAb8-3	huAb8-3 V_H	SEQ ID NO:115	huAb8-1 V_L	SEQ ID NO:162
Humanized muAb9 #1	huAb9-1	huAb9-1 V_H	SEQ ID NO:116	huAb9-1 V_L	SEQ ID NO:163
Humanized muAb9 #2	huAb9-2	huAb9-2 V_H	SEQ ID NO:117	huAb9-1 V_L	SEQ ID NO:163
Humanized muAb9 #3	huAb9-3	huAb9-3 V_H	SEQ ID NO:118	huAb9-1 V_L	SEQ ID NO:163
Humanized muAb9 #4	huAb9-4	huAb9-1 V_H	SEQ ID NO:116	huAb9-4 V_L	SEQ ID NO:164
Humanized muAb9 #5	huAb9-5	huAb9-2 V_H	SEQ ID NO:117	huAb9-4 V_L	SEQ ID NO:164
Humanized muAb9 #6	huAb9-6	huAb9-3 V_H	SEQ ID NO:118	huAb9-4 V_L	SEQ ID NO:164
Humanized muAb9 #7	huAb9-7	huAb9-7 V_H	SEQ ID NO:119	huAb9-7 V_L	SEQ ID NO:165
Humanized muAb9 #8	huAb9-8	huAb9-8 V_H	SEQ ID NO:120	huAb9-7 V_L	SEQ ID NO:165
Humanized muAb9 #9	huAb9-9	huAb9-9 V_H	SEQ ID NO:121	huAb9-9 V_L	SEQ ID NO:166
Rehumanized muAb9 version #1	huAb9 rehu#1	huAb9 rehuVH4 V_H	SEQ ID NO:122	huAb9 VK1 V_L	SEQ ID NO:167
Rehumanized muAb9 version #2	huAb9 rehu#2	huAb9 rehuVH4 V_H	SEQ ID NO:122	huAb9 rehuVK2 V_L	SEQ ID NO:168
Rehumanized muAb9 version #3	huAb9 rehu#3	huAb9 rehuVH3 V_H	SEQ ID NO:123	huAb9 rehuVK1 V_L	SEQ ID NO:169
Humanized muAb9 A2I	huAb9 A2I	huAb9-2V_H	SEQ ID NO:117	huAb9A2I V_L	SEQ ID NO:170
Humanized muAb9 A2V	huAb9 A2V	huAb9-2V_H	SEQ ID NO:117	huAb9A2V V_L	SEQ ID NO:171

7.2. Definitions

[0037] Unless otherwise defined herein, scientific and technical terms used in connection with the present disclosure shall have the meanings that are commonly understood by those of ordinary skill in the art.

7.3. Anti-CD40 Antibodies and Binding Fragments

[0038] In one aspect, the disclosure concerns antibodies and/or binding fragments thereof that specifically bind human CD40 receptor (also known as tumor necrosis factor receptor superfamily member 5, TNFRSF5, Bp50, and CD40L receptor).

[0039] As used herein, the term "antibody" (Ab) refers to an immunoglobulin molecule that specifically binds to a particular antigen- here, CD40. In some embodiments, the anti-CD40 antibodies of the disclosure bind to human CD40 and thereby modulate, *e.g.*, activate, the immune system. The resulting immune system response inhibits proliferation of cells such as tumor cells, and in some instances are cytotoxic to the tumor cells. Anti-CD40 antibodies of the disclosure comprise complementarity determining regions (CDRs), also known as hypervariable regions, in both the light chain and the heavy chain variable domains. The more highly conserved portions of variable domains are called the framework (FR). As is known in the art, the amino acid position/boundary delineating a hypervariable region of an antibody can vary, depending on the context and the various definitions known in the art. Some positions within a variable domain may be viewed as hybrid hypervariable positions in that these positions can be deemed to be within a hypervariable region under one set of criteria while being deemed to be outside a hypervariable region under a different set of criteria. One or more of these positions can also be found in extended hypervariable regions. The disclosure provides antibodies comprising modifications in these hybrid hypervariable positions. The variable domains of native heavy and light chains each comprise four FR regions, largely by adopting a β-sheet configuration, connected by three CDRs, which form loops connecting, and in some cases forming part of, the β-sheet structure. The CDRs in each chain are held together in close proximity by the FR regions and, with the CDRs from the other chain, contribute to the formation of the target binding site of antibodies. *See* Kabat *et al.,* Sequences of Proteins of Immunological Interest (National Institute of Health, Bethesda, Md. 1987). As used herein, numbering of immunoglobulin amino acid residues is done according to the immunoglobulin amino acid residue numbering system of Kabat *et al.* unless otherwise indicated.

[0040] The antibodies of the disclosure may be polyclonal, monoclonal, genetically engineered, and/or otherwise modified in nature, including but not limited to chimeric antibodies, humanized antibodies, human antibodies, primatized antibodies, single chain antibodies, *etc*. In various embodiments, the antibodies comprise all or a portion of a constant region of an antibody. In some embodiments, the constant region is an isotype selected from: IgA (*e.g.*, IgA_1 or IgA_2), IgD, IgE, IgG (*e.g.*, IgG_1, IgG_2, IgG_3 or IgG_4), and IgM. In specific embodiments, the anti-CD40 antibodies described herein comprise an IgG_1. In other embodiments, the anti-CD40 antibodies comprise an IgG_2. In yet other embodiments, the anti-CD40 antibodies comprise an IgG_4. As used herein, the "constant region" of an antibody includes the natural constant region, allotypes or natural variants, such as D356E and L358M, or A431G in human IgG_1. *See*, *e.g.*, Jefferis and Lefranc, MAbs, 1(4): 332-338 (Jul-Aug 2009).

[0041] The light constant region of an anti-CD40 antibody may be a kappa (κ) light region or a lambda (λ) region. A λ light region can be any one of the known subtypes, e.g., λ_1, λ_2, λ_3, or λ_4. In some embodiments, the anti-CD40 antibody comprises a kappa (κ) light region.

[0042] The term "monoclonal antibody" as used herein is not limited to antibodies produced through hybridoma technology. A monoclonal antibody is derived from a single clone, including any eukaryotic, prokaryotic, or phage clone, by any means available or known in the art. Monoclonal antibodies useful with the present disclosure can be prepared using a wide variety of techniques known in the art including the use of hybridoma, recombinant, and phage display technologies, or a combination thereof. In many uses of the present disclosure, including *in vivo* use of the anti-CD40 antibodies in humans, chimeric, primatized, humanized, or human antibodies can suitably be used.

[0043] The term "chimeric" antibody as used herein refers to an antibody having variable sequences derived from a non-human immunoglobulin, such as a rat or a mouse antibody, and human immunoglobulin constant regions, typically chosen from a human immunoglobulin template. Methods for producing chimeric antibodies are known in the art. See, *e.g.*, Morrison, 1985, Science 229(4719):1202-7; Oi *et al.*, 1986, BioTechniques 4:214-221; Gillies *et al.*, 1985, J. Immunol. Methods 125:191-202; U.S. Pat. Nos. 5,807,715; 4,816,567; and 4,816,397.

[0044] "Humanized" forms of non-human (*e.g.*, murine) antibodies are chimeric immunoglobulins that contain minimal sequences derived from non-human immunoglobulin. In general, a humanized antibody will comprise substantially all of at least one, and typically two, variable domains, in which all or substantially all of the CDR regions correspond to those of a non-human immunoglobulin and

all or substantially all of the FR regions are those of a human immunoglobulin sequence. The humanized antibody can also comprise at least a portion of an immunoglobulin constant region (Fc), typically that of a human immunoglobulin consensus sequence. Methods of antibody humanization are known in the art. See, *e.g.*, Riechmann *et al.,* 1988, Nature 332:323-7; U.S. Patent Nos: 5,530,101; 5,585,089; 5,693,761; 5,693,762; and 6,180,370 to Queen *et al.*; EP239400; PCT publication WO 91/09967; U.S. Patent No. 5,225,539; EP592106; EP519596; Padlan, 1991, Mol. Immunol., 28:489-498; Studnicka *et al.,* 1994, Prot. Eng. 7:805-814; Roguska *et al.,* 1994, Proc. Natl. Acad. Sci. 91:969-973; and U.S. Patent No. 5,565,332.

[0045] "Human antibodies" include antibodies having the amino acid sequence of a human immunoglobulin and include antibodies isolated from human immunoglobulin libraries or from animals transgenic for one or more human immunoglobulin and that do not express endogenous immunoglobulins. Human antibodies can be made by a variety of methods known in the art including phage display methods using antibody libraries derived from human immunoglobulin sequences. See U.S. Patent Nos. 4,444,887 and 4,716,111; and PCT publications WO 98/46645; WO 98/50433; WO 98/24893; WO 98/16654; WO 96/34096; WO 96/33735; and WO 91/10741. Human antibodies can also be produced using transgenic mice which are incapable of expressing functional endogenous immunoglobulins but which can express human immunoglobulin genes. See, *e.g.*, PCT publications WO 98/24893; WO 92/01047; WO 96/34096; WO 96/33735; U.S. Patent Nos. 5,413,923; 5,625,126; 5,633,425; 5,569,825; 5,661,016; 5,545,806; 5,814,318; 5,885,793; 5,916,771; and 5,939,598. In addition, companies such as LakePharma, Inc. (Belmont, CA) or Creative BioLabs (Shirley, NY) can be engaged to provide human antibodies directed against a selected antigen using technology similar to that described above. Fully human antibodies that recognize a selected epitope can be generated using a technique referred to as "guided selection." In this approach, a selected non-human monoclonal antibody, *e.g.*, a mouse antibody, is used to guide the selection of a completely human antibody recognizing the same epitope (see, Jespers *et al.,* 1988, Biotechnology 12:899-903).

[0046] "Primatized antibodies" comprise monkey variable regions and human constant regions. Methods for producing primatized antibodies are known in the art. See, *e.g.*, U.S. Patent Nos. 5,658,570; 5,681,722; and 5,693,780.

[0047] Anti-CD40 antibodies of the disclosure include full-length (intact) antibody molecules that are capable of specifically binding CD40, *e.g.*, human CD40 (SEQ ID NO:40).

[0048] Also disclosed are anti-CD40 binding fragments that are capable of specifically binding human CD40. Examples of antibody binding fragments include by way of example and not limitation, Fab, Fab', $F(ab')_2$, Fv fragments, single chain Fv fragments and single domain fragments.

[0049] A Fab fragment contains the constant and variable domains of the light chain and the first constant domain (CH1) and the variable domain of the heavy chain. Fab' fragments differ from Fab fragments by the addition of a few residues at the carboxyl terminus of the heavy chain CH1 domain including one or more cysteines from the antibody hinge region. F(ab') fragments are produced by cleavage of the disulfide bond at the hinge cysteines of the $F(ab')_2$ pepsin digestion product. Additional chemical couplings of antibody fragments are known to those of ordinary skill in the art. Fab and $F(ab')_2$ fragments lack the Fc fragment of an intact antibody, clear more rapidly from the circulation of animals, and may have less non-specific tissue binding than an intact antibody (see, *e.g.*, Wahl *et al.,* 1983, J. Nucl. Med. 24:316).

[0050] An "Fv" fragment is the minimum fragment of an antibody that contains a complete target recognition and binding site. This region consists of a dimer of one heavy and one light chain variable domain in a tight, non-covalent association (V_H-V_L dimer). It is in this configuration that the three CDRs of each variable domain interact to define a target binding site on the surface of the V_H-V_L dimer. Often, the six CDRs confer target binding specificity to the antibody. However, in some instances even a single variable domain (or half of an Fv comprising only three CDRs specific for a target) can have the ability to recognize and bind target, although at a lower affinity than the entire binding site.

[0051] "Single-chain Fv" or "scFv" antibody binding fragments comprise the V_H and V_L domains of an antibody, where these domains are present in a single polypeptide chain. Generally, the Fv polypeptide further comprises a polypeptide linker between the V_H and V_L domains which enables the scFv to form the desired structure for target binding.

[0052] "Single domain fragments" are composed of a single V_H or V_L domains which exhibit sufficient affinity to human CD40. In a specific embodiment, the single domain fragment is a camelized fragment (*See*, *e.g.*, Riechmann, 1999, Journal of Immunological Methods 231:25–38).

[0053] The anti-CD40 antibodies of the disclosure include derivatized antibodies. For example, but not by way of limitation, derivatized antibodies are typically modified by glycosylation, acetylation, pegylation, phosphorylation, amidation, derivatization by known protecting/blocking groups, proteolytic cleavage, linkage to a cellular ligand or other protein. Any of numerous chemical

modifications can be carried out by known techniques, including, but not limited to, specific chemical cleavage, acetylation, formylation, metabolic synthesis of tunicamycin, *etc.* Additionally, the derivative can contain one or more non-natural amino acids, *e.g.*, using Ambryx technology (*See, e.g.*, Wolfson, 2006, Chem. Biol. 13(10):1011-2).

[0054] The anti-CD40 antibodies or binding fragments may be antibodies or fragments whose sequences have been modified to alter at least one constant region-mediated biological effector function. For example, in some embodiments, an anti-CD40 antibody may be modified to reduce at least one constant region-mediated biological effector function relative to the unmodified antibody, *e.g.*, reduced binding to one or more of the Fc receptors (FcγR) such as FcγRI, FcγRIIA, FcγRIIB, FcγRIIIA and/or FcγRIIIB. FcγR binding can be reduced by mutating the immunoglobulin constant region segment of the antibody at particular regions necessary for FcγR interactions (*See*, *e.g.*, Canfield and Morrison, 1991, J. Exp. Med. 173:1483-1491; and Lund *et al.*, 1991, J. Immunol. 147:2657-2662). Reduction in FcγR binding ability of the antibody can also reduce other effector functions which rely on FcγR interactions, such as opsonization, phagocytosis and antigen-dependent cellular cytotoxicity ("ADCC").

[0055] The anti-CD40 antibody or binding fragment described herein include antibodies that have been modified to acquire or improve at least one constant region-mediated biological effector function relative to an unmodified antibody, *e.g.*, to enhance FcγR interactions (*See*, *e.g.*, US Patent Appl. No. 2006/0134709). For example, an anti-CD40 antibody of the disclosure can have a constant region that binds FcγRI, FcγRIIA, FcγRIIB, FcγRIIIA and/or FcγRIIIB with greater affinity than the corresponding wild type constant region.

[0056] Thus, antibodies of the disclosure may have alterations in biological activity that result in increased or decreased opsonization, phagocytosis, or ADCC. Such alterations are known in the art. For example, modifications in antibodies that reduce ADCC activity are described in U.S. Patent No. 5,834,597. An exemplary ADCC lowering variant corresponds to "mutant 3" (also known as "M3," shown in FIG. 4 of U.S. Patent No. 5,834,597) in which residues 234 and 237 (using EU numbering) are substituted with alanines. A mutant 3 (also known as "M3") variation may be used in a number of antibody isotypes, *e.g.*, IgG_2.

[0057] In some embodiments, the anti-CD40 antibodies of the disclosure have low levels of, or lack, fucose. Antibodies lacking fucose have been correlated with enhanced ADCC activity, especially at low doses of antibody. *See* Shields *et al.*, 2002, J. Biol. Chem. 277:26733-26740; Shinkawa *et al.*,

2003, J. Biol. Chem. 278:3466-73. Methods of preparing fucose-less antibodies include growth in rat myeloma YB2/0 cells (ATCC CRL 1662). YB2/0 cells express low levels of FUT8 mRNA, which encodes α-1,6-fucosyltransferase, an enzyme necessary for fucosylation of polypeptides.

[0058] The anti-CD40 antibodies of the disclosure can comprise modified (or variant) CH2 domains or entire Fc domains that include amino acid substitutions that increase binding to FcγRIIB and/or reduced binding to FcγRIIIA as compared to the binding of a corresponding wild-type CH2 or Fc region. Variant CH2 or variant Fc domains have been described in U.S. Patent Appl. No. 2014/0377253. A variant CH2 or variant Fc domain typically includes one or more substitutions at position 263, position 266, position 273, and position 305, wherein the numbering of the residues in the Fc domain is that of the EU index as in Kabat. In some embodiments, the anti-CD40 antibodies comprise one or more substitutions selected from V263L, V266L, V273C, V273E, V273F, V273L, V273M, V273S, V273Y, V305K, and V305W, relative to the wild-type CH2 domain. In specific embodiments, the one or more substitutions of the CH2 domain are selected from V263L, V273E, V273F, V273M, V273S, and V273Y, relative to the CH2 domain of a human IgG_1. For example, the one or more substitutions of an IgG_1 CH2 domain can be V273E. In another specific embodiment, the anti-CD40 antibody of the disclosure comprises a variant IgG_1 CH2 region comprising the amino acid substitution V263L.

[0059] Other examples of variant CH2 or variant Fc domains that can afford increased binding to FcγRIIB and/or reduced binding to FcγRIIIA as compared to the binding of a corresponding wild-type CH2 or Fc region include those found in Vonderheide, et al. Clin. Cancer Res., 19(5), 1035-1043 (2013), such as S267E or S267E/L328F in human IgG_1.

[0060] In some embodiments, the anti-CD40 antibodies or binding fragments include modifications that increase or decrease their binding affinities to the fetal Fc receptor, FcRn, for example, by mutating the immunoglobulin constant region segment at particular regions involved in FcRn interactions (see, *e.g.*, WO 2005/123780). In particular embodiments, an anti-CD40 antibody of the IgG class is mutated such that at least one of amino acid residues 250, 314, and 428 of the heavy chain constant region is substituted alone, or in any combinations thereof, such as at positions 250 and 428, or at positions 250 and 314, or at positions 314 and 428, or at positions 250, 314, and 428, with positions 250 and 428 a specific combination. For position 250, the substituting amino acid residue can be any amino acid residue other than threonine, including, but not limited to, alanine, cysteine, aspartic acid, glutamic acid, phenylalanine, glycine, histidine, isoleucine, lysine, leucine,

methionine, asparagine, proline, glutamine, arginine, serine, valine, tryptophan, or tyrosine. For position 314, the substituting amino acid residue can be any amino acid residue other than leucine, including, but not limited to, alanine, cysteine, aspartic acid, glutamic acid, phenylalanine, glycine, histidine, isoleucine, lysine, methionine, asparagine, proline, glutamine, arginine, serine, threonine, valine, tryptophan, or tyrosine. For position 428, the substituting amino acid residues can be any amino acid residue other than methionine, including, but not limited to, alanine, cysteine, aspartic acid, glutamic acid, phenylalanine, glycine, histidine, isoleucine, lysine, leucine, asparagine, proline, glutamine, arginine, serine, threonine, valine, tryptophan, or tyrosine. An exemplary substitution known to modify Fc effector function is the Fc substitution M428L, which can occur in combination with the Fc substitution T250Q. Additional specific combinations of suitable amino acid substitutions are identified in Table 1 of U.S. Patent No. 7,217,797. Such mutations increase binding to FcRn, which protects the antibody from degradation and increases its half-life.

[0061] An anti-CD40 antibody may have one or more amino acids inserted into one or more of its CDRs, for example as described in Jung and Plückthun, 1997, Protein Engineering 10:9, 959-966; Yazaki *et al.*, 2004, Protein Eng. Des Sel. 17(5):481-9. Epub 2004 Aug 17; and U.S. Pat. Appl. No. 2007/0280931.

[0062] Anti-CD40 antibodies with affinity for human CD40 may be desirable for therapeutic and diagnostic uses. Accordingly, the present disclosure contemplates antibodies having binding affinity to human CD40. In specific embodiments, the anti-CD40 antibodies that bind human CD40 with an affinity of at least about 1000 nM, but may exhibit higher affinity, for example, at least about 900 nM, 800 nM, 700 nM, 600 nM, 500 nM, 400 nM, 300 nM, 250 nM, 200 nM, 150 nM, 100 nM, 90 nM, 80 nM, 70 nM, 60 nM, 50 nM, 40 nM, 30 nM, 25 nM, 20 nM, 15 nM, 10 nM, 7 nM, 6 nM, 5 nM, 4 nM, 3 nM, 2 nM, 1 nM, 0.1 nM, 0.01 nM, or even higher. In some embodiments, the antibodies bind human CD40 with an affinity in the range of about 1 pM to about 1000 nM, or an affinity ranging between any of the foregoing values.

[0063] Affinity of anti-CD40 antibodies for human CD40 can be determined using techniques well known in the art or described herein, such as for example, but not by way of limitation, ELISA, isothermal titration calorimetry (ITC), surface plasmon resonance, or fluorescent polarization assay.

[0064] Anti-CD40 antibodies generally comprise a heavy chain comprising a variable region (V_H) having three complementarity determining regions ("CDRs") referred to herein (in N→C order) as V_H CDR#1, V_H CDR#2, and V_H CDR#3, and a light chain comprising a variable region (V_L) having

three complementarity determining regions referred to herein (in N→C order) as V_L CDR#1, V_L CDR#2, and V_L CDR#3. The amino acid sequences of exemplary CDRs, as well as the amino acid sequence of the V_H and V_L regions of the heavy and light chains of exemplary anti-CD40 are provided herein. Specific embodiments of anti-CD40 antibodies include these exemplary CDRs and/or V_H and/or V_L sequences, as well as antibodies that compete for binding human CD40 with such antibodies.

[0065] In some embodiments, the amino acid sequences of the CDRs of an anti-CD40 antibody are selected from the following sequences:

CDR	Sequence (N→C)	Identifier
V_H CDR#1:	GYTFTSYWIT	(SEQ ID NO:1)
	GYTFTGYWIQ	(SEQ ID NO:2)
	GYTFTDYYMN	(SEQ ID NO:3)
	GFTFSDYYMS	(SEQ ID NO:4)
	GYSITTNYNWN	(SEQ ID NO:5)
	GYTFTSYWMH	(SEQ ID NO:6)
	GYTFTDYYIN	(SEQ ID NO:7)
	GYSITSNYYWN	(SEQ ID NO:8)
	GYSISSNYYWN	(SEQ ID NO:9)
	GYDITSNYYWN	(SEQ ID NO:10)
V_H CDR#2:	EINPGSGSTNYNEKFKS	(SEQ ID NO:11)
	EILPGGDHTKYNEKFRG	(SEQ ID NO:12)
	DINPNNGGTSYNQKFKG	(SEQ ID NO:13)
	FIRNKANGYTTEFSASVKG	(SEQ ID NO:14)
	YIRHDGTNNYNPSLKN	(SEQ ID NO:15)
	NIDPSNGETHYNQKFKD	(SEQ ID NO:16)
	WIFPGSGSVYCNEQFKG	(SEQ ID NO:17)
	YIRYDGSNNYNPSLKN	(SEQ ID NO:18)
	NIDPSNGETHYAQKFQG	(SEQ ID NO:19)
	WIFPGSGSVYSNEQFKG	(SEQ ID NO:20)
	YIRYDGSNNYNPSLKS	(SEQ ID NO:21)
	YIRYDGSNNYNPSLKG	(SEQ ID NO:22)

CDR	Sequence (N→C)	Identifier
V_H CDR#3:	NRGTGDY	(SEQ ID NO:31)
	VGGDY	(SEQ ID NO:32)
	RGGLGRGTYALDY	(SEQ ID NO:33)
	YGGLRQGWYFDV	(SEQ ID NO:34)
	LDY	(SEQ ID NO:35)
	ERIYYSGSTYDGYFDV	(SEQ ID NO:36)
	SLGKFAY	(SEQ ID NO:37)
V_L CDR#1:	RSSQSLVHSYGNTYLH	(SEQ ID NO:51)
	RSSQSLVNSNENTYLH	(SEQ ID NO:52)
	RASQDISNYLN	(SEQ ID NO:53)
	RASQDIRNYLN	(SEQ ID NO:54)
	RSSQSLENSYGNTFLN	(SEQ ID NO:55)
	SASSSLSYMH	(SEQ ID NO:56)
	KASQSVVTAVA	(SEQ ID NO:57)
	RSSQSLENTNGNTFLN	(SEQ ID NO:58)
	RSSQSLENSNGNTFLN	(SEQ ID NO:59)
V_L CDR#2:	KVSNRIS	(SEQ ID NO:61)
	KVFNRYS	(SEQ ID NO:62)
	YTSRLHL	(SEQ ID NO:63)
	YTSRLHS	(SEQ ID NO:64)
	RVSNRFC	(SEQ ID NO:65)
	DTSKLAS	(SEQ ID NO:66)
	SASNRYT	(SEQ ID NO:67)
	RVSNRFS	(SEQ ID NO:68)
	RISNRFS	(SEQ ID NO:69)

CDR	Sequence (N→C)	Identifier
V_L CDR#3:	SQSTHVPYT	(SEQ ID NO:81)
	FQSTHVPWT	(SEQ ID NO:82)
	QQGNTLPLT	(SEQ ID NO:83)
	QQGKTLPWT	(SEQ ID NO:84)
	LQVTHVPYT	(SEQ ID NO:85)
	QQWSSNPWT	(SEQ ID NO:86)
	QQYSSYPYT	(SEQ ID NO:87)
	LQVTHVPFT	(SEQ ID NO:88)

[0066] In some embodiments, each CDR of an anti-CD40 antibody, independently of the others, is selected to correspond in sequence to the respective CDR of an antibody provided in TABLE 3. In some embodiments, an anti-CD40 antibody is an IgG, and has a V_H and V_L corresponding in sequence to the V_H and V_L of an antibody provided in TABLE 3.

[0067] In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to any one of SEQ ID NOS:101, 102, 103, 104, 105, 106, 107, 108, or 109; and a V_L chain corresponding in sequence to any one of SEQ ID NOS:151, 152, 153, 154, 155, 156, 157, 158, 159, or 160. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:101 and a V_L chain corresponding in sequence to SEQ ID NO:151. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:102 and a V_L chain corresponding in sequence to SEQ ID NO:152. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:103 and a V_L chain corresponding in sequence to SEQ ID NO:153. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:104 and a V_L chain corresponding in sequence to SEQ ID NO:154. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:105 and a V_L chain corresponding in sequence to SEQ ID NO:155. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:106 and a V_L chain corresponding in sequence to SEQ ID NO:156. In some embodiments, an anti-CD40 antibody and comprises a V_H chain corresponding in sequence to SEQ ID NO:106 and a V_L chain corresponding in sequence to SEQ ID NO:157. In some embodiments, an anti-CD40 antibody and comprises a V_H chain corresponding in sequence to SEQ ID NO:107 and a

V_L chain corresponding in sequence to SEQ ID NO:158. In some embodiments, an anti-CD40 antibody and comprises a V_H chain corresponding in sequence to SEQ ID NO:108 and a V_L chain corresponding in sequence to SEQ ID NO:159. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:109 and a V_L chain corresponding in sequence to SEQ ID NO:160.

[0068] Specific exemplary embodiments of anti-CD40 antibodies with the above CDRs are described herein. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 1, 11, 31, 51, 61, and 81. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 2, 12, 32, 52, 62, and 82. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 3, 13, 33, 53, 63, and 83. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 4, 14, 34, 54, 64, and 84. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 5, 15, 35, 55, 65, and 85. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 6, 16, 36, 56, 66, and 86. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 6, 19, 36, 56, 66, and 86. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 7, 17, 37, 57, 67, and 87. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 7, 20, 37, 57, 67, and 87. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 8, 18, 35, 58, 68, and 88. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 9, 21, 35, 58, 68, and 88. In some embodiments, an anti-CD40 antibody has the CDRs of SEQ ID NOS: 10, 22, 35, 58, 68, and 88.

[0069] In some embodiments, an anti-CD40 antibody is suitable for administration to humans. In a specific embodiment, the anti-CD40 antibody is humanized. In another specific embodiment, the amino acid sequences of the CDRs of the anti-CD40 antibody are selected from:

CDR	**Sequence (N→C)**	**Identifier**
V_H CDR#1:	GYTFTSYWMH	(SEQ ID NO:6)
	GYTFTDYYIN	(SEQ ID NO:7)
	GYSITSNYYWN	(SEQ ID NO:8)
	GYSISSNYYWN	(SEQ ID NO:9)
	GYDITSNYYWN	(SEQ ID NO:10)

CDR	Sequence (N→C)	Identifier
V_H CDR#2:	WIFPGSGSVYCNEQFKG	(SEQ ID NO:17)
	YIRYDGSNNYNPSLKN	(SEQ ID NO:18)
	NIDPSNGETHYAQKFQG	(SEQ ID NO:19)
	WIFPGSGSVYSNEQFKG	(SEQ ID NO:20)
	YIRYDGSNNYNPSLKS	(SEQ ID NO:21)
	YIRYDGSNNYNPSLKG	(SEQ ID NO:22)
V_H CDR#3:	LDY	(SEQ ID NO:35)
	ERIYYSGSTYDGYFDV	(SEQ ID NO:36)
	SLGKFAY	(SEQ ID NO:37)
V_L CDR#1:	SASSSLSYMH	(SEQ ID NO:56)
	KASQSVVTAVA	(SEQ ID NO:57)
	RSSQSLENTNGNTFLN	(SEQ ID NO:58)
V_L CDR#2:	DTSKLAS	(SEQ ID NO:66)
	SASNRYT	(SEQ ID NO:67)
	RVSNRFS	(SEQ ID NO:68)
V_L CDR#3:	QQWSSNPWT	(SEQ ID NO:86)
	QQYSSYPYT	(SEQ ID NO:87)
	LQVTHVPFT	(SEQ ID NO:88)

[0070] In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to any one of SEQ ID NOS:110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, or 123; and a V_L chain corresponding in sequence to any one of SEQ ID NOS:161, 162, 163, 164, 165, 166, 167, 168, 169, 170, or 171. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:110 and a V_L chain corresponding in sequence to SEQ ID NO:161. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:111 and a V_L chain corresponding in sequence to SEQ ID NO:161. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:112 and a V_L chain corresponding in sequence to SEQ ID NO:161. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:113 and a V_L chain corresponding in sequence to SEQ ID NO:162. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:114 and a V_L chain corresponding in

sequence to SEQ ID NO:162. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:115 and a V_L chain corresponding in sequence to SEQ ID NO:162. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:116 and a V_L chain corresponding in sequence to SEQ ID NO:163. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:163. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:118 and a V_L chain corresponding in sequence to SEQ ID NO:163. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:116 and a V_L chain corresponding in sequence to SEQ ID NO:164. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:164. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:119 and a V_L chain corresponding in sequence to SEQ ID NO:165. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:120 and a V_L chain corresponding in sequence to SEQ ID NO:165. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:121 and a V_L chain corresponding in sequence to SEQ ID NO:166. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:167. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:168. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:169. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:170. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:117 and a V_L chain corresponding in sequence to SEQ ID NO:171. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:118 and a V_L chain corresponding in sequence to SEQ ID NO:164. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:122 and a V_L chain corresponding in sequence to SEQ ID NO:167. In some embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:122 and a V_L chain corresponding in sequence to SEQ ID NO:168. In some

embodiments, an anti-CD40 antibody comprises a V_H chain corresponding in sequence to SEQ ID NO:123 and a V_L chain corresponding in sequence to SEQ ID NO:169.

[0071] In some embodiments, the anti-CD40 antibodies compete for binding human CD40 in *in vitro* assays with a reference antibody. In some embodiments, the anti-CD40 antibodies compete for binding human CD40 on cells expressing human CD40. The reference antibody may be any of the anti-CD40 antibodies described herein. In some embodiments, the reference antibody is an antibody provided in TABLE 3. In specific embodiments, the reference antibody is selected from antibody AD163.9.3 ("muAb1"); antibody AD166.4.4 ("muAb2"); antibody AD175.14.11 ("muAb3"); antibody AD163.10.7 ("muAb4"); antibody AD165.1.2 ("muAb5"); antibody AD163.162.1 ("muAb6"); antibody AD163.27.12 ("muAb7"); antibody AD163.7.2 ("muAb8"); antibody AD164.14.6 ("muAb9"); and antibody AD164.76.2 ("muAb10"). In some embodiments, the reference antibody is a humanized version of an antibody provided in TABLE 3. In some embodiments, the reference antibody is a humanized version of muAb6, muAb8, or muAb9. In a specific embodiment, the reference antibody is huAb9-2. In another embodiment, the reference antibody is huAb9-5. In another specific embodiment, the reference antibody is huAb9 A2I.

[0072] Post-translational modifications to the sequences of an anti-CD40 antibody may occur, such as cleavage of one or more (*e.g.*, 1, 2, 3, or more) amino acid residues on the C-terminal end of the antibody heavy chain.

[0073] In some embodiments, an anti-CD40 antibody comprises a heavy chain according to any one of SEQ ID NOS: 130-135, and a light chain according to SEQ ID NOS: 140-142. In certain embodiments, an anti-CD40 antibody comprises a heavy chain according to SEQ ID NOS: 130 or 131, and a light chain according to SEQ ID NO: 140. In certain embodiments, an anti-CD40 antibody comprises a heavy chain according to SEQ ID NOS: 132 or 133, and a light chain according to SEQ ID NO: 140. In certain embodiments, an anti-CD40 antibody comprises a heavy chain according to SEQ ID NOS: 134 or 135, and a light chain according to SEQ ID NO: 140. In certain embodiments, an anti-CD40 antibody comprises a heavy chain according to SEQ ID NOS: 132 or 133, and a light chain according to SEQ ID NO: 141. In certain embodiments, an anti-CD40 antibody comprises a heavy chain according to SEQ ID NOS: 132 or 133, and a light chain according to SEQ ID NO: 142.

[0074] The anti-CD40 antibodies described herein generally bind specifically to human CD40. Cross reactivity of the antibodies for binding to CD40 from other species, for example, from monkey, *e.g.*, cynomolgus monkey, may offer advantages, such as the ability to test in monkey animal models

for biological activity. Such animal model testing may be used to screen anti-CD40 antibodies to select for properties, *e.g.*, favorable pharmacokinetics. In some embodiments, the anti-CD40 antibodies bind to cynomolgus CD40.

[0075] Assays for competition include, but are not limited to, a radioactive material labeled immunoassay (RIA), an enzyme-linked immunosorbent assay (ELISA), a sandwich ELISA, fluorescence activated cell sorting (FACS) assays, and surface plasmon resonance assays.

[0076] In conducting an antibody competition assay between a reference antibody and a test antibody (irrespective of species or isotype), one may first label the reference with a detectable label, such as a fluorophore, biotin or an enzymatic (or even radioactive) label to enable subsequent identification. In this case, cells expressing human CD40 are incubated with unlabeled test antibody, labeled reference antibody is added, and the intensity of the bound label is measured. If the test antibody competes with the labeled reference antibody by binding to an overlapping epitope, the intensity will be decreased relative to a control reaction carried out without test antibody.

[0077] In a specific embodiment of this assay, the concentration of labeled reference antibody that yields 80% of maximal binding ("$conc_{80\%}$") under the assay conditions (*e.g.*, a specified density of cells) is first determined, and a competition assay carried out with 10X $conc_{80\%}$ of unlabeled test antibody and $conc_{80\%}$ of labeled reference antibody.

[0078] The inhibition can be expressed as an inhibition constant, or K_i, which is calculated according to the following formula:

$$K_i = IC_{50} / (1 + [\text{reference Ab concentration}]/K_d),$$

where IC_{50} is the concentration of test antibody that yields a 50% reduction in binding of the reference antibody and K_d is the dissociation constant of the reference antibody, a measure of its affinity for human CD40. Antibodies that compete with anti-CD40 antibodies disclosed herein can have a K_i from 10 pM to 1000 nM under assay conditions described herein.

[0079] In various embodiments, a test antibody is considered to compete with a reference antibody if it decreases binding of the reference antibody by at least about 20% or more, for example, by at least about 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95% or even more, or by a percentage ranging between any of the foregoing values, at a reference antibody concentration that is 80% of maximal binding under the specific assay conditions used, and a test antibody concentration that is 10-fold higher than the reference antibody concentration.

[0080] The anti-CD40 antibodies described herein are capable of agonizing human CD40 (SEQ ID NO:40) by activating human CD40 via at least two mechanisms of action. In some embodiments, an anti-CD40 antibody binds human CD40 in the absence of CD40L (SEQ ID NO:41), and enhances the signaling of human CD40. In some embodiments, an anti-CD40 antibody binds the human CD40L-CD40 bound complex, and enhances the signaling of human CD40. In some embodiments, an anti-CD40 antibody competes for binding human CD40 (SEQ ID NO:40) with a control antibody selected from a humanized antibody listed in TABLE 3, and activates human CD40 independent of human CD40 ligand (SEQ ID NO:41), *i.e.*, in the absence or presence of CD40L.

[0081] The effect of the anti-CD40 antibodies on human CD40-CD40L interaction can be determined by assays known in the art, such as the CD40L competitive assay described in Example 2. A ratio of an OD_{450} measured in samples containing anti-CD40 antibodies to an OD_{450} taken from isotype control antibody samples (an "OD_{450} ratio") can be used to determine the effect of an anti-CD40 antibody on human CD40L binding to human CD40. A OD_{450} ratio of 1 indicates no effect; less than 1 indicates competition with CD40L; greater than 1 indicates an enhancement of CD40L binding with CD40. In some embodiments, the anti-CD40 antibody increases (*i.e.*, enhances) binding of human CD40L (SEQ ID NO:41) to human CD40 (SEQ ID NO:40) as determined by OD_{450} ratio. An enhancement of CD40L binding to CD40 by OD_{450} ratio is at least about 1.2, such as about 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.2, 2.4, 2.5, 2.6, 2.8, 3.0 or greater.

[0082] A specific assay and assay conditions useful for assessing whether an antibody competes for binding human CD40 with a reference antibody as described herein is provided in Example 2. Antibody competition can be determined by a surface plasmon resonance assay as described in Example 2, or in competitive binding protocol described in Section 8.4.3.

[0083] While an agonistic anti-CD40 antibody activates the immune system to exert an antitumor effect, broad systemic immune activation across all cell types may lead to undesired side effects. Accordingly, in some embodiments, an anti-CD40 antibody activates a dendritic cell-mediated immune response selectively over a B-cell immune response as compared to a reference anti-CD40 antibody. In some embodiments, the reference anti-CD40 antibody is CP-870,893. In some embodiments, an anti-CD40 antibody has a similar activity, *e.g.*, a production of IL-12p70 at a given dose, within about 200%, such as within about 180%, 150%, 130%, 110%, 100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 25%, 20%, 15%, 10%, or about 5%, in activating a dendritic cell as compared to the production of IL-12p70 at the same dose of a reference anti-CD40 antibody in the assay

described in Section 8.1.3. In some embodiments, an anti-CD40 antibody has a lower potency in activating a B cell as compared to a reference anti-CD40 antibody. The B cell EC_{50} ratio of the anti-CD40 antibody to the reference anti-CD40 antibody can be greater than about 1.5, such as about 2, 3, 4, 5, 6, 8, 10, 15, 20, 30, 40, 50 or greater, in the assay described in Section 8.5.3. In some embodiments, an anti-CD40 antibody has a similar activity in activating a dendritic cell and a lower potency in activating a B cell as compared to a reference anti-CD40 antibody.

7.4. Polynucleotides Encoding the Anti-CD40 Antibodies, Expression Systems and Methods of Making the Antibodies

[0084] The present disclosure encompasses nucleic acid molecules encoding immunoglobulin light and heavy chain genes for anti-CD40 antibodies, vectors comprising such nucleic acids, and host cells capable of producing the anti-CD40 antibodies of the disclosure.

[0085] An anti-CD40 antibody of the disclosure can be prepared by recombinant expression of immunoglobulin light and heavy chain genes in a host cell. To express an antibody recombinantly, a host cell is transfected with one or more recombinant expression vectors carrying DNA fragments encoding the immunoglobulin light and heavy chains of the antibody such that the light and heavy chains are expressed in the host cell and, optionally, secreted into the medium in which the host cells are cultured, from which medium the antibodies can be recovered. Standard recombinant DNA methodologies are used to obtain antibody heavy and light chain genes, incorporate these genes into recombinant expression vectors and introduce the vectors into host cells, such as those described in Molecular Cloning; A Laboratory Manual, Second Edition (Sambrook, Fritsch and Maniatis (eds), Cold Spring Harbor, N. Y., 1989), Current Protocols in Molecular Biology (Ausubel, F.M. *et al.,* eds., Greene Publishing Associates, 1989) and in U.S. Patent No. 4,816,397.

[0086] To generate nucleic acids encoding such anti-CD40 antibodies, DNA fragments encoding the light and heavy chain variable regions are first obtained. These DNAs can be obtained by amplification and modification of germline DNA or cDNA encoding light and heavy chain variable sequences, for example using the polymerase chain reaction (PCR). Germline DNA sequences for human heavy and light chain variable region genes are known in the art (*See, e.g.*, the "VBASE" human germline sequence database; see also Kabat, E. A. *et al.,* 1991, Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH

Publication No. 91-3242; Tomlinson *et al.,* 1992, J. Mol. Biol. 22T:116-198; and Cox *et al.,* 1994, Eur. J. Immunol. 24:827-836; the contents of each of which are incorporated herein by reference).

[0087] Once DNA fragments encoding anti-CD40 antibody-related V_H and V_L segments are obtained, these DNA fragments can be further manipulated by standard recombinant DNA techniques, for example to convert the variable region genes to full-length antibody chain genes, to Fab fragment genes or to a scFv gene. In these manipulations, a V_L- or V_H-encoding DNA fragment is operatively linked to another DNA fragment encoding another protein, such as an antibody constant region or a flexible linker. The term "operatively linked," as used in this context, is intended to mean that the two DNA fragments are joined such that the amino acid sequences encoded by the two DNA fragments remain in-frame.

[0088] The isolated DNA encoding the V_H region can be converted to a full-length heavy chain gene by operatively linking the V_H-encoding DNA to another DNA molecule encoding heavy chain constant regions (CH1, CH2, CH3 and, optionally, CH4). The sequences of human heavy chain constant region genes are known in the art (*See, e.g.*, Kabat, E.A., *et al.,* 1991, Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242) and DNA fragments encompassing these regions can be obtained by standard PCR amplification. The heavy chain constant region can be an IgG_1, IgG_2, IgG_3, IgG_4, IgA, IgE, IgM or IgD constant region, but in certain embodiments is an IgG_1 or IgG_4. For a Fab fragment heavy chain gene, the V_H-encoding DNA can be operatively linked to another DNA molecule encoding only the heavy chain CH1 constant region.

[0089] The isolated DNA encoding the V_L region can be converted to a full-length light chain gene (as well as a Fab light chain gene) by operatively linking the V_L-encoding DNA to another DNA molecule encoding the light chain constant region, CL. The sequences of human light chain constant region genes are known in the art (*See, e.g.*, Kabat, *et al.,* 1991, Sequences of Proteins of Immunological Interest, Fifth Edition, U.S. Department of Health and Human Services, NIH Publication No. 91-3242) and DNA fragments encompassing these regions can be obtained by standard PCR amplification. The light chain constant region can be a kappa or lambda constant region, but in certain embodiments is a kappa constant region. To create a scFv gene, the V_H- and V_L-encoding DNA fragments are operatively linked to another fragment encoding a flexible linker, *e.g.*, encoding the amino acid sequence $(Gly_4\sim Ser)_3$ (SEQ ID NO:200), such that the V_H and V_L sequences can be expressed as a contiguous single-chain protein, with the V_L and V_H regions joined

by the flexible linker (*See, e.g.*, Bird *et al.,* 1988, Science 242:423-426; Huston *et al.,* 1988, Proc. Natl. Acad. Sci. USA 85:5879-5883; McCafferty *et al.*, 1990, Nature 348:552-554).

[0090] To express the anti-CD40 antibodies of the disclosure, DNAs encoding partial or full-length light and heavy chains, obtained as described above, are inserted into expression vectors such that the genes are operatively linked to transcriptional and translational control sequences. In this context, the term "operatively linked" is intended to mean that an antibody gene is ligated into a vector such that transcriptional and translational control sequences within the vector serve their intended function of regulating the transcription and translation of the antibody gene. The expression vector and expression control sequences are chosen to be compatible with the expression host cell used. The antibody light chain gene and the antibody heavy chain gene can be inserted into separate vectors or, more typically, both genes are inserted into the same expression vector.

[0091] The antibody genes are inserted into the expression vector by standard methods (*e.g.*, ligation of complementary restriction sites on the antibody gene fragment and vector, or blunt end ligation if no restriction sites are present). Prior to insertion of the anti-CD40 antibody-related light or heavy chain sequences, the expression vector can already carry antibody constant region sequences. For example, one approach to converting the anti-CD40 monoclonal antibody-related V_H and V_L sequences to full-length antibody genes is to insert them into expression vectors already encoding heavy chain constant and light chain constant regions, respectively, such that the V_H segment is operatively linked to the CH segment(s) within the vector and the V_L segment is operatively linked to the CL segment within the vector. Additionally or alternatively, the recombinant expression vector can encode a signal peptide that facilitates secretion of the antibody chain from a host cell. The antibody chain gene can be cloned into the vector such that the signal peptide is linked in-frame to the amino terminus of the antibody chain gene. The signal peptide can be an immunoglobulin signal peptide or a heterologous signal peptide (*i.e.*, a signal peptide from a non-immunoglobulin protein).

[0092] In addition to the antibody chain genes, the recombinant expression vectors of the disclosure carry regulatory sequences that control the expression of the antibody chain genes in a host cell. The term "regulatory sequence" is intended to include promoters, enhancers and other expression control elements (*e.g.*, polyadenylation signals) that control the transcription or translation of the antibody chain genes. Such regulatory sequences are described, for example, in Goeddel, Gene Expression Technology: Methods in Enzymology 185, Academic Press, San Diego, CA, 1990. It will be appreciated by those skilled in the art that the design of the expression vector, including the selection

of regulatory sequences may depend on such factors as the choice of the host cell to be transformed, the level of expression of protein desired, *etc.* Suitable regulatory sequences for mammalian host cell expression include viral elements that direct high levels of protein expression in mammalian cells, such as promoters and/or enhancers derived from cytomegalovirus (CMV) (such as the CMV promoter/enhancer), Simian Virus 40 (SV40) (such as the SV40 promoter/enhancer), adenovirus, (*e.g.*, the adenovirus major late promoter (AdMLP)) and polyoma. For further description of viral regulatory elements, and sequences thereof, *see*, *e.g.*, U.S. Patent No. 5,168,062 by Stinski, U.S. Patent No. 4,510,245 by Bell *et al.,* and U.S. Patent No. 4,968,615 by Schaffner *et al.*

[0093] In addition to the antibody chain genes and regulatory sequences, the recombinant expression vectors of the disclosure can carry additional sequences, such as sequences that regulate replication of the vector in host cells (*e.g.*, origins of replication) and selectable marker genes. The selectable marker gene facilitates selection of host cells into which the vector has been introduced (*See, e.g.*, U.S. Patents Nos. 4,399,216, 4,634,665 and 5,179,017, all by Axel *et al.*). For example, typically the selectable marker gene confers resistance to drugs, such as G418, hygromycin or methotrexate, on a host cell into which the vector has been introduced. Suitable selectable marker genes include the dihydrofolate reductase (DHFR) gene (for use in $DHFR^-$ host cells with methotrexate selection/amplification) and the neo gene (for G418 selection). For expression of the light and heavy chains, the expression vector(s) encoding the heavy and light chains is transfected into a host cell by standard techniques. The various forms of the term "transfection" are intended to encompass a wide variety of techniques commonly used for the introduction of exogenous DNA into a prokaryotic or eukaryotic host cell, *e.g.*, electroporation, lipofection, calcium-phosphate precipitation, DEAE-dextran transfection and the like.

[0094] It is possible to express the antibodies of the disclosure in either prokaryotic or eukaryotic host cells. In certain embodiments, expression of antibodies is performed in eukaryotic cells, *e.g.*, mammalian host cells, of optimal secretion of a properly folded and immunologically active antibody. Exemplary mammalian host cells for expressing the recombinant antibodies of the disclosure include Chinese Hamster Ovary (CHO cells) (including $DHFR^-$ CHO cells, described in Urlaub and Chasin, 1980, Proc. Natl. Acad. Sci. USA 77:4216-4220, used with a DHFR selectable marker, *e.g.*, as described in Kaufman and Sharp, 1982, Mol. Biol. 159:601-621), NSO myeloma cells, COS cells and SP2 cells. When recombinant expression vectors encoding antibody genes are introduced into mammalian host cells, the antibodies are produced by culturing the host cells for a period of time

sufficient to allow for expression of the antibody in the host cells or secretion of the antibody into the culture medium in which the host cells are grown. Antibodies can be recovered from the culture medium using standard protein purification methods. Host cells can also be used to produce portions of intact antibodies, such as Fab fragments or scFv molecules. It is understood that variations on the above procedure are within the scope of the present disclosure. For example, it can be desirable to transfect a host cell with DNA encoding either the light chain or the heavy chain (but not both) of an anti-CD40 antibody of this disclosure.

[0095] Recombinant DNA technology can also be used to remove some or all of the DNA encoding either or both of the light and heavy chains that is not necessary for binding to human CD40. The molecules expressed from such truncated DNA molecules are also encompassed by the antibodies of the disclosure.

[0096] For recombinant expression of an anti-CD40 antibody of the disclosure, the host cell can be co-transfected with two expression vectors of the disclosure, the first vector encoding a heavy chain derived polypeptide and the second vector encoding a light chain derived polypeptide. The two vectors can contain identical selectable markers, or they can each contain a separate selectable marker. Alternatively, a single vector can be used which encodes both heavy and light chain polypeptides.

[0097] Once a nucleic acid encoding one or more portions of an anti-CD40 antibody, further alterations or mutations can be introduced into the coding sequence, for example to generate nucleic acids encoding antibodies with different CDR sequences, antibodies with reduced affinity to the Fc receptor, or antibodies of different subclasses.

[0098] The anti-CD40 antibodies of the disclosure can also be produced by chemical synthesis (*e.g.*, by the methods described in Solid Phase Peptide Synthesis, 2nd ed., 1984 The Pierce Chemical Co., Rockford, Ill.). Variant antibodies can also be generated using a cell-free platform (*See*, *e.g.*, Chu *et al.*, Biochemia No. 2, 2001 (Roche Molecular Biologicals) and Murray *et al.*, 2013, Current Opinion in Chemical Biology, 17:420–426).

[0099] Once an anti-CD40 antibody of the disclosure has been produced by recombinant expression, it can be purified by any method known in the art for purification of an immunoglobulin molecule, for example, by chromatography (*e.g.*, ion exchange, affinity, and sizing column chromatography), centrifugation, differential solubility, or by any other standard technique for the purification of

proteins. Further, the anti-CD40 antibodies of the present disclosure can be fused to heterologous polypeptide sequences described herein or otherwise known in the art to facilitate purification.

[0100] Once isolated, the anti-CD40 antibody can, if desired, be further purified, *e.g.*, by high performance liquid chromatography (*see*, *e.g.*, Fisher, Laboratory Techniques In Biochemistry And Molecular Biology, Work and Burdon, eds., Elsevier, 1980), or by gel filtration chromatography on a Superdex™ 75 column (Pharmacia Biotech AB, Uppsala, Sweden).

7.5. Pharmaceutical Compositions

[0101] The anti-CD40 antibodies described herein may be in the form of compositions comprising the antibody and one or more carriers, excipients and/or diluents. The compositions may be formulated for specific uses, such as for veterinary uses or pharmaceutical uses in humans. The form of the composition (*e.g.*, dry powder, liquid formulation, *etc.*) and the excipients, diluents and/or carriers used will depend upon the intended uses of the antibody and, for therapeutic uses, the mode of administration.

[0102] For therapeutic uses, the compositions may be supplied as part of a sterile, pharmaceutical composition that includes a pharmaceutically acceptable carrier. This composition can be in any suitable form (depending upon the desired method of administering it to a subject, *e.g.*, a human subject, *i.e.*, patient). The pharmaceutical composition can be administered to a subject by a variety of routes such as orally, transdermally, subcutaneously, intranasally, intravenously, intramuscularly, intratumorally, intrathecally, topically or locally. The most suitable route for administration in any given case will depend on the particular antibody, the subject, and the nature and severity of the disease and the physical condition of the subject. Typically, the pharmaceutical composition will be administered intravenously or subcutaneously.

[0103] Pharmaceutical compositions can be conveniently presented in unit dosage forms containing a predetermined amount of an anti-CD40 antibody described herein per dose. The quantity of anti-CD40 antibody included in a unit dose will depend on the disease being treated, as well as other factors as are well known in the art. Such unit dosages may be in the form of a lyophilized dry powder containing an amount of antibody suitable for a single administration, or in the form of a liquid. Dry powder unit dosage forms may be packaged in a kit with a syringe, a suitable quantity of diluent and/or other components useful for administration. Unit dosages in liquid form may be conveniently supplied in the form of a syringe pre-filled with a quantity of the anti-CD40 antibody suitable for a single administration.

[0104] The pharmaceutical compositions may also be supplied in bulk form containing quantities of anti-CD40 antibody suitable for multiple administrations.

[0105] Pharmaceutical compositions may be prepared for storage as lyophilized formulations or aqueous solutions by mixing an antibody having the desired degree of purity with optional pharmaceutically-acceptable carriers, excipients or stabilizers typically employed in the art (all of which are referred to herein as "carriers"), *i.e.*, buffering agents, stabilizing agents, preservatives, isotonifiers, non-ionic detergents, antioxidants, and other miscellaneous additives. *See*, Remington's Pharmaceutical Sciences, 16th edition (Osol, ed. 1980). Such additives should be nontoxic to the recipients at the dosages and concentrations employed.

[0106] Buffering agents help to maintain the pH in the range which approximates physiological conditions. They may be present at a wide variety of concentrations, but will typically be present in concentrations ranging from about 2 mM to about 50 mM. Suitable buffering agents for use with the present disclosure include both organic and inorganic acids and salts thereof such as citrate buffers (*e.g.*, monosodium citrate-disodium citrate mixture, citric acid-trisodium citrate mixture, citric acid-monosodium citrate mixture, *etc.*), succinate buffers (*e.g.*, succinic acid-monosodium succinate mixture, succinic acid-sodium hydroxide mixture, succinic acid-disodium succinate mixture, *etc.*), tartrate buffers (*e.g.*, tartaric acid-sodium tartrate mixture, tartaric acid-potassium tartrate mixture, tartaric acid-sodium hydroxide mixture, *etc.*), phosphate buffers (*e.g.*, phosphoric acid-monosodium phosphate mixture, phosphoric acid-disodium phosphate mixture, monosodium phosphate -disodium phosphate mixture, *etc.*), gluconate buffers (*e.g.*, gluconic acid-sodium gluconate mixture, gluconic acid-sodium hydroxide mixture, gluconic acid-potassium gluconate mixture, *etc.*), oxalate buffer (*e.g.*, oxalic acid-sodium oxalate mixture, oxalic acid-sodium hydroxide mixture, oxalic acid-potassium oxalate mixture, *etc.*), lactate buffers (*e.g.*, lactic acid-sodium lactate mixture, lactic acid-sodium hydroxide mixture, lactic acid-potassium lactate mixture, *etc.*) and acetate buffers (*e.g.*, acetic acid-sodium acetate mixture, acetic acid-sodium hydroxide mixture, *etc.*). Additionally, fumarate buffers, histidine buffers and trimethylamine salts such as 2-amino-2-hydroxymethyl-propane-1,3-diol (*i.e.*, Tris, THAM, or tris(hydroxymethyl)aminomethane) can be used.

[0107] Isotonicifiers sometimes known as "stabilizers" can be added to ensure isotonicity of liquid compositions of the present disclosure and include polyhydric sugar alcohols, for example trihydric or higher sugar alcohols, such as glycerin, erythritol, arabitol, xylitol, sorbitol and mannitol. Stabilizers refer to a broad category of excipients which can range in function from a bulking agent to an

additive which solubilizes the therapeutic agent or helps to prevent denaturation or adherence to the container wall. Typical stabilizers can be polyhydric sugar alcohols (enumerated above); amino acids such as arginine, lysine, glycine, glutamine, asparagine, histidine, alanine, ornithine, leucine, 2-phenylalanine, glutamic acid, threonine, *etc.*, organic sugars or sugar alcohols, such as lactose, trehalose, stachyose, mannitol, sorbitol, xylitol, ribitol, myoinositol, galactitol, glycerol and the like, including cyclitols such as inositol; polyethylene glycol; amino acid polymers; sulfur containing reducing agents, such as urea, glutathione, thioctic acid, sodium thioglycolate, thioglycerol, α-monothioglycerol and sodium thiosulfate; low molecular weight polypeptides (*e.g.*, peptides of 10 residues or fewer); hydrophilic polymers, such as polyvinylpyrrolidone monosaccharides, such as xylose, mannose, fructose, glucose; disaccharides such as lactose, maltose, sucrose and trehalose; and trisaccacharides such as raffinose; and polysaccharides such as dextran. Stabilizers may be present in amounts ranging from 0.5 to 10 weight% per weight of anti-CD40 antibody.

[0108] Non-ionic surfactants or detergents (also known as "wetting agents") may be added to help solubilize the glycoprotein as well as to protect the glycoprotein against agitation-induced aggregation, which also permits the formulation to be exposed to shear surface stressed without causing denaturation of the protein. Suitable non-ionic surfactants include polysorbates (20, 80, *etc.*), poloxamers (184, 188 *etc.*), and pluronic polyols. Non-ionic surfactants may be present in a range of about 0.05 mg/mL to about 1.0 mg/mL.

[0109] A specific exemplary embodiment of an aqueous composition suitable for administration via intravenous infusion comprises 10 mg/mL of anti-CD40 antibody, 15 mM histidine buffer, pH 6.0, 8.0% (w/v) sucrose, and 0.05% (w/v) polysorbate 80. In certain embodiments, the anti-CD40 antibody is any one of the humanized antibodies described in TABLE 3. The composition may be in the form of a lyophilized powder that, upon reconstitution with 2.0 mL sterile water or other solution suitable for injection or infusion (for example, 0.9% saline, Ringer's solution, lactated Ringer's solution, etc.) provides the above aqueous composition. The composition, or other embodiments of compositions, may also be in the form of a syringe or other device suitable for injection and/or infusion pre-filled with a quantity of composition suitable for a single administration of the anti-CD40 antibody.

7.6. Methods of Use

7.6.1. Therapeutic benefit

[0110] Data provided herein demonstrate that anti-CD40 antibodies described herein that agonize CD40 in the presence of tumor cells exert potent anti-tumor activity against these solid tumors *in vivo*. Accordingly, the anti-CD40 antibodies, binding fragments, and/or pharmaceutical compositions comprising the anti-CD40 antibodies may be used therapeutically to treat solid tumors.

[0111] Generally, the methods involve administering to a human patient having a solid tumor an effective amount of an anti-CD40 antibody that agonizes CD40, and kills and/or reduces proliferation of tumor cells to provide therapeutic benefit. Solid tumors that may be treated with the anti-CD40 antibody include, but are not limited to, adrenal cancers, bone cancers, brain cancers, breast cancers, colorectal cancers, esophageal cancers, eye cancers, gastric cancers, head and neck cancers, kidney cancers, liver cancers, lung cancers (*e.g.*, non-small cell lung cancer, mesothelioma), head and neck cancers (*e.g.*, squamous cell carcinoma of the head and neck), lymphomas (*e.g.*, B cell lymphomas), melanomas (*e.g.*, advanced malignant melanoma, cutaneous melanoma), oral cancers, ovarian cancers, penile cancers, prostate cancers, pancreatic cancers, skin cancers, testicular cancers, thyroid cancers, uterine cancers, and vaginal cancers. In some embodiments, the solid tumor is head and neck cancer, lung cancer, melanoma or pancreatic cancer.

[0112] The cancer may be newly diagnosed and naïve to treatment, or may be relapsed, refractory, or relapsed and refractory, or a metastatic form of a solid tumor. Indeed, *in vivo* data in mouse PC3 prophylactic models (FIG. 12) show that the anti-CD40 antibodies are effective in reducing tumor size in comparison to dosing with isotype antibody.

[0113] Without wishing to be limited by theory, it is believed that an anti-CD40 antibody activates the immune system by agonizing CD40. The subsequent immune response then exerts an antitumor effect on adjacent tumor cells, without regard to CD40 expression levels. Accordingly, an anti-CD40 antibody of the disclosure is expected to be effective against CD40-positive or CD40-negative solid tumors.

[0114] An anti-CD40 antibody of the disclosure may be administered alone (monotherapy) or adjunctive to, or with, other anti-cancer therapies and/or targeted or non-targeted anti-cancer agents. Whether administered as monotherapy or adjunctive to, or with, other therapies or agents, an amount

of anti-CD40 antibody is administered such that the overall treatment regimen provides therapeutic benefit.

[0115] By therapeutic benefit is meant that the use of anti-CD40 antibodies to treat cancer in a patient results in any demonstrated clinical benefit compared with no therapy (when appropriate) or to a known standard of care. Clinical benefit can be assessed by any method known to one of ordinary skill in the art. In one embodiment, clinical benefit is assessed based on objective response rate (ORR) (determined using RECIST version 1.1), duration of response (DOR), progression-free survival (PFS), and/or overall survival (OS). In some embodiments, a complete response indicates therapeutic benefit. In some embodiments, a partial response indicates therapeutic benefit. In some embodiments, stable disease indicates therapeutic benefit. In some embodiments, an increase in overall survival indicates therapeutic benefit. In some embodiments, therapeutic benefit may constitute an improvement in time to disease progression and/or an improvement in symptoms or quality of life. In other embodiments, therapeutic benefit may not translate to an increased period of disease control, but rather a markedly reduced symptom burden resulting in improved quality of life. As will be apparent to those of skill in the art, a therapeutic benefit may be observed using the anti-CD40 antibodies alone (monotherapy) or adjunctive to, or with, other anti-cancer therapies and/or targeted or non-targeted anti-cancer agents.

[0116] Typically, therapeutic benefit is assessed using standard clinical tests designed to measure the response to a new treatment for cancer. To assess the therapeutic benefits of the anti-CD40 antibodies described herein one or a combination of the following tests can be used: (1) the Response Evaluation Criteria In Solid Tumors (RECIST) version 1.1, (2) the Eastern Cooperative Oncology Group (ECOG) Performance Status, (3) immune-related response criteria (irRC), (4) disease evaluable by assessment of tumor antigens, (5) validated patient reported outcome scales, and/or (6) Kaplan-Meier estimates for overall survival and progression free survival.

[0117] Assessment of the change in tumor burden is an important feature of the clinical evaluation of cancer therapeutics. Both tumor shrinkage (objective response) and time to the development of disease progression are important endpoints in cancer clinical trials. Standardized response criteria, known as RECIST (Response Evaluation Criteria in Solid Tumors), were published in 2000. An update (RECIST 1.1) was released in 2009. RECIST criteria are typically used in clinical trials where objective response is the primary study endpoint, as well as in trials where assessment of stable disease, tumor progression or time to progression analyses are undertaken because these outcome

measures are based on an assessment of anatomical tumor burden and its change over the course of the trial. TABLE 4 provides the definitions of the response criteria used to determine objective tumor response to a study drug, such as the anti-CD40 antibodies described herein.

TABLE 4

Response	**Criteria**
Complete Response (CR)	Disappearance of all target lesions. Any pathological lymph nodes (whether target or non-target) must have reduction in short axis to <10 mm.
Partial Response (PR)	At least a 30% decrease in the sum of diameters of target lesions, taking as reference the baseline sum diameters.
Progressive Disease (PD)	At least a 20% increase in the sum of diameters of target lesions, taking as reference the smallest sum on study (this includes the baseline sum if that is the smallest on study). In addition to the relative increase of 20%, the sum must also demonstrate an absolute increase of at least 5 mm. (Note: the appearance of one or more new lesions is also considered progression).
Stable Disease (SD)	Neither sufficient shrinkage to qualify for PR nor sufficient increase to qualify for PD, taking as reference the smallest sum diameters while on study.

[0118] Secondary outcome measures that can be used to determine the therapeutic benefit of the anti-CD40 antibodies described herein include, Objective Response Rate (ORR), Progression Free Survival (PFS), Overall Survival (OS), Duration of Overall Response (DOR), and Depth of Response (DpR). ORR is defined as the proportion of the participants who achieve a complete response (CR) or partial response (PR). PFS is defined as the time from the first dose date of an anti-CD40 antibody to either disease progression or death, whichever occurs first. OS is defined as the length of time from either the date of diagnosis or the start of treatment for a disease, that patients diagnosed with the disease are still alive. DOR is defined as the time from the participant's initial CR or PR to the time of disease progression. DpR is defined as the percentage of tumor shrinkage observed at the maximal response point compared to baseline tumor load. Clinical endpoints for both ORR and PFS can be determined based on RECIST 1.1 criteria described above.

[0119] The ECOG Scale of Performance Status shown in TABLE 5 is used to describe a patient's level of functioning in terms of their ability to care for themselves, daily activity, and physical ability.

The scale was developed by the Eastern Cooperative Oncology Group (ECOG), now part of the ECOG-ACRIN Cancer Research Group, and published in 1982.

TABLE 5	
Grade	**ECOG Performance Status**
0	Fully active, able to carry on all pre-disease performance without restriction
1	Restricted in physically strenuous activity but ambulatory and able to carry out work of a light or sedentary nature, *e.g.*, light house work, office work
2	Ambulatory and capable of all selfcare but unable to carry out any work activities; up and about more than 50% of waking hours
3	Capable of only limited selfcare; confined to bed or chair more than 50% of waking hours
4	Completely disabled; cannot carry on any selfcare; totally confined to bed or chair
5	Dead

[0120] Another set of criteria that can be used to characterize fully and to determine response to immunotherapeutic agents, such as antibody-based cancer therapies, is the immune-related response criteria (irRC), which was developed for measurement of solid tumors in 2009, and updated in 2013 (Wolchok, et al. Clin. Cancer Res. 2009; 15(23): 7412-7420 and Nishino, et al. Clin. Cancer Res. 2013; 19(14): 3936-3943, each of which is incorporated by reference in its entirety). The updated irRC criteria are typically used to assess the effect of an immunotherapeutic agent, such as an anti-CD40 antibody described herein, on tumor burden, and defines response according to TABLE 6.

TABLE 6	
Response	**Criteria**
Complete Response (CR)	Disappearance of all target lesions in two consecutive observations not less than 4 weeks apart
Partial Response (PR)	At least a 30% decrease in the sum of the longest diameters of target lesions, taking as reference the baseline sum diameters.

TABLE 6	
Response	**Criteria**
Progressive Disease (PD)	At least a 20% increase in the sum of diameters of target lesions, taking as reference the smallest sum on study (this includes the baseline sum if that is the smallest on study). (Note: the appearance of one or more new lesions is not considered progression. The measurement of new lesions is included in the sum of the measurements).
Stable Disease (SD)	Neither sufficient shrinkage to qualify for PR nor sufficient increase to qualify for PD, taking as reference the smallest sum diameters while on study.

[0121] One exemplary therapeutic benefit resulting from the use of anti-CD40 antibodies described herein to treat solid tumors, whether administered as monotherapy or adjunctive to, or with, other therapies or agents, is a complete response. Another exemplary therapeutic benefit resulting from the use of anti-CD40 antibodies described herein to treat solid tumors, whether administered as monotherapy or adjunctive to, or with, other therapies or agents, is a partial response.

[0122] Validated patient reported outcome scales can also be used to denote response provided by each patient through a specific reporting system. Rather than being disease focused, such outcome scales are concerned with retained function while managing a chronic condition. One non-limiting example of a validated patient reported outcome scale is PROMIS® (Patient Reported Outcomes Measurement Information System) from the United States National Institutes of Health. For example, PROMIS® Physical Function Instrument for adult cancer patients can evaluate self-reported capabilities for the functioning of upper extremities (*e.g.*, dexterity), lower extremities (*e.g.*, walking or mobility), and central regions (*e.g.*, neck, back mobility), and includes routine daily activities, such as running errands.

[0123] Kaplan-Meier curves (Kaplan and Meier, J. Am. Stat. Assoc. 1958; 53(282): 457-481) can also be used to estimate overall survival and progression free survival for cancer patients undergoing anti-CD40 antibody therapy in comparison to standard of care.

7.6.2. Adjunctive Therapies

[0124] The anti-CD40 antibodies may be used adjunctive to, or with, other agents or treatments having anti-cancer properties. When used adjunctively, the anti-CD40 antibody and other agent(s)

may be formulated together in a single, combination pharmaceutical formulation, or may be formulated and administered separately, either on a single coordinated dosing regimen or on different dosing regimens. Agents administered adjunctive to or with the anti-CD40 antibodies will typically have complementary activities to the anti-CD40 antibodies such that the antibodies and other agents do not adversely affect each other.

[0125] Agents that may be administered adjunctive to or with an anti-CD40 antibody include, but are not limited to, alkylating agents, angiogenesis inhibitors, antibodies, antimetabolites, antimitotics, antiproliferatives, antivirals, aurora kinase inhibitors, apoptosis promoters (for example, Bcl-2 family inhibitors), activators of death receptor pathway, Bcr-Abl kinase inhibitors, BiTE (Bi-Specific T cell Engager) antibodies, antibody drug conjugates, biologic response modifiers, cyclin-dependent kinase inhibitors, cell cycle inhibitors, cyclooxygenase-2 inhibitors, DVDs, leukemia viral oncogene homolog (ErbB2) receptor inhibitors, growth factor inhibitors, heat shock protein (HSP)-90 inhibitors, histone deacetylase (HDAC) inhibitors, hormonal therapies, immunologicals, inhibitors of inhibitors of apoptosis proteins (IAPs), intercalating antibiotics, kinase inhibitors, kinesin inhibitors, Jak2 inhibitors, mammalian target of rapamycin (mTor) inhibitors, microRNAs, mitogen-activated extracellular signal-regulated kinase inhibitors, non-steroidal anti-inflammatory drugs (NSAIDs), poly ADP (adenosine diphosphate)-ribose polymerase (PARP) inhibitors, platinum chemotherapeutics, Bruton's tyrosine kinase (BTK) inhibitors (*e.g.*, ibrutinib, acalabrutinib), polo-like kinase (Plk) inhibitors, phosphoinositide-3 kinase (PI3K) inhibitors, proteasome inhibitors, purine analogs, pyrimidine analogs, receptor tyrosine kinase inhibitors, retinoids/deltoids plant alkaloids, small inhibitory ribonucleic acids (siRNAs), topoisomerase inhibitors, ubiquitin ligase inhibitors, and the like, as well as combinations of one or more of these agents.

[0126] Examples of immunologicals include, but are not limited to, interferons, immune checkpoint inhibitors, and other immune-enhancing agents. Interferons include interferon alpha, interferon alpha-2a, interferon alpha-2b, interferon beta, interferon gamma-1a, ACTIMMUNE® (interferon gamma-1b) or interferon gamma-n1, combinations thereof and the like. Immune check point inhibitors include antibodies that target PD-1 (*e.g.*, pembrolizumab and nivolumab), PD-L1 (*e.g.*, durvalumab, atezolizumab, avelumab, MEDI4736, MSB0010718C and MPDL3280A), and CTLA4 (cytotoxic lymphocyte antigen 4; *e.g.*, ipilimumab, tremelimumab). Immune-enhancing agents include anti-OX40 agonist antibodies that activate T cells. In certain embodiments, a humanized anti-CD40 antibody shown in TABLE 3 is administered adjunctive to pembrolizumab. In other certain

embodiments, a humanized anti-CD40 antibody shown in TABLE 3 is administered adjunctive to nivolumab.

[0127] An anti-CD40 antibody may also be used to enhance the efficacy of radiation therapy. Examples of radiation therapy include external beam radiation therapy, internal radiation therapy (*i.e.*, brachytherapy) and systemic radiation therapy.

7.7. Dosages and Administration Regimens

[0128] The amount of anti-CD40 antibodies administered will depend upon a variety of factors, including but not limited to, the particular type of solid tumor treated, the stage of the solid tumor being treated, the mode of administration, the frequency of administration, the desired therapeutic benefit, and other parameters such as the age, weight and other characteristics of the patient, *etc.* Determination of dosages effective to provide therapeutic benefit for specific modes and frequency of administration is within the capabilities of those skilled in the art.

[0129] Dosages effective to provide therapeutic benefit may be estimated initially from *in vivo* animal models or clinical. Suitable animal models for a wide variety of diseases are known in the art.

[0130] The anti-CD40 antibodies disclosed herein may be administered by any route appropriate to the condition to be treated. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. An anti-CD40 antibody will typically be administered parenterally, *i.e.*, infusion, subcutaneous, intramuscular, intravenous (IV), intradermal, intrathecal, bolus, intratumoral (IT) injection or epidural ((Shire *et al.*, 2004, *J. Pharm. Sciences* 93(6):1390-1402)). In one embodiment, an anti-CD40 antibody is provided as a lyophilized powder in a vial. The vials may contain 21 mg of anti-CD40 antibody. Prior to administration, the lyophilized powder is reconstituted with sterile water for injection (SWFI) or other suitable medium to provide a solution containing 10 mg/mL anti-CD40 antibody. In some embodiments, the resulting reconstituted solution is further diluted with saline or other suitable medium and administered via an IV infusion twice every 7 days, once every 7 days, once every 14 days, once every 21 days, once every 28 days, once every 35 days, once every 42 days, once every 49 days, or once every 56 days. In some embodiments, for the first cycle, the infusion occurs over 90 minutes. In some embodiments, subsequent infusions are over 60 minutes. In other embodiments, the resulting reconstituted solution is further diluted with saline or other suitable medium and administered via an IT injection twice every 7 days, once every 7 days, once every 14 days, once every 21 days, once every 28 days, once every 35 days, once every 42 days, once every 49 days, or once every 56 days.

[0131] In one exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IV infusion once every 7 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg.

[0132] In another exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IV infusion once every 14 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg.

[0133] In another exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IV infusion once every 28 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg.

[0134] In another exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 7 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg.

[0135] In another exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 14 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007

mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg.

[0136] In another exemplary embodiment, an anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 28 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg.

[0137] When administered adjunctive to or with other agents, such as other chemotherapeutic agents, the anti-CD40 antibodies may be administered on the same schedule as the other agent(s), or on a different schedule. When administered on the same schedule, the anti-CD40 antibody may be administered before, after, or concurrently with the other agent. In some embodiments where an anti-CD40 antibody is administered adjunctive to, or with, standards of care, the anti-CD40 antibody may be initiated prior to commencement of the standard therapy, for example a day, several days, a week, several weeks, a month, or even several months before commencement of standard of care therapy.

[0138] In one exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via IV infusion once every 7 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0139] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via

IV infusion once every 14 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0140] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via IV infusion once every 28 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0141] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 7 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0142] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 14 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0143] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to nivolumab (OPDIVO®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 28 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Nivolumab is administered by intravenous infusion at a dose of 3 mg/kg over 60 minutes once every two weeks. The adjunctive anti-CD40 antibody / nivolumab therapy is continued until disease progression or no longer tolerated by the patient.

[0144] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via IV infusion once every 7 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks.

The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0145] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via IV infusion once every 14 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks. The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0146] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered via IV infusion once every 28 days at 0.005 mg/kg, 0.01 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, 2.0 mg/kg, 2.2 mg/kg, 2.4 mg/kg, 2.6 mg/kg, 2.8 mg/kg, 3.0 mg/kg, 3.2 mg/kg, 3.4 mg/kg, 3.6 mg/kg, 3.8 mg/kg, or 4.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks. The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0147] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 7 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3

mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks. The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0148] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 14 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks. The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0149] In another exemplary embodiment, an anti-CD40 antibody is used adjunctive to pembrolizumab (Keytruda®) to treat non-small cell lung cancer. In some embodiments, the anti-CD40 antibody is any one of the humanized antibodies listed in TABLE 3. The anti-CD40 antibody is administered as an IT injection once every 28 days at 0.001 mg/kg, 0.002 mg/kg, 0.003 mg/kg, 0.004 mg/kg, 0.005 mg/kg, 0.006 mg/kg, 0.007 mg/kg, 0.008 mg/kg, 0.009 mg/kg, 0.01 mg/kg, 0.015 mg/kg, 0.02 mg/kg, 0.03 mg/kg, 0.04 mg/kg, 0.05 mg/kg, 0.06 mg/kg, 0.08 mg/kg, 0.1 mg/kg, 0.2 mg/kg, 0.3 mg/kg, 0.4 mg/kg, 0.5 mg/kg, 0.6 mg/kg, 0.8 mg/kg, 1.0 mg/kg, 1.1 mg/kg, 1.2 mg/kg, 1.3 mg/kg, 1.4 mg/kg, 1.5 mg/kg, 1.6 mg/kg, 1.7 mg/kg, 1.8 mg/kg, 1.9 mg/kg, or 2.0 mg/kg. Pembrolizumab is administered by intravenous infusion at a dose of 2 mg/kg over 30 minutes once every three weeks. The adjunctive anti-CD40 antibody / pembrolizumab therapy is continued until disease progression or no longer tolerated by the patient.

[0150] As will be appreciated by those of skill in the art, the recommended dosages for the various agents described above may need to be adjusted to optimize patient response and maximize therapeutic benefit.

8. EXAMPLES

[0151] The following Examples, which highlight certain features and properties of the exemplary embodiments of the anti-CD40 antibodies described herein are provided for purposes of illustration, and not limitation.

Example 1: Generation of Mouse anti-Human CD40 Antibodies

[0152] Monoclonal antibodies were generated by immunizing Balb/C mice or SJL mice intraperitoneally with mouse 3T12 cells overexpressing human CD40. Spleens were harvested, and splenocytes were fused with the multiple myeloma cell line NS0. Hybridomas were selected using aminopterin. Selected hybridomas expressing anti-CD40 antibodies with agonistic activities were screened and subcloned to isolate individual clones.

[0153] To screen for antibodies with agonistic activity, a panel of functional assays was developed, including NFκB pathway stimulation, monocytes activation, dendritic cell (DC) activation and CD40 ligand (CD40L) competition. In these assays, anti-human CD40 G28-5 (mouse IgG1) (Biolegend) was included as positive control and an isotype matched mouse antibody (mIgG1) as negative control.

8.1.1. HEK293 blue CD40 NFκB reporter assay

[0154] HEK293 blue CD40 cell line (InVivogen) stably expressing human CD40 and a NFκB reporter gene were maintained in DMEM, 10% heat-inactivated fetal bovine serum (FBS), supplemented with 30 μg/mL Blasticidin and 100 μg/mL Zeocin. Activation of CD40 on the surface of HEK293 blue CD40 cells triggers a signaling cascade leading to the activation of NFκB and the subsequent secretion of embryonic alkaline phosphatase (SEAP). Incubation of hybridoma supernatants containing agonistic anti-CD40 with $2.5x10^5$/mL of HEK293 blue CD40 cells stimulated production of SEAP which was measured by a colorimetic enzyme assay. The level of SEAP thus corresponded to the activity of anti-CD40 in the hybridoma supernatants.

8.1.2. Monocyte activation assay

[0155] The monocyte activity assay was performed using the monocytic cell line THP1-XBlue cells (InVivogen). This cell line stably expresses an NFκB and AP-1-inducible SEAP reporter gene and was maintained in RPMI 1640 with 10% heat-inactivated FBS and 200 μg/mL Zeocin. In the assay, $5x10^5$/mL THP1-XBlue cells were first primed with 40 ng/mL IFNγ for 24 hours, and were subsequently incubated with testing samples for an additional 24 hours. Agonistic anti-CD40-induced SEAP activity was monitored by enzymatic assay.

8.1.3. Primary dendritic cell IL-12p70 production assay

[0156] Anti-CD40 clones were also screened for their ability to activate monocyte-derived dendritic cells (moDC). Activation was monitored by IL-12p70 production. Human peripheral blood mononuclear cells (PBMC) were first isolated on a Ficoll gradient. Briefly, whole blood from healthy human donors, diluted with an equal volume of PBS, was added to a Leucosep (Greiner Bio One) tube, containing Ficoll-Paque Plus below the frit (15 mL). The blood was then centrifuged at 1,000g for 15 minutes without brake. PBMC were collected and washed once with PBS, centrifuged at 1,300 rpm for 5 minutes at room temperature, and washed once with RPMI 1640. Cells were re-suspended in culture medium (RPMI1640+10% heat-inactivated FBS). Monocytes were subsequently isolated from PBMC with an enrichment kit from StemCell and were cultured in StemSep serum free medium supplemented with 10 ng/mL GM-CSF and 20 ng/mL IL-4 at 37 °C, 5% CO_2 for 6 days. Fresh GM-CSF and IL-4 were added to the culture at day 3 to help maintain DC differentiation. After 6 days in culture, monocyte-derived immature DC were subject to FACS analysis to verify immature DC phenotype: Lin-, CD80/CD86+, HLA-DR+, or CD11c+. Immature moDC were primed with IFNγ and stimulated with samples containing an anti-CD40 antibody for 48 hours in StemSep serum free medium supplemented with GM-CSF and IL-4. The culture supernatant was harvested and assayed for IL-12p70 production by a commercially available ELISA kit. The screening results and representative activity are summarized in Table 1-1.

[0157] Table 1-1 shows the range of agonistic anti-CD40 activity across isolated hybridomas. All of the new clones demonstrated monocyte activation comparable to literature CD40 antibody G28-5 (*see, e.g.*, Bishop, G. A. Journal of Immunology 188, 4127-4129 (2012)). Clones AD166.4.4 and AD175.14.11 demonstrated monocyte activation but did not show dendritic cell activation. The remainder of the clones displayed monocyte activation comparable to G28-5, as well as enhanced dendritic cell activation as compared with G28-5.

Table 1-1
Summary of agonistic anti-CD40 clone screen

Clone	Monocyte activation[1] (THP1-Xblue, OD_{655})	moDC activation (IL-12p70, pg/mL)
AD163.7.2	0.13	905.3
AD163.9.3	0.19	2216.3
AD163.10.7	0.16	1318.8

Table 1-1
Summary of agonistic anti-CD40 clone screen

Clone	Monocyte activation[1] (THP1-Xblue, OD_{655})	moDC activation (IL-12p70, pg/mL)
AD163.27.12	0.12	1514.5
AD163.162.1	0.11	2155.5
AD164.14.6	0.15	878
AD164.76.3	0.16	769.8
AD165.1.2	0.14	719.8
AD166.4.4	0.24	0
AD175.14.11	0.2	0
G28-5	0.12	138.8
muIgG1	0.06	0

[1]Monocyte activation is SEAP activity released from THP1-XBlue cells recorded at OD_{655}

[0158] The cDNA sequences encoding the heavy and light chain variable regions of ten monoclonal antibodies were cloned from hybridomas AD163.9.3, AD166.4.4, AD175.14.11, AD163.10.7, AD165.1.2, AD163.162.1, AD163.27.12, AD163.7.2, AD164.14.6, and AD164.76.3, respectively, using standard PCR techniques and were sequenced using standard DNA sequencing techniques. The full corresponding antibody amino acid sequences encoded by the DNA are shown in FIGS. 2A-2C.

Example 2: Epitope Classification of Mouse anti-Human CD40 Antibodies

[0159] BIAcore analysis and an ELISA method were used to classify mouse anti-human CD40 agonistic antibodies based on their ability to compete with each other or CD40 ligand (CD40L) for binding to CD40.

[0160] BIAcore analysis was performed using a BIAcore T100 instrument at 12 °C. A goat anti-mouse Fc antibody (Pierce, cat# 31170) was first immobilized on CM5 sensor chip followed by capture of the first test antibody on the surface. After blocking by 50 μg/mL of mouse isotype antibody cocktail, the flow cells were injected with the soluble form of the extracellular domain of human CD40 (Creative BioMart, cat# CD402221H). Subsequently, the second test antibody or CD40L (PeproTech, cat# 0308145) was injected to measure their binding to the complex of CD40 and the first test antibody. As shown in Table 2-1, the anti-CD40 antibodies of the disclosure were

classified into three epitope groups. Epitope group 1 was exemplified by AD163.7.2 ("muAb8") and AD175.14.11 ("muAb3"), which blocked CD40L binding to CD40. Epitope group 2 was determined from clones AD163.162.1 ("muAb6") and AD163.27.12 ("muAb7"), which did not compete with CD40L or to antibodies in epitope group 1. The third epitope group was exemplified by clones AD163.9.3 ("muAb1"), AD166.4.4 ("muAb2"), and AD165.1.2 ("muAb5"), which did not compete with CD40L binding to CD40, but did compete with antibodies in epitope groups 1 and 2.

TABLE 2-1
Epitope classification by BIAcore analysis

first antibody	second antibody							
	muAb6	muAb1	muAb2	muAb7	muAb5	muAb8	muAb3	CD40L
muAb6	—	X	X	X	X	Y	Y	Y
muAb1	X	—	X	X	X	X	X	Y
muAb2	X	X	—	X	X	X	X	Y
muAb7	X	X	X	—	X	Y	Y	Y
muAb5	X	X	X	X	—	X	X	Y
muAb8	Y	X	X	Y	X	—	X	X
muAb3	Y	X	X	Y	X	X	—	X

X: second antibody unable to bind; Y: simultaneous binding

[0161] An ELISA assay was developed to measure the effects of the anti-CD40 antibodies on the human CD40-CD40L interaction. Briefly, a CD40-human Fc (huFc) fusion protein (Creative BioMart) was mixed with an anti-CD40 antibody or an isotype control antibody and added to 96-well plates coated with HA-tagged CD40L (R&D Systems). The binding of the CD40-huFc complex to the plate-bound CD40L was detected by HRP conjugated anti-human Fc antibody (Jackson ImmunoResearch). After development with TMB (3, 3', 5, 5'-tetramethylbenzidine) substrate, the plates were read at OD_{450}.

[0162] The effect of the anti-CD40 antibodies on CD40-CD40L interaction was determined by calculating the ratio of the OD_{450} in the samples containing anti-CD40 antibodies to the OD_{450} in the sample containing the isotype control antibody ("OD_{450} ratio"). OD_{450} ratios of ≤ 0.1 showed inhibition of human CD40L binding to human CD40. OD_{450} ratios between 0.1 and 1 showed partial

inhibition of CD40L binding to CD40. OD_{450} ratios > 1 showed enhanced binding of human CD40L to human CD40, thereby enhancing CD40 signaling.

[0163] The data are summarized in Table 2-2. Antibodies muAb8 and muAb3 blocked CD40 binding to CD40L exhibited a ratio less than 0.1. Antibodies muAb6 and muAb7 showed a ratio around 0.5, suggesting a modest effect on CD40-CD40L interaction. Antibodies muAb1, muAb2, muAb4, muAb5, muAb9, and muAb10 exhibited an OD_{450} ratio of about 1 or greater than 1, indicating either no effect or an effect that promoted CD40 binding to CD40L.

TABLE 2-2
Competition with CD40 for CD40L Binding

Antibody	OD_{450} with anti-CD40 antibody	OD_{450} Ratio
muAb8	0.066	0.08
muAb3	0.068	0.09
muAb7	0.328	0.41
muAb6	0.455	0.57
muAb1	1.779	2.22
muAb4	1.343	1.68
muAb9	1.883	2.35
muAb10	2.107	2.63
muAb5	0.989	1.24
muAb2	1.025	1.28

Example 3: Humanization of Mouse anti-Human CD40 Antibodies

[0164] Humanization of the antibody V region was carried out as outlined by Queen, C. et al. (Proc. Natl. Acad. Sci. USA, 1989; 86:10029-10033). The canonical structures of the CDRs were determined according to Huang et al. (Methods, 2005; 36:35-42). Human variable germline sequences with the same or most similar CDR canonical structures were identified, and appropriate human V_H, V_L, and J segment sequences were selected to provide the frameworks for the anti-CD40 variable region. At framework positions in which the computer model suggested significant contact with the CDRs, the amino acids from the murine anti-CD40 V regions were substituted for the original human framework amino acids (back-mutations). The constant regions of human IgG_1 with

natural variants D356E and L358M in the heavy chain, and a kappa light chain were used unless otherwise specified. Full amino acid sequences of the V_H and V_L regions of the humanized antibodies are shown in FIGS. 2D-2G.

[0165] Anti-CD40 clone AD163.162.1 ("muAb6") was humanized according to the method described above. The humanized versions of muAb6 were huAb6-1, huAb6-2 and huAb6-3. Antibody huAb6-1 carried V_H (SEQ ID NO: 110) framework back-mutations: M48I, V67A, I69L, and A71V. Antibody huAb6-2 carried V_H (SEQ ID NO: 111) framework back-mutations M48I and A71V. Antibody huAb6-3 carried V_H (SEQ ID NO: 112) framework back-mutations M48I and A71V, as well as V_H CDR germlining changes N60A, K64Q and D65G to increase identity to human germline sequence. Antibodies huAb6-1, huAb6-2 and huAb6-3 carried V_L (SEQ ID NO: 161) framework back-mutations: A43S, L46R, L47W and F71Y.

[0166] The humanized versions of anti-CD40 clone AD163.7.2 ("muAb8") were huAb8-1, huAb8-2 and huAb8-3 (FIGS. 2D-2E). Antibody huAb8-1 carried V_H (SEQ ID NO: 113) framework back-mutations: M48I, V67A, I69L, A71V, K73R, Y91F, and R94S. Antibody huAb8-2 carried V_H (SEQ ID NO: 114) framework back-mutations: M48I, V67A, I69L, A71V, K73R, Y91F, and R94S; as well as VH CDR C59S mutation. Antibody huAb8-3 carried V_H (SEQ ID NO: 115) framework back-mutations: M48I, A71V and R94S. Antibodies huAb8-1, huAb8-2 and huAb8-3 all carried V_L (SEQ ID NO: 162) framework back-mutations: A43S, and Y87F.

[0167] Anti-CD40 clone AD164.14.6 ("muAb9") was humanized to provide huAb9-1, huAb9-2, huAb9-3, huAb9-4, huAb9-5 and huAb9-6. Antibodies huAb9-1 and huAb9-4 displayed V_H (SEQ ID NO: 116) framework back-mutations: I48M, V67I and V71R. Antibodies huAb9-2 and huAb9-5 carried V_H (SEQ ID NO: 117) framework back-mutations: I48M and V71R. Antibodies huAb9-3 and huAb9-6 carried V_H (SEQ ID NO: 118) framework back-mutations: I48M and V71R, as well as additional two CDR germline changes T30S and N65S to improve identity to human germline sequence. Antibodies huAb9-1, huAb9-2 and huAb9-3 carried V_L (SEQ ID NO: 163) framework back-mutations: I2A, Y36F and Y87F. Antibodies huAb9-4, huAb9-5 and huAb9-6 carried V_L (SEQ ID NO: 164) framework back-mutation I2A. Clone AD164.14.6 was further modified to remove a signal peptide cleavage site found at the second position of the light chain, by reverting the framework back-mutation I2A of the V_L. Antibodies huAb9 A2I and huAb9 A2V carried V_H (SEQ ID NO:117) and V_L containing framework revert mutations A2I (SEQ ID NO:170) and A2V (SEQ ID NO:171), respectively, prevented the formation of an undesired cleavage product.

[0168] Humanized antibodies in the present Example were generated with a human IgG1 heavy chain constant region and kappa light chain constant region. The C-terminal lysine may be partially cleaved by post-translational processing after protein expression of the human IgG1 heavy chain. Accordingly, huAb9-5 had a heavy chain according to SEQ ID NOS:130 or 131 and a light chain according to SEQ ID NO:140. Antibody huAb9-5 also was produced with V273E and V273Y amino acid mutations in the heavy chain constant region, corresponding to a heavy chain according to SEQ ID NOS:132 or 133 and SEQ ID NOS:134 or 135, respectively, and a light chain according to SEQ ID NO:140. Antibodies huAb9 A2I and huAb9 A2V were generated with a human IgG1 V273E heavy chain constant region. Accordingly, huAb9 A2I had a heavy chain according to SEQ ID NOS:132 or 133 and a light chain according to SEQ ID NO:141. Analogously, huAb9 A2V had a heavy chain according to SEQ ID NOS:132 or 133 and a light chain according to SEQ ID NO:142.

Example 4: Characterization of the Humanized anti-Human CD40 Antibodies

[0169] To ensure the humanized anti-CD40 antibodies retained the agonistic and other desired properties of the parental murine antibodies, a panel of characterization assays was performed to determine NFκB activation, CD40 binding kinetics, species cross-reactivity and epitope classes of the humanized antibodies of the disclosure.

8.4.1. NFκB activation

[0170] NFκB activation by humanized anti-CD40 antibody of the invention was evaluated in HEK293 blue CD40 NFκB reporter cells. The activation was represented as SEAP (secreted embryonic alkaline phosphatase) reporter gene activity measured at OD_{655}. The maximal OD_{655} measured and the concentration for half-maximal activation (EC_{50}) are summarized in Table 4-1.

Table 4-1

NFκB activation in HEK293 blue CD40 NFκB reporter cells

Humanized antibody	EC_{50} (μg/mL)	Maximal activation (OD_{655})
huAb6-1	1.09	0.26
huAb6-2	1.21	0.20
huAb6-3	4.31	0.32
huAb8-1	0.14	0.45

Table 4-1 NFκB activation in HEK293 blue CD40 NFκB reporter cells		
Humanized antibody	**EC_{50} (μg/mL)**	**Maximal activation (OD_{655})**
huAb8-3	0.07	0.46
huAb9-1	0.19	0.26
huAb9-2	0.29	0.27
huAb9-3	0.18	0.27
huAb9-4	5.55	0.61
huAb9-5	1.13	0.67
huAb9-6	5.95	0.54

8.4.2. CD40 binding kinetics and species cross-reactivity

[0171] The binding affinities of the disclosed humanized anti-CD40 antibodies were analyzed by both BIAcore and flow cytometry analysis.

[0172] CD40 binding kinetics was analyzed by BIAcore assay with a BIAcore T200 instrument. Briefly, a goat anti-mouse Fc antibody (Pierce, cat# 31170) or goat anti-human Fc (Pierce, cat#31125) was immobilized on a CM5 sensor chip, followed by capture of the anti-CD40 antibodies on the test surface. Subsequently, the soluble form of the extracellular domain of human CD40 (Creative BioMart, cat# CD402221H) or cynomolgus (cyno) CD40 (Creative BioMart, cat# CD40-8824C) was injected, and the binding and dissociation were measured.

[0173] Surface plasmon resonance data indicated that humanized huAb8-1, huAb9-5, huAb9 A2I, and huAb9 A2V antibodies retained similar binding affinities (K_D) as that of their parental clones AD163.7.2 ("muAb8") or clone AD164.14.6 ("muAb9"), and showed similar binding to human or cynomolgus CD40 (Table 4-2).

TABLE 4-2

Affinity measured by BIAcore*

Antibody	Human CD40			Cynomolgus CD40		
	k_a (1/Ms)	k_d (1/s)	K_D (M)	k_a (1/Ms)	k_d (1/s)	K_D (M)
muAb6	7.6E+04	4.8E-03	6.3E-08	Not determined		
muAb7	7.5E+04	4.8E-03	6.4E-08	Not determined		
muAb8	1.0E+06	4.2E-03	4.1E-09	Not determined		
muAb3	6.9E+04	1.2E-02	1.7E-07	Not determined		
muAb1	4.7E+05	1.6E-02	3.5E-08	Not determined		
muAb2	2.8E+06	9.6E-03	3.5E-09	Not determined		
muAb4	2.3E+06	1.7E-01	7.6E-08	Not determined		
muAb5	2.3E+06	2.0E-03	8.8E-10	Not determined		
muAb10	2.6E+06	3.4E-02	1.3E-08	Not determined		
muAb9	2.8E+06	5.2E-02	1.9E-08	Not determined		
huAb8-1	7.7E+05	2.3E-03	3.0E-09	1.0E+06	7.1E-03	7.1E-09
huAb9-5	1.7E+06	2.6E-02	1.5E-08	1.8E+06	2.4E-02	1.3E-08
huAb9 A2I	1.3E+06	2.2E-01	1.7E-07	1.7E+06	2.5E-01	1.5E-07
huAb9 A2V	1.5E+06	2.6E-01	1.7E-07	1.9E+06	2.7E-01	1.4E-07

*Numbers refer to scientific notation, *e.g.*, 3.0E-09 = 3.0×10^{-9}.

[0174] The humanized anti-CD40 antibodies were also evaluated for binding to cell-surface CD40 on HEK293 cells stably transfected with human or cynomolgus CD40, as well as B cells derived from cynomolgus or human PBMC. Humanized anti-CD40 antibodies were incubated with HEK293 transfectants for 15 minutes on ice, and the binding was detected with a fluorescence-conjugated anti-human secondary antibody (Jackson ImmunoResearch). FACS analysis of the cells confirmed that the humanized antibodies bound to human and cynomolgus CD40 stable cell lines. In contrast, no binding was observed in similar experiments performed with mouse, rat or dog CD40.

[0175] The anti-CD40 antibodies were also assessed for their ability to bind to primary human and cynomolgus CD40-expressing cells. PBMCs isolated from human or cynomolgus blood were incubated with anti-CD40 antibodies conjugated to the fluorescence dye CF640R. After FACS analysis, the data were analyzed by FlowJo (FlowJo, LLC) software. These results demonstrated that

the humanized antibodies bound to primary CD40-positive cells derived from both human and cynomolgus PBMC.

8.4.3. Epitope classification

[0176] Flow cytometry analysis and an ELISA method were used to classify humanized agonistic anti-CD40 antibodies based on their ability to compete with each other or CD40 ligand (CD40L) for binding to CD40.

[0177] A flow cytometry analysis was developed to assess whether an antibody competes for binding human CD40 with another antibody. In this assay, CP-870,893, prepared from a fully human IgG_2 anti-human CD40 antibody clone 21.4.1 (see, Gladue, RP. et al., Cancer Immunol. Immunother. 2011; 60:1009-17 and US Patent No. 7,618,633), was used as the reference antibody. The heavy and light chains, respectively, of CP-870,893 were:

QVQLVQSGAEVKKPGASVKVSCKASGYTFTGYYMHWVRQAPGQGLEWMGWINPDSGGTN
YAQKFQGRVTMTRDTSISTAYMELNRLRSDDTAVYYCARDQPLGYCTNGVCSYFDYWGQG
TLVTVSSASTKGPSVFPLAPCSRSTSESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAV
LQSSGLYSLSSVVTVPSSNFGTQTYTCNVDHKPSNTKVDKTVERKCCVECPPCPAPPVAGPS
VFLFPPKPKDTLMISRTPEVTCVVVDVSHEDPEVQFNWYVDGVEVHNAKTKPREEQFNSTFR
VVSVLTVVHQDWLNGKEYKCKVSNKGLPAPIEKTISKTKGQPREPQVYTLPPSREEMTKNQ
VSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPMLDSDGSFFLYSKLTVDKSRWQQGNVFS
CSVMHEALHNHYTQKSLSLSPGK (SEQ ID NO: 181), and

DIQMTQSPSSVSASVGDRVTITCRASQGIYSWLAWYQQKPGKAPNLLIYTASTLQSGVPSRFS
GSGSGTDFTLTISSLQPEDFATYYCQQANIFPLTFGGGTKVEIKRTVAAPSVFIFPPSDEQLKSG
TASVVCLLNNFYPREAKVQWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSKADYEKH
KVYACEVTHQGLSSPVTKSFNRGEC (SEQ ID NO: 182).

[0178] All anti-CD40 human or humanized antibodies, including huAb6-1, huAb8-1, huAb9 A2I, and CP-870,893, were labeled with Alexa Fluor (AF)-488. Each fluorescence-labeled antibody with fixed concentration at 1 μg/mL was separately mixed with increasing amount of other unlabeled anti-CD40 antibodies ranging from 0.5 ng/mL up to 50 μg/mL, and incubated with HEK293 cells stably expressing human CD40. The binding of fluorescence-labeled antibody was then monitored by flow cytometry.

[0179] The competitive antibodies identified by dose-dependent reduction of mean fluorescence intensity (MFI) and non-competitive antibodies identified by constant MFI were summarized in Table 4-3. While huAb6-1 did not compete for binding human CD40 with huAb8-1, both huAb9 A2I and the CP-870,893 competed with huAb6-1 and huAb8-1. Additionally, huAb9 A2I and CP-870,893 competed with each other.

TABLE 4-3
Epitope classification by flow cytometry analysis

first antibody	second antibody			
	huAb6-1	huAb8-1	huAb9 A2I	CP-870,893
huAb6-1	—	Y	X	X
huAb8-1	Y	—	X	X
huAb9 A2I	X	X	—	X
CP-870,893	X	X	X	—

X: mutually competitive; Y: mutually non-competitive

[0180] Epitope classification of the humanized antibodies of the invention was also confirmed by an ELISA assay measuring the binding of anti-CD40 antibody and CD40 complex to plate-bound CD40L as described in Example 2. In this assay, CP-870,893 as prepared above was used as a reference anti-CD40 antibody. Increasing amounts of anti-CD40 antibodies or human IgG_1 ($huIgG_1$) control antibody were incubated with 1 μg/mL of CD40-huFc fusion protein, and added to a plate coated with CD40L. As shown in FIG. 3, humanized antibodies huAb8-1 and huAb8-3 blocked interaction of CD40 and CD40L (upper left); huAb6-1 and huAb6-2 showed minimal effect on CD40-CD40L interaction (upper right); and huAb9-5 and huAb9-6 promoted CD40 binding to CD40L (lower left). Humanized antibody huAb9 A2I also promoted CD40 binding to CD40L as compared to CP-870,893, which showed minimal effect on CD40-CD40L interaction (lower right).

[0181] The results were consistent with those obtained in a flow cytometry based assay with cells expressing CD40L (FIG. 4). CD40L+ Jurkat cells were incubated with fluorochrome Alexa Fluor 488-conjugated soluble human CD40 protein at a constant concentration of 1 μg/mL. The binding of fluorochrome-conjugated CD40 to Jurkat cell surface CD40L was measured by flow cytometry analysis in the presence of humanized antibody huAb9 A2I and reference anti-CD40 antibody CP-870,893. Enhanced fluorescence intensity was detected upon increased amount of huAb9 A2I in the

sample, but not with reference antibody CP-870,893. These results suggested that huAb9 A2I promoted CD40 binding to CD40L+ Jurkat cells while the reference CP-870,893 did not.

[0182] The functional impact of huAb9 A2I on CD40 signaling driven by CD40L was also determined in an assay comprising both CD40 and CD40L expressing cells. CD40-expressing cells (HEK293 blue CD40 NFκB reporter cells described in Section 8.1.1) were mixed with CD40L- or CD40L+ Jurkat cells at the ratio of 1:1, and incubated with either huAb9 A2I, CP-870,893 or control antibody at 3 μg/mL. The CD40 signaling was measured by SEAP reporter activity through a colorimetric assay as described in Section 8.4.1. When CD40 reporter cells were co-cultured with CD40L- Jurkat cells (FIG. 5A), CD40 signaling was significantly enhanced only after addition of either huAb9 A2I or CP-870,893, but not with treatment of control antibody or with no addition. Although both antibodies activated CD40, huAb9 A2I was not significantly more potent than CP-870,893 in stimulating CD40 under these conditions. When CD40 reporter cells were co-cultured with CD40L+ Jurkat cells (FIG. 5B), cell surface CD40L activated CD40 as indicated by SEAP reporter activity. Treatment with CP-870,893 did not further enhance CD40 activity signaling with SEAP reporter activity similar to the control huIgG1 or huIgG2 isotype, or no antibody (media only) treatment. In contrast, treatment with huAb9 A2I further increased CD40 signaling with reporter activity significantly greater than CP-870,893 and the control treatments ($p<0.001$).

[0183] These data indicated that when cell surface CD40 was activated by a saturated amount of cell surface CD40L, huAb9 A2I further enhanced CD40 activation by effecting greater downstream NFκB signaling as compared with an equivalent amount of known anti-CD40 antibody CP-870,893.

Example 5: Fc Region Variants of anti-CD40 Antibodies

[0184] Greater agonistic activity of CD40 can be achieved through modifying the Fc region to enhance FcγRIIB binding (Li and Ravetch, Science, 2011; 333:1030-1034; and White, et al., J. Immunol, 2011; 187:1754-1763). Two mutations, V273E and V273Y, at position 273 in the human IgG1 constant region were introduced into the humanized anti-CD40 antibodies huAb6-1, huAb8-1, huAb9-5, and huAb9 A2I. The impact of the Fc mutations on binding to Fcγ receptors was monitored by FACS analysis and by antibody-dependent cell-mediated cytotoxicity (ADCC). The agonistic activities of humanized anti-CD40 with Fc modification were monitored through activation of NF-kB reporter, B cells, monocyte-derived DC and T cells.

8.5.1. Fcγ receptor binding and ADCC function

[0185] Increasing amounts of anti-CD40 human IgG_1 antibodies and their Fc variants were incubated with CHO cells stably expressing different human Fcγ receptors, including FcγRI (CD64), FcγRIIA (CD32a), FcγRIIB (CD32b), and FcγRIIIA (CD16) with either F or V polymorphism. The binding was detected with a fluorescence-conjugated anti-human $F(ab')_2$ specific secondary antibody (Jackson ImmunoResearch). The mutations V273E or V273Y reduced binding to FcγRIIIA (CD16F or V) while maintaining FcγRI (CD64) binding, and enhancing FcγRIIA (CD32a) or FcγRIIB (CD32b) binding (FIGS. 6A-6B).

[0186] The ADCC of the Fc variants of the humanized anti-CD40 antibodies was measured using a standard protocol (Law *et al.*, 2005, Cancer Res. 65:8331-8). In an illustrative example, ADCC was reduced with constant region variants V273E or V273Y as compared with wild type IgG_1 for antibody huAb9-5 in RL cells (FIG. 7).

8.5.2. Enhanced agonistic activity upon FcγR binding

[0187] To evaluate the impact of Fcγ receptor binding on agonistic activity of anti-CD40, huAb9 A2I with $huIgG_1$ V273E mutation was used to treat HEK293 blue CD40 NFκB reporter cells co-cultured with CHO cells stably expressing different human Fcγ receptors, and NFκB activity was monitored. As shown in Table 5-1, agonistic activity of CP-870,893 in stimulating NFκB activation was independent of Fcγ receptor binding, while agonistic activity of huAb9 A2I was found to be dependent on Fcγ receptor binding. The potency of huAb9 A2I was ten-fold higher in stimulating NFκB activity when reporter cells were co-cultured with CHO cells expressing CD32a, CD32b or CD64 than when co-cultured with CHO cells without Fcγ receptor expression, or expressing CD16V or CD16F.

Table 5-1
NFκB activity (EC_{50}, nM)

CHO (FcγR)	huAb9 A2I ($huIgG_1$ V273E)	CP-870,893 ($huIgG_2$)
FcγR negative	0.72	0.03
CD16F	0.39	0.03

Table 5-1 NFκB activity (EC_{50}, nM)		
CHO (FcγR)	huAb9 A2I (huIgG$_1$ V273E)	CP-870,893 (huIgG$_2$)
CD16V	0.30	0.02
CD32a	0.08	0.02
CD32b	0.07	0.02
CD64	0.01	0.02

8.5.3. Fc variants on B cell proliferation

[0188] The impact of Fc V273E or V273Y mutation on agonistic activity of anti-CD40 was also evaluated with B cell proliferation assay. In this assay, human B cells were enriched by B cell enrichment kit (StemCell Technologies) through negative selection. The purified B cells were seeded into 96 well plates at 5×10^5/ml, 200 μL per well in AIM-V serum free medium (GIBCO). Serially diluted anti-CD40 antibodies were added and cultured with B cells for 6 days. In the last 16 hours of culture, 1 μCi of H^3TdR were added to each well of the culture and B cell proliferation was determined by H^3TdR incorporation. The radioactivity associated with H^3TdR incorporation was recorded by a scintillation counter as count per minute (CPM). Compared to the corresponding human IgG1 wild-type antibodies, the anti-CD40 (huAb6-1, huAb8-1 and huAb9-5) human IgG1 Fc variants V273E and V273Y showed enhanced B cell activation (FIG. 8). However, when compared to CP-870,893, huAb9 A2I (human IgG$_1$ V273E) showed about ten-fold lower potency in stimulating B cell proliferation (lower right graph).

8.5.4. Fc variants on DC IL-12p70 production

[0189] The impact of Fc V273E or V273Y mutation on agonistic activity of anti-CD40 was further evaluated with DC activation assay using IL-12p70 as read-out. In this assay, immature DCs were first derived from monocytes purified from human PBMC and treated with IL4 and GM-CSF. DC maturation and IL-12p70 production were induced by anti-CD40 after priming with IFNγ. The V273E or V273Y Fc mutated versions enhanced potency on DC activation by enhancing IL-12p70 production. As illustrated in FIG. 9, huAb6-1 (upper left), huAb8-1 (upper right), and huAb9-5 (lower left) with huIgG$_1$ Fc variants V273E or V273Y showed increased IL-12p70 production as

compared with their corresponding antibodies having wild type huIgG$_1$. For huAb6-1 and huAb8-1, the variant with huIgG$_1$ V273Y mutation was more effective at enhancing in vitro IL-12p70 production than the one with the V273E mutation. For huAb9-5, variants with huIgG$_1$ V273E or V273Y showed similar potency. In the case of huAb9 A2I (lower right graph), the variant with huIgG$_1$ V273E mutation demonstrated similar potency as CP-870,893 in stimulating DC to produce IL-12p70.

8.5.5. Fc variants on T cell activation in allogeneic DC and T cell co-culture

[0190] To demonstrate anti-CD40 could drive T cell activation through stimulating antigen presenting cells such as DC, anti-CD40 Fc variants were tested in allogeneic DC and T cell co-culture. In this assay, dendritic cells (5×10^3) were first derived from monocytes using the method described above, then mixed with 1×10^5 T cells purified from a different donor. Various amounts of anti-CD40 antibody huAb6-1, huAb8-1, or huAb9-5 with either the wild-type human IgG$_1$ constant region or their Fc variants V273Y were added to the DC and T cell co-culture. After 4 days incubation, supernatants were collected and IFN-γ was measured by ELISA.

[0191] FIG. 10 illustrates exemplary antibodies that showed enhanced IFN-γ production in the co-culture with cells from two different donor-pairs. In each instance, the V273Y variants of huAb6-1, huAb8-1, and huAb9-5 demonstrated T cell activation as evidenced by significant increases in IFN-γ as compared with an isotype control huIgG$_1$ antibody.

Example 6: In vivo Antitumor Activity of anti-CD40 Antibodies

[0192] The humanized anti-CD40 antibodies huAb6-1, huAb9-5, and huAb9 A2I with wild-type human IgG$_1$ or Fc variants were assessed for their ability to inhibit tumor growth in NSG mice bearing the prostate PC3 tumors in the presence of human immune cells.

[0193] NSG mice were inoculated subcutaneously with a mixture of PC3 cells (1×10^6), purified T cells (5×10^5), and autologous DCs (1×10^5). A single dose of the anti-CD40 antibodies or control antibodies at 1 mg/kg was injected intraperitoneally immediately after inoculation. Tumor volumes were measured every other day with calipers. Anti-CD40 antibodies including huAb6-1, huAb9-5, huAb9 A2I and their Fc variants V273E or V273Y reduced tumor growth as compared to isotype control antibody in the PC3 model as shown in FIG. 11.

Example 7: Proof-of-concept Studies In Mouse Syngeneic Tumor Model

[0194] Due to the lack of mouse CD40 binding of exemplary anti-CD40 antibodies of the disclosure, evaluation of pharmacologic effects in mouse was performed using a murine CD40 agonist antibody 1C10 muIgG$_1$. In analogy to the huIgG$_1$ Fc V273E mutation discussed above, 1C10 with murine IgG$_1$ (muIgG$_1$) Fc demonstrated strong binding to muFcγRIIB and minimal binding to muFcγRI and muFcγRIV, the functional equivalent to human FcγRIII. Similar to the anti-CD40 antibodies of the disclosure, 1C10 muIgG$_1$ demonstrated potency in stimulating mouse splenic B cell activation in vitro and in vivo. Therefore, anti-murine CD40 antibody 1C10 with murine IgG$_1$ constant region was used as a proof of concept molecule to explore potential clinical development paths, which included using intratumoral delivery or combination therapy with co-administration of an anti-PD-1 antibody.

8.7.1. Intratumoral administration

[0195] A CT26 syngeneic model in which mice harbored bilateral subcutaneous tumors was used to investigate intratumoral administration. Viable cells (1×10^5) per mouse were inoculated subcutaneously into the right and left hind flanks of female Balb/c mice on Day 0. Animals were randomized into groups on Day 12 with ten mice per group. The mean tumor volume of the right flank at initiation of dosing was about 85 mm^3. Three animals from each group were sacrificed 24 hr after the first dose for assessment of serum ALT. The remaining animals were monitored for growth of both tumors. Tumor volume was determined twice weekly. Measurements of the length (L), width (W) and height (H) of the tumor were taken via electronic caliper and the volume was calculated according to the following equation: $L \times W \times H / 2$. Antibody dosing began immediately following randomization.

[0196] When anti-CD40 antibody 1C10 was directly injected into one tumor (3 mg/kg, 2 to 3 times a week), the growth of tumors at both the injected site ("IT dosed") as well as at a distal site ("Not IT dosed") was reduced, suggesting the establishment of systemic anti-tumor immunity (FIG. 12). Liver toxicity was monitored by liver enzyme ALT measured by VetScan (Abaxis Inc., Union City, CA). Intratumoral (IT) dosing of anti-CD40 antibody 1C10 incurred lower ALT elevation than systemic intraperitoneal (IP) dosing.

8.7.2. Combination therapy with co-administration of an anti-PD-1 antibody

[0197] CT26 tumor was established by inoculating 1×10^5 viable cells per mouse subcutaneously into the right flank of female BALB/c mice on Day 0. Animals were randomized into groups on Day

15. Anti-CD40 antibody 1C10 (0.6 mg/kg) in combination with a proprietary anti-PD1 muIgG_{2a} antibody (10 mg/kg) were dosed IP twice a week in a syngeneic CT26 mouse model. The combined administration regimen exhibited significant anti-tumor activity (7 out of 10 mice showed tumor regression vs. 0 in control and 1 out of 10 in each of anti-PD1 or anti-CD40 treated group), supporting the development of this combination (FIG. 13).

[0198] Treatment of anti-CD40 antibody 1C10 was performed at 0.6 mg/kg, which was a sub-therapeutic dose for monotherapy in this model. In some cases, maintaining a level of anti-tumor efficacy at such doses of each monoclonal antibody may afford reduced toxicity, as evidenced, *e.g.*, by liver enzyme levels. In this experiment, the combination treatment did not increase liver enzyme levels, spleen weight, or cytokine levels, such as TNFα or IL-6 (FIG. 14). Liver enzyme levels were measured by VetScan, and cytokine levels were measured with MILLIPLEX Map Mouse Cytokine Kit (EMD Millipore).

[0199] All publications, patents, patent applications and other documents cited in this application are hereby incorporated by reference in their entireties for all purposes to the same extent as if each individual publication, patent, patent application or other document were individually indicated to be incorporated by reference for all purposes.

[0200] While various specific embodiments have been illustrated and described, it will be appreciated that various changes can be made without departing from the spirit and scope of the invention(s).

WHAT IS CLAIMED IS:

1. An anti-CD40 antibody or binding fragment which comprises (i) a V_H chain comprising three CDRs; and (ii) a V_L chain comprising three CDRs, wherein:

   V_H CDR#1 is GYSITSNYYWN (SEQ ID NO:8);
   V_H CDR#2 is YIRYDGSNNYNPSLKN (SEQ ID NO:18);
   V_H CDR#3 is LDY (SEQ ID NO:35);
   V_L CDR#1 is RSSQSLENTNGNTFLN (SEQ ID NO:58);
   V_L CDR#2 is RVSNRFS (SEQ ID NO:68); and
   V_L CDR#3 is LQVTHVPFT (SEQ ID NO:88).

2. The anti-CD40 antibody or binding fragment of **claim 1** which is human or humanized.

3. The anti-CD40 antibody or binding fragment of **claim 1** which comprises a V_H chain corresponding to the sequence of SEQ ID NO:117 and a V_L chain corresponding to the sequence of SEQ ID NO:170.

4. The anti-CD40 antibody or binding fragment of **claim 1**, which is an IgG.

5. The anti-CD40 antibody of **claim 4**, which is an IgG_1 and comprises a variant CH2 region comprising the amino acid substitution V273E or V273Y.

6. The anti-CD40 antibody of **claim 4**, which is an IgG_1 and comprises a variant Fc region comprising the amino acid substitutions D356E and L358M.

7. The anti-CD40 antibody of **claim 4** comprising a kappa light chain constant region.

8. The anti-CD40 antibody of **claim 1** having a heavy chain sequence according to SEQ ID NOS:130 or 131, and a light chain sequence according to SEQ ID NO:140.

9. The anti-CD40 antibody of **claim 1** having a heavy chain sequence according to SEQ ID NOS:132 or 133, and a light chain sequence according to SEQ ID NO:141.

10. The anti-CD40 antibody of **claim 1** having a heavy chain sequence according to SEQ ID NO: 132 and a light chain sequence according to SEQ ID NO: 141.

11. The anti-CD40 antibody of **claim 1** having a heavy chain sequence according to SEQ ID NO: 133 and a light chain sequence according to SEQ ID NO: 141.

12. The anti-CD40 antibody of **claim 1** having a heavy chain sequence according to SEQ ID NOS:132 or 133, and a light chain sequence according to SEQ ID NO:142.

13. A pharmaceutical composition comprising an anti-CD40 antibody or binding fragment of **claim 1**, and a pharmaceutically acceptable carrier.