ANTI-CD40 ANTIBODIES AND METHODS OF USE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application No. 61/622,435 filed on April 10, 2012 and U.S. Provisional Application No. 61/480,863 filed on April 29, 2011, which applications are incorporated by reference herein in their entirety.

STATEMENT REGARDING SEQUENCE LISTING

The Sequence Listing associated with this application is provided in text format in lieu of a paper copy, and is hereby incorporated by reference into the specification. The name of the text file containing the Sequence Listing is APEX-013_02US_ST25.txt. The text file is 86 KB, was created on April 27, 2012, and is being submitted electronically via EFS-Web.

BACKGROUND

Technical Field

The present invention relates generally to anti-CD40 antibodies, compositions and methods of using same. Such antibodies are useful, for example, in methods for treating a variety of oncological diseases.

Description of the Related Art

The majority of leukemias and lymphomas originate from malignant transformation of B-lineage cells. The expression of cell surface B-lineage–restricted antigens such as CD20 makes it an attractive target for antibody therapy. Antibody therapeutics have dramatically changed the management of patients with non-Hodgkin lymphoma (NHL) and chronic lymphocytic leukemia (CLL). Since the approval of rituximab, the antibody alone or in combination with chemotherapy has remarkably improved response rates, long-term outcomes, and quality of life (Chinn P, Braslawsky G, White C, et al. Antibody therapy of non-Hodgkin's B-cell

lymphoma. Cancer Immunol Immunother 2003; 52:257–280.; Rastetter W, Molina A, White CA. Rituximab: Expanding role in therapy for lymphomas and autoimmune diseases. Annu Rev Med 2004; 55:477–503). However, a substantial number of patients exhibit either primary or acquired resistance to rituximab, suggesting that current approaches targeting CD20 have limitations in clinical outcomes, and there is a need for improvement by developing novel immunotherapeutics for B cell lymphoma and leukemia with distinct mechanisms of action (Stolz C, Schuler M. Molecular mechanisms of resistance to Rituximab and pharmacologic strategies for its circumvention. Leukemia and lymphoma. 2009; 50(6):873 – 885; Bello C, Sotomayor EM. Monoclonal antibodies for B-cell lymphomas: Rituximab and beyond. Hematology Am Soc Hematol Educ Program 2007; 233-242; Dupire S, Coiffier B. Targeted treatment and new agents in diffuse large B cell lymphoma. Int J Hematol 2010; Jun 18 (online)), such as the anti-CD40 mAb, APX005.

The Role of CD40 in the Regulation of Immune Responses

Full activation of T cells requires two distinct but synergistic signals. The first signal, delivered through the T-cell antigen receptor, is provided by antigen and MHC complex on APCs and is responsible for the specificity of the immune response. The secondary, or costimulatory signal is through the interaction of CD28 with B7-1 (CD80)/B7-2 (CD86), and CD40 with CD40L, which are required to mount a full scale T cell response. In the absence of costimulatory signals, T cells may undergo unresponsiveness (anergy) or programmed cell death (apoptosis) upon antigen stimulation.

CD40, a member of the TNF receptor (TNFR) superfamily, is expressed primarily on B cells and other antigen-presenting cells (APCs) such as dendritic cells and macrophages. CD40 ligand (CD40L) is expressed primarily by activated T cells.

CD40 and CD40L interaction serves as a costimulatory signal for T cell activation. CD40-CD40L engagement on resting B cells induces proliferation, immunoglobulin class switching, antibody secretion, and also has a role in the development of germinal centers and the survival of memory B cells, all of which are essential to humoral immune responses (Kehry MR. J Immunol 1996; 156: 2345–

2348). Binding of CD40L to CD40 on dendritic cells induces DC maturation as manifested by increasing expression of co-stimulatory molecules such as B7 family (CD80, CD86) and production of proinflammatory cytokines such as interleukin 12. These lead to potent T cell responses (Stout, R. D., J. Suttles. 1996. Immunol. Today 17:487-492; Brendan O'Sullivan, Ranjeny Thomas. Critical Reviews in Immunology 2003; 23: 83-107; Cella, M., D. Scheidegger, K. Palmer-Lehmann, P. Lane, A. Lanzavecchia, G. Alber. J. Exp. Med. 1996; 184:747-452).

CD40 signal transduction activates multiple pathways including NF-KappaB (Nuclear Factor-KappaB), MAPK (Mitogen-Activated Protein Kinase) and STAT3 (Signal Transducers and Activators of Transcription-3) (Pype S,et al. J Biol Chem. 2000 Jun 16;275(24):18586-93) that regulate gene expression through activation of Activating Proteins, c-Jun, ATF2 (Activating Transcription Factor-2) and Rel transcription factors (Dadgostar H, et al. Proc Natl Acad Sci U S A. 2002 Feb 5;99(3):1497-502). The TNFR-receptor associated factor adaptor proteins (*e.g.*, TRAF1,TRAF2,TRAF3,TRAF5,and TRAF6) interact with this receptor and serve as mediators of the signal transduction. Depending on the particular cell type, CD40 engagement results in a particular gene expression pattern. Genes activated in response to CD40 signalling include numerous cytokines and chemokines (IL-1, IL-6, IL-8, IL-10, IL-12, TNF-Alpha, and Macrophage Inflammatory Protein-1Alpha (MIP1Alpha). In certain cell types, activation of CD40 may result in production of cytotoxic radicals (Dadgostar et al., *Supra*), COX2 (Cyclooxygenase-2), and production of NO (Nitric Oxide).

The Role of CD40 in Tumors

CD40 is not only expressed by normal immune cells but also by many malignant cells. In particular, CD40 is over-expressed in B-lineage NHLs, chronic lymphocytic leukemias (CLLs), hairy cell leukemias (HCLs), Hodgkin's disease (Uckun FM, Gajl-Peczalska K, Myers DE, et al. Blood 1990;76:2449–2456 ; O'Grady JT, Stewart S, Lowrey J, et al. Am J Pathol 1994;144: 21–26), multiple myeloma (Pellat-Deceunynck C, Bataille R, Robillard N, Harousseau JL, Rapp MJ, Juge-Morineau N, Wijdenes J, Amiot M. Blood. 1994; 84(8):2597-603), as well as in carcinomas of the bladder, kidney, ovary, cervix, breast, lung, nasopharynx, and

malignant melanoma (Young LS, Eliopoulos AG, Gallagher NJ, et al. Immunol Today 1998;19:502–6; Ziebold JL, Hixon J, Boyd A, et al. Arch Immunol Ther Exp (Warsz) 2000; 48: 225–33; Gladue R, Cole S, Donovan C, et al. J Clin Oncol 2006;24 (18S):103s).

Ligation of CD40 on the surface of tumor cells, which in many cases, mediates a direct cytotoxic effect, results in tumor regression through apoptosis and necrosis (Grewal IS, Flavell RA. Annu Rev Immunol 1998;16:111–35; van Kooten C, Banchereau J. J Leukoc Biol 2000; 67(1):2–17). Although the exact functions of CD40 in tumor cells are unclear (Tong AW, Stone MJ. Cancer Gene Ther. 2003 10(1):1-13), engagement of CD40 *in vitro* inhibits the growth of solid tumor cells and high-grade B cell lymphoma cells (Magi Khalil and Robert H. Vonderheide. Update Cancer Ther 2007; 2(2): 61–65; Young LS, Eliopoulos AG, Gallagher NJ, Dawson CW. Immunol Today 1998;19(11):502–6; Funakoshi S, Longo DL, Beckwith M, et al. Blood 1994;83(10):2787–94; Hess S, Engelmann H. J Exp Med 1996;183(1):159–67; Eliopoulos AG, Dawson CW, Mosialos G, et al. Oncogene 1996;13(10):2243–54; von Leoprechting A, van der Bruggen P, Pahl HL, Aruffo A, Simon JC. Cancer Res 1999;59(6):1287–94). These effects contrast with proliferation induced after engagement of CD40 on non-neoplastic B cells and dendritic cells.

In addition to direct tumor inhibition, activation of CD40 signaling rescues the function of antigen-presenting cells in tumor-bearing hosts and triggers or restores active immune responses against tumor-associated antigens. CD40 agonists have been reported to overcome T-cell tolerance in tumor-bearing mice, evoke effective cytotoxic T-cell responses against tumor-associated antigens, and enhance the efficacy of antitumor vaccines (Eliopoulos AG, Davies C, Knox PG, et al. Mol Cell Biol 2000;20(15): 5503–15; Tong AW, Papayoti MH, Netto G, et al. Clin Cancer Res 2001;7(3):691–703).

CD40 as Molecular Target

CD40 is overexpressed on a wide range of malignant cells. The roles of CD40 in tumor inhibition and stimulation of the immune system make CD40 an attractive target for an antibody-based immunotherapy (van Mierlo GJ, den Boer AT, Medema JP, et al. Proc Natl Acad Sci U S A. 2002; 99(8): 5561-5566; French RR,

Chan HT, Tutt AL, Glennie MJ. Nat Med. 1999;5(5):548-553). Anti-CD40 antibodies may act against cancer cells via multiple mechanisms: (i) antibody effector function such as ADCC, (ii) a direct cytotoxic effect on the tumor cells, and (iii) activation of anti-tumor immune responses.

Anti-CD40 Therapeutic Antibodies in Development

Several anti-CD40 antibodies have been reported to have potential as anti-tumor therapeutics. CP-870,893 is a fully human IgG_2 CD40 agonist antibody developed by Pfizer. It binds CD40 with a K_D of 3.48×10^{-10} M, but does not block binding of CD40L (see *e.g.*, U.S. patent no. 7,338,660). CP-870893 has shown ADCC effects; possibly due to its IgG2 isotype. Thus, this antibody acts as a CD40 agonist (*i.e.*, does not affect CD40L binding), induces proapoptotic signaling, and activates DCs and immune surveilance. However, this antibody does not mediate ADCC.

HCD122 is a fully human IgG1 CD40 antagonist antibody developed by Novartis. It binds to CD40 with a K_D of 5.1×10^{-10} M, blocks CD40 binding to CD40L, inhibits CD40-ligand induced signaling and biological effects on B cells and certain primary CLL and MM cells (Tai YT, et al. Cancer Res. 2005 Jul 1;65(13):5898-906; Luqman M, Klabunde S, et al: Blood 112:711-720, 2008). The major mechanism of action for its anti-tumor effect *in vivo* is ADCC (Long L, et al. 2005 IMF Oral Presentation and Abstract No. 3; Blood 2004, 104(11, Part 1): Abst 3281). Due to its antagonist feature, this antibody may not directly induce CD40-mediated anti-tumor immune response.

SGN-40 is a humanized IgG1 antibody developed by Seattle Genetics from mouse antibody clone S2C6, which was generated using a human bladder carcinoma cell line as the immunogen. It binds to CD40 with a K_D of 1.0×10^{-9} M and works through enhancing the interaction between CD40 and CD40L, thus exhibiting a partial agonist effect (Francisco JA, et al., Cancer Res, 60: 3225-31, 2000). SGN-40 delivers proliferation inhibitory and apoptosis signals to a panel of B lymphoma lines originated from high-grade non-Hodgkin's lymphoma and MM cells (Tai YT, Catley LP, Mitsiades CS, et al. Cancer Res 2004;64(8):2846-2852). *In vitro* and *in vivo* studies suggest that both apoptotic signaling and antibody effector function via

ADCC contribute to antitumor activity of SGN-40 (Law CL, Gordon KA, Collier J, et al: Cancer Res 2005; 65:8331-8338). A Recent study suggested that the anti-tumour activity of SGN-40 significantly depends on Fc interactions with the effector cells and that macrophages are the major effectors contributing to its therapeutic activities (Oflazoglu E, et al. Br J Cancer. 2009 Jan 13;100(1):113-7. Epub 2008 Dec 9). Since SGN-40 is a partial agonist and requires CD40L expressed on T cells, SGN-40 may have limited ability to fully boost the anti-tumor immune response.

Accordingly, there remains a need in the art for novel immunotherapeutics that target CD40 and that act as agonist for this target, activate dendritic cells and immune surveillance and which activate ADCC, thereby providing improved anti-cancer properties.

BRIEF SUMMARY

In a first aspect of the present disclosure, there is provided an isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising (i) a heavy chain variable region comprising the VHCDR1, VHCDR2, and VHCDR3 set forth in SEQ ID NOs:3-5; and (ii) a light chain variable region comprising the VLCDR1, the VLCDR2, and the VLCDR3 set forth in SEQ ID NOs:6-8; or a variant of said antibody, or an antigen-binding fragment thereof, comprising heavy and light chain variable regions identical to the heavy and light chain variable regions of (i) and (ii) except for up to 8 amino acid substitutions in said CDR regions.

In a second aspect of the present disclosure, there is provided an isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:9 and a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:10.

In a third aspect of the present disclosure, there is provided an isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:10 and a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:9.

In a fourth aspect of the present disclosure, there is provided a composition comprising a physiologically acceptable carrier and a therapeutically effective amount of the isolated antibody or antigen-binding fragment thereof as defined herein.

In a fifth aspect of the present disclosure, there is provided a composition comprising a physiologically acceptable carrier and a therapeutically effective amount of the isolated antibody or antigen-binding fragment thereof as defined herein.

The present disclosure provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising (i) a heavy chain variable region comprising the VHCDR1 region set forth in SEQ ID NO:3, the VHCDR2 region set forth in SEQ ID NO:4, and the VHCDR3 region set forth SEQ ID NO:5; and (ii) a light chain variable region comprising the VLCDR1 region set forth in SEQ ID NO:6, the VLCDR2 region set forth in SEQ ID NO:7, and the VLCDR3 region set forth in SEQ ID NO: 8; or a variant of said antibody, or an antigen-binding fragment thereof, comprising heavy and light chain variable regions identical to the heavy and light chain variable regions of (i) and (ii) except for up to 8 amino acid substitutions in said CDR regions. In one embodiment of the antibodies disclosed herein, the heavy chain variable region comprises the amino acid sequence set forth in SEQ ID NO:1. In a further embodiment, the light chain variable region comprises the amino acid sequence set forth in SEQ ID NO:2.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:1. In one embodiment, the isolated antibody, or antigen-binding fragment thereof comprises a light chain variable region which comprises an amino

acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:2. In a further embodiment, the isolated antibody, or an antigen-binding fragment thereof comprises a light chain variable region which comprises the amino acid sequence set forth in SEQ ID NO:2.

The present disclosure further provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:2. In one embodiment, the isolated antibody, or antigen binding fragment thereof comprises a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:1.

In certain embodiments, the isolated antibodies as disclosed herein are humanized. Illustrative humanized antibody variable regions are set forth in the VH region amino acid sequence of SEQ ID NO:9 and the VL region amino acid sequence of SEQ ID NO:10.

In one embodiment, an isolated antibody disclosed herein may be single chain antibody, a ScFv, a univalent antibody lacking a hinge region, a minibody, a Fab, a Fab' fragment, or a $F(ab')_2$ fragment. In certain embodiments, the antibodies herein are whole antibodies.

In another embodiment, the isolated antibodies as described herein comprise a human IgG constant domain, such as, but not limited to an IgG1 CH1 domain or an IgG1 Fc region.

A further embodiment of the disclosure provides an isolated antibody, or an antigen-binding fragment thereof, that competes with the anti-CD40 antibodies described herein for binding to human CD40.

The present disclosure also provides an isolated antibody, or antigen-binding fragment thereof, that binds CD40, binds with a KD of 0.96 nM or lower. In a further embodiment, the isolated antibody, or antigen-binding fragment thereof, that binds CD40, binds with a Kd of between 1.1 nM and 0.90 nM. In a further embodiment, the isolated antibody, or antigen-binding fragment thereof, that binds CD40, binds with a Kd of about 1.2, 1.1, 1.0, 0.99, 0.98, 0.97, 0.96, 0.95, 0.94, 0.93,

0.92, 0.91, 0.90, 0.85, or about 0.80 nM. In another embodiment, the antibody binds CD40 with a Kd of about 2.5, 2.4, 2.3, 2.2, 2.1, 2.0, 1.9, 1.8, 1.7, 1.6, 1.5, 1.4, or 1.3 nM.

The present disclosure also provides an isolated antibody, or antigen-binding fragment thereof as described herein, wherein the isolated antibody, or antigen-binding fragment thereof: blocks binding of CD40 to CD40L; is a CD40 agonist; activates antigen presenting cells; stimulates cytokine release from antigen presenting cells; induces tumor cell apoptosis; inhibits tumor cell proliferation; kills tumor cells via induction of effector functions selected from the group consisting of antibody dependent cellular cytotoxicity, complement dependent cytotoxicty, and antibody dependent cellular phagocytosis; stimulates anti-tumor T cell responses; reduces established tumors; inhibits rituximab-resistant tumors; or a combination of any one or more of the aforementioned.

The present disclosure also provides an isolated antibody, or an antigen binding fragment thereof, that binds to CD40, comprising: (i) a heavy chain variable region comprising the VH CDR1, the VHCDR2, and VHCDR3 of any one of the VH regions shown in Figure 16; and (ii) a light chain variable region comprising the VLCDR1, the VLCDR2, and the VLCDR3 region of the corresponding VL region of any one of the VL regions shown in Figure 16; or a variant of said antibody, or an antigen binding fragment thereof, comprising heavy and light chain variable regions identical to the heavy and light chain variable regions of (i) and (ii) except for up to 8 amino acid substitutions in said CDR regions.

The present disclosure further provides an isolated antibody, or an antigen binding fragment thereof that binds to CD40, comprising a heavy chain variable region comprising any one of the VH regions shown in Figure 16. In one embodiment such an antibody further comprises a light chain variable region comprising an amino acid sequence having at least 90% identity to the corresponding VL region as shown in Figure 16. In another embodiment, such an antibody or antigen binding fragment thereof further comprises the corresponding light chain variable region as shown in Figure 16.

The present disclosure also provides an isolated antibody, or an antigen binding fragment thereof that binds to CD40, comprising a light chain variable region comprising any one of the VL regions shown in Figure 16. In one embodiment such an antibody further comprises a heavy chain variable region comprising an amino acid sequence having at least 90% identity to the corresponding VH region as shown in Figure 16. In another embodiment, such an antibody or antigen binding fragment thereof further comprises the corresponding heavy chain variable region as shown in Figure 16.

The present disclosure also provides isolated polynucleotides encoding the isolated antibodies, or antigen-binding fragments thereof as disclosed herein.

The present disclosure also provides compositions comprising a physiologically acceptable carrier and a therapeutically effective amount of an anti-CD40 antibody or antigen-binding fragment thereof as described herein.

The present disclosure also provides a method for treating a patient having a cancer, comprising administering to the patient a composition comprising a physiologically acceptable carrier and a therapeutically effective amount of an anti-CD40 antibody or antigen-binding fragment thereof as described herein, thereby treating the cancer. In certain embodiments, the cancer is associated with aberrant CD40 expression. In further embodiments, the cancer is selected from the group consisting of non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney, ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias.

The present disclosure also provides a method for treating a patient having cancer and/or autoimmune disease, and/or inflammatory disease, comprising administering to the patient a composition comprising a physiologically acceptable carrier and a therapeutically effective amount of an anti-CD40 antibody or antigen-binding fragment thereof as described herein, thereby treating the patient having autoimmune and inflammatory dieseases.

The present disclosure also provides a method for ameliorating the symptoms in a patient having cancer, and/or autoimmune disease and/or inflammatory disease, comprising administering to the patient a composition comprising a physiologically acceptable carrier and a therapeutically effective amount of an anti-CD40 antibody or antigen-binding fragment thereof as described herein, thereby ameliorating the symptoms in the patient having cancer, and/or autoimmune and/or inflammatory dieseases.

The present disclosure also provides isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:11. In one embodiment, the isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprises a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:11 and comprises a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:22 or a light chain comprising the amino acid sequence set forth in SEQ ID NO:22. In certain embodiments, an isolated antibody described herein comprises the light chain as set forth in SEQ ID NO:22 and comprises a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:11.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:13. In one embodiment, the antibody comprises a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:13 and a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:24. In one embodiment, the light chain comprises the amino acid sequence set forth in SEQ ID NO:24.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40,

comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:24. In one embodiment, the antibody comprises a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:24 and a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:13.

In certain embodiments, the isolated antibody, or antigen-binding fragment thereof, that binds CD40 comprises a heavy chain variable region which comprises the amino acid sequence set forth in SEQ ID NO:17. In one embodiment, the isolated antibody that binds CD40 comprises a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:17 and a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:28. In one embodiment, the light chain variable region comprises the amino acid sequence set forth in SEQ ID NO:28.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:28. In one embodiment, the isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprises a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:28 and a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:17.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:19. In one embodiment, the isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprises a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:19 and a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:30. In one particular

embodiment, the light chain variable region comprises the amino acid sequence set forth in SEQ ID NO:30.

The present disclosure further provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:30. In one embodiment, the isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprises a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:30 and a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:19.

The present disclosure also provides an isolated antibody, or an antigen-binding fragment thereof, that binds to human CD40, comprising a heavy chain variable region that comprises heavy chain variable region CDRs and a light chain variable region that comprises corresponding light chain variable region CDRs, wherein the CDRs are as shown in Figure 16.

BRIEF DESCRIPTION OF THE SEQUENCES

SEQ ID NO:1 is the amino acid sequence of the VH region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:2 is the amino acid sequence of the VL region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:3 is the amino acid sequence of the VHCDR1 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:4 is the amino acid sequence of the VHCDR2 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:5 is the amino acid sequence of the VHCDR3 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:6 is the amino acid sequence of the VLCDR1 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:7 is the amino acid sequence of the VLCDR2 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:8 is the amino acid sequence of the VLCDR3 region of the R-8 rabbit anti-CD40 antibody.

SEQ ID NO:9 is the amino acid sequence of the VH region of APX005, the humanized version of the R-8 rabbit anti-CD40 antibody, without a signal peptide.

SEQ ID NO:10 is the amino acid sequence of the VL region of APX005, the humanized version of the R-8 rabbit anti-CD40 antibody, without a signal peptide.

SEQ ID NOs:11-21 and 33-44 are heavy chain amino acid sequences of rabbit anti-CD40 antibody candidates that showed functional activity (see Figure 16).

SEQ ID NOs:22-32 and 45-56 are light chain amino acid sequences of rabbit anti-CD40 antibody candidates that showed functional activity (see Figure 16).

SEQ ID Nos:57-79 are the VHCDR1 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

SEQ ID Nos:80-102 are the VHCDR2 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

SEQ ID Nos:103-125 are the VHCDR3 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

SEQ ID Nos:126-148 are the VLCDR1 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

SEQ ID Nos:149-171 are the VLCDR2 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

SEQ ID Nos:172-194 are the VLCDR3 amino acid sequences for the anti-CD40 antibodies shown in Figure 16.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A-1D show the results of screening agonist antibodies by measuring DC maturation and T cell activation as described in Example 1. 1A: CD83 expression; 1B: CD80 expression; 1C: CD86 expression; 1D: T cell proliferation in a mixed lymphocyte reaction.

Figure 2 is a graph showing the comparison of lead candidates in the inhibition of Ramos cell proliferation.

Figure 3 is a bar graph showing the results of an ADCC assay. Effector (human PBMC):target cell (Ramos cell) ratio of 40:1.

Figure 4A and Figure 4B are graphs showing the results of *in vivo* screening of anti-tumor activity of anti-CD40 candidates.

Figure 5 is a graph showing the results of an ELISA assay demonstrating that APX005 selectively binds to CD40 but not to other TNFR family members.

Figure 6 is a graph showing the results of an ELISA assay demonstrating that APX005 blocks the binding of CD40L to CD40.

Figure 7 is a graph showing that APX005 is not Internalized upon Binding to CD40 positive cells.

Figure 8A and Figure 8B are graphs showing APX005–mediated ADCC of CD40 positive Ramos (A) and Daudi (B) tumor cells.

Figure 9A and Figure 9B are graphs showing *in vitro* inhibition of Ramos tumor cell proliferation by APX005. Panel A: without Fc crosslinking; Panel B: with Fc crosslinking.

Figure 10 is a bar graph showing induction of DC activation by APX005.

Figure 11A and 11B show that APX005 binds to human and monkey CD40 but not mouse CD40.

Figure 12A is a graph showing APX005 inhibition of tumor growth in a Ramos model. Figure 12B is a bar graph showing levels of serum human IgG in mice at day 34, two days after the last dosing.

Figure 13A and 13B are graphs showing inhibition of Rituximab pre-treated and resistant tumors in a mouse model.

Figure 14 is a graph showing APX005 inhibition of tumor growth in the Raji mouse model.

Figure 15 is a graph showing potent anti-tumor activity of APX005 against human multiple myeloma in the IM-9 xenograft model.

Figure 16A-16L is a sequence alignment of rabbit anti-CD40 heavy (16A-16F) and light chain (16G-16L) antibody sequences. Heavy and light chain CDRs1-3 are underlined. SEQ ID NOs are as follows: Heavy chain: R-3 and R-6: SEQ ID NOs:11, 12; R-8: SEQ ID NO:1; R-9, -16, -18, -24, -33, -36, 19-21, -45, -59: SEQ ID NOs:13-21, respectively; R-2, R-5, R-7, R-10, R-12, R-20, R-26, R-30, R-35, 19-35, 19-41, 19-57: SEQ ID Nos:33-44, respectively. Light chain: R-3 and R-6: SEQ ID NOs:22 and 23; R-8: SEQ ID NO:2; R-9, -16, -18, -24, -33, -36, 19-21, -45, -59: SEQ ID NOs:24-32, respectively; R-2, R-5, R-7, R-10, R-12, R-20, R-26, R-30, R-35, 19-35, 19-41, 19-57: SEQ ID Nos:45-56, respectively. The amino acid sequences include the VH and VL signal peptide. The R-8 VHCDR and VLCDR amino acid sequences are set forth in SEQ ID Nos:3-8. The VHCDR amino acid sequences and the VLCDR amino acid sequences for the remaining antibodies are set forth in SEQ ID Nos:57-125 and SEQ ID Nos:126-194, respectively.

Figure 17A and 17B show inhibition of tumor growth in the ramos model by APX005 as compared with SGN-40 and Rituximab.

Figure 18A and 18B show inhibition by APX005 of tumor growth in rituximab-resistant human Namalwa lymphoma xenograft model.

DETAILED DESCRIPTION

The present disclosure relates to antibodies and antigen-binding fragments thereof the specifically bind to CD40 in particular antibodies having specific epitopic specificity and functional properties. One embodiment of the invention encompasses specific humanized antibodies and fragments thereof capable of binding to CD40 and functions as a CD40 agonist by inducing/enhancing CD40-mediated downstream cell signaling and biological effects. In more specific embodiments of the invention, the antibodies described herein specifically bind to CD40 with very high affinity, such as an affinity of at least between 980 and 950 picomolar, at least between 970 and 950 picomolar, and in certain embodiments with an affinity of 960 picomolar. The antibodies described herein, among other attributes, induce CD40 signalling in tumor cells, activate dendritic cells and immune surveillance, activate antibody dependent cellular cytotoxicity (ADCC) against tumor

cells, block binding of CD40 to CD40L; have CD40 agonistic activity; activate antigen presenting cells; stimulate cytokine release from antigen presenting cells; induce tumor cell apoptosis; Inhibit tumor cell proliferation; kill tumor cells via induction of effector functions including but not limited to ADCC, CDC and ADCP; stimulate anti-tumor T cell responses; reduce established tumors; and inhibit rituximab-resistant tumors. The antibodies described herein may have or induce a combination of any one or more of these attributes or activities.

Embodiments of the invention pertain to the use of anti-CD40 antibodies or antigen-binding fragments thereof for the diagnosis, assessment and treatment of diseases and disorders associated with CD40 or aberrant expression thereof. The subject antibodies are used in the treatment or prevention of cancers including, but not limited to, non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias, autoimmune diseases and inflammatory diseases among other diseases.

The practice of the present invention will employ, unless indicated specifically to the contrary, conventional methods of virology, immunology, microbiology, molecular biology and recombinant DNA techniques within the skill of the art, many of which are described below for the purpose of illustration. Such techniques are explained fully in the literature. See, *e.g.*, *Current Protocols in Molecular Biology* or *Current Protocols in Immunology*, John Wiley & Sons, New York, N.Y.(2009); Ausubel *et al.*, *Short Protocols in Molecular Biology*, 3rd ed., Wiley & Sons, 1995; Sambrook and Russell, *Molecular Cloning: A Laboratory Manual* (3rd Edition, 2001); Maniatis *et al. Molecular Cloning: A Laboratory Manual* (1982); *DNA Cloning: A Practical Approach*, vol. I & II (D. Glover, ed.); *Oligonucleotide Synthesis* (N. Gait, ed., 1984); *Nucleic Acid Hybridization* (B. Hames & S. Higgins, eds., 1985); *Transcription and Translation* (B. Hames & S. Higgins, eds., 1984); *Animal Cell Culture* (R. Freshney, ed., 1986); Perbal, *A Practical Guide to Molecular Cloning* (1984) and other like references.

As used in this specification and the appended claims, the singular forms "a," "an" and "the" include plural references unless the content clearly dictates otherwise.

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element or integer or group of elements or integers but not the exclusion of any other element or integer or group of elements or integers.

Each embodiment in this specification is to be applied *mutatis mutandis* to every other embodiment unless expressly stated otherwise.

Standard techniques may be used for recombinant DNA, oligonucleotide synthesis, and tissue culture and transformation (*e.g.*, electroporation, lipofection). Enzymatic reactions and purification techniques may be performed according to manufacturer's specifications or as commonly accomplished in the art or as described herein. These and related techniques and procedures may be generally performed according to conventional methods well known in the art and as described in various general and more specific references that are cited and discussed throughout the present specification. Unless specific definitions are provided, the nomenclature utilized in connection with, and the laboratory procedures and techniques of, molecular biology, analytical chemistry, synthetic organic chemistry, and medicinal and pharmaceutical chemistry described herein are those well known and commonly used in the art. Standard techniques may be used for recombinant technology, molecular biological, microbiological, chemical syntheses, chemical analyses, pharmaceutical preparation, formulation, and delivery, and treatment of patients.

Embodiments of the present invention relate to antibodies that bind to CD40. In particular, the antibodies described herein specifically bind to CD40 with unexpectedly high affinity, enhance CD40 signalling activity, activate the immune system, activate ADCC and have therapeutic utility for the treatment of diseases associated with aberrant expression CD40.

Sequences of illustrative antibodies, or antigen-binding fragments, or complementarity determining regions (CDRs) thereof, are set forth in SEQ ID NOs:1-194.

As is well known in the art, an antibody is an immunoglobulin molecule capable of specific binding to a target, such as a carbohydrate, polynucleotide, lipid, polypeptide, etc., through at least one epitope recognition site, located in the variable region of the immunoglobulin molecule. As used herein, the term encompasses not only intact polyclonal or monoclonal antibodies, but also fragments thereof (such as dAb, Fab, Fab', $F(ab')_2$, Fv), single chain (ScFv), synthetic variants thereof, naturally occurring variants, fusion proteins comprising an antibody portion with an antigen-binding fragment of the required specificity, humanized antibodies, chimeric antibodies, and any other modified configuration of the immunoglobulin molecule that comprises an antigen-binding site or fragment (epitope recognition site) of the required specificity. "Diabodies", multivalent or multispecific fragments constructed by gene fusion (WO94/13804; P. Holliger et al., Proc. Natl. Acad. Sci. USA 90 6444-6448, 1993) are also a particular form of antibody contemplated herein. Minibodies comprising a scFv joined to a CH3 domain are also included herein (S. Hu et al., Cancer Res., 56, 3055-3061, 1996). See *e.g.*, Ward, E. S. *et al.*, Nature 341, 544-546 (1989); Bird et al., Science, 242, 423-426, 1988; Huston et al., PNAS USA, 85, 5879-5883, 1988); PCT/US92/09965; WO94/13804; P. Holliger et al., Proc. Natl. Acad. Sci. USA 90 6444-6448, 1993; Y. Reiter et al., Nature Biotech, 14, 1239-1245, 1996; S. Hu et al., Cancer Res., 56, 3055-3061, 1996.

The term "antigen-binding fragment" as used herein refers to a polypeptide fragment that contains at least one CDR of an immunoglobulin heavy and/or light chains that binds to the antigen of interest, in particular to CD40. In this regard, an antigen-binding fragment of the herein described antibodies may comprise 1, 2, 3, 4, 5, or all 6 CDRs of a VH and VL sequence set forth herein from antibodies that bind CD40. An antigen-binding fragment of the CD40-specific antibodies described herein is capable of binding to CD40. In certain embodiments, an antigen-binding fragment or an antibody comprising an antigen-binding fragment, prevents or inhibits CD40L binding to the CD40. In certain embodiments, the

antigen-binding fragment binds specifically to and/or enhances or modulates the biological activity of human CD40. Such biological activity includes, but is not limited to, cell signalling, activation of dendritic cells,

The term "antigen" refers to a molecule or a portion of a molecule capable of being bound by a selective binding agent, such as an antibody, and additionally capable of being used in an animal to produce antibodies capable of binding to an epitope of that antigen. An antigen may have one or more epitopes.

The term "epitope" includes any determinant, preferably a polypeptide determinant, capable of specific binding to an immunoglobulin or T-cell receptor. An epitope is a region of an antigen that is bound by an antibody. In certain embodiments, epitope determinants include chemically active surface groupings of molecules such as amino acids, sugar side chains, phosphoryl or sulfonyl, and may in certain embodiments have specific three-dimensional structural characteristics, and/or specific charge characteristics. In certain embodiments, an antibody is said to specifically bind an antigen when it preferentially recognizes its target antigen in a complex mixture of proteins and/or macromolecules. An antibody is said to specifically bind an antigen when the equilibrium dissociation constant is $\leq 10^{-7}$ or 10^{-8} M. In some embodiments, the equilibrium dissociation constant may be $\leq 10^{-9}$ M or $\leq 10^{-10}$ M.

In certain embodiments, antibodies and antigen-binding fragments thereof as described herein include a heavy chain and a light chain CDR set, respectively interposed between a heavy chain and a light chain framework region (FR) set which provide support to the CDRs and define the spatial relationship of the CDRs relative to each other. As used herein, the term "CDR set" refers to the three hypervariable regions of a heavy or light chain V region. Proceeding from the N-terminus of a heavy or light chain, these regions are denoted as "CDR1," "CDR2," and "CDR3" respectively. An antigen-binding site, therefore, includes six CDRs, comprising the CDR set from each of a heavy and a light chain V region. A polypeptide comprising a single CDR, (*e.g.*, a CDR1, CDR2 or CDR3) is referred to herein as a "molecular recognition unit." Crystallographic analysis of a number of antigen-antibody complexes has demonstrated that the amino acid residues of CDRs

form extensive contact with bound antigen, wherein the most extensive antigen contact is with the heavy chain CDR3. Thus, the molecular recognition units are primarily responsible for the specificity of an antigen-binding site.

As used herein, the term "FR set" refers to the four flanking amino acid sequences which frame the CDRs of a CDR set of a heavy or light chain V region. Some FR residues may contact bound antigen; however, FRs are primarily responsible for folding the V region into the antigen-binding site, particularly the FR residues directly adjacent to the CDRs. Within FRs, certain amino residues and certain structural features are very highly conserved. In this regard, all V region sequences contain an internal disulfide loop of around 90 amino acid residues. When the V regions fold into a binding-site, the CDRs are displayed as projecting loop motifs which form an antigen-binding surface. It is generally recognized that there are conserved structural regions of FRs which influence the folded shape of the CDR loops into certain "canonical" structures—regardless of the precise CDR amino acid sequence. Further, certain FR residues are known to participate in non-covalent interdomain contacts which stabilize the interaction of the antibody heavy and light chains.

The structures and locations of immunoglobulin variable domains may be determined by reference to Kabat, E. A. et al., Sequences of Proteins of Immunological Interest. 4th Edition. US Department of Health and Human Services. 1987, and updates thereof, now available on the Internet (immuno.bme.nwu.edu).

A "monoclonal antibody" refers to a homogeneous antibody population wherein the monoclonal antibody is comprised of amino acids (naturally occurring and non-naturally occurring) that are involved in the selective binding of an epitope. Monoclonal antibodies are highly specific, being directed against a single epitope. The term "monoclonal antibody" encompasses not only intact monoclonal antibodies and full-length monoclonal antibodies, but also fragments thereof (such as Fab, Fab', $F(ab')_2$, Fv), single chain (ScFv), variants thereof, fusion proteins comprising an antigen-binding portion, humanized monoclonal antibodies, chimeric monoclonal antibodies, and any other modified configuration of the immunoglobulin molecule that comprises an antigen-binding fragment (epitope recognition site) of the required

specificity and the ability to bind to an epitope. It is not intended to be limited as regards the source of the antibody or the manner in which it is made (*e.g.*, by hybridoma, phage selection, recombinant expression, transgenic animals, etc.). The term includes whole immunoglobulins as well as the fragments etc. described above under the definition of "antibody".

The proteolytic enzyme papain preferentially cleaves IgG molecules to yield several fragments, two of which (the F(ab) fragments) each comprise a covalent heterodimer that includes an intact antigen-binding site. The enzyme pepsin is able to cleave IgG molecules to provide several fragments, including the $F(ab')_2$ fragment which comprises both antigen-binding sites. An Fv fragment for use according to certain embodiments of the present invention can be produced by preferential proteolytic cleavage of an IgM, and on rare occasions of an IgG or IgA immunoglobulin molecule. Fv fragments are, however, more commonly derived using recombinant techniques known in the art. The Fv fragment includes a non-covalent $V_H::V_L$ heterodimer including an antigen-binding site which retains much of the antigen recognition and binding capabilities of the native antibody molecule. Inbar *et al.* (1972) *Proc. Nat. Acad. Sci. USA 69*:2659-2662; Hochman *et al.* (1976) *Biochem 15*:2706-2710; and Ehrlich *et al.* (1980) *Biochem 19*:4091-4096.

In certain embodiments, single chain Fv or scFV antibodies are contemplated. For example, Kappa bodies (Ill *et al.*, *Prot. Eng.* 10: 949-57 (1997); minibodies (Martin *et al.*, *EMBO J* 13: 5305-9 (1994); diabodies (Holliger *et al.*, *PNAS* 90: 6444-8 (1993); or Janusins (Traunecker *et al.*, *EMBO J* 10: 3655-59 (1991) and Traunecker *et al.*, *Int. J. Cancer Suppl.* 7: 51-52 (1992), may be prepared using standard molecular biology techniques following the teachings of the present application with regard to selecting antibodies having the desired specificity. In still other embodiments, bispecific or chimeric antibodies may be made that encompass the ligands of the present disclosure. For example, a chimeric antibody may comprise CDRs and framework regions from different antibodies, while bispecific antibodies may be generated that bind specifically to CD40 through one binding domain and to a second molecule through a second binding domain. These

antibodies may be produced through recombinant molecular biological techniques or may be physically conjugated together.

A single chain Fv (sFv) polypeptide is a covalently linked V_H::V_L heterodimer which is expressed from a gene fusion including V_H- and V_L-encoding genes linked by a peptide-encoding linker. Huston *et al.* (1988) *Proc. Nat. Acad. Sci. USA 85*(16):5879-5883. A number of methods have been described to discern chemical structures for converting the naturally aggregated—but chemically separated—light and heavy polypeptide chains from an antibody V region into an sFv molecule which will fold into a three dimensional structure substantially similar to the structure of an antigen-binding site. See, *e.g.*, U.S. Pat. Nos. 5,091,513 and 5,132,405, to Huston *et al.*; and U.S. Pat. No. 4,946,778, to Ladner *et al.*

In certain embodiments, a CD40 binding antibody as described herein is in the form of a diabody. Diabodies are multimers of polypeptides, each polypeptide comprising a first domain comprising a binding region of an immunoglobulin light chain and a second domain comprising a binding region of an immunoglobulin heavy chain, the two domains being linked (*e.g.* by a peptide linker) but unable to associate with each other to form an antigen binding site: antigen binding sites are formed by the association of the first domain of one polypeptide within the multimer with the second domain of another polypeptide within the multimer (WO94/13804).

A dAb fragment of an antibody consists of a VH domain (Ward, E. S. *et al.*, Nature 341, 544-546 (1989)).

Where bispecific antibodies are to be used, these may be conventional bispecific antibodies, which can be manufactured in a variety of ways (Holliger, P. and Winter G. *Current Opinion Biotechnol.* 4, 446-449 (1993)), *e.g.* prepared chemically or from hybrid hybridomas, or may be any of the bispecific antibody fragments mentioned above. Diabodies and scFv can be constructed without an Fc region, using only variable domains, potentially reducing the effects of anti-idiotypic reaction.

Bispecific diabodies, as opposed to bispecific whole antibodies, may also be particularly useful because they can be readily constructed and expressed in

E. coli. Diabodies (and many other polypeptides such as antibody fragments) of appropriate binding specificities can be readily selected using phage display (WO94/13804) from libraries. If one arm of the diabody is to be kept constant, for instance, with a specificity directed against antigen X, then a library can be made where the other arm is varied and an antibody of appropriate specificity selected. Bispecific whole antibodies may be made by knobs-into-holes engineering (J. B. B. Ridgeway et al., *Protein Eng.*, 9, 616-621, 1996).

In certain embodiments, the antibodies described herein may be provided in the form of a UniBody®. A UniBody® is an IgG4 antibody with the hinge region removed (see GenMab Utrecht, The Netherlands; see also, *e.g.*, US20090226421). This proprietary antibody technology creates a stable, smaller antibody format with an anticipated longer therapeutic window than current small antibody formats. IgG4 antibodies are considered inert and thus do not interact with the immune system. Fully human IgG4 antibodies may be modified by eliminating the hinge region of the antibody to obtain half-molecule fragments having distinct stability properties relative to the corresponding intact IgG4 (GenMab, Utrecht). Halving the IgG4 molecule leaves only one area on the UniBody® that can bind to cognate antigens (*e.g.*, disease targets) and the UniBody® therefore binds univalently to only one site on target cells. For certain cancer cell surface antigens, this univalent binding may not stimulate the cancer cells to grow as may be seen using bivalent antibodies having the same antigen specificity, and hence UniBody® technology may afford treatment options for some types of cancer that may be refractory to treatment with conventional antibodies. The small size of the UniBody® can be a great benefit when treating some forms of cancer, allowing for better distribution of the molecule over larger solid tumors and potentially increasing efficacy.

In certain embodiments, the antibodies of the present disclosure may take the form of a nanobody. Nanobodies are encoded by single genes and are efficiently produced in almost all prokaryotic and eukaryotic hosts *e.g. E. coli* (see *e.g.* U.S. Pat. No. 6,765,087), moulds (for example *Aspergillus* or *Trichoderma*) and yeast (for example *Saccharomyces, Kluyvermyces, Hansenula* or *Pichia* (see *e.g.*

U.S. Pat. No. 6,838,254). The production process is scalable and multi-kilogram quantities of nanobodies have been produced. Nanobodies may be formulated as a ready-to-use solution having a long shelf life. The Nanoclone method (see, e.g., WO 06/079372) is a proprietary method for generating Nanobodies against a desired target, based on automated high-throughput selection of B-cells.

In certain embodiments, the anti-CD40 antibodies or antigen-binding fragments thereof as disclosed herein are humanized. This refers to a chimeric molecule, generally prepared using recombinant techniques, having an antigen-binding site derived from an immunoglobulin from a non-human species and the remaining immunoglobulin structure of the molecule based upon the structure and/or sequence of a human immunoglobulin. The antigen-binding site may comprise either complete variable domains fused onto constant domains or only the CDRs grafted onto appropriate framework regions in the variable domains. Epitope binding sites may be wild type or modified by one or more amino acid substitutions. This eliminates the constant region as an immunogen in human individuals, but the possibility of an immune response to the foreign variable region remains (LoBuglio, A. F. *et al.*, (1989) *Proc Natl Acad Sci USA* 86:4220-4224; Queen *et al.*, *PNAS* (1988) 86:10029-10033; Riechmann *et al.*, *Nature* (1988) 332:323-327). Illustrative methods for humanization of the anti-CD40 antibodies disclosed herein include the methods described in U.S. patent no. 7,462,697. Illustrative humanized antibodies according to certain embodiments of the present invention comprise the humanized sequences provided in SEQ ID NOs:9 and 10.

Another approach focuses not only on providing human-derived constant regions, but modifying the variable regions as well so as to reshape them as closely as possible to human form. It is known that the variable regions of both heavy and light chains contain three complementarity-determining regions (CDRs) which vary in response to the epitopes in question and determine binding capability, flanked by four framework regions (FRs) which are relatively conserved in a given species and which putatively provide a scaffolding for the CDRs. When nonhuman antibodies are prepared with respect to a particular epitope, the variable regions can be "reshaped" or "humanized" by grafting CDRs derived from nonhuman antibody on

the FRs present in the human antibody to be modified. Application of this approach to various antibodies has been reported by Sato, K., *et al.*, (1993) *Cancer Res* 53:851-856. Riechmann, L., *et al.*, (1988) *Nature* 332:323-327; Verhoeyen, M., *et al.*, (1988) *Science* 239:1534-1536; Kettleborough, C. A., *et al.*, (1991) *Protein Engineering* 4:773-3783; Maeda, H., *et al.*, (1991) *Human Antibodies Hybridoma* 2:124-134; Gorman, S. D., *et al.*, (1991) *Proc Natl Acad Sci USA* 88:4181-4185; Tempest, P. R., *et al.*, (1991) *Bio/Technology* 9:266-271; Co, M. S., *et al.*, (1991) *Proc Natl Acad Sci USA* 88:2869-2873; Carter, P., *et al.*, (1992) *Proc Natl Acad Sci USA* 89:4285-4289; and Co, M. S. *et al.*, (1992) *J Immunol* 148:1149-1154. In some embodiments, humanized antibodies preserve all CDR sequences (for example, a humanized mouse antibody which contains all six CDRs from the mouse antibodies). In other embodiments, humanized antibodies have one or more CDRs (one, two, three, four, five, six) which are altered with respect to the original antibody, which are also termed one or more CDRs "derived from" one or more CDRs from the original antibody.

In certain embodiments, the antibodies of the present disclosure may be chimeric antibodies. In this regard, a chimeric antibody is comprised of an antigen-binding fragment of an anti-CD40 antibody operably linked or otherwise fused to a heterologous Fc portion of a different antibody. In certain embodiments, the heterologous Fc domain is of human origin. In other embodiments, the heterologous Fc domain may be from a different Ig class from the parent antibody, including IgA (including subclasses IgA1 and IgA2), IgD, IgE, IgG (including subclasses IgG1, IgG2, IgG3, and IgG4), and IgM. In further embodiments, the heterologous Fc domain may be comprised of CH2 and CH3 domains from one or more of the different Ig classes. As noted above with regard to humanized antibodies, the anti-CD40 antigen-binding fragment of a chimeric antibody may comprise only one or more of the CDRs of the antibodies described herein (*e.g.*, 1, 2, 3, 4, 5, or 6 CDRs of the antibodies described herein), or may comprise an entire variable domain (VL, VH or both).

In certain embodiments, a CD40-binding antibody comprises one or more of the CDRs of the antibodies described herein. In this regard, it has been

shown in some cases that the transfer of only the VHCDR3 of an antibody can be performed while still retaining desired specific binding (Barbas *et al.*, *PNAS* (1995) 92: 2529-2533). See also, McLane *et al.*, *PNAS* (1995) 92:5214-5218, Barbas *et al.*, *J. Am. Chem. Soc.* (1994) 116:2161-2162.

Marks et al (*Bio/Technology*, 1992, 10:779-783) describe methods of producing repertoires of antibody variable domains in which consensus primers directed at or adjacent to the 5' end of the variable domain area are used in conjunction with consensus primers to the third framework region of human VH genes to provide a repertoire of VH variable domains lacking a CDR3. Marks et al further describe how this repertoire may be combined with a CDR3 of a particular antibody. Using analogous techniques, the CDR3-derived sequences of the presently described antibodies may be shuffled with repertoires of VH or VL domains lacking a CDR3, and the shuffled complete VH or VL domains combined with a cognate VL or VH domain to provide an antibody or antigen-binding fragment thereof that binds CD40. The repertoire may then be displayed in a suitable host system such as the phage display system of WO92/01047 so that suitable antibodies or antigen-binding fragments thereof may be selected. A repertoire may consist of at least from about 10^4 individual members and upwards by several orders of magnitude, for example, to about from 10^6 to 10^8 or 10^{10} or more members. Analogous shuffling or combinatorial techniques are also disclosed by Stemmer (Nature, 1994, 370:389-391), who describes the technique in relation to a β-lactamase gene but observes that the approach may be used for the generation of antibodies.

A further alternative is to generate novel VH or VL regions carrying one or more CDR-derived sequences of the herein described invention embodiments using random mutagenesis of one or more selected VH and/or VL genes to generate mutations within the entire variable domain. Such a technique is described by Gram et al (1992, Proc. Natl. Acad. Sci., USA, 89:3576-3580), who used error-prone PCR. Another method which may be used is to direct mutagenesis to CDR regions of VH or VL genes. Such techniques are disclosed by Barbas et al., (1994, Proc. Natl. Acad. Sci., USA, 91:3809-3813) and Schier et al (1996, J. Mol. Biol. 263:551-567).

In certain embodiments, a specific VH and/or VL of the antibodies described herein may be used to screen a library of the complementary variable domain to identify antibodies with desirable properties, such as increased affinity for CD40. Such methods are described, for example, in Portolano *et al.*, J. Immunol. (1993) 150:880-887; Clarkson *et al.*, Nature (1991) 352:624-628.

Other methods may also be used to mix and match CDRs to identify antibodies having desired binding activity, such as binding to CD40. For example: Klimka *et al.*, *British Journal of Cancer* (2000) 83: 252-260, describe a screening process using a mouse VL and a human VH library with CDR3 and FR4 retained from the mouse VH. After obtaining antibodies, the VH was screened against a human VL library to obtain antibodies that bound antigen. Beiboer *et al.*, J. Mol. Biol. (2000) 296:833-849 describe a screening process using an entire mouse heavy chain and a human light chain library. After obtaining antibodies, one VL was combined with a human VH library with the CDR3 of the mouse retained. Antibodies capable of binding antigen were obtained. Rader *et al.*, PNAS (1998) 95:8910-8915 describe a process similar to Beiboer et al above.

These just-described techniques are, in and of themselves, known as such in the art. The skilled person will, however, be able to use such techniques to obtain antibodies or antigen-binding fragments thereof according to several embodiments of the invention described herein, using routine methodology in the art.

Also disclosed herein is a method for obtaining an antibody antigen binding domain specific for CD40 antigen, the method comprising providing by way of addition, deletion, substitution or insertion of one or more amino acids in the amino acid sequence of a VH domain set out herein a VH domain which is an amino acid sequence variant of the VH domain, optionally combining the VH domain thus provided with one or more VL domains, and testing the VH domain or VH/VL combination or combinations to identify a specific binding member or an antibody antigen binding domain specific for CD40 and optionally with one or more desired properties. The VL domains may have an amino acid sequence which is substantially as set out herein. An analogous method may be employed in which

one or more sequence variants of a VL domain disclosed herein are combined with one or more VH domains.

An epitope that "specifically binds" or "preferentially binds" (used interchangeably herein) to an antibody or a polypeptide is a term well understood in the art, and methods to determine such specific or preferential binding are also well known in the art. A molecule is said to exhibit "specific binding" or "preferential binding" if it reacts or associates more frequently, more rapidly, with greater duration and/or with greater affinity with a particular cell or substance than it does with alternative cells or substances. An antibody "specifically binds" or "preferentially binds" to a target if it binds with greater affinity, avidity, more readily, and/or with greater duration than it binds to other substances. For example, an antibody that specifically or preferentially binds to a CD40 epitope is an antibody that binds one CD40 epitope with greater affinity, avidity, more readily, and/or with greater duration than it binds to other CD40 epitopes or non-CD40 epitopes. It is also understood by reading this definition that, for example, an antibody (or moiety or epitope) that specifically or preferentially binds to a first target may or may not specifically or preferentially bind to a second target. As such, "specific binding" or "preferential binding" does not necessarily require (although it can include) exclusive binding. Generally, but not necessarily, reference to binding means preferential binding.

Immunological binding generally refers to the non-covalent interactions of the type which occur between an immunoglobulin molecule and an antigen for which the immunoglobulin is specific, for example by way of illustration and not limitation, as a result of electrostatic, ionic, hydrophilic and/or hydrophobic attractions or repulsion, steric forces, hydrogen bonding, van der Waals forces, and other interactions. The strength, or affinity of immunological binding interactions can be expressed in terms of the dissociation constant (K_d) of the interaction, wherein a smaller K_d represents a greater affinity. Immunological binding properties of selected polypeptides can be quantified using methods well known in the art. One such method entails measuring the rates of antigen-binding site/antigen complex formation and dissociation, wherein those rates depend on the concentrations of the complex partners, the affinity of the interaction, and on geometric parameters that

equally influence the rate in both directions. Thus, both the "on rate constant" (K_{on}) and the "off rate constant" (K_{off}) can be determined by calculation of the concentrations and the actual rates of association and dissociation. The ratio of K_{off} /K_{on} enables cancellation of all parameters not related to affinity, and is thus equal to the dissociation constant K_d. See, generally, Davies *et al.* (1990) *Annual Rev. Biochem. 59*:439-473.

In certain embodiments, the anti-CD40 antibodies described herein have an affinity of about 100, 150, 155, 160, 170, 175, 180, 185, 190, 191, 192, 193, 194, 195, 196, 197, 198 or 199 picomolar, and in some embodiments, the antibodies may have even higher affinity for CD40.

The term "immunologically active", with reference to an epitope being or "remaining immunologically active", refers to the ability of an antibody (*e.g.*, anti-CD40 antibody) to bind to the epitope under different conditions, for example, after the epitope has been subjected to reducing and denaturing conditions.

An antibody or antigen-binding fragment thereof according to certain preferred embodiments of the present application may be one that competes for binding to CD40 with any antibody described herein which both (i) specifically binds to the antigen and (ii) comprises a VH and/or VL domain disclosed herein, or comprises a VH CDR3 disclosed herein, or a variant of any of these. Competition between antibodies may be assayed easily *in vitro*, for example using ELISA and/or by tagging a specific reporter molecule to one antibody which can be detected in the presence of other untagged antibodies, to enable identification of specific antibodies which bind the same epitope or an overlapping epitope. Thus, there is provided herein a specific antibody or antigen-binding fragment thereof, comprising a human antibody antigen-binding site which competes with an antibody described herein that binds to CD40.

In this regard, as used herein, the terms “competes with”, "inhibits binding" and "blocks binding" (*e.g.*, referring to inhibition/blocking of binding of CD40L to CD40 or referring to inhibition/blocking of binding of an anti-CD40 antibody to CD40) are used interchangeably and encompass both partial and complete inhibition/blocking. Inhibition and blocking are also intended to include any

measurable decrease in the binding of CD40L to CD40 when in contact with an anti-CD40 antibody as disclosed herein as compared to the ligand not in contact with an anti-CD40 antibody, *e.g.*, the blocking of CD40L to CD40 by at least about 10%, 20%, 30%, 40%, 50%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 91%, 92%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, or 100%.

The constant regions of immunoglobulins show less sequence diversity than the variable regions, and are responsible for binding a number of natural proteins to elicit important biochemical events. In humans there are five different classes of antibodies including IgA (which includes subclasses IgA1 and IgA2), IgD, IgE, IgG (which includes subclasses IgG1, IgG2, IgG3, and IgG4), and IgM. The distinguishing features between these antibody classes are their constant regions, although subtler differences may exist in the V region.

The Fc region of an antibody interacts with a number of Fc receptors and ligands, imparting an array of important functional capabilities referred to as effector functions. For IgG the Fc region comprises Ig domains CH2 and CH3 and the N-terminal hinge leading into CH2. An important family of Fc receptors for the IgG class are the Fc gamma receptors (FcγRs). These receptors mediate communication between antibodies and the cellular arm of the immune system (Raghavan *et al.*, 1996, Annu Rev Cell Dev Biol 12:181-220; Ravetch *et al.*, 2001, Annu Rev Immunol 19:275-290). In humans this protein family includes FcγRI (CD64), including isoforms FcγRIa, FcγRIb, and FcγRIc; FcγRII (CD32), including isoforms FcγRIIa (including allotypes H131 and R131), FcγRIIb (including FcγRIIb-1 and FcγRIIb-2), and FcγRIIc; and FcγRIII (CD16), including isoforms FcγRIIIa (including allotypes V158 and F158) and FcγRIIIb (including allotypes FcγRIIIb-NA1 and FcγRIIIb-NA2) (Jefferis *et al.*, 2002, Immunol Lett 82:57-65). These receptors typically have an extracellular domain that mediates binding to Fc, a membrane spanning region, and an intracellular domain that may mediate some signaling event within the cell. These receptors are expressed in a variety of immune cells including monocytes, macrophages, neutrophils, dendritic cells, eosinophils, mast cells, platelets, B cells, large granular lymphocytes, Langerhans' cells, natural killer (NK) cells, and T cells. Formation of the Fc/FcγR complex recruits these effector cells to

sites of bound antigen, typically resulting in signaling events within the cells and important subsequent immune responses such as release of inflammation mediators, B cell activation, endocytosis, phagocytosis, and cytotoxic attack.

The ability to mediate cytotoxic and phagocytic effector functions is a potential mechanism by which antibodies destroy targeted cells. The cell-mediated reaction wherein nonspecific cytotoxic cells that express FcγRs recognize bound antibody on a target cell and subsequently cause lysis of the target cell is referred to as antibody dependent cell-mediated cytotoxicity (ADCC) (Raghavan *et al.*, 1996, Annu Rev Cell Dev Biol 12:181-220; Ghetie *et al.*, 2000, Annu Rev Immunol 18:739-766; Ravetch *et al.*, 2001, Annu Rev Immunol 19:275-290). The cell-mediated reaction wherein nonspecific cytotoxic cells that express FcγRs recognize bound antibody on a target cell and subsequently cause phagocytosis of the target cell is referred to as antibody dependent cell-mediated phagocytosis (ADCP). All FcγRs bind the same region on Fc, at the N-terminal end of the Cg2 (CH2) domain and the preceding hinge. This interaction is well characterized structurally (Sondermann *et al.*, 2001, J Mol Biol 309:737-749), and several structures of the human Fc bound to the extracellular domain of human FcγRIIIb have been solved (pdb accession code 1E4K)(Sondermann *et al.*, 2000, Nature 406:267-273.) (pdb accession codes 1IIS and 1IIX)(Radaev *et al.*, 2001, J Biol Chem 276:16469-16477.)

The different IgG subclasses have different affinities for the FcγRs, with IgG1 and IgG3 typically binding substantially better to the receptors than IgG2 and IgG4 (Jefferis *et al.*, 2002, Immunol Lett 82:57-65). All FcγRs bind the same region on IgG Fc, yet with different affinities: the high affinity binder FcγRI has a Kd for IgG1 of 10^{-8} M^{-1}, whereas the low affinity receptors FcγRII and FcγRIII generally bind at 10^{-6} and 10^{-5} respectively. The extracellular domains of FcγRIIIa and FcγRIIIb are 96% identical, however FcγRIIIb does not have a intracellular signaling domain. Furthermore, whereas FcγRI, FcγRIIa/c, and FcγRIIIa are positive regulators of immune complex-triggered activation, characterized by having an intracellular domain that has an immunoreceptor tyrosine-based activation motif (ITAM), FcγRIIb has an immunoreceptor tyrosine-based inhibition motif (ITIM) and is therefore inhibitory. Thus the former are referred to as activation receptors, and FcγRIIb is

referred to as an inhibitory receptor. The receptors also differ in expression pattern and levels on different immune cells. Yet another level of complexity is the existence of a number of FcγR polymorphisms in the human proteome. A particularly relevant polymorphism with clinical significance is V158/F158 FcγRIIIa. Human IgG1 binds with greater affinity to the V158 allotype than to the F158 allotype. This difference in affinity, and presumably its effect on ADCC and/or ADCP, has been shown to be a significant determinant of the efficacy of the anti-CD20 antibody rituximab (Rituxan®, a registered trademark of IDEC Pharmaceuticals Corporation). Patients with the V158 allotype respond favorably to rituximab treatment; however, patients with the lower affinity F158 allotype respond poorly (Cartron *et al.*, 2002, Blood 99:754-758). Approximately 10-20% of humans are V158/V158 homozygous, 45% are V158/F158 heterozygous, and 35-45% of humans are F158/F158 homozygous (Lehrnbecher *et al.*, 1999, Blood 94:4220-4232; Cartron *et al.*, 2002, Blood 99:754-758). Thus 80-90% of humans are poor responders, that is they have at least one allele of the F158 FcγRIIIa.

The Fc region is also involved in activation of the complement cascade. In the classical complement pathway, C1 binds with its C1q subunits to Fc fragments of IgG or IgM, which has formed a complex with antigen(s). In certain embodiments of the invention, modifications to the Fc region comprise modifications that alter (either enhance or decrease) the ability of a CD40-specific antibody as described herein to activate the complement system (see *e.g.*, U.S. Patent 7,740,847). To assess complement activation, a complement-dependent cytotoxicity (CDC) assay may be performed (See, *e.g.*, Gazzano-Santoro *et al.*, J. Immunol. Methods, 202:163 (1996)).

Thus in certain embodiments, the present invention provides anti-CD40 antibodies having a modified Fc region with altered functional properties, such as reduced or enhanced CDC, ADCC, or ADCP activity, or enhanced binding affinity for a specific FcγR or increased serum half-life. Other modified Fc regions contemplated herein are described, for example, in issued U.S. patents 7,317,091; 7,657,380; 7,662,925; 6,538,124; 6,528,624; 7,297,775; 7,364,731; Published U.S. Applications US2009092599; US20080131435; US20080138344; and published

International Applications WO2006/105338; WO2004/063351; WO2006/088494; WO2007/024249.

Thus, in certain embodiments, antibody variable domains with the desired binding specificities are fused to immunoglobulin constant domain sequences. In certain embodiments, the fusion is with an Ig heavy chain constant domain, comprising at least part of the hinge, C_H2, and C_H3 regions. It is preferred to have the first heavy-chain constant region (C_H1) containing the site necessary for light chain bonding, present in at least one of the fusions. DNAs encoding the immunoglobulin heavy chain fusions and, if desired, the immunoglobulin light chain, are inserted into separate expression vectors, and are co-transfected into a suitable host cell. This provides for greater flexibility in adjusting the mutual proportions of the three polypeptide fragments in embodiments when unequal ratios of the three polypeptide chains used in the construction provide the optimum yield of the desired bispecific antibody. It is, however, possible to insert the coding sequences for two or all three polypeptide chains into a single expression vector when the expression of at least two polypeptide chains in equal ratios results in high yields or when the ratios have no significant affect on the yield of the desired chain combination.

Antibodies of the present invention (and antigen-binding fragments and variants thereof) may also be modified to include an epitope tag or label, *e.g.*, for use in purification or diagnostic applications. There are many linking groups known in the art for making antibody conjugates, including, for example, those disclosed in U.S. Pat. No. 5,208,020 or EP Patent 0 425 235 B1, and Chari *et al.*, Cancer Research 52: 127-131 (1992). The linking groups include disufide groups, thioether groups, acid labile groups, photolabile groups, peptidase labile groups, or esterase labile groups, as disclosed in the above-identified patents, disulfide and thioether groups being preferred.

In another contemplated embodiment, a CD40-specific antibody as described herein may be conjugated or operably linked to another therapeutic compound, referred to herein as a conjugate. The conjugate may be a cytotoxic agent, a chemotherapeutic agent, a cytokine, an anti-angiogenic agent, a tyrosine kinase inhibitor, a toxin, a radioisotope, or other therapeutically active agent.

Chemotherapeutic agents, cytokines, anti-angiogenic agents, tyrosine kinase inhibitors, and other therapeutic agents have been described above, and all of these aforemention therapeutic agents may find use as antibody conjugates.

In an alternate embodiment, the antibody is conjugated or operably linked to a toxin, including but not limited to small molecule toxins and enzymatically active toxins of bacterial, fungal, plant or animal origin, including fragments and/or variants thereof. Small molecule toxins include but are not limited to saporin (Kuroda K, *et al.*, The Prostate 70:1286-1294 (2010); Lip, WL. *et al.*, 2007 Molecular Pharmaceutics 4:241-251; Quadros EV., *et al.*, 2010 Mol Cancer Ther; 9(11); 3033–40; Polito L., *et al.* 2009 British Journal of Haematology, 147, 710–718), calicheamicin, maytansine (U.S. Pat. No. 5,208,020), trichothene, and CC1065. Toxins include but are not limited to RNase, gelonin, enediynes, ricin, abrin, diptheria toxin, cholera toxin, gelonin, *Pseudomonas* exotoxin (PE40), *Shigella* toxin, *Clostridium perfringens* toxin, and pokeweed antiviral protein.

In one embodiment, an antibody or antigen-binding fragment thereof of the disclosure is conjugated to one or more maytansinoid molecules. Maytansinoids are mitototic inhibitors that act by inhibiting tubulin polymerization. Maytansine was first isolated from the east African shrub Maytenus serrata (U.S. Pat. No. 3,896,111). Subsequently, it was discovered that certain microbes also produce maytansinoids, such as maytansinol and C-3 maytansinol esters (U.S. Pat. No. 4,151,042). Synthetic maytansinol and derivatives and analogues thereof are disclosed, for example, in U.S. Pat. Nos. 4,137,230; 4,248,870; 4,256,746; 4,260,608; 4,265,814; 4,294,757; 4,307,016; 4,308,268; 4,308,269; 4,309,428; 4,313,946; 4,315,929; 4,317,821; 4,322,348; 4,331,598; 4,361,650; 4,364,866; 4,424,219; 4,450,254; 4,362,663; and 4,371,533. Immunoconjugates containing maytansinoids and their therapeutic use are disclosed, for example, in U.S. Pat. Nos. 5,208,020, 5,416,064 and European Patent EP 0 425 235 B1. Liu *et al.*, Proc. Natl. Acad. Sci. USA 93:8618-8623 (1996) described immunoconjugates comprising a maytansinoid designated DM1 linked to the monoclonal antibody C242 directed against human colorectal cancer. The conjugate was found to be highly cytotoxic towards cultured colon cancer cells, and showed antitumor activity in an in vivo tumor growth assay.

Antibody-maytansinoid conjugates are prepared by chemically linking an antibody to a maytansinoid molecule without significantly diminishing the biological activity of either the antibody or the maytansinoid molecule. An average of 3-4 maytansinoid molecules conjugated per antibody molecule has shown efficacy in enhancing cytotoxicity of target cells without negatively affecting the function or solubility of the antibody, although even one molecule of toxin/antibody would be expected to enhance cytotoxicity over the use of naked antibody. Maytansinoids are well known in the art and can be synthesized by known techniques or isolated from natural sources. Suitable maytansinoids are disclosed, for example, in U.S. Pat. No. 5,208,020 and in the other patents and nonpatent publications referred to hereinabove. Preferred maytansinoids are maytansinol and maytansinol analogues modified in the aromatic ring or at other positions of the maytansinol molecule, such as various maytansinol esters.

Another conjugate of interest comprises an antibody conjugated to one or more calicheamicin molecules. The calicheamicin family of antibiotics are capable of producing double-stranded DNA breaks at sub-picomolar concentrations. Structural analogues of calicheamicin that may also be used (Hinman *et al.*, 1993, Cancer Research 53:3336-3342; Lode *et al.*, 1998, Cancer Research 58:2925-2928) (U.S. Pat. No. 5,714,586; U.S. Pat. No. 5,712,374; U.S. Pat. No. 5,264,586; U.S. Pat. No. 5,773,001). Dolastatin 10 analogs such as auristatin E (AE) and monomethylauristatin E (MMAE) may find use as conjugates for the presently disclosed antibodies, or variants thereof (Doronina *et al.*, 2003, Nat Biotechnol 21(7):778-84; Francisco *et al.*, 2003 Blood 102(4):1458-65). Useful enzymatically active toxins include but are not limited to diphtheria A chain, nonbinding active fragments of diphtheria toxin, exotoxin A chain (from *Pseudomonas aeruginosa*), ricin A chain, abrin A chain, modeccin A chain, alpha-sarcin, *Aleurites fordii* proteins, dianthin proteins, *Phytolaca americana* proteins (PAPI, PAPII, and PAP-S), *momordica charantia* inhibitor, curcin, crotin, *sapaonaria officinalis* inhibitor, gelonin, mitogellin, restrictocin, phenomycin, enomycin and the tricothecenes. See, for example, PCT WO 93/21232. The present disclosure further contemplates embodiments in which a conjugate or fusion is formed between a CD40-specific

antibody as described herein and a compound with nucleolytic activity, for example a ribonuclease or DNA endonuclease such as a deoxyribonuclease (DNase).

In an alternate embodiment, a herein-disclosed antibody may be conjugated or operably linked to a radioisotope to form a radioconjugate. A variety of radioactive isotopes are available for the production of radioconjugate antibodies. Examples include, but are not limited to ^{90}Y, ^{123}I, ^{125}I, ^{131}I, ^{186}Re, ^{188}Re, ^{211}At, and ^{212}Bi.

Antibodies described herein may in certain other embodiments be conjugated to a therapeutic moiety such as a cytotoxin (*e.g.*, a cytostatic or cytocidal agent), a therapeutic agent or a radioactive element (*e.g.*, alpha-emitters, gamma-emitters, etc.). Cytotoxins or cytotoxic agents include any agent that is detrimental to cells. Examples include paclitaxel/paclitaxol, cytochalasin B, gramicidin D, ethidium bromide, emetine, mitomycin, etoposide, tenoposide, vincristine, vinblastine, colchicin, doxorubicin, daunorubicin, dihydroxy anthracin dione, mitoxantrone, mithramycin, actinomycin D, 1-dehydrotestosterone, glucocorticoids, procaine, tetracaine, lidocaine, propranolol, and puromycin and analogs or homologs thereof. One preferred exemplary cytotoxin is saporin (available from Advanced Targeting Systems, San Diego, CA). Therapeutic agents include, but are not limited to, antimetabolites (*e.g.*, methotrexate, 6-mercaptopurine, 6-thioguanine, cytarabine, 5-fluorouracil decarbazine), alkylating agents (*e.g.*, mechlorethamine, thioepa chlorambucil, melphalan, carmustine (BSNU) and lomustine (CCNU), cyclothosphamide, busulfan, dibromomannitol, streptozotocin, mitomycin C, and cisdichlorodiamine platinum (II) (DDP) cisplatin), anthracyclines (*e.g.*, daunorubicin (formerly daunomycin) and doxorubicin), antibiotics (*e.g.*, dactinomycin (formerly actinomycin), bleomycin, mithramycin, and anthramycin (AMC), and anti-mitotic agents (*e.g.*, vincristine and vinblastine).

Moreover, a CD40-specific antibody (including a functional fragment thereof as provided herein such as an antigen-binding fragment) may in certain embodiments be conjugated to therapeutic moieties such as a radioactive materials or macrocyclic chelators useful for conjugating radiometal ions. In certain embodiments, the macrocyclic chelator is 1,4,7,10-tetraazacyclododecane-

N,N',N",N"'-tetraacetic acid (DOTA) which can be attached to the antibody via a linker molecule. Such linker molecules are commonly known in the art and described in Denardo *et al.*, 1998, Clin Cancer Res. 4:2483-90; Peterson *et al.*, 1999, Bioconjug. Chem. 10:553; and Zimmerman *et al.*, 1999, Nucl. Med. Biol. 26:943-50.

In yet another embodiment, an antibody may be conjugated to a "receptor" (such as streptavidin) for utilization in tumor pretargeting wherein the antibody-receptor conjugate is administered to the patient, followed by removal of unbound conjugate from the circulation using a clearing agent and then administration of a "ligand" (*e.g.* avidin) which is conjugated to a cytotoxic agent (*e.g.* a radionucleotide). In an alternate embodiment, the antibody is conjugated or operably linked to an enzyme in order to employ Antibody Dependent Enzyme Mediated Prodrug Therapy (ADEPT). ADEPT may be used by conjugating or operably linking the antibody to a prodrug-activating enzyme that converts a prodrug (*e.g.* a peptidyl chemotherapeutic agent, see PCT WO 81/01145) to an active anti-cancer drug. See, for example, PCT WO 88/07378 and U.S. Pat. No. 4,975,278. The enzyme component of the immunoconjugate useful for ADEPT includes any enzyme capable of acting on a prodrug in such a way so as to convert it into its more active, cytotoxic form. Enzymes that are useful in the method of these and related embodiments include but are not limited to alkaline phosphatase useful for converting phosphate-containing prodrugs into free drugs; arylsulfatase useful for converting sulfate-containing prodrugs into free drugs; cytosine deaminase useful for converting non-toxic 5-fluorocytosine into the anti-cancer drug, 5-fluorouracil; proteases, such as serratia protease, thermolysin, subtilisin, carboxypeptidases and cathepsins (such as cathepsins B and L), that are useful for converting peptide-containing prodrugs into free drugs; D-alanylcarboxypeptidases, useful for converting prodrugs that contain D-amino acid substituents; carbohydrate-cleaving enzymes such as -galactosidase and neuramimidase useful for converting glycosylated prodrugs into free drugs; beta-lactamase useful for converting drugs derivatized with -lactams into free drugs; and penicillin amidases, such as penicillin V amidase or penicillin G amidase, useful for converting drugs derivatized at their amine nitrogens

with phenoxyacetyl or phenylacetyl groups, respectively, into free drugs. Alternatively, antibodies with enzymatic activity, also known in the art as "abzymes", may be used to convert prodrugs into free active drugs (see, for example, Massey, 1987, Nature 328: 457-458). Antibody-abzyme conjugates can be prepared for delivery of the abzyme to a tumor cell population.

Immunoconjugates may be made using a variety of bifunctional protein coupling agents such as N-succinimidyl-3-(2-pyridyldithio)propionate (SPDP), succinimidyl-4-(N-maleimidomethyl)cyclohexane-1-carboxylate, iminothiolane (IT), bifunctional derivatives of imidoesters (such as dimethyl adipimidate HCL), active esters (such as disuccinimidyl suberate), aldehydes (such as glutareldehyde), bis-azido compounds (such as bis (p-azidobenzoyl)hexanediamine), bis-diazonium derivatives (such as bis-(p-diazoniumbenzoyl)-ethylenediamine), diisocyanates (such as toluene 2,6-diisocyanate), and bis-active fluorine compounds (such as 1,5-difluoro-2,4-dinitrobenzene). Particular coupling agents include N-succinimidyl-3-(2-pyridyldithio)propionate (SPDP) (Carlsson *et al.*, Biochem. J. 173:723-737 [1978]) and N-succinimidyl-4-(2-pyridylthio)pentanoate (SPP) to provide for a disulfide linkage. The linker may be a "cleavable linker" facilitating release of one or more cleavable components. For example, an acid-labile linker may be used (Cancer Research 52: 127-131 (1992); U.S. Pat. No. 5,208,020).

Other modifications of the antibodies (and polypeptides) of the invention are also contemplated herein. For example, the antibody may be linked to one of a variety of nonproteinaceous polymers, *e.g.*, polyethylene glycol, polypropylene glycol, polyoxyalkylenes, or copolymers of polyethylene glycol and polypropylene glycol. The antibody also may be entrapped in microcapsules prepared, for example, by coacervation techniques or by interfacial polymerization (for example, hydroxymethylcellulose or gelatin-microcapsules and poly-(methylmethacylate)microcapsules, respectively), in colloidal drug delivery systems (for example, liposomes, albumin microspheres, microemulsions, nano-particles and nanocapsules), or in macroemulsions. Such techniques are disclosed in Remington's Pharmaceutical Sciences, 16th edition, Oslo, A., Ed., (1980).

"Carriers" as used herein include pharmaceutically acceptable carriers, excipients, or stabilizers that are nontoxic to the cell or mammal being exposed thereto at the dosages and concentrations employed. Often the physiologically acceptable carrier is an aqueous pH buffered solution. Examples of physiologically acceptable carriers include buffers such as phosphate, citrate, and other organic acids; antioxidants including ascorbic acid; low molecular weight (less than about 10 residues) polypeptide; proteins, such as serum albumin, gelatin, or immunoglobulins; hydrophilic polymers such as polyvinylpyrrolidone; amino acids such as glycine, glutamine, asparagine, arginine or lysine; monosaccharides, disaccharides, and other carbohydrates including glucose, mannose, or dextrins; chelating agents such as EDTA; sugar alcohols such as mannitol or sorbitol; salt-forming counterions such as sodium; and/or nonionic surfactants such as polysorbate 20 (TWEEN™) polyethylene glycol (PEG), and poloxamers (PLURONICS™), and the like.

As noted elsewhere herein, the antibodies of the present disclosure induce CD40 signalling in tumor cells, activate dendritic cells and immune surveillance, activate antibody dependent cellular cytotoxicity (ADCC) against tumor cells, block binding of CD40 to CD40L; have CD40 agonistic activity; activate antigen presenting cells; stimulate cytokine release from antigen presenting cells; induce tumor cell apoptosis; inhibit tumor cell proliferation; kill tumor cells via induction of effector functions including but not limited to ADCC, CDC and ADCP; stimulate anti-tumor T cell responses; reduce established tumors; and inhibit rituximab-resistant tumors. The antibodies described herein may have or induce a combination of any one or more of these attributes or activities. The desired functional properties of anti-CD40 antibodies may be assessed using a variety of methods known to the skilled person, such as affinity/binding assays (for example, surface plasmon resonance, competitive inhibition assays); cytotoxicity assays, cell viability assays, cell proliferation, activation or differentiation assays, ADCC and CDC assays, other cellular activity resulting from CD40 cell signalling events (*e.g.*, STAT3 phosporylation, production of cytokines including IL-1, IL-6, IL-8, IL-10, IL-12, TNF-Alpha, and MIP1Alpha), and cancer cell and/or tumor growth inhibition using *in vitro* or *in vivo* models. Other assays may test the ability of antibodies described herein to

block normal CD40L binding to CD40 or CD40-mediated responses, such as cell signalling, cell activation (e.g., immune cell activation, proliferation; antigen presenting cell activation (*e.g.*, dendritic cells, B cells, macrophages) and maturation assays), immune responses (including cell mediated and humoral responses), *etc.* The antibodies described herein may also be tested for effects on CD40 internalisation, *in vitro* and *in vivo* efficacy, *etc.* Such assays may be performed using well-established protocols known to the skilled person (see *e.g.*, Current Protocols in Molecular Biology (Greene Publ. Assoc. Inc. & John Wiley & Sons, Inc., NY, NY); Current Protocols in Immunology (Edited by: John E. Coligan, Ada M. Kruisbeek, David H. Margulies, Ethan M. Shevach, Warren Strober 2001 John Wiley & Sons, NY, NY); or commercially available kits.

The present invention further provides in certain embodiments an isolated nucleic acid encoding an antibody or antigen-binding fragment thereof as described herein, for instance, a nucleic acid which codes for a CDR or VH or VL domain as described herein. Nucleic acids include DNA and RNA. These and related embodiments may include polynucleotides encoding antibodies that bind CD40 as described herein. The term "isolated polynucleotide" as used herein shall mean a polynucleotide of genomic, cDNA, or synthetic origin or some combination thereof, which by virtue of its origin the isolated polynucleotide (1) is not associated with all or a portion of a polynucleotide in which the isolated polynucleotide is found in nature, (2) is linked to a polynucleotide to which it is not linked in nature, or (3) does not occur in nature as part of a larger sequence.

The term "operably linked" means that the components to which the term is applied are in a relationship that allows them to carry out their inherent functions under suitable conditions. For example, a transcription control sequence "operably linked" to a protein coding sequence is ligated thereto so that expression of the protein coding sequence is achieved under conditions compatible with the transcriptional activity of the control sequences.

The term "control sequence" as used herein refers to polynucleotide sequences that can affect expression, processing or intracellular localization of coding sequences to which they are ligated or operably linked. The nature of such

control sequences may depend upon the host organism. In particular embodiments, transcription control sequences for prokaryotes may include a promoter, ribosomal binding site, and transcription termination sequence. In other particular embodiments, transcription control sequences for eukaryotes may include promoters comprising one or a plurality of recognition sites for transcription factors, transcription enhancer sequences, transcription termination sequences and polyadenylation sequences. In certain embodiments, "control sequences" can include leader sequences and/or fusion partner sequences.

The term "polynucleotide" as referred to herein means single-stranded or double-stranded nucleic acid polymers. In certain embodiments, the nucleotides comprising the polynucleotide can be ribonucleotides or deoxyribonucleotides or a modified form of either type of nucleotide. Said modifications include base modifications such as bromouridine, ribose modifications such as arabinoside and 2',3'-dideoxyribose and internucleotide linkage modifications such as phosphorothioate, phosphorodithioate, phosphoroselenoate, phosphorodiselenoate, phosphoroanilothioate, phoshoraniladate and phosphoroamidate. The term "polynucleotide" specifically includes single and double stranded forms of DNA.

The term "naturally occurring nucleotides" includes deoxyribonucleotides and ribonucleotides. The term "modified nucleotides" includes nucleotides with modified or substituted sugar groups and the like. The term "oligonucleotide linkages" includes oligonucleotide linkages such as phosphorothioate, phosphorodithioate, phosphoroselenoate, phosphorodiselenoate, phosphoroanilothioate, phoshoraniladate, phosphoroamidate, and the like. See, *e.g.*, LaPlanche *et al.*, 1986, Nucl. Acids Res., 14:9081; Stec *et al.*, 1984, J. Am. Chem. Soc., 106:6077; Stein *et al.*, 1988, Nucl. Acids Res., 16:3209; Zon *et al.*, 1991, Anti-Cancer Drug Design, 6:539; Zon *et al.*, 1991, OLIGONUCLEOTIDES AND ANALOGUES: A PRACTICAL APPROACH, pp. 87-108 (F. Eckstein, Ed.), Oxford University Press, Oxford England; Stec et al., U.S. Pat. No. 5,151,510; Uhlmann and Peyman, 1990, Chemical Reviews, 90:543, the disclosures of which are hereby incorporated by reference for any purpose. An oligonucleotide can include a detectable label to enable detection of the oligonucleotide or hybridization thereof.

The term "vector" is used to refer to any molecule (*e.g.*, nucleic acid, plasmid, or virus) used to transfer coding information to a host cell. The term "expression vector" refers to a vector that is suitable for transformation of a host cell and contains nucleic acid sequences that direct and/or control expression of inserted heterologous nucleic acid sequences. Expression includes, but is not limited to, processes such as transcription, translation, and RNA splicing, if introns are present.

As will be understood by those skilled in the art, polynucleotides may include genomic sequences, extra-genomic and plasmid-encoded sequences and smaller engineered gene segments that express, or may be adapted to express, proteins, polypeptides, peptides and the like. Such segments may be naturally isolated, or modified synthetically by the skilled person.

As will be also recognized by the skilled artisan, polynucleotides may be single-stranded (coding or antisense) or double-stranded, and may be DNA (genomic, cDNA or synthetic) or RNA molecules. RNA molecules may include HnRNA molecules, which contain introns and correspond to a DNA molecule in a one-to-one manner, and mRNA molecules, which do not contain introns. Additional coding or non-coding sequences may, but need not, be present within a polynucleotide according to the present disclosure, and a polynucleotide may, but need not, be linked to other molecules and/or support materials. Polynucleotides may comprise a native sequence or may comprise a sequence that encodes a variant or derivative of such a sequence.

Therefore, according to these and related embodiments, the present disclosure also provides polynucleotides encoding the anti-CD40 antibodies described herein. In certain embodiments, polynucleotides are provided that comprise some or all of a polynucleotide sequence encoding an antibody as described herein and complements of such polynucleotides.

In other related embodiments, polynucleotide variants may have substantial identity to a polynucleotide sequence encoding an anti-CD40 antibody described herein. For example, a polynucleotide may be a polynucleotide comprising at least 70% sequence identity, preferably at least 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% or higher, sequence identity compared to a reference

polynucleotide sequence such as a sequence encoding an antibody described herein, using the methods described herein, (*e.g.*, BLAST analysis using standard parameters, as described below). One skilled in this art will recognize that these values can be appropriately adjusted to determine corresponding identity of proteins encoded by two nucleotide sequences by taking into account codon degeneracy, amino acid similarity, reading frame positioning and the like.

Typically, polynucleotide variants will contain one or more substitutions, additions, deletions and/or insertions, preferably such that the binding affinity of the antibody encoded by the variant polynucleotide is not substantially diminished relative to an antibody encoded by a polynucleotide sequence specifically set forth herein.

In certain other related embodiments, polynucleotide fragments may comprise or consist essentially of various lengths of contiguous stretches of sequence identical to or complementary to a sequence encoding an antibody as described herein. For example, polynucleotides are provided that comprise or consist essentially of at least about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 120, 130, 140, 150, 200, 300, 400, 500 or 1000 or more contiguous nucleotides of a sequences the encodes an antibody, or antigen-binding fragment thereof, disclosed herein as well as all intermediate lengths there between. It will be readily understood that "intermediate lengths", in this context, means any length between the quoted values, such as 50, 51, 52, 53, *etc.*; 100, 101, 102, 103, *etc.*; 150, 151, 152, 153, *etc.*; including all integers through 200-500; 500-1,000, and the like. A polynucleotide sequence as described here may be extended at one or both ends by additional nucleotides not found in the native sequence. This additional sequence may consist of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 nucleotides at either end of a polynucleotide encoding an antibody described herein or at both ends of a polynucleotide encoding an antibody described herein.

In another embodiment, polynucleotides are provided that are capable of hybridizing under moderate to high stringency conditions to a polynucleotide

sequence encoding an antibody, or antigen-binding fragment thereof, provided herein, or a fragment thereof, or a complementary sequence thereof. Hybridization techniques are well known in the art of molecular biology. For purposes of illustration, suitable moderately stringent conditions for testing the hybridization of a polynucleotide as provided herein with other polynucleotides include prewashing in a solution of 5 X SSC, 0.5% SDS, 1.0 mM EDTA (pH 8.0); hybridizing at 50°C-60°C, 5 X SSC, overnight; followed by washing twice at 65°C for 20 minutes with each of 2X, 0.5X and 0.2X SSC containing 0.1% SDS. One skilled in the art will understand that the stringency of hybridization can be readily manipulated, such as by altering the salt content of the hybridization solution and/or the temperature at which the hybridization is performed. For example, in another embodiment, suitable highly stringent hybridization conditions include those described above, with the exception that the temperature of hybridization is increased, *e.g.*, to 60°C-65°C or 65°C-70°C.

In certain embodiments, the polynucleotides described above, *e.g.*, polynucleotide variants, fragments and hybridizing sequences, encode antibodies that bind CD40, or antigen-binding fragments thereof. In other embodiments, such polynucleotides encode antibodies or antigen-binding fragments, or CDRs thereof, that bind to CD40 at least about 50%, at least about 70%, and in certain embodiments, at least about 90% as well as an antibody sequence specifically set forth herein. In further embodiments, such polynucleotides encode antibodies or antigen-binding fragments, or CDRs thereof, that bind to CD40 with greater affinity than the antibodies set forth herein, for example, that bind quantitatively at least about 105%, 106%, 107%, 108%, 109%, or 110% as well as an antibody sequence specifically set forth herein.

As described elsewhere herein, determination of the three-dimensional structures of representative polypeptides (*e.g.*, variant CD40-specific antibodies as provided herein, for instance, an antibody protein having an antigen-binding fragment as provided herein) may be made through routine methodologies such that substitution, addition, deletion or insertion of one or more amino acids with selected natural or non-natural amino acids can be virtually modeled for purposes of determining whether a so derived structural variant retains the space-filling

properties of presently disclosed species. A variety of computer programs are known to the skilled artisan for determining appropriate amino acid substitutions (or appropriate polynucleotides encoding the amino acid sequence) within an antibody such that, for example, affinity is maintained or better affinity is achieved.

The polynucleotides described herein, or fragments thereof, regardless of the length of the coding sequence itself, may be combined with other DNA sequences, such as promoters, polyadenylation signals, additional restriction enzyme sites, multiple cloning sites, other coding segments, and the like, such that their overall length may vary considerably. It is therefore contemplated that a nucleic acid fragment of almost any length may be employed, with the total length preferably being limited by the ease of preparation and use in the intended recombinant DNA protocol. For example, illustrative polynucleotide segments with total lengths of about 10,000, about 5000, about 3000, about 2,000, about 1,000, about 500, about 200, about 100, about 50 base pairs in length, and the like, (including all intermediate lengths) are contemplated to be useful.

When comparing polynucleotide sequences, two sequences are said to be "identical" if the sequence of nucleotides in the two sequences is the same when aligned for maximum correspondence, as described below. Comparisons between two sequences are typically performed by comparing the sequences over a comparison window to identify and compare local regions of sequence similarity. A "comparison window" as used herein, refers to a segment of at least about 20 contiguous positions, usually 30 to about 75, 40 to about 50, in which a sequence may be compared to a reference sequence of the same number of contiguous positions after the two sequences are optimally aligned.

Optimal alignment of sequences for comparison may be conducted using the Megalign program in the Lasergene suite of bioinformatics software (DNASTAR, Inc., Madison, WI), using default parameters. This program embodies several alignment schemes described in the following references: Dayhoff, M.O. (1978) A model of evolutionary change in proteins – Matrices for detecting distant relationships. In Dayhoff, M.O. (ed.) *Atlas of Protein Sequence and Structure*, National Biomedical Research Foundation, Washington DC Vol. 5, Suppl. 3, pp. 345-

358; Hein J., *Unified Approach to Alignment and Phylogenes*, pp. 626-645 (1990); *Methods in Enzymology* vol. 183, Academic Press, Inc., San Diego, CA; Higgins, D.G. and Sharp, P.M., *CABIOS 5*:151-153 (1989); Myers, E.W. and Muller W., *CABIOS 4*:11-17 (1988); Robinson, E.D., *Comb. Theor 11*:105 (1971); Santou, N. Nes, M., *Mol. Biol. Evol. 4*:406-425 (1987); Sneath, P.H.A. and Sokal, R.R., *Numerical Taxonomy – the Principles and Practice of Numerical Taxonomy*, Freeman Press, San Francisco, CA (1973); Wilbur, W.J. and Lipman, D.J., *Proc. Natl. Acad., Sci. USA 80*:726-730 (1983).

Alternatively, optimal alignment of sequences for comparison may be conducted by the local identity algorithm of Smith and Waterman, *Add. APL. Math* 2:482 (1981), by the identity alignment algorithm of Needleman and Wunsch, *J. Mol. Biol.* 48:443 (1970), by the search for similarity methods of Pearson and Lipman, *Proc. Natl. Acad. Sci. USA* 85: 2444 (1988), by computerized implementations of these algorithms (GAP, BESTFIT, BLAST, FASTA, and TFASTA in the Wisconsin Genetics Software Package, Genetics Computer Group (GCG), 575 Science Dr., Madison, WI), or by inspection.

One preferred example of algorithms that are suitable for determining percent sequence identity and sequence similarity are the BLAST and BLAST 2.0 algorithms, which are described in Altschul *et al., Nucl. Acids Res.* 25:3389-3402 (1977), and Altschul *et al., J. Mol. Biol.* 215:403-410 (1990), respectively. BLAST and BLAST 2.0 can be used, for example with the parameters described herein, to determine percent sequence identity among two or more the polynucleotides. Software for performing BLAST analyses is publicly available through the National Center for Biotechnology Information. In one illustrative example, cumulative scores can be calculated using, for nucleotide sequences, the parameters M (reward score for a pair of matching residues; always >0) and N (penalty score for mismatching residues; always <0). Extension of the word hits in each direction are halted when: the cumulative alignment score falls off by the quantity X from its maximum achieved value; the cumulative score goes to zero or below, due to the accumulation of one or more negative-scoring residue alignments; or the end of either sequence is reached. The BLAST algorithm parameters W, T and X determine the sensitivity and speed of

the alignment. The BLASTN program (for nucleotide sequences) uses as defaults a wordlength (W) of 11, and expectation (E) of 10, and the BLOSUM62 scoring matrix (see Henikoff and Henikoff, *Proc. Natl. Acad. Sci. USA* 89:10915 (1989)) alignments, (B) of 50, expectation (E) of 10, M=5, N=-4 and a comparison of both strands.

In certain embodiments, the "percentage of sequence identity" is determined by comparing two optimally aligned sequences over a window of comparison of at least 20 positions, wherein the portion of the polynucleotide sequence in the comparison window may comprise additions or deletions (*i.e.*, gaps) of 20 percent or less, usually 5 to 15 percent, or 10 to 12 percent, as compared to the reference sequences (which does not comprise additions or deletions) for optimal alignment of the two sequences. The percentage is calculated by determining the number of positions at which the identical nucleic acid bases occurs in both sequences to yield the number of matched positions, dividing the number of matched positions by the total number of positions in the reference sequence (*i.e.*, the window size) and multiplying the results by 100 to yield the percentage of sequence identity.

It will be appreciated by those of ordinary skill in the art that, as a result of the degeneracy of the genetic code, there are many nucleotide sequences that encode an antibody as described herein. Some of these polynucleotides bear minimal sequence identity to the nucleotide sequence of the native or original polynucleotide sequence that encode antibodies that bind to CD40. Nonetheless, polynucleotides that vary due to differences in codon usage are expressly contemplated by the present disclosure. In certain embodiments, sequences that have been codon-optimized for mammalian expression are specifically contemplated.

Therefore, in another embodiment of the invention, a mutagenesis approach, such as site-specific mutagenesis, may be employed for the preparation of variants and/or derivatives of the antibodies described herein. By this approach, specific modifications in a polypeptide sequence can be made through mutagenesis of the underlying polynucleotides that encode them. These techniques provides a straightforward approach to prepare and test sequence variants, for example,

incorporating one or more of the foregoing considerations, by introducing one or more nucleotide sequence changes into the polynucleotide.

Site-specific mutagenesis allows the production of mutants through the use of specific oligonucleotide sequences which encode the DNA sequence of the desired mutation, as well as a sufficient number of adjacent nucleotides, to provide a primer sequence of sufficient size and sequence complexity to form a stable duplex on both sides of the deletion junction being traversed. Mutations may be employed in a selected polynucleotide sequence to improve, alter, decrease, modify, or otherwise change the properties of the polynucleotide itself, and/or alter the properties, activity, composition, stability, or primary sequence of the encoded polypeptide.

In certain embodiments, the inventors contemplate the mutagenesis of the polynucleotide sequences that encode an antibody disclosed herein, or an antigen-binding fragment thereof, to alter one or more properties of the encoded polypeptide, such as the binding affinity of the antibody or the antigen-binding fragment thereof, or the function of a particular Fc region, or the affinity of the Fc region for a particular FcγR. The techniques of site-specific mutagenesis are well-known in the art, and are widely used to create variants of both polypeptides and polynucleotides. For example, site-specific mutagenesis is often used to alter a specific portion of a DNA molecule. In such embodiments, a primer comprising typically about 14 to about 25 nucleotides or so in length is employed, with about 5 to about 10 residues on both sides of the junction of the sequence being altered.

As will be appreciated by those of skill in the art, site-specific mutagenesis techniques have often employed a phage vector that exists in both a single stranded and double stranded form. Typical vectors useful in site-directed mutagenesis include vectors such as the M13 phage. These phage are readily commercially-available and their use is generally well-known to those skilled in the art. Double-stranded plasmids are also routinely employed in site directed mutagenesis that eliminates the step of transferring the gene of interest from a plasmid to a phage.

In general, site-directed mutagenesis in accordance herewith is performed by first obtaining a single-stranded vector or melting apart of two strands of a double-stranded vector that includes within its sequence a DNA sequence that encodes the desired peptide. An oligonucleotide primer bearing the desired mutated sequence is prepared, generally synthetically. This primer is then annealed with the single-stranded vector, and subjected to DNA polymerizing enzymes such as *E. coli* polymerase I Klenow fragment, in order to complete the synthesis of the mutation-bearing strand. Thus, a heteroduplex is formed wherein one strand encodes the original non-mutated sequence and the second strand bears the desired mutation. This heteroduplex vector is then used to transform appropriate cells, such as *E. coli* cells, and clones are selected which include recombinant vectors bearing the mutated sequence arrangement.

The preparation of sequence variants of the selected peptide-encoding DNA segments using site-directed mutagenesis provides a means of producing potentially useful species and is not meant to be limiting as there are other ways in which sequence variants of peptides and the DNA sequences encoding them may be obtained. For example, recombinant vectors encoding the desired peptide sequence may be treated with mutagenic agents, such as hydroxylamine, to obtain sequence variants. Specific details regarding these methods and protocols are found in the teachings of Maloy *et al.*, 1994; Segal, 1976; Prokop and Bajpai, 1991; Kuby, 1994; and Maniatis *et al.*, 1982, each incorporated herein by reference, for that purpose.

As used herein, the term "oligonucleotide directed mutagenesis procedure" refers to template-dependent processes and vector-mediated propagation which result in an increase in the concentration of a specific nucleic acid molecule relative to its initial concentration, or in an increase in the concentration of a detectable signal, such as amplification. As used herein, the term "oligonucleotide directed mutagenesis procedure" is intended to refer to a process that involves the template-dependent extension of a primer molecule. The term template dependent process refers to nucleic acid synthesis of an RNA or a DNA molecule wherein the sequence of the newly synthesized strand of nucleic acid is dictated by the well-

known rules of complementary base pairing (see, for example, Watson, 1987). Typically, vector mediated methodologies involve the introduction of the nucleic acid fragment into a DNA or RNA vector, the clonal amplification of the vector, and the recovery of the amplified nucleic acid fragment. Examples of such methodologies are provided by U. S. Patent No. 4,237,224, specifically incorporated herein by reference in its entirety.

In another approach for the production of polypeptide variants, recursive sequence recombination, as described in U.S. Patent No. 5,837,458, may be employed. In this approach, iterative cycles of recombination and screening or selection are performed to "evolve" individual polynucleotide variants having, for example, increased binding affinity. Certain embodiments also provide constructs in the form of plasmids, vectors, transcription or expression cassettes which comprise at least one polynucleotide as described herein.

In many embodiments, the nucleic acids encoding a subject monoclonal antibody are introduced directly into a host cell, and the cell incubated under conditions sufficient to induce expression of the encoded antibody. The antibodies of this disclosure are prepared using standard techniques well known to those of skill in the art in combination with the polypeptide and nucleic acid sequences provided herein. The polypeptide sequences may be used to determine appropriate nucleic acid sequences encoding the particular antibody disclosed thereby. The nucleic acid sequence may be optimized to reflect particular codon "preferences" for various expression systems according to standard methods well known to those of skill in the art.

According to certain related embodiments there is provided a recombinant host cell which comprises one or more constructs as described herein; a nucleic acid encoding any antibody, CDR, VH or VL domain, or antigen-binding fragment thereof; and a method of production of the encoded product, which method comprises expression from encoding nucleic acid therefor. Expression may conveniently be achieved by culturing under appropriate conditions recombinant host cells containing the nucleic acid. Following production by expression, an antibody or

antigen-binding fragment thereof, may be isolated and/or purified using any suitable technique, and then used as desired.

Antibodies or antigen-binding fragments thereof as provided herein, and encoding nucleic acid molecules and vectors, may be isolated and/or purified, *e.g.* from their natural environment, in substantially pure or homogeneous form, or, in the case of nucleic acid, free or substantially free of nucleic acid or genes of origin other than the sequence encoding a polypeptide with the desired function. Nucleic acid may comprise DNA or RNA and may be wholly or partially synthetic. Reference to a nucleotide sequence as set out herein encompasses a DNA molecule with the specified sequence, and encompasses a RNA molecule with the specified sequence in which U is substituted for T, unless context requires otherwise.

Systems for cloning and expression of a polypeptide in a variety of different host cells are well known. Suitable host cells include bacteria, mammalian cells, yeast and baculovirus systems. Mammalian cell lines available in the art for expression of a heterologous polypeptide include Chinese hamster ovary cells, HeLa cells, baby hamster kidney cells, NSO mouse melanoma cells and many others. A common, preferred bacterial host is *E. coli*.

The expression of antibodies and antigen-binding fragments in prokaryotic cells such as *E. coli* is well established in the art. For a review, see for example Pluckthun, A. Bio/Technology 9: 545-551 (1991). Expression in eukaryotic cells in culture is also available to those skilled in the art as an option for production of antibodies or antigen-binding fragments thereof, see recent reviews, for example Ref, M. E. (1993) Curr. Opinion Biotech. 4: 573-576; Trill J. J. *et al.* (1995) Curr. Opinion Biotech 6: 553-560.

Suitable vectors can be chosen or constructed, containing appropriate regulatory sequences, including promoter sequences, terminator sequences, polyadenylation sequences, enhancer sequences, marker genes and other sequences as appropriate. Vectors may be plasmids, viral *e.g.* phage, or phagemid, as appropriate. For further details see, for example, Molecular Cloning: a Laboratory Manual: 2nd edition, Sambrook *et al.*, 1989, Cold Spring Harbor Laboratory Press. Many known techniques and protocols for manipulation of nucleic acid, for example

in preparation of nucleic acid constructs, mutagenesis, sequencing, introduction of DNA into cells and gene expression, and analysis of proteins, are described in detail in Current Protocols in Molecular Biology, Second Edition, Ausubel *et al.* eds., John Wiley & Sons, 1992, or subsequent updates thereto.

The term "host cell" is used to refer to a cell into which has been introduced, or which is capable of having introduced into it, a nucleic acid sequence encoding one or more of the herein described antibodies, and which further expresses or is capable of expressing a selected gene of interest, such as a gene encoding any herein described antibody. The term includes the progeny of the parent cell, whether or not the progeny are identical in morphology or in genetic make-up to the original parent, so long as the selected gene is present. Accordingly there is also contemplated a method comprising introducing such nucleic acid into a host cell. The introduction may employ any available technique. For eukaryotic cells, suitable techniques may include calcium phosphate transfection, DEAE-Dextran, electroporation, liposome-mediated transfection and transduction using retrovirus or other virus, *e.g.* vaccinia or, for insect cells, baculovirus. For bacterial cells, suitable techniques may include calcium chloride transformation, electroporation and transfection using bacteriophage. The introduction may be followed by causing or allowing expression from the nucleic acid, *e.g.* by culturing host cells under conditions for expression of the gene. In one embodiment, the nucleic acid is integrated into the genome (*e.g.* chromosome) of the host cell. Integration may be promoted by inclusion of sequences which promote recombination with the genome, in accordance-with standard techniques.

The present invention also provides, in certain embodiments, a method which comprises using a construct as stated above in an expression system in order to express a particular polypeptide such as a CD40-specific antibody as described herein. The term "transduction" is used to refer to the transfer of genes from one bacterium to another, usually by a phage. "Transduction" also refers to the acquisition and transfer of eukaryotic cellular sequences by retroviruses. The term "transfection" is used to refer to the uptake of foreign or exogenous DNA by a cell, and a cell has been "transfected" when the exogenous DNA has been introduced

inside the cell membrane. A number of transfection techniques are well known in the art and are disclosed herein. See, *e.g.*, Graham *et al.*, 1973, Virology 52:456; Sambrook *et al.*, 2001, MOLECULAR CLONING, A LABORATORY MANUAL, Cold Spring Harbor Laboratories; Davis *et al.*, 1986, BASIC METHODS 1N MOLECULAR BIOLOGY, Elsevier; and Chu *et al.*, 1981, Gene 13:197. Such techniques can be used to introduce one or more exogenous DNA moieties into suitable host cells.

The term "transformation" as used herein refers to a change in a cell's genetic characteristics, and a cell has been transformed when it has been modified to contain a new DNA. For example, a cell is transformed where it is genetically modified from its native state. Following transfection or transduction, the transforming DNA may recombine with that of the cell by physically integrating into a chromosome of the cell, or may be maintained transiently as an episomal element without being replicated, or may replicate independently as a plasmid. A cell is considered to have been stably transformed when the DNA is replicated with the division of the cell. The term "naturally occurring" or "native" when used in connection with biological materials such as nucleic acid molecules, polypeptides, host cells, and the like, refers to materials which are found in nature and are not manipulated by a human. Similarly, "non-naturally occurring" or "non-native" as used herein refers to a material that is not found in nature or that has been structurally modified or synthesized by a human.

The terms "polypeptide" "protein" and "peptide" and "glycoprotein" are used interchangeably and mean a polymer of amino acids not limited to any particular length. The term does not exclude modifications such as myristylation, sulfation, glycosylation, phosphorylation and addition or deletion of signal sequences. The terms "polypeptide" or "protein" means one or more chains of amino acids, wherein each chain comprises amino acids covalently linked by peptide bonds, and wherein said polypeptide or protein can comprise a plurality of chains non-covalently and/or covalently linked together by peptide bonds, having the sequence of native proteins, that is, proteins produced by naturally-occurring and specifically non-recombinant cells, or genetically-engineered or recombinant cells, and comprise molecules having the amino acid sequence of the native protein, or

molecules having deletions from, additions to, and/or substitutions of one or more amino acids of the native sequence. The terms "polypeptide" and "protein" specifically encompass the antibodies that bind to CD40 of the present disclosure, or sequences that have deletions from, additions to, and/or substitutions of one or more amino acid of an anti-CD40 antibody. Thus, a "polypeptide" or a "protein" can comprise one (termed "a monomer") or a plurality (termed "a multimer") of amino acid chains.

The term "isolated protein" referred to herein means that a subject protein (1) is free of at least some other proteins with which it would typically be found in nature, (2) is essentially free of other proteins from the same source, *e.g.*, from the same species, (3) is expressed by a cell from a different species, (4) has been separated from at least about 50 percent of polynucleotides, lipids, carbohydrates, or other materials with which it is associated in nature, (5) is not associated (by covalent or noncovalent interaction) with portions of a protein with which the "isolated protein" is associated in nature, (6) is operably associated (by covalent or noncovalent interaction) with a polypeptide with which it is not associated in nature, or (7) does not occur in nature. Such an isolated protein can be encoded by genomic DNA, cDNA, mRNA or other RNA, of may be of synthetic origin, or any combination thereof. In certain embodiments, the isolated protein is substantially free from proteins or polypeptides or other contaminants that are found in its natural environment that would interfere with its use (therapeutic, diagnostic, prophylactic, research or otherwise).

The term "polypeptide fragment" refers to a polypeptide, which can be monomeric or multimeric, that has an amino-terminal deletion, a carboxyl-terminal deletion, and/or an internal deletion or substitution of a naturally-occurring or recombinantly-produced polypeptide. In certain embodiments, a polypeptide fragment can comprise an amino acid chain at least 5 to about 500 amino acids long. It will be appreciated that in certain embodiments, fragments are at least 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 110, 150, 200, 250, 300, 350, 400, or 450 amino acids

long. Particularly useful polypeptide fragments include functional domains, including antigen-binding domains or fragments of antibodies. In the case of an anti-CD40 antibody, useful fragments include, but are not limited to: a CDR region, especially a CDR3 region of the heavy or light chain; a variable region of a heavy or light chain; a portion of an antibody chain or just its variable region including two CDRs; and the like.

Polypeptides may comprise a signal (or leader) sequence at the N-terminal end of the protein, which co-translationally or post-translationally directs transfer of the protein. Any polypeptide amino acid sequences provided herein that include a signal peptide are also contemplated for any use described herein without such a signal or leader peptide. As would be recognized by the skilled person, the signal peptide is usually cleaved during processing and is not included in the active antibody protein. The polypeptide may also be fused in-frame or conjugated to a linker or other sequence for ease of synthesis, purification or identification of the polypeptide (*e.g.*, poly-His), or to enhance binding of the polypeptide to a solid support.

A peptide linker/spacer sequence may also be employed to separate multiple polypeptide components by a distance sufficient to ensure that each polypeptide folds into its secondary and/or tertiary structures, if desired. Such a peptide linker sequence can be incorporated into a fusion polypeptide using standard techniques well known in the art.

Certain peptide spacer sequences may be chosen, for example, based on: (1) their ability to adopt a flexible extended conformation; (2) their inability to adopt a secondary structure that could interact with functional epitopes on the first and second polypeptides; and/or (3) the lack of hydrophobic or charged residues that might react with the polypeptide functional epitopes.

In one illustrative embodiment, peptide spacer sequences contain, for example, Gly, Asn and Ser residues. Other near neutral amino acids, such as Thr and Ala, may also be included in the spacer sequence.

Other amino acid sequences which may be usefully employed as spacers include those disclosed in Maratea *et al.*, *Gene 40*:39 46 (1985); Murphy *et*

al., Proc. Natl. Acad. Sci. USA 83:8258 8262 (1986); U.S. Pat. No. 4,935,233 and U.S. Pat. No. 4,751,180.

Other illustrative spacers may include, for example, Glu-Gly-Lys-Ser-Ser-Gly-Ser-Gly-Ser-Glu-Ser-Lys-Val-Asp (Chaudhary et al., 1990, Proc. Natl. Acad. Sci. U.S.A. 87:1066-1070) and Lys-Glu-Ser-Gly-Ser-Val-Ser-Ser-Glu-Gln-Leu-Ala-Gln-Phe-Arg-Ser-Leu-Asp (Bird et al., 1988, Science 242:423-426).

In some embodiments, spacer sequences are not required when the first and second polypeptides have non-essential N-terminal amino acid regions that can be used to separate the functional domains and prevent steric interference. Two coding sequences can be fused directly without any spacer or by using a flexible polylinker composed, for example, of the pentamer Gly-Gly-Gly-Gly-Ser repeated 1 to 3 times. Such a spacer has been used in constructing single chain antibodies (scFv) by being inserted between VH and VL (Bird et al., 1988, Science 242:423-426; Huston et al., 1988, Proc. Natl. Acad. Sci. U.S.A. 85:5979-5883).

A peptide spacer, in certain embodiments, is designed to enable the correct interaction between two beta-sheets forming the variable region of the single chain antibody.

In certain illustrative embodiments, a peptide spacer is between 1 to 5 amino acids, between 5 to 10 amino acids, between 5 to 25 amino acids, between 5 to 50 amino acids, between 10 to 25 amino acids, between 10 to 50 amino acids, between 10 to 100 amino acids, or any intervening range of amino acids.

In other illustrative embodiments, a peptide spacer comprises about 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 or more amino acids in length.

Amino acid sequence modification(s) of the antibodies described herein are contemplated. For example, it may be desirable to improve the binding affinity and/or other biological properties of the antibody. For example, amino acid sequence variants of an antibody may be prepared by introducing appropriate nucleotide changes into a polynucleotide that encodes the antibody, or a chain thereof, or by peptide synthesis. Such modifications include, for example, deletions from, and/or insertions into and/or substitutions of, residues within the amino acid sequences of the antibody. Any combination of deletion, insertion, and substitution

may be made to arrive at the final antibody, provided that the final construct possesses the desired characteristics (*e.g.*, high affinity binding to CD40). The amino acid changes also may alter post-translational processes of the antibody, such as changing the number or position of glycosylation sites. Any of the variations and modifications described above for polypeptides of the present invention may be included in antibodies of the present invention.

The present disclosure provides variants of the antibodies disclosed herein. In certain embodiments, such variant antibodies or antigen-binding fragments, or CDRs thereof, bind to CD40 at least about 50%, at least about 70%, and in certain embodiments, at least about 90% as well as an antibody sequence specifically set forth herein. In further embodiments, such variant antibodies or antigen-binding fragments, or CDRs thereof, bind to CD40 with greater affinity than the antibodies set forth herein, for example, that bind quantitatively at least about 105%, 106%, 107%, 108%, 109%, or 110% as well as an antibody sequence specifically set forth herein.

In particular embodiments, a subject antibody may have: a) a heavy chain variable region having an amino acid sequence that is at least 80% identical, at least 95% identical, at least 90%, at least 95% or at least 98% or 99% identical, to the heavy chain variable region of an anti-CD40 antibody described herein; and b) a light chain variable region having an amino acid sequence that is at least 80% identical, at least 85%, at least 90%, at least 95% or at least 98% or 99% identical, to the light chain variable region of an anti-CD40 antibody described herein. The amino acid sequence of illustrative heavy and light chain regions are set forth in SEQ ID NOs:1-56.

In particular embodiments, the antibody may comprise: a) a heavy chain variable region comprising: i. a CDR1 region that is identical in amino acid sequence to the heavy chain CDR1 region of a selected antibody described herein; ii. a CDR2 region that is identical in amino acid sequence to the heavy chain CDR2 region of the selected antibody; and iii. a CDR3 region that is identical in amino acid sequence to the heavy chain CDR3 region of the selected antibody; and b) a light chain variable domain comprising: i. a CDR1 region that is identical in amino acid

sequence to the light chain CDR1 region of the selected antibody; ii. a CDR2 region that is identical in amino acid sequence to the light chain CDR2 region of the selected antibody; and iii. a CDR3 region that is identical in amino acid sequence to the light chain CDR3 region of the selected antibody; wherein the antibody specifically binds a selected target (e.g., CD40). In a further embodiment, the antibody, or antigen-binding fragment thereof, is a variant antibody wherein the variant comprises a heavy and light chain identical to the selected antibody except for up to 8, 9, 10, 11, 12, 13, 14, 15, or more amino acid substitutions in the CDR regions of the VH and VL regions. In this regard, there may be 1, 2, 3, 4, 5, 6, 7, 8, or in certain embodiments, 9, 10, 11, 12, 13, 14, 15 more amino acid substitutions in the CDR regions of the selected antibody. Substitutions may be in CDRs either in the VH and/or the VL regions. (See *e.g.*, Muller, 1998, Structure 6:1153-1167).

Determination of the three-dimensional structures of representative polypeptides (*e.g.*, variant CD40-specific antibodies as provided herein, for instance, an antibody protein having an antigen-binding fragment as provided herein) may be made through routine methodologies such that substitution, addition, deletion or insertion of one or more amino acids with selected natural or non-natural amino acids can be virtually modeled for purposes of determining whether a so derived structural variant retains the space-filling properties of presently disclosed species. *See*, for instance, Donate et al., 1994 *Prot. Sci.* 3:2378; Bradley et al., *Science* 309: 1868-1871 (2005); Schueler-Furman et al., *Science* 310:638 (2005); Dietz et al., *Proc. Nat. Acad. Sci. USA* 103:1244 (2006); Dodson et al., *Nature* 450:176 (2007); Qian et al., *Nature* 450:259 (2007); Raman *et al.* Science 327:1014-1018 (2010). Some additional non-limiting examples of computer algorithms that may be used for these and related embodiments, such as for rational design of CD40-specific antibodies antigen-binding domains thereof as provided herein, include VMD which is a molecular visualization program for displaying, animating, and analyzing large biomolecular systems using 3-D graphics and built-in scripting (see the website for the Theoretical and Computational Biophysics Group, University of Illinois at Urbana-Champagne, at ks.uiuc.edu/Research/vmd/. Many other computer programs are known in the art and available to the skilled person and which allow for determining

atomic dimensions from space-filling models (van der Waals radii) of energy-minimized conformations; GRID, which seeks to determine regions of high affinity for different chemical groups, thereby enhancing binding, Monte Carlo searches, which calculate mathematical alignment, and CHARMM (Brooks et al. (1983) *J. Comput. Chem.* 4:187-217) and AMBER (Weiner et al (1981) *J. Comput. Chem.* 106: 765), which assess force field calculations, and analysis (see also, Eisenfield et al. (1991) *Am. J. Physiol.* 261:C376-386; Lybrand (1991) *J. Pharm. Belg.* 46:49-54; Froimowitz (1990) *Biotechniques* 8:640-644; Burbam et al. (1990) *Proteins* 7:99-111; Pedersen (1985) *Environ. Health Perspect.* 61:185-190; and Kini et al. (1991) *J. Biomol. Struct. Dyn.* 9:475-488). A variety of appropriate computational computer programs are also commercially available, such as from Schrödinger (Munich, Germany).

In another embodiment of invention, the anti-CD40 antibodies and humanized versions thereof are derived from rabbit monoclonal antibodies, and in particular are generated using RabMAb® technology. These antibodies are advantageous as they require minimal sequence modifications, thereby facilitating retention of functional properties after humanization using mutational lineage guided (MLG) humanization technology (see e.g., U.S. Patent No. 7,462,697). Thus, illustrative methods for making the anti-CD40 antibodies of the present disclosure include the RabMab® rabbit monoclonal antibody technology described, for example, in U.S. Patents 5,675,063 and 7,429,487. In this regard, in certain embodiments, the anti-CD40 antibodies of the disclosure are produced in rabbits. In particular embodiments, a rabbit-derived immortal B-lymphocyte capable of fusion with a rabbit splenocyte is used to produce a hybrid cell that produces an antibody. The immortal B-lymphocyte does not detectably express endogenous immunoglobulin heavy chain and may contain, in certain embodiments, an altered immunoglobulin heavy chain-encoding gene.

Compositions and Methods of Use

The present disclosure provides compositions comprising the CD40-specific antibodies, antigen-binding fragments thereof and administration of such composition in a variety of therapeutic settings.

Administration of the CD40-specific antibodies described herein, in pure form or in an appropriate pharmaceutical composition, can be carried out via any of the accepted modes of administration of agents for serving similar utilities. The pharmaceutical compositions can be prepared by combining an antibody or antibody-containing composition with an appropriate physiologically acceptable carrier, diluent or excipient, and may be formulated into preparations in solid, semi-solid, liquid or gaseous forms, such as tablets, capsules, powders, granules, ointments, solutions, suppositories, injections, inhalants, gels, microspheres, and aerosols. In addition, other pharmaceutically active ingredients (including other anti-cancer agents as described elsewhere herein) and/or suitable excipients such as salts, buffers and stabilizers may, but need not, be present within the composition. Administration may be achieved by a variety of different routes, including oral, parenteral, nasal, intravenous, intradermal, subcutaneous or topical. Preferred modes of administration depend upon the nature of the condition to be treated or prevented. An amount that, following administration, reduces, inhibits, prevents or delays the progression and/or metastasis of a cancer is considered effective.

In certain embodiments, the amount administered is sufficient to result in tumor regression, as indicated by a statistically significant decrease in the amount of viable tumor, for example, at least a 50% decrease in tumor mass, or by altered (*e.g.*, decreased with statistical significance) scan dimensions. In other embodiments, the amount administered is sufficient to result in clinically relevant reduction in symptoms of a particular disease indication known to the skilled clinician.

The precise dosage and duration of treatment is a function of the disease being treated and may be determined empirically using known testing protocols or by testing the compositions in model systems known in the art and extrapolating therefrom. Controlled clinical trials may also be performed. Dosages may also vary with the severity of the condition to be alleviated. A pharmaceutical composition is generally formulated and administered to exert a therapeutically useful effect while minimizing undesirable side effects. The composition may be administered one time, or may be divided into a number of smaller doses to be

administered at intervals of time. For any particular subject, specific dosage regimens may be adjusted over time according to the individual need.

The CD40-specific antibody-containing compositions may be administered alone or in combination with other known cancer treatments, such as radiation therapy, chemotherapy, transplantation, immunotherapy, hormone therapy, photodynamic therapy, *etc*. The compositions may also be administered in combination with antibiotics.

Typical routes of administering these and related pharmaceutical compositions thus include, without limitation, oral, topical, transdermal, inhalation, parenteral, sublingual, buccal, rectal, vaginal, and intranasal. The term parenteral as used herein includes subcutaneous injections, intravenous, intramuscular, intrasternal injection or infusion techniques. Pharmaceutical compositions according to certain embodiments of the present invention are formulated so as to allow the active ingredients contained therein to be bioavailable upon administration of the composition to a patient. Compositions that will be administered to a subject or patient may take the form of one or more dosage units, where for example, a tablet may be a single dosage unit, and a container of a herein described CD40-specific antibody in aerosol form may hold a plurality of dosage units. Actual methods of preparing such dosage forms are known, or will be apparent, to those skilled in this art; for example, see *Remington: The Science and Practice of Pharmacy*, 20th Edition (Philadelphia College of Pharmacy and Science, 2000). The composition to be administered will, in any event, contain a therapeutically effective amount of an antibody of the present disclosure, for treatment of a disease or condition of interest in accordance with teachings herein.

A pharmaceutical composition may be in the form of a solid or liquid. In one embodiment, the carrier(s) are particulate, so that the compositions are, for example, in tablet or powder form. The carrier(s) may be liquid, with the compositions being, for example, an oral oil, injectable liquid or an aerosol, which is useful in, for example, inhalatory administration. When intended for oral administration, the pharmaceutical composition is preferably in either solid or liquid

form, where semi-solid, semi-liquid, suspension and gel forms are included within the forms considered herein as either solid or liquid.

As a solid composition for oral administration, the pharmaceutical composition may be formulated into a powder, granule, compressed tablet, pill, capsule, chewing gum, wafer or the like. Such a solid composition will typically contain one or more inert diluents or edible carriers. In addition, one or more of the following may be present: binders such as carboxymethylcellulose, ethyl cellulose, microcrystalline cellulose, gum tragacanth or gelatin; excipients such as starch, lactose or dextrins, disintegrating agents such as alginic acid, sodium alginate, Primogel, corn starch and the like; lubricants such as magnesium stearate or Sterotex; glidants such as colloidal silicon dioxide; sweetening agents such as sucrose or saccharin; a flavoring agent such as peppermint, methyl salicylate or orange flavoring; and a coloring agent. When the pharmaceutical composition is in the form of a capsule, for example, a gelatin capsule, it may contain, in addition to materials of the above type, a liquid carrier such as polyethylene glycol or oil.

The pharmaceutical composition may be in the form of a liquid, for example, an elixir, syrup, solution, emulsion or suspension. The liquid may be for oral administration or for delivery by injection, as two examples. When intended for oral administration, preferred composition contain, in addition to the present compounds, one or more of a sweetening agent, preservatives, dye/colorant and flavor enhancer. In a composition intended to be administered by injection, one or more of a surfactant, preservative, wetting agent, dispersing agent, suspending agent, buffer, stabilizer and isotonic agent may be included.

The liquid pharmaceutical compositions, whether they be solutions, suspensions or other like form, may include one or more of the following adjuvants: sterile diluents such as water for injection, saline solution, preferably physiological saline, Ringer's solution, isotonic sodium chloride, fixed oils such as synthetic mono or diglycerides which may serve as the solvent or suspending medium, polyethylene glycols, glycerin, propylene glycol or other solvents; antibacterial agents such as benzyl alcohol or methyl paraben; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid; buffers such as

acetates, citrates or phosphates and agents for the adjustment of tonicity such as sodium chloride or dextrose. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose vials made of glass or plastic. Physiological saline is a preferred adjuvant. An injectable pharmaceutical composition is preferably sterile.

A liquid pharmaceutical composition intended for either parenteral or oral administration should contain an amount of a CD40-specific antibody as herein disclosed such that a suitable dosage will be obtained. Typically, this amount is at least 0.01% of the antibody in the composition. When intended for oral administration, this amount may be varied to be between 0.1 and about 70% of the weight of the composition. Certain oral pharmaceutical compositions contain between about 4% and about 75% of the antibody. In certain embodiments, pharmaceutical compositions and preparations according to the present invention are prepared so that a parenteral dosage unit contains between 0.01 to 10% by weight of the antibody prior to dilution.

The pharmaceutical composition may be intended for topical administration, in which case the carrier may suitably comprise a solution, emulsion, ointment or gel base. The base, for example, may comprise one or more of the following: petrolatum, lanolin, polyethylene glycols, bee wax, mineral oil, diluents such as water and alcohol, and emulsifiers and stabilizers. Thickening agents may be present in a pharmaceutical composition for topical administration. If intended for transdermal administration, the composition may include a transdermal patch or iontophoresis device. The pharmaceutical composition may be intended for rectal administration, in the form, for example, of a suppository, which will melt in the rectum and release the drug. The composition for rectal administration may contain an oleaginous base as a suitable nonirritating excipient. Such bases include, without limitation, lanolin, cocoa butter and polyethylene glycol.

The pharmaceutical composition may include various materials, which modify the physical form of a solid or liquid dosage unit. For example, the composition may include materials that form a coating shell around the active ingredients. The materials that form the coating shell are typically inert, and may be

selected from, for example, sugar, shellac, and other enteric coating agents. Alternatively, the active ingredients may be encased in a gelatin capsule. The pharmaceutical composition in solid or liquid form may include an agent that binds to the antibody of the invention and thereby assists in the delivery of the compound. Suitable agents that may act in this capacity include other monoclonal or polyclonal antibodies, one or more proteins or a liposome. The pharmaceutical composition may consist essentially of dosage units that can be administered as an aerosol. The term aerosol is used to denote a variety of systems ranging from those of colloidal nature to systems consisting of pressurized packages. Delivery may be by a liquefied or compressed gas or by a suitable pump system that dispenses the active ingredients. Aerosols may be delivered in single phase, bi-phasic, or tri-phasic systems in order to deliver the active ingredient(s). Delivery of the aerosol includes the necessary container, activators, valves, subcontainers, and the like, which together may form a kit. One of ordinary skill in the art, without undue experimentation may determine preferred aerosols.

The pharmaceutical compositions may be prepared by methodology well known in the pharmaceutical art. For example, a pharmaceutical composition intended to be administered by injection can be prepared by combining a composition that comprises a CD40-specific antibody as described herein and optionally, one or more of salts, buffers and/or stabilizers, with sterile, distilled water so as to form a solution. A surfactant may be added to facilitate the formation of a homogeneous solution or suspension. Surfactants are compounds that non-covalently interact with the antibody composition so as to facilitate dissolution or homogeneous suspension of the antibody in the aqueous delivery system.

The compositions may be administered in a therapeutically effective amount, which will vary depending upon a variety of factors including the activity of the specific compound (*e.g.*, CD40-specific antibody) employed; the metabolic stability and length of action of the compound; the age, body weight, general health, sex, and diet of the patient; the mode and time of administration; the rate of excretion; the drug combination; the severity of the particular disorder or condition; and the subject undergoing therapy. Generally, a therapeutically effective daily dose

is (for a 70 kg mammal) from about 0.001 mg/kg (*i.e.*, 0.07 mg) to about 100 mg/kg (*i.e.*, 7.0 g); preferably a therapeutically effective dose is (for a 70 kg mammal) from about 0.01 mg/kg (*i.e.*, 0.7 mg) to about 50 mg/kg (*i.e.*, 3.5 g); more preferably a therapeutically effective dose is (for a 70 kg mammal) from about 1 mg/kg (*i.e.*, 70 mg) to about 25 mg/kg (*i.e.*, 1.75 g).

Compositions comprising the CD40-specific antibodies of the present disclosure may also be administered simultaneously with, prior to, or after administration of one or more other therapeutic agents. Such combination therapy may include administration of a single pharmaceutical dosage formulation which contains a compound of the invention and one or more additional active agents, as well as administration of compositions comprising antibodies of the invention and each active agent in its own separate pharmaceutical dosage formulation. For example, an antibody as described herein and the other active agent can be administered to the patient together in a single oral dosage composition such as a tablet or capsule, or each agent administered in separate oral dosage formulations. Similarly, an antibody as described herein and the other active agent can be administered to the patient together in a single parenteral dosage composition such as in a saline solution or other physiologically acceptable solution, or each agent administered in separate parenteral dosage formulations. Where separate dosage formulations are used, the compositions comprising antibodies and one or more additional active agents can be administered at essentially the same time, *i.e.*, concurrently, or at separately staggered times, *i.e.*, sequentially and in any order; combination therapy is understood to include all these regimens.

Thus, in certain embodiments, also contemplated is the administration of anti-CD40 antibody compositions of this disclosure in combination with one or more other therapeutic agents. Such therapeutic agents may be accepted in the art as a standard treatment for a particular disease state as described herein, such as rheumatoid arthritis, inflammation or cancer. Exemplary therapeutic agents contemplated include cytokines, growth factors, steroids, NSAIDs, DMARDs, anti-inflammatories, chemotherapeutics, radiotherapeutics, or other active and ancillary agents.

In certain embodiments, the anti-CD40 antibodies disclosed herein may be administered in conjunction with any number of chemotherapeutic agents. Examples of chemotherapeutic agents include alkylating agents such as thiotepa and cyclophosphamide (CYTOXAN™); alkyl sulfonates such as busulfan, improsulfan and piposulfan; aziridines such as benzodopa, carboquone, meturedopa, and uredopa; ethylenimines and methylamelamines including altretamine, triethylenemelamine, trietylenephosphoramide, triethylenethiophosphaoramide and trimethylolomelamine; nitrogen mustards such as chlorambucil, chlornaphazine, cholophosphamide, estramustine, ifosfamide, mechlorethamine, mechlorethamine oxide hydrochloride, melphalan, novembichin, phenesterine, prednimustine, trofosfamide, uracil mustard; nitrosureas such as carmustine, chlorozotocin, fotemustine, lomustine, nimustine, ranimustine; antibiotics such as aclacinomysins, actinomycin, authramycin, azaserine, bleomycins, cactinomycin, calicheamicin, carabicin, carminomycin, carzinophilin, chromomycins, dactinomycin, daunorubicin, detorubicin, 6-diazo-5-oxo-L-norleucine, doxorubicin, epirubicin, esorubicin, idarubicin, marcellomycin, mitomycins, mycophenolic acid, nogalamycin, olivomycins, peplomycin, potfiromycin, puromycin, quelamycin, rodorubicin, streptonigrin, streptozocin, tubercidin, ubenimex, zinostatin, zorubicin; anti-metabolites such as methotrexate and 5-fluorouracil (5-FU); folic acid analogues such as denopterin, methotrexate, pteropterin, trimetrexate; purine analogs such as fludarabine, 6-mercaptopurine, thiamiprine, thioguanine; pyrimidine analogs such as ancitabine, azacitidine, 6-azauridine, carmofur, cytarabine, dideoxyuridine, doxifluridine, enocitabine, floxuridine, 5-FU; androgens such as calusterone, dromostanolone propionate, epitiostanol, mepitiostane, testolactone; anti-adrenals such as aminoglutethimide, mitotane, trilostane; folic acid replenisher such as frolinic acid; aceglatone; aldophosphamide glycoside; aminolevulinic acid; amsacrine; bestrabucil; bisantrene; edatraxate; defofamine; demecolcine; diaziquone; elformithine; elliptinium acetate; etoglucid; gallium nitrate; hydroxyurea; lentinan; lonidamine; mitoguazone; mitoxantrone; mopidamol; nitracrine; pentostatin; phenamet; pirarubicin; podophyllinic acid; 2-ethylhydrazide; procarbazine; PSK.RTM.; razoxane; sizofiran; spirogermanium; tenuazonic acid; triaziquone; 2,

2',2"-*trichlorotriethylamine*; *urethan*; *vindesine*; *dacarbazine*; *mannomustine*; mitobronitol; mitolactol; pipobroman; gacytosine; arabinoside ("Ara-C"); cyclophosphamide; thiotepa; taxoids, e.g. paclitaxel (TAXOL®, Bristol-Myers Squibb Oncology, Princeton, N.J.) and doxetaxel (TAXOTERE®., Rhne-Poulenc Rorer, Antony, France); chlorambucil; gemcitabine; 6-thioguanine; mercaptopurine; methotrexate; platinum analogs such as cisplatin and carboplatin; vinblastine; platinum; etoposide (VP-16); ifosfamide; mitomycin C; mitoxantrone; vincristine; vinorelbine; navelbine; novantrone; teniposide; daunomycin; aminopterin; xeloda; ibandronate; CPT-11; topoisomerase inhibitor RFS 2000; difluoromethylomithine (DMFO); retinoic acid derivatives such as Targretin™ (bexarotene), Panretin™ (alitretinoin) ; ONTAK™ (denileukin diftitox) ; esperamicins; capecitabine; and pharmaceutically acceptable salts, acids or derivatives of any of the above. Also included in this definition are anti-hormonal agents that act to regulate or inhibit hormone action on tumors such as anti-estrogens including for example tamoxifen, raloxifene, aromatase inhibiting 4(5)-imidazoles, 4-hydroxytamoxifen, trioxifene, keoxifene, LY117018, onapristone, and toremifene (Fareston); and anti-androgens such as flutamide, nilutamide, bicalutamide, leuprolide, and goserelin; and pharmaceutically acceptable salts, acids or derivatives of any of the above.

A variety of other therapeutic agents may be used in conjunction with the anti-CD40 antibodies described herein. In one embodiment, the antibody is administered with an anti-inflammatory agent. Anti-inflammatory agents or drugs include, but are not limited to, steroids and glucocorticoids (including betamethasone, budesonide, dexamethasone, hydrocortisone acetate, hydrocortisone, hydrocortisone, methylprednisolone, prednisolone, prednisone, triamcinolone), nonsteroidal anti-inflammatory drugs (NSAIDS) including aspirin, ibuprofen, naproxen, methotrexate, sulfasalazine, leflunomide, anti-TNF medications, cyclophosphamide and mycophenolate.

Exemplary NSAIDs are chosen from the group consisting of ibuprofen, naproxen, naproxen sodium, Cox-2 inhibitors such as VIOXX® (rofecoxib) and CELEBREX® (celecoxib), and sialylates. Exemplary analgesics are chosen from the group consisting of acetaminophen, oxycodone, tramadol of proporxyphene

hydrochloride. Exemplary glucocorticoids are chosen from the group consisting of cortisone, dexamethasone, hydrocortisone, methylprednisolone, prednisolone, or prednisone. Exemplary biological response modifiers include molecules directed against cell surface markers (*e.g.*, CD4, CD5, etc.), cytokine inhibitors, such as the TNF antagonists (*e.g.*, etanercept (ENBREL®), adalimumab (HUMIRA®) and infliximab (REMICADE®)), chemokine inhibitors and adhesion molecule inhibitors. The biological response modifiers include monoclonal antibodies as well as recombinant forms of molecules. Exemplary DMARDs include azathioprine, cyclophosphamide, cyclosporine, methotrexate, penicillamine, leflunomide, sulfasalazine, hydroxychloroquine, Gold (oral (auranofin) and intramuscular) and minocycline.

In certain embodiments, the antibodies described herein are administered in conjunction with a cytokine. By "cytokine" as used herein is meant a generic term for proteins released by one cell population that act on another cell as intercellular mediators. Examples of such cytokines are lymphokines, monokines, and traditional polypeptide hormones. Included among the cytokines are growth hormones such as human growth hormone, N-methionyl human growth hormone, and bovine growth hormone; parathyroid hormone; thyroxine; insulin; proinsulin; relaxin; prorelaxin; glycoprotein hormones such as follicle stimulating hormone (FSH), thyroid stimulating hormone (TSH), and luteinizing hormone (LH); hepatic growth factor; fibroblast growth factor; prolactin; placental lactogen; tumor necrosis factor-alpha and -beta; mullerian-inhibiting substance; mouse gonadotropin-associated peptide; inhibin; activin; vascular endothelial growth factor; integrin; thrombopoietin (TPO); nerve growth factors such as NGF-beta; platelet-growth factor; transforming growth factors (TGFs) such as TGF-alpha and TGF-beta; insulin-like growth factor-I and -II; erythropoietin (EPO); osteoinductive factors; interferons such as interferon-alpha, beta, and -gamma; colony stimulating factors (CSFs) such as macrophage-CSF (M-CSF); granulocyte-macrophage-CSF (GM-CSF); and granulocyte-CSF (G-CSF); interleukins (ILs) such as IL-1, IL-1alpha, IL-2, IL-3, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-11, IL-12; IL-15, a tumor necrosis factor such as TNF-alpha or TNF-beta; and other polypeptide factors including LIF and kit

ligand (KL). As used herein, the term cytokine includes proteins from natural sources or from recombinant cell culture, and biologically active equivalents of the native sequence cytokines.

The compositions comprising herein described CD40-specific antibodies may be administered to an individual afflicted with a disease as described herein, including, but not limited to non-Hodgkin's lymphomas, Hodgkin's lymphoma, *chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias*, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias, autoimmune and inflammatory diseases . Autoimmune diseases include but are not limited to, arthritis (including rheumatoid arthritis, reactive arthritis), systemic lupus erythematosus (SLE), psoriasis and inflammatory bowel disease (IBD), encephalomyelitis, uveitis, myasthenia gravis, multiple sclerosis, insulin dependent diabetes, Addison's disease, celiac disease, chronic fatigue syndrome, autoimmune hepatitis, autoimmune alopecia, ankylosing spondylitis, ulcerative colitis, Crohn's disease, fibromyalgia, pemphigus vulgaris, Sjogren's syndrome, Kawasaki's Disease, hyperthyroidism/Graves disease, hypothyroidism/Hashimoto's disease, endometriosis, scleroderma, pernicious anemia, Goodpasture syndrome, Guillain-Barré syndrome, Wegener's disease, glomerulonephritis, aplastic anemia (including multiply transfused aplastic anemia patients), paroxysmal nocturnal hemoglobinuria, myelodysplastic syndrome, idiopathic thrombocytopenic purpura, autoimmune hemolytic anemia, Evan's syndrome, Factor VIII inhibitor syndrome, systemic vasculitis, dermatomyositis, polymyositis and rheumatic fever, autoimmune lymphoproliferative syndrome (ALPS), autoimmune bullous pemphigoid, Parkinson's disease, sarcoidosis, vitiligo, primary biliary cirrhosis, and autoimmune myocarditis.

Inflammatory diseases include, but are not limited to, Crohn's disease, colitis, dermatitis, psoriasis, diverticulitis, hepatitis, irritable bowel syndrom (IBS), lupus erythematous, nephritis, Parkinson's disease, ulcerative colitis, multiple sclerosis (MS), Alzheimer's disease, arthritis, rheumatoid arthritis, asthma, and various cardiovascular diseases such as atherosclerosis and vasculitis. In certain

embodiments, the inflammatory disease is selected from the group consisting of rheumatoid arthritis, diabetes, gout, cryopyrin-associated periodic syndrome, and chronic obstructive pulmonary disorder. In this regard, one embodiment provides a method of treating, reducing the severity of or preventing inflammation or an inflammatory disease by administering to a patient in need thereof a therapeutically effective amount of a herein disclosed compositions comprising anti-CD40 antibodies.

For *in vivo* use for the treatment of human disease, the antibodies described herein are generally incorporated into a pharmaceutical composition prior to administration. A pharmaceutical composition comprises one or more of the antibodies described herein in combination with a physiologically acceptable carrier or excipient as described elsewhere herein. To prepare a pharmaceutical composition, an effective amount of one or more of the compounds is mixed with any pharmaceutical carrier(s) or excipient known to those skilled in the art to be suitable for the particular mode of administration. A pharmaceutical carrier may be liquid, semi-liquid or solid. Solutions or suspensions used for parenteral, intradermal, subcutaneous or topical application may include, for example, a sterile diluent (such as water), saline solution, fixed oil, polyethylene glycol, glycerin, propylene glycol or other synthetic solvent; antimicrobial agents (such as benzyl alcohol and methyl parabens); antioxidants (such as ascorbic acid and sodium bisulfite) and chelating agents (such as ethylenediaminetetraacetic acid (EDTA)); buffers (such as acetates, citrates and phosphates). If administered intravenously, suitable carriers include physiological saline or phosphate buffered saline (PBS), and solutions containing thickening and solubilizing agents, such as glucose, polyethylene glycol, polypropylene glycol and mixtures thereof.

The compositions comprising CD40-specific antibodies as described herein may be prepared with carriers that protect the antibody against rapid elimination from the body, such as time release formulations or coatings. Such carriers include controlled release formulations, such as, but not limited to, implants and microencapsulated delivery systems, and biodegradable, biocompatible

polymers, such as ethylene vinyl acetate, polyanhydrides, polyglycolic acid, PEGs, polyorthoesters, polylactic acid and others known to those of ordinary skill in the art.

Provided herein are methods of treatment using the antibodies that bind CD40. In one embodiment, an antibody of the present invention is administered to a patient having a disease involving inappropriate expression of CD40, which is meant in the context of the present disclosure to include diseases and disorders characterized by aberrant CD40 expression or activity, due for example to alterations (*e.g.*, statistically significant increases or decreases) in the amount of a protein present, or the presence of a mutant protein, or both. An overabundance may be due to any cause, including but not limited to overexpression at the molecular level, prolonged or accumulated appearance at the site of action, or increased (*e.g.*, in a statistically significant manner) activity of CD40 relative to that which is normally detectable. Such an overabundance of CD40 can be measured relative to normal expression, appearance, or activity of CD40 signalling events, and said measurement may play an important role in the development and/or clinical testing of the antibodies described herein.

The present antibodies are useful for the treatment of a variety of cancers. In certain embodiments, the antibodies described herein exert anti-tumor activity by activating anti-tumor immune responses. In certain embodiments, the present antibodies are useful for the treatment of a variety of cancers associated with the aberrant expression of CD40. In one embodiment of the invention provides a method for the treatment of a cancer including, but not limited to, non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias, by administering to a cancer patient a therapeutically effective amount of a herein disclosed CD40-specific antibody. An amount that, following administration, inhibits, prevents or delays the progression and/or metastasis of a cancer in a statistically significant manner (*i.e.*, relative to an appropriate control as will be known to those skilled in the art) is considered effective.

Another embodiment provides a method for preventing metastasis of a cancer including, but not limited to, non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias, by administering to a cancer patient a therapeutically effective amount of a herein disclosed CD40-specific antibody (*e.g.*, an amount that, following administration, inhibits, prevents or delays metastasis of a cancer in a statistically significant manner, *i.e.*, relative to an appropriate control as will be known to those skilled in the art).

Another embodiment provides a method for preventing a cancer including, but not limited to, non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias, by administering to a cancer patient a therapeutically effective amount of a herein disclosed CD40-specific antibody.

Another embodiment provides a method for treating, ameliorating the symptoms of, inhibiting the progression of or prevention of non-Hodgkin's lymphomas, Hodgkin's lymphoma, chronic lymphocytic leukemias, hairy cell leukemias, acute lymphoblastic leukemias, multiple myeloma, carcinomas of the pancreas, colon, gastric intestine, prostate, bladder, kidney ovary, cervix, breast, lung, nasopharynx, malignant melanoma and rituximab resistant NHL and leukemias by administering to a patient afflicted by one or more of these diseases a therapeutically effective amount of a herein disclosed CD40-specific antibody.

Another embodiment provides a method for treating, ameliorating the symptoms of, inhibiting the progression of or prevention of an autoimmune disease by administering to a patient afflicted by one or more of these diseases a therapeutically effective amount of a herein disclosed anti-CD40 antibody. In this regard, autoimmune diseases include, but are not limited to, arthritis (including rheumatoid arthritis, reactive arthritis), systemic lupus erythematosus (SLE),

psoriasis and inflammatory bowel disease (IBD), encephalomyelitis, uveitis, myasthenia gravis, multiple sclerosis, insulin dependent diabetes, Addison's disease, celiac disease, chronic fatigue syndrome, autoimmune hepatitis, autoimmune alopecia, ankylosing spondylitis, ulcerative colitis, Crohn's disease, fibromyalgia, pemphigus vulgaris, Sjogren's syndrome, Kawasaki's Disease, hyperthyroidism/Graves disease, hypothyroidism/Hashimoto's disease, endometriosis, scleroderma, pernicious anemia, Goodpasture syndrome, Guillain-Barré syndrome, Wegener's disease, glomerulonephritis, aplastic anemia (including multiply transfused aplastic anemia patients), paroxysmal nocturnal hemoglobinuria, myelodysplastic syndrome, idiopathic thrombocytopenic purpura, autoimmune hemolytic anemia, Evan's syndrome, Factor VIII inhibitor syndrome, systemic vasculitis, dermatomyositis, polymyositis and rheumatic fever, autoimmune lymphoproliferative syndrome (ALPS), autoimmune bullous pemphigoid, Parkinson's disease, sarcoidosis, vitiligo, primary biliary cirrhosis, and autoimmune myocarditis.

Another embodiment provides a method for treating, ameliorating the symptoms of, inhibiting the progression of or prevention of an inflammatory disease by administering to a patient afflicted by one or more of these diseases a therapeutically effective amount of a herein disclosed anti-CD40 antibody. Inflammatory diseases include, but are not limited to, Crohn's disease, colitis, dermatitis, psoriasis, diverticulitis, hepatitis, irritable bowel syndrom (IBS), lupus erythematous, nephritis, Parkinson's disease, ulcerative colitis, multiple sclerosis (MS), Alzheimer's disease, arthritis, rheumatoid arthritis, asthma, and various cardiovascular diseases such as atherosclerosis and vasculitis. In certain embodiments, the inflammatory disease is selected from the group consisting of rheumatoid arthritis, diabetes, gout, cryopyrin-associated periodic syndrome, and chronic obstructive pulmonary disorder.

In another embodiment, anti-CD40 antibodies of the present invention are used to determine the structure of bound antigen, *e.g.*, conformational epitopes, which structure may then be used to develop compounds having or mimicking this structure, *e.g.*, through chemical modeling and SAR methods.

Various other embodiments of the present invention relate, in part, to diagnostic applications for detecting the presence of cells or tissues expressing CD40. Thus, the present disclosure provides methods of detecting CD40 in a sample, such as detection of cells or tissues expressing CD40. Such methods can be applied in a variety of known detection formats, including, but not limited to immunohistochemistry (IHC), immunocytochemistry (ICC), *in situ* hybridization (ISH), whole-mount *in situ* hybridization (WISH), fluorescent DNA *in situ* hybridization (FISH), flow cytometry, enzyme immuno-assay (EIA), and enzyme linked immuno-assay (ELISA).

ISH is a type of hybridization that uses a labeled complementary DNA or RNA strand (*i.e.*, primary binding agent) to localize a specific DNA or RNA sequence in a portion or section of a cell or tissue (*in situ*), or if the tissue is small enough, the entire tissue (whole mount ISH). One having ordinary skill in the art would appreciate that this is distinct from immunohistochemistry, which localizes proteins in tissue sections using an antibody as a primary binding agent. DNA ISH can be used on genomic DNA to determine the structure of chromosomes. Fluorescent DNA ISH (FISH) can, for example, be used in medical diagnostics to assess chromosomal integrity. RNA ISH (hybridization histochemistry) is used to measure and localize mRNAs and other transcripts within tissue sections or whole mounts.

In various embodiments, the antibodies described herein are conjugated to a detectable label that may be detected directly or indirectly. In this regard, an antibody "conjugate" refers to an anti-CD40 antibody that is covalently linked to a detectable label. In the present invention, DNA probes, RNA probes, monoclonal antibodies, antigen-binding fragments thereof, and antibody derivatives thereof, such as a single-chain-variable-fragment antibody or an epitope tagged antibody, may all be covalently linked to a detectable label. In "direct detection", only one detectable antibody is used, *i.e.*, a primary detectable antibody. Thus, direct detection means that the antibody that is conjugated to a detectable label may be detected, per se, without the need for the addition of a second antibody (secondary antibody).

A "detectable label" is a molecule or material that can produce a detectable (such as visually, electronically or otherwise) signal that indicates the presence and/or concentration of the label in a sample. When conjugated to a antibody, the detectable label can be used to locate and/or quantify the target to which the specific antibody is directed. Thereby, the presence and/or concentration of the target in a sample can be detected by detecting the signal produced by the detectable label. A detectable label can be detected directly or indirectly, and several different detectable labels conjugated to different specific-antibodies can be used in combination to detect one or more targets.

Examples of detectable labels, which may be detected directly, include fluorescent dyes and radioactive substances and metal particles. In contrast, indirect detection requires the application of one or more additional antibodies, *i.e.*, secondary antibodies, after application of the primary antibody. Thus, the detection is performed by the detection of the binding of the secondary antibody or binding agent to the primary detectable antibody. Examples of primary detectable binding agents or antibodies requiring addition of a secondary binding agent or antibody include enzymatic detectable binding agents and hapten detectable binding agents or antibodies.

In some embodiments, the detectable label is conjugated to a nucleic acid polymer which comprises the first binding agent (*e.g.*, in an ISH, WISH, or FISH process). In other embodiments, the detectable label is conjugated to an antibody which comprises the first binding agent (*e.g.*, in an IHC process).

Examples of detectable labels which may be conjugated to antibodies used in the methods of the present disclosure include fluorescent labels, enzyme labels, radioisotopes, chemiluminescent labels, electrochemiluminescent labels, bioluminescent labels, polymers, polymer particles, metal particles, haptens, and dyes.

Examples of fluorescent labels include 5-(and 6)-carboxyfluorescein, 5- or 6-carboxyfluorescein, 6-(fluorescein)-5-(and 6)-carboxamido hexanoic acid, fluorescein isothiocyanate, rhodamine, tetramethylrhodamine, and dyes such as Cy2, Cy3, and Cy5, optionally substituted coumarin including AMCA, PerCP,

phycobiliproteins including R-phycoerythrin (RPE) and allophycoerythrin (APC), Texas Red, Princeton Red, green fluorescent protein (GFP) and analogues thereof, and conjugates of R-phycoerythrin or allophycoerythrin, inorganic fluorescent labels such as particles based on semiconductor material like coated CdSe nanocrystallites.

Examples of polymer particle labels include micro particles or latex particles of polystyrene, PMMA or silica, which can be embedded with fluorescent dyes, or polymer micelles or capsules which contain dyes, enzymes or substrates.

Examples of metal particle labels include gold particles and coated gold particles, which can be converted by silver stains. Examples of haptens include DNP, fluorescein isothiocyanate (FITC), biotin, and digoxigenin. Examples of enzymatic labels include horseradish peroxidase (HRP), alkaline phosphatase (ALP or AP), β-galactosidase (GAL), glucose-6-phosphate dehydrogenase, β-N-acetylglucosamimidase, β-glucuronidase, invertase, Xanthine Oxidase, firefly luciferase and glucose oxidase (GO). Examples of commonly used substrates for horseradishperoxidase include 3,3'-diaminobenzidine (DAB), diaminobenzidine with nickel enhancement, 3-amino-9-ethylcarbazole (AEC), Benzidine dihydrochloride (BDHC), Hanker-Yates reagent (HYR), Indophane blue (IB), tetramethylbenzidine (TMB), 4-chloro-1-naphtol (CN), .alpha.-naphtol pyronin (.alpha.-NP), o-dianisidine (OD), 5-bromo-4-chloro-3-indolylphosp- hate (BCIP), Nitro blue tetrazolium (NBT), 2-(p-iodophenyl)-3-p-nitropheny- l-5-phenyl tetrazolium chloride (INT), tetranitro blue tetrazolium (TNBT), 5-bromo-4-chloro-3-indoxyl-beta-D-galactoside/ferro-ferricyanide (BCIG/FF).

Examples of commonly used substrates for Alkaline Phosphatase include Naphthol-AS-B 1-phosphate/fast red TR (NABP/FR), Naphthol-AS-MX-phosphate/fast red TR (NAMP/FR), Naphthol-AS-B1-phosphate/- fast red TR (NABP/FR), Naphthol-AS-MX-phosphate/fast red TR (NAMP/FR), Naphthol-AS-B1-phosphate/new fuschin (NABP/NF), bromochloroindolyl phosphate/nitroblue tetrazolium (BCIP/NBT), 5-Bromo-4-chloro-3-indolyl-b-- d-galactopyranoside (BCIG).

Examples of luminescent labels include luminol, isoluminol, acridinium esters, 1,2-dioxetanes and pyridopyridazines. Examples of electrochemiluminescent

labels include ruthenium derivatives. Examples of radioactive labels include radioactive isotopes of iodide, cobalt, selenium, tritium, carbon, sulfur and phosphorous.

Detectable labels may be linked to the antibodies described herein or to any other molecule that specifically binds to a biological marker of interest, *e.g.*, an antibody, a nucleic acid probe, or a polymer. Furthermore, one of ordinary skill in the art would appreciate that detectable labels can also be conjugated to second, and/or third, and/or fourth, and/or fifth binding agents or antibodies, etc. Moreover, the skilled artisan would appreciate that each additional binding agent or antibody used to characterize a biological marker of interest may serve as a signal amplification step. The biological marker may be detected visually using, *e.g.*, light microscopy, fluorescent microscopy, electron microscopy where the detectable substance is for example a dye, a colloidal gold particle, a luminescent reagent. Visually detectable substances bound to a biological marker may also be detected using a spectrophotometer. Where the detectable substance is a radioactive isotope detection can be visually by autoradiography, or non-visually using a scintillation counter. See, *e.g.*, Larsson, 1988, Immunocytochemistry: Theory and Practice, (CRC Press, Boca Raton, Fla.); Methods in Molecular Biology, vol. 80 1998, John D. Pound (ed.) (Humana Press, Totowa, N.J.).

The invention further provides kits for detecting CD40 or cells or tissues expressing CD40 in a sample, wherein the kits contain at least one antibody, polypeptide, polynucleotide, vector or host cell as described herein. In certain embodiments, a kit may comprise buffers, enzymes, labels, substrates, beads or other surfaces to which the antibodies of the invention are attached, and the like, and instructions for use.

EXAMPLES

EXAMPLE 1

PRODUCTION AND HUMANIZATION OF ANTI-CD40 ANTIBODIES

Four New Zealand white rabbits were immunized with recombinant rabbit Fc-hCD40. The rabbit with the highest serum titers of specific binding to human CD40 was chosen for cell fusion. A total of 172 hybridomas were identified as positive binders to soluble Fc-hCD40, of which 44 clones were found to be positive binders to cell surface CD40. After the epitope clustering assay, 24 representative hybridomas were selected for recombinant expression and further characterization. Secondary functional screening was carried out as described further below and included: 1) induction of DC maturation as measured by CD80, CD83, CD86 upregulation (agonist activity); 2) induction of direct tumor growth inhibition (agonist activity); and 3) ADCC antibody effector function. Candidates were selected based on dual functional screenings which included two arms: 1) binding affinity, antibody internalization, antibody dependent cellular cytotoxicity (ADCC), complement dependent cytotoxicty (CDC), and antibody dependent cellular phagocytosis (ADCP); and 2) agonist DC activation/maturation function, receptor-ligand interaction, mixed lymphocyte reaction (MLR), cell proliferation and apoptosis.

Screening Agonist Antibodies Via Dendritic Cell Maturation

To further clarify the agonist or antagonist effect of the initial panel of anti-CD40 antibodies, a DC maturation assay was used as an indicator to screen for functional antibodies. Anti-CD40 or control antibodies were added to human monocyte-derived DC culture solution for 2 days. Upregulation of CD83, one of the best-known maturation markers for human dendritic cells, was measured to screen for agonist antibodies. 5C11, a mouse monoclonal antibody that induces dendritic cell maturation was used as positive control. Antibodies R-3, R-6, R-8, R-9, R-16, R-18, R-24, R-33, R-36, 19-21, 19-45 and 19-59 increased more than 50% of CD83 expression as compared with Ig control (Figure 1A). DC maturation was further

determined by measuring the antibody-induced up-regulation of co-stimulatory molecules CD80 and CD86 for the selected antibodies. As shown in Figure 1B and Figure 1C, antibodies R-3, R-8, R-9, R-33 and 19-21 up-regulated both CD80 and CD86, while the other antibodies had only modest effects. These results were consistent with the CD83 modulation effects by these antibodies. Interestingly, among the antibodies capable of inducting DC maturation, only clone 19-21 showed strong activity to enhance T cells proliferation in a mixed-lymphocyte reaction (Figure 1D).

Screening For Direct Inhibition of Tumor Growth

The panel of agonist anti-CD40 antibodies was further assessed for the ability to induce the tumor growth inhibition of CD40 expressing tumor cells. All anti-CD40 antibodies tested inhibited tumor cell proliferation. The antibody 19-21 demonstrated the highest potency.(Figure 2).

Screening For ADCC Activity

In addition to induction of APC activation and tumor growth inhibition, antibody effector function, ADCC, was used as an important criterion to screen and rank the antibody candidates. In order to conduct the ADCC assay using human PBMC, all the selected antibodies were converted from rabbit mAb to chimeric mAb with rabbit Fab and human IgG1. As shown in Figure 3, all the selected candidates showed significant ADCC activity as compared to IgG1 control. Based on the maximal ADCC activity, the lead mAbs can be ranked cR-8 > cR-3 > cR-33 > c19-21> c R-9 > c19-59.

Four candidates (c19-21, cR-8, cR-3, cR-33) were selected based on *in vitro* functional screening. Their *in vitro* characterizations are summarized in Table 1. Antibody c19-21strongly enhances DC activation and tumor growth inhibition, while antibodies cR-8 and cR-3 showed more potent ADCC activity.

Table 1. Characteristics of 4 candidate anti-CD40 antibodies:

Antibody	**c19-21**	**cR-8**	**cR3**	**cR33**

Blocks CD40L binding	Yes	Yes	Yes	Yes
Enhances DC maturation	Strong	Strong	Strong	Strong
Pro- apoptosis activity (IC50)	0.02 μg/ml	0.45 μg/ml	0.57 μg/ml	0.90 μg/ml
ADCC (% cytotoxicity of Ramos cell at 1 μg/ml)	26%	33%	30%	29%

In vivo Anti-Tumor Activity Screening

As the top 4 candidates showed different potencies in different *in vitro* assays, we conducted *in vivo* studies to evaluate and compare their anti-tumor activity for lead selection. The Ramos tumor xenograft model was used. Tumor bearing mice were treated i.p. with 5mg/kg of chimeric antibodies cR-3, cR-8, cR-33 or c19-21 3 times per week for a total of 9 doses (eight animals per group). The anti-tumor activity of rituximab with the same regimen was used as a reference. As shown in Figure 4A, cR-8 and cR-3 showed the strongest anti-tumor effect. In contrast, 19-21 exhibited lower anti-tumor activity with faster tumor rebound after termination of dosing. The anti-tumor effect of cR-33 was in between, but still exhibited better *in vivo* efficacy than rituximab. The *in vivo* potency of antibodies cR-3 and cR-8 was further evaluated in a dose-response study. As shown in Figure 4B, cR-8 showed more potent anti-tumor efficacy than cR-3, and thus was identified as the lead anti-CD40 antibody.

The amino acid sequence of the heavy chain and light chain variable regions of the R-8 clone are set forth in SEQ ID NOs:1 and 2. The amino acid sequences of the CDRs of the VH and VL are set forth in SEQ ID NOs:3-5 and 6-8, respectively. The amino acid sequence of the heavy and light chain sequences of several of the other antibody candidates that showed functional activity are set forth in SEQ ID NOs:11-56. VHCDR and VLCDR amino acid sequences for these antibodies are provided in SEQ ID Nos:57-194. Figure 16 shows an alignment of these sequences, including the R-8 clone, with CDRs underlined.

R-8 was humanized using a proprietary mutational lineage guided (MLG) humanization technology (see *e.g.*, U.S. Patent No. 7,462,697). The light and heavy chain framework of the humanized R-8 (APX005) are 95% identical to the human germline sequences. The amino acid sequence of the humanized VH and VL regions are set forth in SEQ ID NOs:9 and 10, respectively. The binding of APX005 to CD40 were found to be similar to its parental clone R-8.

EXAMPLE 2

In Vitro Characterization of the APX005 Humanized Anti-CD40 Antibody

Numerous *in vitro* experiments were conducted to further characterize the APX005 humanized antibody.

APX005 Selectively Binds to CD40

Binding selectivity of APX005 was assessed by direct ELISA to a panel of TNFR family proteins. A total of 1μg/ml of fusion protein of rabbit Fc and CD40, RANK, TweakR, OX40, DR5 and 4-1BB were coated on ELISA plates. Bound APX005 was detected using goat anti-human HRP-conjugated IgG. As shown in Figure 5, APX005 selectively binds to human CD40 but not other TNFR family proteins tested.

APX005 Blocks Binding of CD40L to CD40

An ELISA was conducted to assess the effect of APX005 on CD40L binding to CD40. In particular, CD40L (4 μg/ml final concentration) was used to bind the immobilized human CD40 onto an ELISA plate, and changes in the binding amount of CD40L to CD40 were measured after pre-incubating immobilized CD40 with APX005. CD40L binding to immobilized CD40 was detected by a mouse anti-CD40L monoclonal antibody. As shown in Figure 6, APX005 blocks the binding of CD40L to CD40. In contrast, SGN-40 increases the binding.

APX005/CD40 Complex Is Not Internalized

In order to assess the target mediated-internalization of APX005 for evaluating its impact on ADCC activity, Ramos cells were incubated with APX005 for 4 h at 37 °C, a temperature permissive for internalization, or at 4 °C for 30 minutes, a temperature at which internalization is minimized. Cells were washed with staining buffer, followed by incubation with Alexa 488 labeled goat anti-human IgG for an additional 30 minutes at 4°C. FACS analysis was performed to examine the level of APX005 on the cell surface. As shown in Figure 7, there was no reduction (slight increase) of APX005 level on the cell surface after incubation at 37 °C. The data suggest that upon binding to CD40 APX005/CD40 complex was not internalized by tumor cells, thus providing optimal conditions for recruiting the effector cells for ADCC.

APX005 Mediates ADCC

In order to assess ADCC activity of APX005 on CD40 expressing tumor cells, CD40 expressing Ramos and Daudi were used as target cells and fresh human peripheral blood mononuclear cell (PBMC) were used as the effector cells. ADCC was measured by a calcein-AM release assay. Target cells were labeled with calcein-AM (15 uM/10^6 cells), washed, and plated in triplicate at 5 x10^3 per well in round-bottomed 96-well plates. Increasing concentrations (0.0001-10 μg/mL) of either APX005 or control antibodies were pre-incubated at 4°C for 30 minutes, after which PBMC effector cells from healthy human donors were added with a final effector:target cell ratio of 40:1 in a final volume of 200 uL per well. Experiments were performed using PBMC from at least three different donors. After a 4-hour incubation, 100μL culture supernatants were transferred to a Black View Plate-96 plate and arbitrary fluorescent units (AFU) were read on a Victor II plate reader (485 nm excitation/535 nm emission). Percent specific lysis = (AFU mean experimental release – AFU mean spontaneous release)/(AFU mean maximal release – AFU mean spontaneous release). As showin in Figure 8, APX005 induced ADCC in a dose-dependent fashion. A similar effect was observed for SGN-40. The different

sensitivity of Ramos and Daudi cells to the ADCC may be due to different CD40 expression level (Cancer Res 2005; 65: 8331-8338).

APX005 Inhibits Tumor Cell Proliferation

To assess the ability of APX005 to inhibit tumor cell proliferation, Ramos cells were seeded in 96-well flat-bottom plates at 50,000 cells/well in 200 μL RPMI 1640 supplemented with 10% FBS containing varying concentrations of APX005 , SGN-40 or a control human IgG. For cross-linking, APX005, SGN-40 or control IgG was pre-inbubated with F(ab')2 fragments of a goat anti-human IgG Fc fragment-specific antibody in the medium for 30 minutes at room temperature before being added to the cells. Cells were treated for a total of 72 hours. Then 10% AlamarBlue® (Serotec, Oxford, UK) was added to each well and incubated for an additional 24 hours. Cell viability was measured by a CytoFluor fluorescence reader with an excitation wavelength of 530 nm and emission wavelength of 590 nm. All studies were conducted twice and in triplicates for each sample concentration. As shown in Figure 9, monomer APX005 inhibited proliferation of Ramos cells (Figure 9A). When APX005 was cross-linked by a secondary antibody, it delivered an increased and dose-dependent proliferation inhibitory effect (Figure 9B). The cross-linking of APX005 can be achieved *in vivo* by Fc receptor expressing cells.

APX005 Induces DC Activation

In order to assess the ability of APX005 to stimulate the maturation of DC cells, PBMC were prepared by density gradient centrifugation using lymphocyte isolation solution. Adherent monocytes were harvested after incubating for 2 hours at 37°C. Isolated monocytes were cultured with 100 ng/ml of recombinant human GM-CSF and 100 ng/ml of recombinant human IL-4 in RPMI1640 media supplemented with 10% FCS in a 24-well plate. Half of the medium was changed after 3 days. On day 5 of culturing, 1.3 nM of anti-CD40 antibodies, CD40L or the control antibody were added to the DC cells, and further cultured for 48 h in a 24-well plate. For DC activation marker staining, PE-conjugated anti-CD83, anti-CD86 antibody and anti-CD80 antibody were used. Analysis was performed using FACS.

The data is from one representative study. As shown in Figure 10, APX005 induced marked DC maturation and its effect appears more potent than SGN-40 and CD40L. Increased activation of DC may lead to more potent anti-tumor T cell responses.

APX005 is Cross Reactive with Monkey CD40 but not Mouse CD40

Cross-reactivity was assessed by direct ELISA. A total of 1μg/ml of human CD40, monkey CD40 or mouse CD40 was coated on ELISA plates followed by incubation with 1μg/ml of APX005 or control IgG1. Antibodies bound to CD40 were detected using goat anti-human IgG conjugated with HRP. APX005 clearly crossreacts with monkey CD40 but not mouse CD40. (Figure 11A)

Cross-reactivity of APX005 with mouse CD40 was further determined by FACS binding to a mouse A20 cell line which expresses mouse CD40. An aliquot of $0.5x10^6$ A20 cells was added to 96 well plates and incubated with 100 μl diluted rat anti-mouse CD40 antibody conjugated with PE, APX005 or IgG1 control antibodies. After washing, 100 μl Goat-anti human IgG (H+L) conjugated with R-PE (Southern Biotech CAT#2040-09) were added at 1:200 dilution in PBS to the sample and incubated for detection of APX005 and control human IgG1. A rat anti-mouse CD40 antibody conjugated with PE was used as positive control. Samples were re-suspended with 0.5 ml PBS and analyzed by FACS. The FACS data showed that APX005 does not crossreact with mouse CD40 (Figure 11B).

In summary, the experiments in this Example showed that APX005 is a humanized IgG1 antibody that binds CD40. APX005 specifically binds to CD40 with a Kd of $9.6 x10^{-10}$ M and blocks CD40L binding to CD40. This is in contrast to the SGN40 anti-CD40 antibody that enhances the CD40-CD40L interaction. This suggests that these two antibodies bind to distinct epitopes. *In vitro*, APX005 showed potent ADCC activity to CD40 positive lymphoma cells (Ramos and Daudi) as well as the ability to directly inhibit tumor cell (Ramos) proliferation upon cross-linking. APX005 also stimulated the maturation of dendritic cells to enhance cellular

immune response. Additionally, APX005 was shown to cross-react with monkey CD40.

EXAMPLE 3

IN VIVO CHARACTERIZATION OF THE APX005 HUMANIZED ANTI-CD40 ANTIBODY

Numerous *in vivo* experiments were conducted to further characterize the APX005 humanized antibody.

APX005 Inhibition of Tumor Growth in the Ramos Model

In order to evaluate the effect of APX005 on the xenograft model of human B cell lymphoma, female BALB/c nu/nu mice 6–8 weeks of age were used for tumor cell innoculation. Xenografts were established by subcutaneous inoculation of 1×10^7 tumor cells/mouse into the dorsal flanks. When tumors reached an average volume of about 100 mm3 (50~200 mm3), the animals were randomized into groups. Antibodies were administered intraperitoneally at 3mg/kg starting at day 13 (see Figure 12). Dosing was administered 3 times per week for a total of 9 doses (eight animals per group). Perpendicular dimensions of the tumor were measured using a Vernier scale caliper. Tumor volumes were calculated using the formula: Volume = (length x width^2)/2. As shown in Figure 12A, APX005 demonstrated potent and long-lasting anti-tumor activity. Serum was taken at day 34, two days after the last dosing, for determining *in vivo* drug levels by measuring human IgG concentrations (see Figure 12B). The anti-tumor efficacy mediated by APX005 was greater than that of SGN-40 and persisted long after the dosing period. Single point PK analysis showed that the superior anti-tumor activity of APX005 was not due to PK difference.

APX005 Inhibition of Rituximab Pre-Treated and Resistant Tumors

The purpose of this experiment was to evaluate the effect of APX005 on rituximab pre-treated and resistant B cell lymphoma. Nude mice bearing established Ramos tumors were first treated with rituximab at 3 mg/kg for 5 doses.

Tumor growth was partially inhibited by rituximab (Figure 13A). When these tumors reached size about 700 mm^3, they were randomized into 4 groups (7 animals per group) and re-treated i.p. with APX005, rituximab, SGN40 analog 3 mg/kg or saline control for 3 weeks (Figure 13B). As shown in Figure 13, rituximab pre-treated tumors failed to respond to rituximab re-treatment, suggesting that these tumors are rituximab resistant (Figure 13B). APX005 exhibited the capability of inhibiting the growth of rituximab resistant tumors.

APX005 Inhibition of Tumor Growth in the Raji Model

The purpose of this experiment was to determine the dose and efficacy relationship of APX005 *in vivo*. Nude mice bearing established CD40 positive Raji tumors were treated with APX005 starting at day 15. Doses of APX005 ranging from 0.1 mg/kg – 10 mg/kg were administered i.p. 3 times/week for 2 weeks (eight animals per group) (see Figure 14). Saline was used as control treatment. Tumor volumes were measured on each dosing day. Serum levels of APX005 in each group were also measured 3 days after last dosing to determine the correlation of the *in vivo* efficacy with the levels of APX005 in the circulation. Clear dose-dependent anti-tumor activity was observed (see Figure 14). Differences in tumor volumes were significant ($P \leq 0.05$) between the control group and antibody treatment groups with dose levels ≥ 1mg/kg on days 29 to 33. The minimal effective dose was determined as 1 mg/kg, which corresponded to a median serum concentration of 0.49 μg/ml at day 36. Differences in tumor volumes between the 3, 5 and 10 mg/kg dose groups were not statistically significant. Thus, the maximal anti-tumor activity was achieved at doses ≥ 3 mg/kg with a median serum concentration ≥ 1.6μg/ml.

Inhibition of Tumor Growth in Human MM IM-9 Model by APX005

In order to evaluate the anti-tumor activity of APX005 in human multiple myeloma model, nude mice bearing established CD40 positive multiple myeloma IM-9 tumors were treated i.p. with APX005 or SGN40 starting at day 15. APX005 was

given at 3 mg/kg, 3 times/week for 3 weeks (5 animals per group). Tumor volumes were measured on each dosing day.

APX005 demonstrated potent anti-tumor activity against human multiple myeloma in the IM-9 xenograft model (see Figure 15). The anti-tumor efficacy mediated by APX005 was significantly greater than that of SGN-40 ($P < 0.05$).

Inhibition of Tumor Growth in the Ramos Model by APX005 as compared with SGN-40 and Rituximab

The purpose of this experiment was to compare the anti-tumor activity of APX005, rituximab and SGN-40 in a human B cell lymphoma Ramos xenograft model. Xenografts were established by subcutaneous inoculation of Ramos cells into the dorsal flanks of female SCID C.B -17 mice. When tumors reached an average volume of about 200-300 mm^3, the animals were randomized into 6 groups. Antibodies were administered intraperitoneally at doses as indicated in Figure 17. Dosing was administered 3 times per week for a total of 9 doses (10 animals per group). Perpendicular dimensions of the tumor were measured using a Vernier scale caliper. Tumor volumes were calculated using the formula: Volume = (length x width^2)/2. Survival of the mice was also determined and recorded.

APX005 demonstrated dose-dependent anti-tumor activity. Treatment with the high dose of APX005 (10 mg/kg) resulted in complete tumor regression, while rituximab at the same dose (10 mg/kg) only delayed tumor growth, suggesting that APX005 is more efficacious than rituximab in this model. APX005 is also more potent than SGN-40 (Figure 17A). APX005 not only inhibited tumor growth but also improved the survival of the tumor bearing animals (Figure 17B).

Inhibition of Tumor Growth in a rituximab-resistant human Namalwa lymphoma xenograft model

The purpose of this experiment was to compare the anti-tumor activity of APX005, rituximab and SGN-40 in the rituximab –resistant human Namalwa lymphoma model. Xenografts were established by subcutaneous inoculation of Namalwa cells into the dorsal flanks of female SCID C.B -17 mice. When tumors reached an average volume of about 200-300 mm3, the animals were randomized into 6 groups. Antibodies were administered i.p. at the doses indicated in Figure 18. Dosing was administered 3 times per week for a total of 9 doses (10 animals per group). Perpendicular dimensions of the tumor were measured using a Vernier scale caliper. Tumor volumes were calculated using the formula: Volume = (length x width^2)/2. Survival of the mice was also determined and recorded.

APX005 demonstrated potent anti-tumor activity in rituximab-resistant Namalwa lymphoma model (Figure 18A). APX005 also improved the survival of mice bearing rituximab-resistant tumors (Figure 18B).

In summary, the experiments in this Example showed that the efficacy of APX005 was examined in multiple xenograft tumor models. APX005 markedly inhibited the tumor growth in the Ramos model. Interestingly, the therapeutic effect persisted far beyond the dosing period. APX005 treatment resulted in inhibition of rituximab pre-treated and resistant tumors. A dose-range finding study was performed in the Raji model and found that minimal effective dose was determined as 1 mg/kg, and the maximal anti-tumor activity was observed at doses ≥ 3 mg/kg. In addition to B-cell lymphoma, APX005 also exhibited significant potent anti-tumor activity in the human multiple myeloma IM-9 model.

Thus, the above Examples demonstrate that APX005 can be used to improve the treatment of patients with NHL, CLL, multiple myeloma and certain solid tumors that express the CD40 target. Upon binding to CD40, APX005 recruits cytotoxic cells to kill tumor cells via ADCC. APX005 can also directly inhibit tumor cell proliferation and activate APC via its agonist activity. *In vivo*, APX005 markedly inhibited the growth of multiple CD40-expressing human tumor xenografts and showed long-lasting anti-tumor effects. APX005 is also capable of inhibiting human multiple myeloma and rituximab pre-treated and resistant tumors.

The various embodiments described above can be combined to provide further embodiments. All of the U.S. patents, U.S. patent application publications, U.S. patent application, foreign patents, foreign patent application and non-patent publications referred to in this specification and/or listed in the Application Data Sheet are incorporated herein by reference, in their entirety. Aspects of the embodiments can be modified, if necessary to employ concepts of the various patents, application and publications to provide yet further embodiments.

These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

CLAIMS

What is claimed is:

1. An isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising (i) a heavy chain variable region comprising the VHCDR1, VHCDR2, and VHCDR3 set forth in SEQ ID NOs:3-5; and (ii) a light chain variable region comprising the VLCDR1, the VLCDR2, and the VLCDR3 set forth in SEQ ID NOs:6-8;

or a variant of said antibody, or an antigen-binding fragment thereof, comprising heavy and light chain variable regions identical to the heavy and light chain variable regions of (i) and (ii) except for up to 8 amino acid substitutions in said CDR regions.

2. The isolated antibody, or an antigen-binding fragment thereof, of claim 1 comprising (i) a heavy chain variable region comprising the VHCDR1, VHCDR2, and VHCDR3 set forth in SEQ ID NOs:3-5; and (ii) a light chain variable region comprising the VLCDR1, the VLCDR2, and the VLCDR3 set forth in SEQ ID NOs:6-8.

3. The isolated antibody, or antigen-binding fragment thereof, of claim 1 wherein the heavy chain variable region comprises the amino acid sequence set forth in SEQ ID NO:9.

4. The isolated antibody, or antigen-binding fragment thereof, of claim 1 wherein the light chain variable region comprises the amino acid sequence set forth in SEQ ID NO:10.

5. An isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising a heavy chain variable region comprising the amino acid sequence set forth in SEQ ID NO:9 and a light chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:10.

6. The isolated antibody, or an antigen-binding fragment thereof, of claim 5 comprising a light chain variable region which comprises the amino acid sequence set forth in SEQ ID NO:10.

7. An isolated antibody, or an antigen-binding fragment thereof, that binds to CD40, comprising a light chain variable region comprising the amino acid sequence set forth in SEQ ID NO:10 and a heavy chain variable region which comprises an amino acid sequence having at least 90% identity to the amino acid sequence set forth in SEQ ID NO:9.

8. The isolated antibody of claim 1, wherein the antibody is humanized.

9. The isolated antibody, or antigen-binding fragment thereof, of claim 1 that binds CD40 with a KD of 0.96 nM or lower.

10. The isolated antibody, or antigen-binding fragment thereof of claim 9, wherein the isolated antibody, or antigen-binding fragment thereof:
a) blocks binding of CD40 to CD40L;
b) is a CD40 agonist;
c) activates antigen presenting cells;
d) stimulates cytokine release from antigen presenting cells;
e) induces tumor cell apoptosis;
f) inhibits tumor cell proliferation;
g) kills tumor cells via induction of effector functions selected from the group consisting of antibody dependent cellular cytotoxicity, complement dependent cytotoxicty, and antibody dependent cellular phagocytosis;
h) stimulates anti-tumor T cell responses;
i) reduces established tumors;
j) inhibits rituximab-resistant tumors and other CD40 expressing tumors; or

k) a combination of any one or more of a)-j).

11. A composition comprising a physiologically acceptable carrier and a therapeutically effective amount of the isolated antibody or antigen-binding fragment thereof according to claim 1.

12. A composition comprising a physiologically acceptable carrier and a therapeutically effective amount of the isolated antibody or antigen-binding fragment thereof according to claim 6.

13. The isolated antibody of claim 1 wherein the antibody is selected from the group consisting of a single chain antibody, a ScFv, a univalent antibody lacking a hinge region, and a minibody.

14. The isolated antibody of claim 1 wherein the antibody is a Fab or a Fab' fragment.

15. The isolated antibody of claim 1 wherein the antibody is a whole antibody.

16. The isolated antibody of claim 1 wherein the isolated antibody comprises an IgG1 Fc region.