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(71) Applicants: **TRANSBIO LTD** [AU/AU]; La Trobe University R&D Park, TEC Building 2, Suite 7, 2 Park Drive, Bundoora, Victoria 3083 (AU). **THE UNIVERSITY OF QUEENSLAND** [AU/AU]; St Lucia, Queensland 4072 (AU). **UNIVERSITY OF CALIFORNIA** [US/US]; A California Corporation, having its statewide administrative offices located at, 1111 Franklin Street, Twelfth Floor, Oakland, California 94607-5200 (US).

(72) Inventors; and

(71) Applicants : **SELDON, Therese Ann** [AU/AU]; c/- Transbio Ltd, La Trobe University R&D Park, TEC Building 2, Suite 7, 2 Park Drive, Bundoora, Victoria 3083 (AU). **MUNSTER, David John** [NZ/AU]; 29A Wyncroft Street, Holland Park, Queensland 4121 (AU). **HART, Derek Nigel John** [AU/AU]; Dendritic Cell Biology and Therapeutics, ANZAC Research Institute, Hospital Road, Concord, New South Wales 2139 (AU). **JONES, Martina Louise** [AU/AU]; 11 Geneva Crescent, Narangba, Queens-

land 4504 (AU). **MUNRO, Trent Phillip** [AU/US]; 1915 Seabreeze Street, Newbury Park, California 91320 (US). **MAHLER, Stephen Michael** [AU/AU]; 149 Taringa Parade, Indooroopilly, Queensland 4068 (AU). **ZHOU, Eunice Yu** [US/US]; 2527 Kirkham Street, San Francisco, California 94122 (US). **MARKS, James D** [US/US]; 107 Ardmore Road, Kensington, California 94707 (US).

(74) Agent: **FB RICE**; Level 14, 90 Queen Street, Melbourne, Victoria 3000 (AU).

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(54) Title: ANTI-CD83 ANTIBODIES AND USE THEREOF

(57) Abstract: The present disclosure relates to proteins that bind to CD83 and uses thereof, for example, in therapy, prophylaxis, diagnosis, or prognosis.

## ANTI-CD83 ANTIBODIES AND USE THEREOF

### FIELD

The present disclosure relates to proteins that bind to CD83 and uses thereof, for  
5 example, in therapy, prophylaxis, diagnosis, or prognosis.

### BACKGROUND

#### CD83

CD83 is a 45 kDa, type-I membrane glycoprotein belonging to the  
10 immunoglobulin superfamily. CD83 is a cell surface marker predominantly expressed  
on mature dendritic cells (DCs). CD83 is minimally expressed on immature blood DC  
(BDC) and monocyte derived DC (MoDC). Due to its preferential expression on  
mature DCs, CD83 is an attractive target for immunotherapy.

#### 15 Dendritic Cells and the Control of Innate and Adaptive Immune Responses

DCs link the innate and cognate (adaptive) immune systems. Innate immunity is  
the primary driver of non-specific immune activation in response to foreign agents.  
Immature DCs specialize in the internalisation of antigens and are distributed  
throughout peripheral tissues allowing for continuous antigenic surveillance. Termed  
20 professional antigen presenting cells (APCs) for their capability to drive primary T cell  
responses, DCs only require minimal quantities of antigen to initiate immune  
activation.

Immature DCs are attuned to a variety of signals from infectious and foreign  
material, which trigger differentiation and maturation (also known as activation) of the  
25 DCs. Whilst mature DCs are capable of antigen capture, this activation process reduces  
the capacity of these cells to internalize antigen, instead up-regulating cytokine release,  
activation marker expression and processing of antigen for major histocompatibility  
complex (MHC) presentation. Mature DCs loaded with processed antigen can  
efficiently recruit T cells, B cells, granulocytes, natural killer (NK) cells, monocytes  
30 and other cells of the innate immune system to amplify the response to antigen.

The molecules which become expressed upon DC differentiation and activation  
aid in linking innate and adaptive immunity. Mature DCs up-regulate the expression of  
chemokine receptors and adhesion molecules such as CD54, facilitating DC migration  
to lymph nodes for increased interaction with lymphocytes. Expression of  
35 costimulatory molecules, such as CD80 and CD86, provides the requisite co-  
stimulatory signals for T cell activation and the initiation of an antigen-specific

immune response. Ligation of CD40 enhances the expression of co-stimulatory molecules and induces the release of IL-12 to facilitate T cell activation; differentiated T cells then orchestrate the complex interactions of the adaptive immune response.

Since DCs exert control over immune responses, activated DCs can be viewed  
5 as a target for intervention across a number of immunological diseases including malignancy and autoimmune diseases.

It will be apparent to the skilled person from the foregoing that compounds that target DCs may modulate the immune response. Accordingly, compounds that bind  
10 DCs are desirable, for example, for their therapeutic, prophylactic, diagnostic and prognostic uses.

## SUMMARY

The present disclosure is based on the inventors' production of a human  
15 antibody (3C12 mAb) that binds specifically to CD83. 3C12 mAb was derived from a phage display library of human scFv sequences; the obtained scFv phage clone reformatted as an IgG1 mAb.

The 3C12 mAb was shown to out compete its polyclonal equivalent, RA83, in competitive binding assays and delay onset of graft versus host disease (GVHD) in  
20 SCID mice transplanted with a xenogeneic graft of human PBMC.

To improve the therapeutic efficacy of the 3C12 mAb, the inventors performed affinity maturation of the light chain to improve the affinity of the 3C12 mAb for CD83. Four new 3C12 scFv variants (3C12.B, 3C12.C, 3C12.D and 3C12.E) with distinct light chain variable region ( $V_L$ ) sequences and enhanced binding properties  
25 relative to the wild type scFv were obtained. The affinity matured antibodies included substitutions in the framework (FR) and complementarity determining regions (CDRs) of the  $V_L$ . The effect of these substitutions were not predictable.

The inventors also produced forms of 3C12 mAb capable of inducing enhanced levels of effector function, with defucosylated 3C12.C mAb having comparable  
30 potency to polyclonal antibody, RA83.

The present disclosure is broadly directed to a CD83 binding protein comprising an antigen binding domain which specifically binds to CD83.

In one example, the present disclosure provides a CD83 binding protein comprising an antigen binding domain which specifically binds to CD83, wherein the  
35 binding protein comprises a heavy chain variable region ( $V_H$ ) which comprises a sequence which is at least 90% identical to the amino acid sequence shown in SEQ ID

NO:1. In one example, the heavy chain variable region ( $V_H$ ) comprises a sequence which is at least 90% identical to the frame work regions of the amino acid sequence shown in SEQ ID NO:1.

The present disclosure additionally or alternatively provides a CD83 binding  
5 protein comprising an antigen binding domain which specifically binds to CD83, wherein the binding protein comprises a heavy chain variable region ( $V_H$ ) which comprises three complementarity determining regions (CDRs) of the amino acid sequence shown in SEQ ID NO:1.

In one example, the  $V_H$  CDR1 comprises amino acids 31 to 35 of SEQ ID NO:1,  
10 the  $V_H$  CDR2 comprises amino acids 50 to 59 of SEQ ID NO:1 and the  $V_H$  CDR3 comprises amino acids 99 to 106 of SEQ ID NO:1.

In one example, the  $V_H$  CDR1 comprises the amino acid sequence shown in SEQ ID NO:2, the  $V_H$  CDR2 comprises the amino acid sequence shown in SEQ ID NO:3 and the  $V_H$  CDR3 comprises the amino acid sequence shown in SEQ ID NO:4.

15 The present disclosure additionally or alternatively provides a CD83 binding protein comprising an antigen binding domain which specifically binds to CD83, wherein the binding protein comprises a light chain variable region ( $V_L$ ) which comprises:

(i) a sequence which is at least 90% identical to any one of the amino acid  
20 sequences shown in SEQ ID NO:5, 6, 7, 8, or 9; or

(ii) three complementarity determining regions (CDRs) of any one of the amino acid sequences shown in SEQ ID NO:5, 6, 7, 8, or 9; or

(iii) a consensus sequence as shown in SEQ ID NO:10; or

(iv) three CDRs, wherein the amino acid sequence of CDR1, CDR2, or CDR3  
25 is a consensus sequence shown in SEQ ID NO:26, 27, or 28.

In one example, the light chain variable region ( $V_L$ ) comprises a sequence which is at least 90% identical to the frame work regions of any one of the amino acid sequences shown in SEQ ID NO:5, 6, 7, 8, or 9.

In one example, the  $V_L$  CDR1 comprises amino acids 24 to 34 of SEQ ID NO:5,  
30 6, 7, 8, or 9, the  $V_L$  CDR2 comprises amino acids 50 to 56 of SEQ ID NO:5, 6, 7, 8, or 9 and the  $V_L$  CDR3 comprises amino acids 89 to 97 of SEQ ID NO:5, 6, 7, 8, or 9.

In one example, the  $V_L$  CDR1 comprises the amino acid sequence shown in SEQ ID NO:11, 14, 17, 20, or 23, the  $V_L$  CDR2 comprises the amino acid sequence shown in SEQ ID NO:12, 15, 18, 21, or 24 and the  $V_L$  CDR3 comprises the amino acid  
35 sequence shown in SEQ ID NO:13, 16, 19, 22, or 25.

In one example, the amino acid sequence of V<sub>L</sub> CDR1 comprises an Alanine (A) or Threonine (T) at position 2 and/or a Lysine (K) or Serine (S) or Arginine (R) at position 7 and/or an Asparagine (N) or Serine (S) at position 8 and/or a Tyrosine (Y) or Histidine (H) or Tryptophan (W) at position 9 and/or a Phenylalanine (F) or Leucine (L) at position 10.

In one example, the amino acid sequence of V<sub>L</sub> CDR2 comprises a Threonine (T) or Alanine (A) at position 2 and/or an Asparagine (N) or Serine (S) or Threonine (T) at position 4.

In one example, the amino acid sequence of V<sub>L</sub> CDR3 comprises a Glutamine (Q) or Lysine (K) at position 2 and/or a Leucine (L) or Valine (V) or Cysteine (C) at position 3 and/or a Glycine (G) or Asparagine (N) or Aspartic Acid (D) or Serine (S) at position 4 and/or an Alanine (A) or Serine (S) or Arginine (R) at position 5 and/or a Tyrosine (Y) or Phenylalanine (F) or Alanine (A) at position 6 and/or a Tyrosine (Y) or Leucine (L) at position 8.

In one example, the V<sub>H</sub> and the V<sub>L</sub> are in a single polypeptide chain. For example, the CD83 binding protein is:

- (i) a single chain Fv fragment (scFv); or
- (ii) a dimeric scFv (di-scFv); or
- (iii) (i) or (ii) linked to a Fc or a heavy chain constant domain (C<sub>H</sub>)<sub>2</sub> and/or C<sub>H</sub>3; or
- (iv) (i) or (ii) linked to a protein that binds to an immune effector cell.

In another example, the V<sub>L</sub> and V<sub>H</sub> are in separate polypeptide chains. For example, the CD83 binding protein is:

- (i) a diabody; or
- (ii) a triabody; or
- (iii) a tetrabody; or
- (iv) a Fab; or
- (v) a F(ab')<sub>2</sub>; or
- (vi) a Fv; or
- (vii) one of (i) to (vi) linked to a Fc or a C<sub>H</sub>2 and/or C<sub>H</sub>3; or
- (viii) one of (i) to (vi) linked to a protein that binds to an immune effector cell.

In one example, a CD83 binding protein of the disclosure comprises an antigen binding domain that competitively inhibits the binding of an antibody to CD83, the antibody comprising a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:30.

Exemplary CD83 binding proteins of the present disclosure comprise a V<sub>H</sub> of the disclosure and a chimeric, de-immunized, humanized, human, synhumanized or primatized light chain or V<sub>L</sub>.

In an exemplary form of the present disclosure, the CD83 binding protein is an antibody. The antibody may comprise:

- (i) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:5; or
- (ii) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:6; or
- 10 (iii) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:7; or
- (iv) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:8; or
- (v) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in  
15 SEQ ID NO:9; or
- (vi) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:30; or
- (vii) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:31; or
- 20 (viii) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:32; or
- (ix) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:33; or
- (x) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain  
25 sequence as shown in SEQ ID NO:34.

In one example, the antibody depletes cells to which it binds, for example, immune cells such as antigen presenting cells (APC) (e.g., dendritic cells (DCs)) and/or lymphocytes (e.g., T cells).

As will be apparent to the skilled artisan from the disclosure herein, exemplary  
30 CD83 binding proteins are capable of depleting cells to which they bind without being conjugated to a toxic compound.

In one example, the CD83 binding protein is capable of inducing an effector function, for example, an effector function that results in killing a cell to which antibody binds. Exemplary effector functions include antibody dependent cell-  
35 mediated cytotoxicity (ADCC), antibody-dependent cell-mediated phagocytosis (ADCP) and/or complement-dependent cytotoxicity (CDC).

In one example, the CD83 binding protein is capable of inducing ADCC.

In one example, the CD83 binding protein comprises an antibody Fc region capable of inducing an effector function. For example, the effector function is Fc-mediated effector function. In one example, the Fc region is an IgG1 Fc region or an  
5 IgG3 Fc region or a hybrid IgG1/IgG2 Fc region.

In one example, the CD83 binding protein is capable of inducing a similar (e.g., not significantly different or within about 10%) or the same level of effector function as a wild-type human IgG1 and/or human IgG3 Fc region.

In one example, the CD83 binding protein is capable of inducing an enhanced  
10 level of effector function.

In one example, the level of effector function induced by the CD83 binding protein is enhanced relative to that of the CD83 binding protein when it comprises a wild-type IgG1 Fc region.

In one example the CD83 binding protein is defucosylated or comprises a Fc  
15 region that is defucosylated.

In another example, the CD83 binding protein has a lower level of fucosylation compared to an antibody produced by a human or a CHO cell that has not been altered to reduce the level of fucosylation of proteins. In accordance with this example, a lower level of fucosylation will be understood to mean that in a composition  
20 comprising the CD83 binding protein, the percentage of fucosylated CD83 binding proteins (e.g., glycosyl groups attached to Asn297 of an antibody comprising fucose) is lower than produced by a human or a CHO cell that has not been altered to reduce the level of fucosylation of proteins.

For example, the CD83 binding protein is a defucosylated antibody comprising  
25 a V<sub>H</sub> comprising an amino acid sequence as shown in SEQ ID NO:1 (or encoded by a nucleotide sequence set forth in SEQ ID NO:35) and a V<sub>L</sub> comprising an amino acid sequence as shown in any one of SEQ ID NOs:5, 6, 7, 8, or 9 (or encoded by a nucleotide sequence as shown in any one of SEQ ID NOs:36, 37, 38, 39, or 40).

In one example, the CD83 binding protein comprises a V<sub>H</sub> comprising an amino  
30 acid sequence as shown in SEQ ID NO:1 (or encoded by a nucleotide sequence as shown in SEQ ID NO:35) and a V<sub>L</sub> comprising an amino acid sequence as shown in any one of SEQ ID NOs:5, 6, 7, 8, or 9 (or encoded by a nucleotide sequence as shown in any one of SEQ ID NO:36, 37, 38, 39, or 40) and is expressed by a mammalian cell (e.g., a CHO cell) that does not express detectable levels of (or expresses reduced levels  
35 of)  $\alpha$ -1,6-fucosyltransferase (FUT8) or is treated with an inhibitor of N-glycan processing such as kifunensine.

In one example, the CD83 binding protein comprises an Fc region comprising one or more amino acid sequence substitutions that enhance the effector function induced by the antibody. For example, the one or more amino acid sequence substitutions increase the affinity of the Fc region for a Fc $\gamma$  receptor (Fc $\gamma$ R) compared to a Fc region not comprising the substitutions. For example, the one or more amino acid substitutions increase the affinity of the Fc region for a Fc $\gamma$ R selected from the group consisting of Fc $\gamma$ RI, Fc $\gamma$ RIIa, Fc $\gamma$ RIIc and Fc $\gamma$ RIIIa compared to a Fc region not comprising the substitutions.

In one example, a CD83 binding protein of the present disclosure is a naked antibody or antigen binding fragment thereof.

In one example, a CD83 binding protein of the present disclosure is a full length antibody.

In one example, a CD83 binding protein of the present disclosure binds to CD83 with an equilibrium dissociation constant ( $K_D$ ) of  $5 \times 10^{-7}$  M or less, such as  $4.5 \times 10^{-7}$  M or less, such as  $4 \times 10^{-7}$  M or less, such as  $3.5 \times 10^{-7}$  M or less, such as  $3 \times 10^{-7}$  M or less, such as  $2.5 \times 10^{-7}$  M or less, such as  $2 \times 10^{-7}$  M or less, such as  $1.5 \times 10^{-7}$  M or less, such as  $1 \times 10^{-7}$  M or less, such as  $9.5 \times 10^{-8}$  M or less, such as  $9 \times 10^{-8}$  M or less, such as  $8.5 \times 10^{-8}$  M or less, such as  $8 \times 10^{-8}$  M or less, such as  $7.5 \times 10^{-8}$  M or less, such as  $7 \times 10^{-8}$  M or less, such as  $6.5 \times 10^{-8}$  M or less, such as  $6 \times 10^{-8}$  M or less,  $5.5 \times 10^{-8}$  M or less, such as  $5 \times 10^{-8}$  M or less, such as  $4.5 \times 10^{-8}$  M or less, such as  $4 \times 10^{-8}$  M or less, such as  $3.5 \times 10^{-8}$  M or less, such as  $3 \times 10^{-8}$  M or less, such as  $2.5 \times 10^{-8}$  M or less, such as  $2 \times 10^{-8}$  M or less, such as  $1.5 \times 10^{-8}$  M or less, such as  $1 \times 10^{-8}$  M or less, such as  $9.5 \times 10^{-9}$  M or less, such as  $9 \times 10^{-9}$  M or less, such as  $8.5 \times 10^{-9}$  M or less, such as  $8 \times 10^{-9}$  M or less, such as  $7.5 \times 10^{-9}$  M or less, such as  $7 \times 10^{-9}$  M or less, such as  $6.5 \times 10^{-9}$  M or less, such as  $6 \times 10^{-9}$  M or less, such as  $5.5 \times 10^{-9}$  M or less, such as  $5 \times 10^{-9}$  M.

In one example, a CD83 binding protein of the present disclosure binds to CD83 with a  $K_D$  of about  $6 \times 10^{-9}$  M or less, for example,  $6.1 \times 10^{-9}$  M. In one example, the  $K_D$  is between about  $5.5 \times 10^{-9}$  M and about  $6.5 \times 10^{-9}$  M, for example, is about  $6 \times 10^{-9}$  M.

In one example, a CD83 binding protein of the present disclosure binds to CD83 with an on rate ( $K_{on}$ ) of  $5 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $4.5 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $4 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $3.5 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $3 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $2.5 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $2 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $1.5 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $1 \times 10^6$   $M^{-1}s^{-1}$  or less, such as  $9.5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $9 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $8.5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $8 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $7.5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $7 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $6.5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $6 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $5.5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $5 \times 10^5$   $M^{-1}s^{-1}$  or less, such as  $4.5 \times 10^5$   $M^{-1}s^{-1}$  or

less, such as  $4 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $3.5 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $3 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $2.5 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $2 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $1.5 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$  or less, such as  $1 \times 10^5 \text{ M}^{-1} \text{ s}^{-1}$ .

In one example, a CD83 binding protein of the present disclosure binds to CD83  
5 with a  $K_{\text{on}}$  of about  $1.5 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$  or less. In one example, the  $K_{\text{D}}$  is between about  $1.2 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$  and about  $1.6 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$ , for example, is about  $1.3 \times 10^6 \text{ M}^{-1} \text{ s}^{-1}$ .

In one example, a CD83 binding protein of the present disclosure dissociates from CD83 with an off rate of ( $K_{\text{off}}$ ) of  $1.5 \times 10^{-1} \text{ s}^{-1}$  or less, such as  $1 \times 10^{-1} \text{ s}^{-1}$  or less, such as  $9.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $9 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $8.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  
10  $8 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $7.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $7 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $6.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $6 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $5.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $4.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $4 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $3.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $3 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $2.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $2 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $1.5 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $1 \times 10^{-2} \text{ s}^{-1}$  or less, such as  $9.5 \times 10^{-3} \text{ s}^{-1}$  or less, such as  $9 \times 10^{-3}$   
15  $\text{ s}^{-1}$  or less, such as  $8.5 \times 10^{-3} \text{ s}^{-1}$  or less, such as  $8 \times 10^{-3} \text{ s}^{-1}$  or less, such as  $7.5 \times 10^{-3} \text{ s}^{-1}$  or less, such as  $7 \times 10^{-3} \text{ s}^{-1}$ .

In one example, a CD83 binding protein of the present disclosure dissociates from CD83 with a  $K_{\text{off}}$  of about  $8 \times 10^{-3} \text{ s}^{-1}$  or less. In one example, the  $K_{\text{D}}$  is between about  $7 \times 10^{-3} \text{ s}^{-1}$  and about  $9 \times 10^{-3} \text{ s}^{-1}$ , for example, is about  $8 \times 10^{-3} \text{ s}^{-1}$ .

20 The disclosure also includes fragments, variants and derivatives of the antibody of the disclosure.

In one example, the disclosure provides a pharmaceutical composition comprising a CD83 binding protein according to the present disclosure and a suitable carrier, for example, a pharmaceutically acceptable carrier, diluent or excipient.

25 The present disclosure also provides an isolated or recombinant nucleic acid encoding a CD83 binding protein of the present disclosure.

Exemplary sequences of nucleic acids are discussed in the context of encoding CD83 binding proteins of the disclosure and are to be taken to apply *mutatis mutandis* to the present example of the disclosure.

30 In one example, the nucleic acid of the disclosure comprises a nucleotide sequence as shown in any one of SEQ ID NOs:35 to 46.

The present disclosure also provides a nucleic acid capable of hybridizing to a nucleic acid of the disclosure under moderate or high stringency hybridization conditions.

35 The disclosure also includes fragments, homologs and derivatives of an isolated nucleic acid of the disclosure.

The present disclosure also provides a genetic construct comprising an isolated or recombinant nucleic acid of the disclosure and one or more additional nucleotide sequences, such as a promoter operably linked to the nucleic acid.

In one example, the genetic construct is an expression construct comprising an  
5 expression vector and an isolated or recombinant nucleic acid of the disclosure, wherein said isolated or recombinant nucleic acid is operably linked to one or more regulatory nucleic acids in said expression vector.

In one example, the genetic construct of the disclosure comprises a nucleic acid encoding a polypeptide (e.g., comprising a  $V_H$ ) operably linked to a promoter and a  
10 nucleic acid encoding another polypeptide (e.g., comprising a  $V_L$ ) operably linked to a promoter.

In another example, the genetic construct is a bicistronic genetic construct, for example, comprising the following operably linked components in 5' to 3' order:

- (i) a promoter;
- 15 (ii) a nucleic acid encoding a first polypeptide;
- (iii) an internal ribosome entry site; and
- (iv) a nucleic acid encoding a second polypeptide.

For example, the first polypeptide comprises a  $V_H$  and the second polypeptide comprises a  $V_L$ , or the first polypeptide comprises a  $V_L$  and the second polypeptide  
20 comprises a  $V_H$ .

The present disclosure also contemplates separate genetic constructs one of which encodes a first polypeptide (e.g., comprising a  $V_H$ ) and another of which encodes a second polypeptide (e.g., comprising a  $V_L$ ). For example, the present disclosure also provides a composition comprising:

- 25 (i) a first genetic construct comprising a nucleic acid encoding a polypeptide (e.g., comprising a  $V_H$ ) operably linked to a promoter; and
- (ii) a second genetic construct comprising a nucleic acid encoding a polypeptide (e.g., comprising a  $V_L$ ) operably linked to a promoter.

The disclosure also provides a cell comprising a genetic construct according to  
30 the present disclosure.

In one example, the present disclosure provides an isolated cell expressing a CD83 binding protein of the disclosure or a recombinant cell genetically-modified to express the CD83 binding protein of the invention.

In one example, the cell comprises the genetic construct of the disclosure or:

- 35 (i) a first genetic construct comprising a nucleic acid encoding a polypeptide (e.g., comprising a  $V_H$ ) operably linked to a promoter; and

(ii) a second genetic construct comprising a nucleic acid encoding a polypeptide (e.g., comprising a V<sub>L</sub>) operably linked to a promoter, wherein the first and second polypeptides form an antibody or an antigen binding fragment of the present disclosure.

5 The genetic construct can be integrated into the cell or remain episomal.

Examples of cells of the present disclosure include bacterial cells, yeast cells, insect cells or mammalian cells.

The present disclosure additionally provides a method for producing a CD83 binding protein of the disclosure, the method comprising maintaining the genetic  
10 construct(s) of the disclosure under conditions sufficient for the CD83 binding protein to be produced.

In one example, the method for producing a CD83 binding protein of the disclosure comprises culturing the cell of the disclosure under conditions sufficient for the CD83 binding protein to be produced and, optionally, secreted.

15 In one example, the method for producing a CD83 binding protein of the disclosure additionally comprises isolating the CD83 binding protein.

The present disclosure additionally provides a method of producing a recombinant CD83 binding protein, the method including the steps of:

(i) culturing a cell containing an expression vector according to the disclosure  
20 such that the recombinant immunoglobulin or antibody is expressed in said host cell; and

(ii) isolating the recombinant CD83 binding protein.

In one example, a method for producing a CD83 binding protein of the disclosure additionally comprises formulating the CD83 binding protein with a pharmaceutically  
25 acceptable carrier.

The present disclosure also provides a method of therapeutic or prophylactic treatment of a disease or condition in a subject, the method including the step of administering the CD83 binding protein of the disclosure to the subject to thereby treat or prevent the disease or condition.

30 In one example, the subject is a mammal.

In one example, the mammal is a human.

In one example, the mammal is in need of treatment or prophylaxis.

In one example, the mammal in need suffers from the disease or condition.

In one example, the mammal in need is at risk of developing the disease or  
35 condition or a relapse thereof.

The present disclosure also provides for use of a CD83 binding protein of the disclosure or a composition of the disclosure in medicine.

The present disclosure additionally or alternatively provides for use of a CD83 binding protein of the disclosure in the manufacture of a medicament for the treatment  
5 of a disease or condition in a subject.

The present disclosure also provides a CD83 binding protein of the disclosure for use in the treatment of a disease or condition in a subject.

In one example, the disease or condition is a CD83 mediated disease or condition.

In one example, the disease or condition is an autoimmune disease or condition,  
10 or an inflammatory disease or condition. For example, the disease or condition is myasthenia gravis, multiple sclerosis, vasculitis, chronic inflammatory bowel diseases such as Morbus Crohn or colitis ulcerosa, HLA B27-associated autoimmune disorders such as Morbus Bechterew, and systemic lupus erythematosus, skin diseases such as psoriasis, rheumatoid arthritis, and insulin-dependent diabetes mellitus.

15 In one example, the disease or condition is caused by the dysfunction or undesired function of the immune system or a cellular response involving antigen presenting cells (APC) (e.g., dendritic cells (DCs)) and/or lymphocytes (e.g., T cells) in a subject.

In another example, the disease or condition is rejection of a tissue or organ graft.  
20 For example, rejection of a tissue or organ transplant occurs as a result of graft versus host disease or host versus graft disease.

In another example, the disease or condition is rejection of a stem cell graft, for example, an hematopoietic stem cell transplantation (HSCT) or an umbilical cord blood transplantation (UCBT). For example, rejection of the stem cell transplant occurs as a  
25 result of graft versus host disease or host versus graft disease. The HSCT may be derived from, for example, the bone marrow directly or from the peripheral blood following mobilization of cells from the bone marrow (e.g. by administration of G-CSF).

In one example, the method comprises administering an effective amount of the  
30 CD83 binding protein, such as a therapeutically effective amount of the CD83 binding protein to the donor and/or recipient. The graft may be contacted with an effective amount of the CD83 binding protein *ex vivo* or *in vivo* prior to or after being transplanted.

The present disclosure also provides a method for down-regulating the  
35 immunoactivity of an allogeneic graft, the method comprising contacting the graft with a CD83 binding protein or a composition of the disclosure.

In one example, the allogeneic graft is an hematopoietic stem cell graft.

In one example, the graft is contacted with a CD83 binding protein or a composition of the disclosure ex vivo.

In another or additional example, the recipient of the graft is administered a  
5 CD83 binding protein or a composition of the disclosure prior to and/or simultaneously  
with and/or following transplant of the graft.

### **BRIEF DESCRIPTION OF THE FIGURES**

#### **Figure 1: Analysis of the expression and purification of 3C12 IgG1**

10 (A) Non-reduced (NR) and 2-mercaptoethanol reduced (R) samples of culture  
supernatants (i, iii) and 5  $\mu\text{g}$  affinity purified material (ii, iv) were separated on 4–12%  
SDS-PAGE and stained with Coomassie Blue R250. (B) Analytical size exclusion  
chromatography (SEC) of protein-A purified recombinant 3C12 antibody at both 280  
nm (top panel) and 215 nm (middle panel), and gel filtration standards at 215 nm  
15 (bottom panel). The sample shows no detectable aggregation and a predicted molecular  
weight of 145kDa.

#### **Figure 2: Functional analysis of purified 3C12, an anti-human CD83 IgG**

(A) 25  $\mu\text{g}\cdot\text{mL}^{-1}$  3C12 IgG1 binds the CD83<sup>+</sup> cell lines KM-H2 and L428 and also  
20 FDCP1 cells transfected with human CD83 (FDCP1 TF). No difference between 3C12  
and an isotype IgG1 control is seen on un-transfected FDCP1 cells (CD83<sup>-</sup>). MFI =  
mean fluorescence intensity. (B) 3C12 IgG1 induced significant lysis of the KM-H2  
cell line relative to Herceptin (negative control) via a CD16-dependent mechanism at  
an effector to target cell ratio of 5:1. Statistical significance was determined by two-  
25 way ANOVA. Error bars represent standard error of the mean (SEM) of five  
replicates.

#### **Figure 3: 3C12 recognises a conformational epitope that overlaps with other CD83 antibodies**

30 (A) Western blot of CD83 antibodies used to detect 5 $\mu\text{g}$  of (i) denatured or (ii) native  
recombinant human CD83ECD-His. Non-denatured CD83 appears as three smeared  
bands (30 kDa, 22 kDa, 19 kDa) on 12% gel, the result of homo-dimerization and  
variability in glycosylation of the three potential N-linked glycosylation motifs. Anti-  
human IgG IRD800 secondary antibody alone was used as a negative control. (Inset  
35 table). Effect of simultaneous addition of CD83 antibodies to KM-H2 cells and the

resulting change in mean fluorescence intensity for 3C12 and other antibodies reported as percent reduction.

**Figure 4: 3C12 mAb improves *in vivo* survival of SCID mice in a xenogeneic GVHD model**

Survival of animals after administration on Day 0 of CD83 antibody or isotype matched control to SCID mice transplanted with human PBMC. The number of animals used per cohort is shown in brackets and significant differences ( $p < 0.05$ ) are asterisked. (A) Dose optimisation of 3C12 IgG in comparison to isotype control (anti-human Her2; Herceptin IgG). (B) Comparison of 0.125 mg dose of 3C12 IgG with rabbit polyclonal RA83 antibody or non-specific rabbit IgG (RAneg). Data displayed is pooled from 5 independent experiments each containing a minimum of five animals in each cohort. (C) Administration of a 1 mg dose of CD83 antibody and combined dose of 3C12 and RA83 treatments.

15

**Figure 5: Glycomodification of 3C12 with kifunesine results in low-fucose IgG**

(A) Production of 3C12 in the presence of  $2 \mu\text{g}\cdot\text{mL}^{-1}$  kifunensine (3C12.kif; top panel) inhibits addition of fucose, whilst fucose is a large component of the sugars present within the control 3C12 transfection (3C12.WT; lower panel) as determined by MALDI TOF/TOF mass spectrometry. Structures typically produced at each predominant signal are annotated and schematically represented by fucose (triangles), GlcNAc (squares), mannose (dark grey circles), and galactose (light grey circles). (B) 3C12.WT and 3C12.Kif are of a standard IgG molecule weight (150 kDa non-reduced (NR), and 50 kDa, 25 kDa bands observed upon reduction (R)) and (C) kifunensine treatment does not alter binding activity of 3C12.kif IgG (MFI = 2573, grey line) to CD83<sup>+</sup> cell line, KM-H2 in comparison to 3C12.WT (MFI = 2581, black line superimposed on grey line) relative to isotype control (MFI = 335, grey fill).

**Figure 6: Selection of scFv with improved affinity for human CD83 from a V<sub>L</sub> shuffled library**

(A) Yeast displaying V<sub>L</sub> shuffled 3C12 scFv were stained with hCD83<sub>ECD</sub>-His at the concentrations indicated for each round and sorted into high affinity collection Gate P2 and less stringent Gate P3 for comparison. Percentage of total cells sorted into P2 and P3 are displayed within the gate. Sort Round 3 incorporates selection for clones with slower off-rate. (B) Deduced framework (FR) and complementarity determining regions (CDR) of V<sub>L</sub> amino acid sequence alignment of 3C12 and affinity-improved V<sub>L</sub>

variants. (C) Comparison of monoclonal yeast expressing wildtype (3C12.WT) and affinity-improved 3C12 variants (3C12.B-E) binding to 0.2 nM hCD83<sub>ECD</sub>-His.

**Figure 7: Characterization of reformatted 3C12 V<sub>L</sub> shuffled variant Fabs**

5 (A) BiaCore traces show binding of 3C12.WT (upper panel) and 3C12.C (lower panel) Fab fragments to immobilised hCD83<sub>ECD</sub>-Fc during the constant injection of Fab for 3 mins (180s; Association Phase) followed by injection of buffer for 10 mins (600s; Dissociation Phase). Two-fold dilutions of Fab were prepared over the concentration series specified. (B) Dilution series of 3C12.WT (circles), 3C12.C (squares) and IgG  
10 isotype control (triangles) binding to CD83<sup>+</sup> cell line, KM-H2.

**Figure 8: Glycomodification and affinity maturation enhance *in vitro* activity of CD83mAb**

Comparative potency of 3C12.WT, 3C12.C, and 3C12.kif *in vitro*. (A) Specific lysis of  
15 CD83 transfected BB88 cells after 4 hours incubation at 37°C with antibody and NK cells (5:1 effector to target cell ratio). Herceptin = human IgG1κ isotype control. (B) Anti-proliferative effects of (i) 3C12 variants and (ii) in comparison to RA83 in two-way MLR. Data shown is the average ± SEM of five replicates, representative of 2-4 independent experiments.

20

**Figure 9: CD83 bright blood dendritic cells are targeted by engineered anti-CD83 mAb *in vitro***

Effect on blood DCs after culturing PBMC with 5 µg.mL<sup>-1</sup> 3C12.C, human IgG1κ isotype control or nil antibody treatment over three days. (i) Live (7AAD<sup>-</sup>), activated  
25 blood DCs are defined as Lineage<sup>-</sup> HLA-DR<sup>+</sup> (HLA-DR gating not shown) cells (= total DC) which co-express CMRF-44 and CD83. (ii) The number within the activated DC gate is the percentage of total DCs. Each experimental condition was performed in triplicate and the results presented are representative of 4 independent experiments.

30 **Figure 10: Density of CD83 antigen correlates with GFP expression levels and *in vitro* ADCC potency**

Characterization of BB88 transfectants with varying levels of CD83 expression; BB88-CD83-TF.5K (5,400MPC), BB88-CD83TF.3K (3,600MPC), or BB88-CD83TF.2K (<2,300MPC). (A) Expression levels of GFP (left) and CD83 detected by HB15a on  
35 BB88 transfectants (right). (B) ADCC induced in a chromium release assay by (i) 3C12.C, (ii) 3C12.Kif or (iii) 3C12.C.Kif on BB88 transfectants at an effector to target

cell ratio of 5:1. Data is displayed as the mean  $\pm$  SEM of five replicates and the results presented are representative of 2 independent experiments.

**Figure 11: 3C12.C has equivalent potency to RA83 *in vivo***

- 5 Survival of SCID mice after xenogeneic human PBMC transplant and administration of 0.125 mg CD83 antibody or isotype matched antibody controls at Day 0. Data displayed is pooled from two experiments that used different human PBMC donors (total number of animals used in each cohort is displayed in brackets following cohort descriptions). Significant differences ( $p < 0.05$ ) are asterisked.

10

**SEQUENCE LISTING**

<b>SEQ ID NO:1</b>	amino acid sequence of 3C12 heavy chain variable region
<b>SEQ ID NO:2</b>	CDR1 of 3C12 heavy chain variable region
<b>SEQ ID NO:3</b>	CDR2 of 3C12 heavy chain variable region
<b>SEQ ID NO:4</b>	CDR3 of 3C12 heavy chain variable region
<b>SEQ ID NO:5</b>	amino acid sequence of 3C12 light chain variable region
<b>SEQ ID NO:6</b>	amino acid sequence of 3C12.B light chain variable region
<b>SEQ ID NO:7</b>	amino acid sequence of 3C12.C light chain variable region
<b>SEQ ID NO:8</b>	amino acid sequence of 3C12.D light chain variable region
<b>SEQ ID NO:9</b>	amino acid sequence of 3C12.E light chain variable region
<b>SEQ ID NO:10</b>	amino acid sequence of V <sub>L</sub> consensus sequence of 3C12 and derivatives
<b>SEQ ID NO:11</b>	CDR1 of 3C12 light chain variable region
<b>SEQ ID NO:12</b>	CDR2 of 3C12 light chain variable region
<b>SEQ ID NO:13</b>	CDR3 of 3C12 light chain variable region
<b>SEQ ID NO:14</b>	CDR1 of 3C12.B light chain variable region
<b>SEQ ID NO:15</b>	CDR2 of 3C12.B light chain variable region
<b>SEQ ID NO:16</b>	CDR3 of 3C12.B light chain variable region
<b>SEQ ID NO:17</b>	CDR1 of 3C12.C light chain variable region
<b>SEQ ID NO:18</b>	CDR2 of 3C12.C light chain variable region
<b>SEQ ID NO:19</b>	CDR3 of 3C12.C light chain variable region
<b>SEQ ID NO:20</b>	CDR1 of 3C12.D light chain variable region
<b>SEQ ID NO:21</b>	CDR2 of 3C12.D light chain variable region
<b>SEQ ID NO:22</b>	CDR3 of 3C12.D light chain variable region

<b>SEQ ID NO:23</b>	CDR1 of 3C12.E light chain variable region
<b>SEQ ID NO:24</b>	CDR2 of 3C12.E light chain variable region
<b>SEQ ID NO:25</b>	CDR3 of 3C12.E light chain variable region
<b>SEQ ID NO:26</b>	amino acid sequence of V <sub>L</sub> consensus sequence of CDR1 of 3C12 and derivatives
<b>SEQ ID NO:27</b>	amino acid sequence of V <sub>L</sub> consensus sequence of CDR2 of 3C12 and derivatives
<b>SEQ ID NO:28</b>	amino acid sequence of V <sub>L</sub> consensus sequence of CDR3 of 3C12 and derivatives
<b>SEQ ID NO:29</b>	amino acid sequence of 3C12 heavy chain
<b>SEQ ID NO:30</b>	amino acid sequence of 3C12 light chain
<b>SEQ ID NO:31</b>	amino acid sequence of 3C12.B light chain
<b>SEQ ID NO:32</b>	amino acid sequence of 3C12.C light chain
<b>SEQ ID NO:33</b>	amino acid sequence of 3C12.D light chain
<b>SEQ ID NO:34</b>	amino acid sequence of 3C12.E light chain
<b>SEQ ID NO:35</b>	Nucleotide sequence of 3C12 heavy chain variable region
<b>SEQ ID NO:36</b>	Nucleotide sequence of 3C12 light chain variable region
<b>SEQ ID NO:37</b>	Nucleotide sequence of 3C12.B light chain variable region
<b>SEQ ID NO:38</b>	Nucleotide sequence of 3C12.C light chain variable region
<b>SEQ ID NO:39</b>	Nucleotide sequence of 3C12.D light chain variable region
<b>SEQ ID NO:40</b>	Nucleotide sequence of 3C12.E light chain variable region
<b>SEQ ID NO:41</b>	Nucleotide sequence of 3C12 heavy chain
<b>SEQ ID NO:42</b>	Nucleotide sequence of 3C12 light chain
<b>SEQ ID NO:43</b>	Nucleotide sequence of 3C12.B light chain
<b>SEQ ID NO:44</b>	Nucleotide sequence of 3C12.C light chain
<b>SEQ ID NO:45</b>	Nucleotide sequence of 3C12.D light chain
<b>SEQ ID NO:46</b>	Nucleotide sequence of 3C12.E light chain
<b>SEQ ID NO:47</b>	amino acid sequence of human CD83 isoform a
<b>SEQ ID NO:48</b>	amino acid sequence of human CD83 isoform b
<b>SEQ ID NO:49</b>	amino acid sequence of human CD83 isoform c
<b>SEQ ID NO:50</b>	3C12_VhFor primer
<b>SEQ ID NO:51</b>	3C12_VhRev primer
<b>SEQ ID NO:52</b>	3C12_VkFor primer
<b>SEQ ID NO:53</b>	3C12_VkRev primer
<b>SEQ ID NO:54</b>	3C12VH5' primer

SEQ ID NO:55	Mod3C12VH3' primer
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## DETAILED DESCRIPTION

### General

Throughout this specification, unless specifically stated otherwise or the context  
5 requires otherwise, reference to a single step, composition of matter, group of steps or  
group of compositions of matter shall be taken to encompass one and a plurality (i.e.  
one or more) of those steps, compositions of matter, groups of steps or groups of  
compositions of matter. Thus, as used herein, the singular forms "a", "an" and "the"  
include plural aspects unless the context clearly dictates otherwise. For example,  
10 reference to "a" includes a single as well as two or more; reference to "an" includes a  
single as well as two or more; reference to "the" includes a single as well as two or  
more and so forth.

Each example of the present disclosure described herein is to be applied mutatis  
mutandis to each and every other example unless specifically stated otherwise.

15 Those skilled in the art will appreciate that the disclosure herein is susceptible to  
variations and modifications other than those specifically described. It is to be  
understood that the disclosure includes all such variations and modifications. The  
disclosure also includes all of the steps, features, compositions and compounds referred  
to or indicated in this specification, individually or collectively, and any and all  
20 combinations or any two or more of said steps or features.

The present disclosure is not to be limited in scope by the specific examples  
described herein, which are intended for the purpose of exemplification only.  
Functionally-equivalent products, compositions and methods are clearly within the  
scope of the disclosure, as described herein.

25 The present disclosure is performed without undue experimentation using,  
unless otherwise indicated, conventional techniques of molecular biology,  
microbiology, virology, recombinant DNA technology, peptide synthesis in solution,  
solid phase peptide synthesis, and immunology. Such procedures are described, for  
example, in Sambrook, Fritsch & Maniatis, *Molecular Cloning: A Laboratory Manual*,  
30 Cold Spring Harbor Laboratories, New York, Second Edition (1989), whole of Vols I,  
II, and III; Benny K.C.Lo, *Antibody Engineering: Methods and Protocols*, (2004)  
Humana Press, Vol. 248; *DNA Cloning: A Practical Approach*, Vols. I and II (D. N.  
Glover, ed., 1985), IRL Press, Oxford, whole of text; *Oligonucleotide Synthesis: A  
Practical Approach* (M. J. Gait, ed, 1984) IRL Press, Oxford, whole of text, and  
35 particularly the papers therein by Gait, ppl-22; Atkinson *et al.*, pp35-81; Sproat *et al.*,

pp 83-115; and Wu *et al.*, pp 135-151; Nucleic Acid Hybridization: A Practical Approach (B. D. Hames & S. J. Higgins, eds., 1985) IRL Press, Oxford, whole of text; Immobilized Cells and Enzymes: A Practical Approach (1986) IRL Press, Oxford, whole of text; Perbal, B., A Practical Guide to Molecular Cloning (1984); Methods In  
5 Enzymology (S. Colowick and N. Kaplan, eds., Academic Press, Inc.), whole of series; J.F. Ramalho Ortigao, "The Chemistry of Peptide Synthesis" In: Knowledge database of Access to Virtual Laboratory website (Interactiva, Germany); Sakakibara Biochem. Biophys. Res. Commun. 73: 336-342, 1976; Merrifield J. Am. Chem. Soc. 85: 2149-2154, 1963; Barany and Merrifield (1979) in The Peptides (Gross, E. and Meienhofer,  
10 J. eds.), vol. 2, pp. 1-284, Academic Press, New York. 12. Wunsch, E., ed. (1974) Synthese von Peptiden in Houben-Weyls Methoden der Organischen Chemie (Müller, E., ed.), vol. 15, 4th edn., Parts 1 and 2, Thieme, Stuttgart; Bodanszky, M. (1984) Principles of Peptide Synthesis, Springer-Verlag, Heidelberg; Bodanszky, M. & Bodanszky, A. (1984) The Practice of Peptide Synthesis, Springer-Verlag, Heidelberg;  
15 Bodanszky Int. J. Peptide Protein Res. 25: 449-474, 1985; Handbook of Experimental Immunology, Vols. I-IV (D. M. Weir and C. C. Blackwell, eds., 1986, Blackwell Scientific Publications); and Animal Cell Culture: Practical Approach, 3rd edn (John R. W. Masters, ed., 2000), ISBN 0199637970, whole of text.

The term "and/or", e.g., "X and/or Y" shall be understood to mean either "X and  
20 Y" or "X or Y" and shall be taken to provide explicit support for both meanings or for either meaning.

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

### Selected Definitions

CD83 is a single-pass type I membrane protein and member of the immunoglobulin superfamily. Three human transcript variants encoding different  
30 isoforms have been found. For the purposes of nomenclature and not limitation, the amino acid sequences of the human CD83 (hCD83) isoforms are shown in SEQ ID NO:47 (NP\_004224.1; isoform a), SEQ ID NO:48 (NP\_001035370.1; isoform b) and SEQ ID NO:49 (NP\_001238830.1; isoform c). Accordingly, in one example, the amino acid sequence of human CD83 comprises an amino acid sequence as shown in  
35 SEQ ID NO:47, 48, or 49. Homologs of CD83 can be found in *Pan troglodytes* (XP\_518248.2), *Macaca mulatta* (XP\_001093591.1), *Canis lupus familiaris*

(XP\_852647.1), *Bos Taurus* (NP\_001040055.1), *Mus musculus* (NP\_033986.1), *Rattus norvegicus* (NP\_001101880.1) and *Gallus gallus* (XP\_418929.1). Exemplary CD83 binding proteins of the disclosure bind to or bind specifically to hCD83, including recombinant forms thereof (rhCD83).

5 The term "isolated protein" or "isolated polypeptide" is intended to mean a protein or polypeptide that by virtue of its origin or source of derivation is not associated with naturally-associated components that accompany it in its native state; is substantially free of other proteins from the same source. A protein may be rendered substantially free of naturally associated components or substantially purified by  
10 isolation, using protein purification techniques known in the art. By "substantially purified" is meant the protein is substantially free of contaminating agents, for example, at least about 70% or 75% or 80% or 85% or 90% or 95% or 96% or 97% or 98% or 99% free of contaminating agents.

The term "recombinant" shall be understood to mean the product of artificial  
15 genetic recombination. Accordingly, in the context of a recombinant protein comprising an antigen binding domain, this term does not encompass an antibody naturally-occurring within a subject's body that is the product of natural recombination that occurs during B cell maturation. However, if such an antibody is isolated, it is to be considered an isolated protein comprising an antigen binding domain. Similarly, if  
20 nucleic acid encoding the protein is isolated and expressed using recombinant means, the resulting protein is a recombinant protein comprising an antigen binding domain. A recombinant protein also encompasses a protein expressed by artificial recombinant means when it is within a cell, tissue or subject, for example, in which it is expressed.

The term "CD83 binding protein" shall be taken to include a single polypeptide  
25 chain (i.e., a series of contiguous amino acids linked by peptide bonds), or a series of polypeptide chains covalently or non-covalently linked to one another (i.e., a polypeptide complex or protein) capable of binding to CD83 in the manner described and/or claimed herein. For example, the series of polypeptide chains can be covalently linked using a suitable chemical or a disulphide bond. Examples of non-covalent bonds  
30 include hydrogen bonds, ionic bonds, Van der Waals forces, and hydrophobic interactions.

The term "polypeptide" or "polypeptide chain" will be understood from the foregoing paragraph to mean a series of contiguous amino acids linked by peptide bonds.

35 As used herein, the term "antigen binding domain" shall be taken to mean a region of an antibody that is capable of specifically binding to an antigen, that is, a V<sub>H</sub>

or a  $V_L$  or an Fv comprising both a  $V_H$  and a  $V_L$ . The antigen binding domain need not be in the context of an entire antibody, for example, it can be in isolation (e.g., a domain antibody) or in another form (e.g., scFv).

For the purposes for the present disclosure, the term "antibody" includes a  
5 protein capable of specifically binding to one or a few closely related antigens (e.g., CD83) by virtue of an antigen binding domain contained within a Fv. This term includes four chain antibodies (e.g., two light (L) chains and two heavy (H) chains), recombinant or modified antibodies (e.g., chimeric antibodies, humanized antibodies, human antibodies, CDR-grafted antibodies, primatized antibodies, de-immunized  
10 antibodies, synhumanized antibodies, half-antibodies, bispecific antibodies). An antibody generally comprises constant domains, which can be arranged into a constant region or constant fragment or fragment crystallizable (Fc). Exemplary forms of antibodies comprise a four-chain structure as their basic unit. Full-length antibodies comprise two heavy chains (~50 to 70 kDa each) covalently linked and two light chains  
15 (~23 kDa each). A light chain generally comprises a variable region (if present) and a constant domain and in mammals is either a  $\kappa$  light chain or a  $\lambda$  light chain. A heavy chain generally comprises a variable region and one or two constant domain(s) linked by a hinge region to additional constant domain(s). Heavy chains of mammals are of one of the following types  $\alpha$ ,  $\delta$ ,  $\epsilon$ ,  $\gamma$ , or  $\mu$ . Each light chain is also covalently linked to  
20 one of the heavy chains. For example, the two heavy chains and the heavy and light chains are held together by inter-chain disulfide bonds and by non-covalent interactions. The number of inter-chain disulfide bonds can vary among different types of antibodies. Each chain has an N-terminal variable region ( $V_H$  or  $V_L$  wherein each are ~110 amino acids in length) and one or more constant domains at the C- terminus.  
25 The constant domain of the light chain (CL which is ~110 amino acids in length) is aligned with and disulfide bonded to the first constant domain of the heavy chain ( $C_{H1}$  which is 330 to 440 amino acids in length). The light chain variable region is aligned with the variable region of the heavy chain. The antibody heavy chain can comprise 2 or more additional  $C_H$  domains (such as,  $C_{H2}$ ,  $C_{H3}$  and the like) and can comprise a  
30 hinge region between the  $C_{H1}$  and  $C_{H2}$  constant domains. Antibodies can be of any type (e.g., IgG, IgE, IgM, IgD, IgA, and IgY), class (e.g., IgG1, IgG2, IgG3, IgG4, IgA1 and IgA2) or subclass. In one example, the antibody is a murine (mouse or rat) antibody or a primate (such as, human) antibody. In one example, the antibody is humanized, synhumanized, chimeric, CDR-grafted or deimmunized.

35 The term "naked antibody" refers to an antibody that is not conjugated to another compound, for example, a toxic compound or radiolabel.

As used herein, "variable region" refers to the portions of the light and/or heavy chains of an antibody as defined herein that is capable of specifically binding to an antigen and, includes amino acid sequences of complementarity determining regions (CDRs), that is, CDR1, CDR2, and CDR3, and framework regions (FRs). For example, 5 the variable region comprises three or four FRs (e.g., FR1, FR2, FR3 and optionally FR4) together with three CDRs.  $V_H$  refers to the variable region of the heavy chain.  $V_L$  refers to the variable region of the light chain.

As used herein, the term "complementarity determining regions" (syn. CDRs, i.e., CDR1, CDR2, and CDR3) refers to the amino acid residues of an antibody variable 10 region the presence of which are major contributors to specific antigen binding. Each variable region domain ( $V_H$  or  $V_L$ ) typically has three CDR regions identified as CDR1, CDR2 and CDR3. In one example, the amino acid positions assigned to CDRs and FRs are defined according to Kabat Sequences of Proteins of Immunological Interest, National Institutes of Health, Bethesda, Md., 1987 and 1991 (also referred to herein as 15 "the Kabat numbering system"). In another example, the amino acid positions assigned to CDRs and FRs are defined according to the Enhanced Chothia Numbering Scheme (<http://www.bioinfo.org.uk/mdex.html>). According to the numbering system of Kabat,  $V_H$  FRs and CDRs are positioned as follows: residues 1 to 30 (FR1), 31 to 35 (CDR1), 36 to 49 (FR2), 50 to 65 (CDR2), 66 to 94 (FR3), 95 to 102 (CDR3) and 103 to 113 20 (FR4). According to the numbering system of Kabat,  $V_L$  FRs and CDRs are positioned as follows: residues 1 to 23 (FR1), 24 to 34 (CDR1), 35 to 49 (FR2), 50 to 56 (CDR2), 57 to 88 (FR3), 89 to 97 (CDR3) and 98 to 107 (FR4). The present disclosure is not limited to FRs and CDRs as defined by the Kabat numbering system, but includes all numbering systems, including the canonical numbering system or of Chothia and Lesk 25 J. Mol. Biol. 196: 901-917, 1987; Chothia *et al.*, Nature 342: 877-883, 1989; and/or Al-Lazikani *et al.*, J. Mol. Biol. 273: 927-948, 1997; the numbering system of Honnegger and Plükthun J. Mol. Biol. 309: 657-670, 2001; or the IMGT system discussed in Giudicelli *et al.*, Nucleic Acids Res. 25: 206-211 1997. In one example, the CDRs are defined according to the Kabat numbering system. Optionally, heavy chain CDR2 30 according to the Kabat numbering system does not comprise the five C-terminal amino acids listed herein or any one or more of those amino acids are substituted with another naturally-occurring amino acid. In an additional, or alternative, option, light chain CDR1 does not comprise the four N-terminal amino acids listed herein or any one or more of those amino acids are substituted with another naturally-occurring amino acid. 35 In this regard, Padlan *et al.*, FASEB J., 9: 133-139, 1995 established that the five C-

terminal amino acids of heavy chain CDR2 and/or the four N-terminal amino acids of light chain CDR1 are not generally involved in antigen binding.

"Framework regions" (FRs) are those variable region residues other than the CDR residues.

5 As used herein, the term "Fv" shall be taken to mean any protein, whether comprised of multiple polypeptides or a single polypeptide, in which a  $V_L$  and a  $V_H$  associate and form a complex having an antigen binding domain that is capable of specifically binding to an antigen. The  $V_H$  and the  $V_L$  which form the antigen binding domain can be in a single polypeptide chain or in different polypeptide chains.  
10 Furthermore, a Fv of the disclosure (as well as any protein of the disclosure) may have multiple antigen binding domains which may or may not bind the same antigen. This term shall be understood to encompass fragments directly derived from an antibody as well as proteins corresponding to such a fragment produced using recombinant means. In some examples, the  $V_H$  is not linked to a heavy chain constant domain ( $C_H$ ) 1 and/or  
15 the  $V_L$  is not linked to a light chain constant domain ( $C_L$ ). Exemplary Fv containing polypeptides or proteins include a Fab fragment, a Fab' fragment, a F(ab') fragment, a scFv, a diabody, a triabody, a tetrabody or higher order complex, or any of the foregoing linked to a constant region or domain thereof, for example,  $C_H2$  or  $C_H3$  domain, for example, a minibody.

20 A "Fab fragment" consists of a monovalent antigen-binding fragment of an immunoglobulin, and can be produced by digestion of a whole antibody with the enzyme papain, to yield a fragment consisting of an intact light chain and a portion of a heavy chain or can be produced using recombinant means.

A "Fab' fragment" of an antibody can be obtained by treating a whole antibody  
25 with pepsin, followed by reduction, to yield a molecule consisting of an intact light chain and a portion of a heavy chain comprising a  $V_H$  and a single constant domain. Two Fab' fragments are obtained per antibody treated in this manner. A Fab' fragment can also be produced by recombinant means.

A "F(ab')<sub>2</sub> fragment" of an antibody consists of a dimer of two Fab' fragments  
30 held together by two disulfide bonds, and is obtained by treating a whole antibody molecule with the enzyme pepsin, without subsequent reduction.

A "Fab<sub>2</sub>" fragment is a recombinant fragment comprising two Fab fragments linked using, for example, a leucine zipper or a  $C_H3$  domain.

A "single chain Fv" or "scFv" is a recombinant molecule containing the variable  
35 region fragment (Fv) of an antibody in which the variable region of the light chain and

the variable region of the heavy chain are covalently linked by a suitable, flexible polypeptide linker.

As used herein, the term "binds" in reference to the interaction of a CD83 binding protein or an antigen binding domain thereof with an antigen means that the interaction is dependent upon the presence of a particular structure (e.g., an antigenic determinant or epitope) on the antigen. For example, an antibody recognizes and binds to a specific protein structure rather than to proteins generally. If an antibody binds to epitope "A", the presence of a molecule containing epitope "A" (or free, unlabeled "A"), in a reaction containing labeled "A" and the antibody, will reduce the amount of labeled "A" bound to the antibody.

As used herein, the term "specifically binds" or "binds specifically" shall be taken to mean that a protein of the disclosure reacts or associates more frequently, more rapidly, with greater duration and/or with greater affinity with a particular antigen or cell expressing same than it does with alternative antigens or cells. For example, a protein that specifically binds to an antigen binds that antigen with greater affinity, avidity, more readily, and/or with greater duration than it binds to other antigens. For example, a protein binds to CD83 (e.g., hCD83) with materially greater affinity than it does to other immunoglobulin superfamily ligands or to antigens commonly recognized by polyreactive natural antibodies (i.e., by naturally occurring antibodies known to bind a variety of antigens naturally found in humans). It is also understood by reading this definition that, for example, a protein that specifically binds to a first antigen may or may not specifically bind to a second antigen. As such, "specific binding" does not necessarily require exclusive binding or non-detectable binding of another antigen, this is meant by the term "selective binding". In one example, "specific binding" of a CD83 binding protein of the disclosure to an antigen, means that the protein binds to the antigen with an equilibrium constant ( $K_D$ ) of 100 nM or less, such as 50 nM or less, for example, 20 nM or less, such as, 15 nM or less or 10 nM or less or 5 nM or less or 1 nM or less or 500 pM or less or 400 pM or less or 300 pM or less or 200 pM or less or 100 pM or less.

As used herein, the term "epitope" (syn. "antigenic determinant") shall be understood to mean a region of CD83 to which a protein comprising an antigen binding domain of an antibody binds. This term is not necessarily limited to the specific residues or structure to which the protein makes contact. For example, this term includes the region spanning amino acids contacted by the protein and/or at least 5 to 10 or 2 to 5 or 1 to 3 amino acids outside of this region. In some examples, the epitope is a linear series amino acids. An epitope may also comprise a series of discontinuous

amino acids that are positioned close to one another when CD83 is folded, that is, a "conformational epitope". The skilled artisan will also be aware that the term "epitope" is not limited to peptides or polypeptides. For example, the term "epitope" includes chemically active surface groupings of molecules such as sugar side chains, phosphoryl side chains, or sulfonyl side chains, and, in certain examples, may have specific three dimensional structural characteristics, and/or specific charge characteristics. An epitope or peptide or polypeptide comprising same can be administered to an animal to generate antibodies against the epitope.

The term "competitively inhibits" shall be understood to mean that a CD83 binding protein of the disclosure reduces or prevents binding of a recited antibody to CD83, for example, to hCD83. This may be due to the protein (or antigen binding domain) binding to the same or an overlapping epitope as the antibody. It will be apparent from the foregoing that the protein need not completely inhibit binding of the antibody, rather it need only reduce binding by a statistically significant amount, for example, by at least about 10% or 20% or 30% or 40% or 50% or 60% or 70% or 80% or 90% or 95%. Methods for determining competitive inhibition of binding are known in the art and/or described herein. For example, the antibody is exposed to CD83 either in the presence or absence of the protein. If less antibody binds in the presence of the protein than in the absence of the protein, the protein is considered to competitively inhibit binding of the antibody. In one example, the competitive inhibition of binding is caused by the antigen binding domain of the protein on CD83 overlapping with the antigen binding domain of the antibody.

"Overlapping" in the context of two epitopes means that two epitopes share a sufficient number of amino acid residues to permit a binding protein of the disclosure that binds to one epitope to competitively inhibit the binding of a recited antibody to CD83 that binds to the other epitope. For example, the "overlapping" epitopes share at least 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 amino acids.

As used herein, a "CD83 associated condition or disease" refers to any condition or disease that is caused by or associated with CD83 or a cell expressing CD83. The skilled artisan will be readily able to determine such conditions or diseases based on the disclosure herein and/or by performing an assay to diagnose a CD83 associated condition or disease. In this regard, in some examples the condition or disease is an inflammatory condition or disease, or an autoimmune condition or disease. A description of exemplary conditions and diseases is included herein.

As used herein, the terms "preventing", "prevent" or "prevention" include administering a protein of the disclosure to thereby stop or hinder the development of at least one symptom of a condition or disease. This term also encompasses treatment of a subject in remission to prevent or hinder relapse. For example, a subject suffering from relapsing-remitting multiple sclerosis is treated during remission to thereby prevent a relapse.

As used herein, the terms "treating", "treat" or "treatment" include administering a protein described herein to thereby reduce or eliminate at least one symptom of a specified condition or disease.

As used herein, the term "subject" shall be taken to mean any animal, such as, a mammal. In one example, the mammal is a human or non-human primate. In one example, the mammal is a human.

Reference herein to a "sample" should be understood as a reference to any sample derived from a subject such as, but not limited to, a body fluid (e.g., blood or blood fraction such as serum or plasma, tears, urine, synovial fluid or cerebrospinal fluid), cellular material (e.g. tissue aspirate), tissue biopsy specimens or surgical specimens. In some examples, the "sample" is any one or more of serum, plasma, PBMCs, or a buffy coat fraction.

As used herein, the term "diagnosis", and variants thereof such as, but not limited to, "diagnose", "diagnosed" or "diagnosing" includes any primary diagnosis of a clinical state or diagnosis of recurrent disease.

"Prognosis", "prognosing" and variants thereof as used herein refer to the likely outcome or course of a disease, including the chance of recovery or recurrence or the outcome of treatment.

The term "expression construct" is to be taken in its broadest context and includes a nucleic acid comprising one or more promoter sequences operably linked with one or more nucleic acids as described herein.

The term "expression vector" refers to a nucleic acid comprising an expression construct that is additionally capable of maintaining and or replicating nucleic acid in an expressible format. For example, an expression vector may comprise a plasmid, bacteriophage, phagemid, cosmid, virus sub-genomic or genomic fragment. Selection of appropriate vectors is within the knowledge of those having skill in the art.

As used herein, the term "promoter" is to be taken in its broadest context and includes the transcriptional regulatory sequences of a genomic gene, including the TATA box or initiator element, which is required for accurate transcription initiation, with or without additional regulatory elements (e.g., upstream activating sequences,

transcription factor binding sites, enhancers and silencers) that alter expression of a nucleic acid, for example, in response to a developmental and/or external stimulus, or in a tissue specific manner. In the present context, the term "promoter" is also used to describe a recombinant, synthetic or fusion nucleic acid, or derivative which confers, 5 activates or enhances the expression of a nucleic acid to which it is operably linked. Exemplary promoters can contain additional copies of one or more specific regulatory elements to further enhance expression and/or alter the spatial expression and/or temporal expression of said nucleic acid.

As used herein, the term "operably linked to" means positioning a promoter 10 relative to a nucleic acid such that expression of the nucleic acid is controlled by the promoter. A promoter can be operably linked to numerous nucleic acids, for example, through an internal ribosome entry site.

### **Proteins Comprising Antigen Binding Domains**

#### 15 Antibodies

##### *Library-Based Methods*

The present disclosure also encompasses screening of libraries of antibodies or proteins comprising antigen binding domains thereof (e.g., comprising variable regions thereof) to identify a CD83 binding protein of the disclosure. For example, a library 20 comprising a  $V_H$  of the disclosure and a plurality of  $V_L$  regions can be screened to identify a CD83 binding protein of the disclosure.

Examples of libraries contemplated by this disclosure include naïve libraries (from unchallenged subjects), immunized libraries (from subjects immunized with an antigen) or synthetic libraries. Nucleic acid encoding antibodies or regions thereof 25 (e.g., variable regions) are cloned by conventional techniques (e.g., as disclosed in Sambrook and Russell, eds, *Molecular Cloning: A Laboratory Manual*, 3rd Ed, vols. 1-3, Cold Spring Harbor Laboratory Press, 2001) and used to encode and display proteins using a method known in the art. Other techniques for producing libraries of proteins are described in, for example in US6300064 (e.g., a HuCAL library of Morphosys AG), 30 US5885793, US6204023, US6291158, or US6248516.

The CD83 binding proteins according to the disclosure may be soluble secreted proteins or may be presented as a fusion protein on the surface of a cell, or particle (e.g., a phage or other virus, a ribosome or a spore). Various display library formats are known in the art. For example, the library is an *in vitro* display library (e.g., a 35 ribosome display library, a covalent display library or a mRNA display library, e.g., as described in US7270969). In yet another example, the display library is a phage

display library wherein proteins comprising antigen binding domains of antibodies are expressed on phage, for example, as described in US6300064, US5885793, US6204023, US6291158, or US6248516. Other phage display methods are known in the art and are contemplated by the present disclosure. Similarly, methods of cell display are contemplated by the disclosure, for example, bacterial display libraries, for example, as described in US5516637; yeast display libraries, for example, as described in US6423538; or a mammalian display library.

Methods for screening display libraries are known in the art. In one example, a display library of the present disclosure is screened using affinity purification, for example, as described in Scopes (In: Protein purification: principles and practice, Third Edition, Springer Verlag, 1994). Methods of affinity purification typically involve contacting proteins comprising antigen binding domains displayed by the library with a target antigen (e.g., CD83) and, following washing, eluting those domains that remain bound to the antigen.

Any variable regions or scFvs identified by screening are readily modified into a complete antibody, if desired. Exemplary methods for modifying or reformatting variable regions or scFvs into a complete antibody are described, for example, in Jones *et al.*, J. Immunol. Methods 354: 85-90, 2010; or Jostock *et al.*, J. Immunol. Methods, 289: 65-80, 2004. Alternatively, or additionally, standard cloning methods are used, e.g., as described in Ausubel *et al.*, (In: Current Protocols in Molecular Biology. Wiley Interscience, ISBN 047 150338, 1987), and/or (Sambrook *et al.*, (In: Molecular Cloning: Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratories, New York, Third Edition 2001).

In one example, the present disclosure provides a method of producing or isolating a CD83 binding protein of the disclosure by screening a display library, for example, a phage display library, for example, as described in US6300064 and/or US5885793. For example, the present inventors have isolated scFvs by biopanning a human scFv immunoglobulin gene library by three rounds of selection against recombinant extracellular domain of human CD83. Once isolated, a CD83 binding protein of the invention can be cloned and expressed and optionally reformatted as, for example, an IgG1 antibody using known methods in the art.

In one example, the present disclosure provides a method of producing a CD83 binding protein, the method comprising:

(i) screening a CD83 binding protein preparation or library for a binding protein that binds to the extracellular domain of CD83, for example, the extracellular domain of recombinant human CD83; and

(ii) isolating a CD83 binding protein having a desired binding affinity for the extracellular domain of CD83.

In one example, a CD83 binding protein preparation is screened. A CD83 preparation may be made by, for example, immunizing an animal with a CD83 antigen  
5 so as to produce antibodies that react with the extracellular domain of CD83.

In another example, a CD83 binding protein library is screened. The library may be a phage library, for example, a scFv phage library or a Fab phage library.

In one example, the method comprises producing a population of phage particles displaying at their surface a population of binding molecules having a range of binding  
10 specificities for a target CD83 epitope or antigen. Such phage particles comprise a phagemid genome comprising a nucleic acid encoding the binding protein. This nucleic acid can be isolated, cloned and expressed in a recombinant system to produce the CD83 binding protein of the invention.

15 Deimmunized, Chimeric, Humanized, Synhumanized, Primatized, Human and Composite CD83 Binding Proteins

The CD83 binding proteins of the present disclosure may be CDR grafted proteins which include CDRs from an antibody from a non-human species (e.g., mouse or rat or non-human primate) grafted onto or inserted into FRs from a human antibody  
20 or which include CDRs from an antibody from one type of antibody (e.g., one type of human antibody) grafted onto or inserted into FRs from another type of antibody (e.g., another type of human antibody). This term also encompasses a composite protein comprising, for example, one or more CDR grafted variable regions and one or more, for example, human variable regions, chimeric variable regions, synhumanized variable  
25 regions, or primatized variable regions.

The CD83 binding proteins of the present disclosure may be humanized proteins.

The term "humanized protein" shall be understood to refer to a protein comprising a human-like variable region, which includes CDRs from an antibody from  
30 a human species (e.g., mouse or rat or non-human primate) grafted onto or inserted into FRs from a non-human antibody (this type of antibody is also referred to as a "CDR-grafted antibody"). Humanized proteins also include proteins in which one or more residues of the human protein are modified by one or more amino acid substitutions and/or one or more FR residues of the human protein are replaced by corresponding  
35 non-human residues. Humanized proteins may also comprise residues which are found in neither the human antibody or in the non-human antibody. Any additional regions of

the protein (e.g., Fc region) are generally human. Humanization can be performed using a method known in the art, for example, as described in US5225539, US6054297, US7566771, or US5585089. The term "humanized protein" also encompasses a super-humanized protein, for example, as described in US7732578. This term also  
5 encompasses a composite protein comprising, for example, one or more humanized variable regions and one or more, for example, human variable regions, chimeric variable regions, synhumanized variable regions or primatized variable regions.

In one example, a humanized CD83 binding protein comprises the regions between 27d and 34, 50 and 55, and 89 and 96 in a light chain sequence disclosed  
10 herein; and 31 and 35b, 50 and 58, and 95 and 101 in a heavy chain sequence disclosed herein (numbering according to the Kabat numbering system). In this regard, Padlan *et al.*, FASEB J., 9: 133-139, 1995 presents evidence that these regions are those most likely to bind or contact antigen.

The CD83 binding proteins of the present disclosure may be human proteins.  
15 The term "human protein" as used herein refers to proteins having variable and, optionally, constant antibody regions found in humans, for example, in the human germline or somatic cells or from libraries produced using such regions. The "human" antibodies can include amino acid residues not encoded by human sequences, for example, mutations introduced by random or site directed mutations *in vitro* (in  
20 particular mutations which involve conservative substitutions or mutations in a small number of residues of the protein, for example, in 1, 2, 3, 4 or 5 of the residues of the protein). These "human antibodies" do not necessarily need to be generated as a result of an immune response of a human, rather, they can be generated using recombinant means (e.g., screening a phage display library) and/or by a transgenic animal (e.g., a  
25 mouse) comprising nucleic acid encoding human antibody constant and/or variable regions and/or using guided selection (e.g., as described in US5565332). This term also encompasses affinity matured forms of such antibodies. For the purposes of the present disclosure, a human protein will also be considered to include a protein comprising FRs from a human antibody or FRs comprising sequences from a consensus  
30 sequence of human FRs and in which one or more of the CDRs are random or semi-random, for example, as described in US6300064 and/or US6248516.

Exemplary human CD83 binding proteins are antibodies comprising the following pairs of variable regions:

(i) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in  
35 SEQ ID NO:5; or

(ii) a  $V_H$  sequence as shown in SEQ ID NO:1 and a  $V_L$  sequence as shown in SEQ ID NO:6;

(iii) a  $V_H$  sequence as shown in SEQ ID NO:1 and a  $V_L$  sequence as shown in SEQ ID NO:7; or

5 (iv) a  $V_H$  sequence as shown in SEQ ID NO:1 and a  $V_L$  sequence as shown in SEQ ID NO:8; or

(v) a  $V_H$  sequence as shown in SEQ ID NO:1 and a  $V_L$  sequence as shown in SEQ ID NO:9.

In one example, the  $V_L$  sequence lacks the c-terminal lysine residue. The C-  
10 terminal lysine of the  $V_L$  sequence of a CD83 binding protein of the disclosure may be removed, for example, during production or purification of the CD83 binding protein, or by recombinantly engineering the nucleic acid encoding the  $V_L$  of the CD83 binding protein. Accordingly, CD83 binding proteins may comprise populations with all C-terminal lysine residues of the  $V_L$  removed, populations with no C-terminal lysine  
15 residues of the  $V_L$  removed, or populations having a mixture of proteins with and without the  $V_L$  C-terminal lysine residue. In some examples, the protein populations may additionally comprise proteins having two  $V_L$ s in which the C-terminal lysine residue is removed in one of the  $V_L$ s. Similarly, a composition of proteins may comprise the same or a similar mix of protein populations with or without the  $V_L$  C-  
20 terminal lysine residue.

Optionally, the  $V_H$  is linked to a heavy chain constant region, for example, an IgG1 heavy chain constant region. In one example, the heavy chain constant region lacks the c-terminal lysine residue.

Optionally, the  $V_L$  is linked to a light chain constant region.

25 The CD83 binding proteins of the present disclosure may be synhumanized proteins. The term "synhumanized protein" refers to a protein prepared by a method described in US20080095767. A synhumanized CD83 binding protein includes a variable region of an antibody, wherein the variable region comprises FRs from a New World primate antibody variable region and CDRs from a non-New World primate  
30 antibody variable region. For example, a synhumanized CD83 binding protein includes a variable region of an antibody, wherein the variable region comprises FRs from a New World primate antibody variable region and CDRs from a mouse or rat antibody. In one example, the synhumanized CD83 binding protein is a CD83 binding antibody in which one or both of the variable regions are synhumanized. This term also  
35 encompasses a composite protein comprising, for example, one or more synhumanized

variable regions and one or more, for example, human variable regions or humanized variable regions or chimeric variable regions.

The CD83 binding proteins of the present disclosure may be primatized proteins. A "primatized protein" comprises variable region(s) from an antibody  
5 generated following immunization of a non-human primate (e.g., a cynomolgus macaque). Optionally, the variable regions of the non-human primate antibody are linked to human constant regions to produce a primatized antibody. Exemplary methods for producing primatized antibodies are described in US6113898. This term also encompasses a composite protein comprising, for example, one or more primatized  
10 variable regions and one or more, for example, human variable regions or humanized variable regions or chimeric variable regions.

In one example, a CD83 binding protein of the disclosure is a chimeric protein. The term "chimeric proteins" refers to proteins in which an antigen binding domain is from a particular species (e.g., murine, such as mouse or rat) or belonging to a  
15 particular antibody class or subclass, while the remainder of the protein is from a protein derived from another species (such as, for example, human or non-human primate) or belonging to another antibody class or subclass. In one example, a chimeric protein is a chimeric antibody comprising a  $V_H$  and/or a  $V_L$  from a non-human antibody (e.g., a murine antibody) and the remaining regions of the antibody are from a  
20 human antibody. The production of such chimeric proteins is known in the art, and may be achieved by standard means (as described, e.g., in US6331415; US5807715; US4816567 and US4816397). This term also encompasses a composite protein comprising, for example, one or more chimeric variable regions and one or more, e.g., human variable regions or humanized variable regions or chimeric variable regions.

25 The present disclosure also contemplates a deimmunized CD83 binding protein, for example, as described in WO2000/34317 and US20070292416. De-immunized antibodies and proteins have one or more epitopes, for example, B cell epitopes or T cell epitopes removed (i.e., mutated) to thereby reduce the likelihood that a subject will raise an immune response against the antibody or protein. For example, a CD83-  
30 binding protein of the disclosure is analyzed to identify one or more B or T cell epitopes and one or more amino acid residues within the epitope is mutated to thereby reduce the immunogenicity of the CD83 binding protein.

It will be apparent to the skilled artisan from the foregoing disclosure that a "composite" protein comprises one form of  $V_H$  (e.g., human) and another form of  $V_L$   
35 (e.g., humanized). The present disclosure explicitly encompasses all combinations of forms of  $V_H$  and  $V_L$ .

### Other CD83 Binding Proteins Comprising an Antigen Binding Domain

The present disclosure also contemplates other CD83 binding proteins comprising a variable region or antigen binding domain of an antibody, such as:

- (i) a single-domain antibody, which is a single polypeptide chain comprising  
5 all or a portion of the  $V_H$  or a  $V_L$  of an antibody, for example, as described in US6248516);
- (ii) diabodies, triabodies and tetrabodies, for example, as described in US5844094 and/or US2008152586;
- (iii) scFvs, for example, as described in US5260203;
- 10 (iv) minibodies, for example, as described in US5837821;
- (v) "key and hole" bispecific proteins, for example, as described in US5731168;
- (vi) heteroconjugate proteins, for example, as described in US4676980;
- (vii) heteroconjugate proteins produced using a chemical cross-linker, for  
15 example, as described in US4676980;
- (viii) Fab'-SH fragments, for example, as described in Shalaby *et al.*, J. Exp. Med., 175: 217-225, 1992; or
- (ix) Fab3 , for example, as described in EP19930302894.

### 20 Constant Domain Fusions

The present disclosure encompasses CD83 binding proteins comprising an antigen binding domain of an antibody and a constant region or Fc or a domain thereof, for example,  $C_{H2}$  and/or  $C_{H3}$  domain. Suitable constant regions and/or domains will be apparent to the skilled artisan and/or the sequences of such polypeptides are readily  
25 available from publicly available databases. Kabat *et al.* also provide description of some suitable constant regions/domains.

Constant regions and/or domains thereof are useful for providing biological activities such as, dimerization, extended serum half life (e.g., by binding to FcRn), antibody-dependent cell cytotoxicity (ADCC), complement dependent cytotoxicity  
30 (CDC), antibody-dependent cell phagocytosis (ADCP).

The present disclosure also contemplates CD83 binding proteins comprising mutant constant regions or domains, for example, as described in US7217797; US7217798; or US20090041770 (having increased half-life) or US7355008 (increased ADCC).

35 The C-terminal lysine of the heavy chain constant region of a CD83 binding protein of the disclosure comprising a constant region or Fc may be removed, for

example, during production or purification of the CD83 binding protein, or by recombinantly engineering the nucleic acid encoding a heavy chain of the CD83 binding protein. Accordingly, CD83 binding proteins may comprise populations with all C-terminal lysine residues of the heavy chain constant region removed, populations  
5 with no C-terminal lysine residues of the heavy chain constant region removed, or populations having a mixture of proteins with and without the heavy chain constant region C-terminal lysine residue. In some examples, the protein populations may additionally comprise proteins having two heavy chain constant regions in which the heavy chain constant region C-terminal lysine residue is removed in one of the heavy  
10 chain constant regions. Similarly, a composition of proteins may comprise the same or a similar mix of protein populations with or without the heavy chain constant region C-terminal lysine residue.

#### Enhancing Effector Function

15 In one example, a CD83 binding protein of the present disclosure may induce effector function or enhanced effector function.

In the context of the present disclosure, "effector functions" refer to those biological activities mediated by cells or proteins that bind to the Fc region (a native sequence Fc region or amino acid sequence variant Fc region) of an antibody that result  
20 in killing of a cell. Examples of effector functions induced by antibodies include: complement dependent cytotoxicity (CDC); antibody-dependent-cell-mediated cytotoxicity (ADCC); antibody-dependent-cell-phagocytosis (ADCP); and B-cell activation.

"Antibody-dependent-cell-mediated cytotoxicity" or "ADCC" refers to lysis of  
25 antibody coated target cells by effector cells (e.g., natural killer ("NK") cells, neutrophils and macrophages) having Fc receptors that recognize the Fc region of the bound antibody. To assess ADCC activity of a molecule of interest, an *in vitro* ADCC assay may be performed. Useful effector cells for such assays include peripheral blood mononuclear cells ("PBMC") and NK cells.

30 In one example, a CD83 binding protein of the present disclosure binds to CD83 on the surface of a cell in such a manner that it is capable of inducing an effector function, such as, ADCC and/or CDC.

For example, the CD83 binding protein remains bound to the CD83 on the surface of the cell for a time sufficient to induce an effector function, such as ADCC  
35 and/or CDC.

In one example, a CD83 binding protein of the present disclosure is capable of inducing enhanced effector function, for example, by virtue of a modified Fc region or by virtue of comprising a region capable of binding to an immune effector cell. For example, the level of effector function is increased compared to the level induced by a human IgG1 or IgG3 Fc region. Enhancing effector function induced by a CD83 binding protein of the disclosure may result in enhanced therapeutic or prophylactic effects, for example, by killing or depleting cells causing a condition, for example, antigen presenting cells (APC) (e.g., dendritic cells (DCs)) and/or lymphocytes (e.g., T cells) that modulate aberrant or unwanted immune responses in, for example, inflammatory and/or autoimmune conditions or diseases. In one example, enhancing effector function prevents allogeneic stimulation of T cells, by for example, killing or depleting CD83+ cells that stimulate allogeneic T cells.

In one example, the Fc region of a CD83 binding protein of the disclosure is modified to increase the level of effector function it is capable of inducing compared to the Fc region without the modification. Such modifications can be at the amino acid level and/or the secondary structural level and/or the tertiary structural level and/or to the glycosylation of the Fc region.

The skilled addressee will appreciate that greater effector function may be manifested in any of a number of ways, for example as a greater level of effect, a more sustained effect or a faster rate of effect.

In one example, the Fc region comprises one or more amino acid modifications that increase its ability to induce enhanced effector function. In one example, the Fc region binds with greater affinity to one or more FcγRs, such as FcγRIII. In one example, the Fc region comprise at least one amino acid substitution at a position selected from the group consisting of: 230, 233, 234, 235, 239, 240, 243, 264, 266, 272, 274, 275, 276, 278, 302, 318, 324, 325, 326, 328, 330, 332, and 335, numbered according to the EU index of Kabat. In one example, the Fc region comprises the following amino acid substitutions S239D/I332E, numbered according to the EU index of Kabat. This Fc region has about 14 fold increase in affinity for FcγRIIIa compared to a wild-type Fc region and about 3.3 increased ability to induce ADCC compared to a wild-type Fc region. In one example, the Fc region comprises the following amino acid substitutions S239D/A330L/I332E, numbered according to the EU index of Kabat. This Fc region has about 138 fold increase in affinity for FcγRIIIa compared to a wild-type Fc region and about 323 fold increased ability to induce ADCC compared to a wild-type Fc region.

Additional amino acid substitutions that increase ability of a Fc region to induce effector function are known in the art and/or described, for example, in US6737056 or US7317091.

In one example, the glycosylation of the Fc region is altered to increase its ability to induce enhanced effector function. In this regard, native antibodies produced by mammalian cells typically comprise a branched, biantennary oligosaccharide that is generally attached by an N-linkage to Asn297 of the C<sub>H</sub>2 domain of the Fc region. The oligosaccharide may include various carbohydrates, for example, mannose, N-acetyl glucosamine (GlcNAc), galactose, and sialic acid, as well as a fucose attached to a GlcNAc in the "stem" of the biantennary oligosaccharide structure. In some examples, Fc regions according to the present disclosure comprise a carbohydrate structure that lacks fucose attached (directly or indirectly) to an Fc region, that is, the Fc region is "defucosylated" or "afucosylated". Such variants may have an improved ability to induce ADCC. Methods for producing defucosylated antibodies include, expressing the antibody or antigen binding fragment thereof in a cell line incapable of expressing  $\alpha$ -1,6-fucosyltransferase (FUT8) (e.g., as described in Yumane-Ohnuki *et al.*, *Biotechnol. Bioengineer.* 87: 614-622, 2004), expressing the antibody or antigen binding fragment thereof in cells expressing a small interfering RNA against FUT8 (e.g., as described in Mori *et al.*, *Biotechnol. Bioengineer.*, 88: 901-908, 2004), expressing the antibody or antigen binding fragment thereof in cells incapable of expressing guanosine diphosphate (GDP)-mannose 4,6-dehydratase (GMD) (e.g., as described in Kanda *et al.*, *J. Biotechnol.*, 130: 300-310, 2007). The present disclosure also contemplates the use of antibody or antigen binding fragment thereof having a reduced level of fucosylation, for example, produced using a cell line modified to express  $\beta$ —(1,4)-N-acetylglucosaminyltransferase III (GnT-III) (e.g., as described in Umāna *et al.*, *Nat. Biotechnol.* 17: 176-180, 1999).

In one example, an antibody according to the present disclosure is defucosylated. For example, the antibody is produced in a cell (e.g., a mammalian cell, such as a CHO cell) that does not express FUT8 or is treated with an inhibitor of N-glycan processing such as kifunensine.

Other methods include the use of cell lines which inherently produce antibodies capable of inducing enhanced Fc-mediated effector function (e.g., duck embryonic derived stem cells for the production of viral vaccines, US20100062489; Recombinant protein production in avian EBX® cells, US20100226912).

CD83 binding proteins of the present disclosure also include those with bisected oligosaccharides, for example, in which a biantennary oligosaccharide attached to the

Fc region is bisected by GlcNAc. Such immunoglobulins may have reduced fucosylation and/or improved ADCC function. Examples of such antibody or antigen binding fragment thereof are described, for example, in US6602684 and US20050123546.

5 CD83 binding proteins with at least one galactose residue in the oligosaccharide attached to the Fc region are also contemplated. Such immunoglobulins may have improved CDC function. Such immunoglobulins are described, for example, in WO1997/30087 and WO1999/22764.

CD83 binding proteins can also comprise a Fc region capable of inducing  
10 enhanced levels of CDC. For example, hybrids of IgG1 and IgG3 produce antibodies having enhanced CDC activity (Natsume *et al.*, Cancer Res. 68: 3863-3872, 2008).

CD83 binding proteins can also or alternatively be fused to or conjugated to proteins (e.g., antibody variable regions) that bind to immune effector cells, for example, by virtue of binding to CD3 or CD16.

15 Methods for determining effector function are known in the art. In one example, the level of ADCC activity is assessed using a <sup>51</sup>Cr release assay, an europium release assay or a <sup>35</sup>S release assay. In each of these assays, cells expressing CD83 are cultured with one or more of the recited compounds for a time and under conditions sufficient for the compound to be taken up by the cell. In the case of a <sup>35</sup>S release  
20 assay, the cells can be cultured with <sup>35</sup>S-labeled methionine and/or cysteine for a time sufficient for the labeled amino acids to be incorporated into newly synthesized proteins. Cells are then cultured in the presence or absence of the protein and in the presence of immune effector cells, for example, PBMCs and/or NK cells. The amount of <sup>51</sup>Cr, europium and/or <sup>35</sup>S in cell culture medium is then detected, and an increase in  
25 the presence of the protein compared to in the absence of immunoglobulin indicates that the binding molecule/agent has effector function. Exemplary publications disclosing assays for assessing the level of ADCC induced by an immunoglobulin include Hellstrom *et al.* Proc. Natl Acad. Sci. USA 83: 7059-7063, 1986 and Bruggemann *et al.*, J. Exp. Med. 166: 1351-1361, 1987.

30 Other assays for assessing the level of ADCC induced by an immunoglobulin include ACTITM nonradioactive cytotoxicity assay for flow cytometry (CellTechnology, Inc. CA, USA) or CytoTox 96® non-radioactive cytotoxicity assay (Promega, WI, USA).

Alternatively, or additionally, effector function of a CD83 binding protein is  
35 assessed by determining its affinity for one or more FcγRs, for example, as described in US7317091.

C1q binding assays may also be carried out to confirm that the CD83 binding protein is able to bind C1q and may induce CDC. To assess complement activation, a CDC assay may be performed (see, e.g., Gazzano-Santoro *et al.*, J. Immunol. Methods 202: 163, 1996).

5 In another example, the CD83 binding protein comprises one or more amino acid substitutions that increase the half-life of the protein. For example, the CD83 binding protein comprises a constant region comprising one or more amino acid substitutions that increase the affinity of the constant region for the neonatal Fc region (FcRn). For example, the constant region has increased affinity for FcRn at lower pH,  
10 for example, about pH 6.0, to facilitate Fc/FcRn binding in an endosome. In one example, the constant region has increased affinity for FcRn at about pH 6 compared to its affinity at about pH 7.4, which facilitates the re-release of Fc into blood following cellular recycling. These amino acid substitutions are useful for extending the half life of a CD83 binding protein, by reducing clearance from the blood.

15 Exemplary amino acid substitutions include T250Q and/or M428L or T252A, T254S and T266F or M252Y, S254T and T256E or H433K and N434F according to the EU numbering system. Additional or alternative amino acid substitutions are described, for example, in US20070135620 or US7083784.

## 20 Mutant CD83 Binding Proteins

The present disclosure also provides a CD83 binding protein or a nucleic acid encoding same having at least 80% identity to a sequence disclosed herein. In one example, a CD83 binding protein or nucleic acid of the disclosure comprises sequence at least about 80% or 81% or 82% or 83% or 84% or 85% or 90% or 95% or 96% or  
25 97% or 98% or 99% identical to a sequence disclosed herein, wherein the protein specifically binds to CD83.

Alternatively, or additionally, the CD83 binding protein comprises a CDR (e.g., three CDRs) at least about 30% or 35% or 40% or 45% or 50% or 55% or 60% or 65% or 70% or 75% or 80% or 85% or 90% or 95% or 97% or 98% or 99% identical to  
30 CDR(s) of a  $V_H$  or  $V_L$  as described herein according to any example, wherein the protein is capable of specifically binding to CD83. In this regard, the inventors have produced numerous antibodies having diverse sequences within their CDRs. Methods for determining binding of a protein CD83 are described herein.

For example, the inventors have identified a group of CD83 binding proteins  
35 sharing at least about 60% identity in their light chain CDR1, such as, for example, with at least about 65% or 70% or 75% or 80% or 85% or 90% or 95% or 96% or 97%

or 98% or 99% identity in their light chain CDR1 according to the Kabat numbering system.

The inventors have also identified a group of CD83 binding proteins sharing 70% identity in their light chain CDR2, such as, for example, with at least about 75%  
5 or 80% or 85% or 90% or 95% or 96% or 97% or 98% or 99% identity in their light chain CDR2 according to the Kabat numbering system.

The inventors have also identified a group of CD83 binding proteins sharing 30% identity in their light chain CDR3, such as, for example, with at least about 35%  
10 or 40% or 45% or 50% or 55% or 60% or 65% or 70% or 75% or 80% or 85% or 90% or 95% or 96% or 97% or 98% or 99% identity in their light chain CDR3 according to the Kabat numbering system.

As discussed herein, the four N-terminal amino acids of a light chain CDR1 can be deleted or any one or more of those amino acids can be substituted with another naturally-occurring amino acid (Padlan *et al.*, FASEB J., 9: 133-139, 1995). Thus, a  
15 CD83 binding protein of the disclosure can comprise a CDR1 having at least about 70% identity to a light chain CDR1 sequence disclosed herein.

In another example, a nucleic acid of the disclosure comprises a sequence at least about 80% or 85% or 90% or 95% or 97% or 98% or 99% identical to a sequence disclosed herein and encoding a CD83 binding protein which is capable of specifically  
20 binding to CD83. The present disclosure also encompasses nucleic acids encoding a CD83 binding protein of the disclosure, which differs from a sequence exemplified herein as a result of degeneracy of the genetic code.

The % identity of a nucleic acid or polypeptide is determined by GAP (Needleman and Wunsch. Mol. Biol. 48, 443-453, 1970) analysis (GCG program) with  
25 a gap creation penalty=5, and a gap extension penalty=0.3. The query sequence is at least 50 residues in length, and the GAP analysis aligns the two sequences over a region of at least 50 residues. For example, the query sequence is at least 100 residues in length and the GAP analysis aligns the two sequences over a region of at least 100 residues. For example, the two sequences are aligned over their entire length.

30 As discussed above, the present disclosure also contemplates a nucleic acid that hybridizes under stringent hybridization conditions to a nucleic acid encoding a CD83 binding protein described herein, for example, nucleic acid encoding a V<sub>H</sub> or V<sub>L</sub> of antibody 3C12, 3C12.B, 3C12.C, 3C12.D, or 3C12.E. A "moderate stringency" is defined herein as being a hybridization and/or washing carried out in 2 x SSC buffer,  
35 0.1% (w/v) SDS at a temperature in the range 45°C to 65°C, or equivalent conditions. A "high stringency" is defined herein as being a hybridization and/or wash carried out

in 0.1 x SSC buffer, 0.1% (w/v) SDS, or lower salt concentration, and at a temperature of at least 65°C, or equivalent conditions. Reference herein to a particular level of stringency encompasses equivalent conditions using wash/hybridization solutions other than SSC known to those skilled in the art. For example, methods for calculating the  
5 temperature at which the strands of a double stranded nucleic acid will dissociate (also known as melting temperature, or T<sub>m</sub>) are known in the art. A temperature that is similar to (e.g., within 5°C or within 10°C) or equal to the T<sub>m</sub> of a nucleic acid is considered to be high stringency. Medium stringency is to be considered to be within 10°C to 20°C or 10°C to 15°C of the calculated T<sub>m</sub> of the nucleic acid.

10 The present disclosure also contemplates mutant forms of a CD83 binding protein of the disclosure comprising one or more conservative amino acid substitutions compared to a sequence set forth herein. In some examples, the CD83 binding protein comprises 10 or fewer, for example, 9 or 8 or 7 or 6 or 5 or 4 or 3 or 2 or 1 conservative amino acid substitutions. A "conservative amino acid substitution" is one in which the  
15 amino acid residue is replaced with an amino acid residue having a similar side chain and/or hydrophobicity and/or hydrophilicity.

Families of amino acid residues having similar side chains have been defined in the art, including basic side chains (e.g., lysine, arginine, histidine), acidic side chains (e.g., aspartic acid, glutamic acid), uncharged polar side chains (e.g., glycine,  
20 asparagine, glutamine, serine, threonine, tyrosine, cysteine), nonpolar side chains (e.g., alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan), β-branched side chains (e.g., threonine, valine, isoleucine) and aromatic side chains (e.g., tyrosine, phenylalanine, tryptophan, histidine). Hydrophobic indices are described, for example, in Kyte and Doolittle J. Mol. Biol., 157: 105-132, 1982 and hydrophilic  
25 indices are described in, for example, US4554101.

The present disclosure also contemplates non-conservative amino acid changes. For example, of particular interest are substitutions of charged amino acids with another charged amino acid and with neutral or positively charged amino acids. In some examples, the CD83 binding protein comprises 10 or fewer, for example, 9 or 8  
30 or 7 or 6 or 5 or 4 or 3 or 2 or 1 non-conservative amino acid substitutions.

In one example, the mutation(s) occur within a FR of an antigen binding domain of a CD83 binding protein of the disclosure. In another example, the mutation(s) occur within a CDR of a CD83 binding protein of the disclosure.

Exemplary methods for producing mutant forms of a CD83 binding protein  
35 include:

- mutagenesis of DNA (Thie *et al.*, Methods Mol. Biol. 525: 309-322, 2009) or RNA (Kopsidas *et al.*, Immunol. Lett. 107:163-168, 2006; Kopsidas *et al.* BMC Biotechnology, 7: 18, 2007; and WO1999/058661);
- introducing a nucleic acid encoding the polypeptide into a mutator cell, for example, XL-1Red, XL-mutS and XL-mutS-Kanr bacterial cells (Stratagene);
- DNA shuffling, for example, as disclosed in Stemmer, Nature 370: 389-91, 1994; and
- site directed mutagenesis, for example, as described in Dieffenbach (ed) and Dveksler (ed) (In: PCR Primer: A Laboratory Manual, Cold Spring Harbor Laboratories, NY, 1995).

Exemplary methods for determining biological activity of the mutant CD83 binding proteins of the disclosure will be apparent to the skilled artisan and/or described herein, for example, antigen binding. For example, methods for determining antigen binding, competitive inhibition of binding, affinity, association, dissociation and therapeutic efficacy are described herein.

Exemplary CD83 Binding Proteins

Exemplary variable region containing CD83 binding proteins produced by the inventors and their encoding nucleic acids are described in Tables 1 and 2.

**Table 1: Sequences of exemplary CD83 binding proteins and encoding nucleic acids**

	Antibody Name	V <sub>H</sub> amino acid SEQ ID NO	V <sub>H</sub> chain nucleotide SEQ ID NO	V <sub>L</sub> amino acid SEQ ID NO	V <sub>L</sub> chain nucleotide SEQ ID NO
1	3C12	1	35	5	36
2	3C12.B	1	35	6	37
3	3C12.C	1	35	7	38
4	3C12.D	1	35	8	39
5	3C12E	1	35	9	40

**Table 2: Amino acid substitutions in V<sub>L</sub> (relative to SEQ ID NO: 5) of exemplary CD83 binding proteins**

	Antibody name	V <sub>L</sub> substitution
1	3C12.B	I2V; L10F, L15I; T20S; A25T; K30S; Y32H; F33L; R39K; T51A; N53S; E70D; F83I; L91V; G92N; A93S; L96Y; G100Q; K103R
2	3C12.C	M4L; L10S; L15V; K30R; F33L; R39K; A43V; N53T; G66R; Q79H; L91V; G92D; A93R; Y94F; L96Y; G100Q; L104V
3	3C12.D	V3Q; L10S; L15V; K30S; N31S; Y32W; F33L; R39K; T51A; N53S; E81D; Q90K; G92S; A93S; L96Y; L104V
4	3C12E	M4L; L10S; L15V; K30S; F33L; R39K; A43V; T51A; N53T; E70H; F83V; Q90K; L91C; G92N; A93S; Y94A; L96Y; G100Q; L104V

## 5 Methods for Producing Proteins

### Recombinant Expression

As discussed herein, a nucleic acid encoding a CD83 binding protein of the disclosure and/or one or more polypeptides thereof is introduced into an expression construct, such that it is operably linked to a promoter to thereby facilitate its expression. Methods for producing expression constructs, for example, cloning into expression constructs/vectors are known in the art and/or described in Ausubel *et al.*, (In: Current Protocols in Molecular Biology. Wiley Interscience, ISBN 047 150338, 1987), and (Sambrook *et al.*, (In: Molecular Cloning: Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratories, New York, Third Edition 2001) and US7270969.

In one example, the CD83 binding protein of the disclosure is expressed in a bacterial cell. Typical promoters suitable for expression in bacterial cells such as, for example, a bacterial cell selected from the group comprising *E. coli*, *Staphylococcus sp.*, *Corynebacterium sp.*, *Salmonella sp.*, *Bacillus sp.*, and *Pseudomonas sp.*, include, but are not limited to a promoter such as lacz, Ipp, a temperature-sensitive L or R promoters, T7, T3, SP6 or semi-artificial promoters such as the IPTG-inducible tac promoter or lacUV5 promoter.

In another example, the CD83 binding protein is expressed in a yeast cell. Typical promoters suitable for expression in yeast cells such as, *Pichia pastoris*, *Saccharomyces cerevisiae* and *S. pombe*, include, but are not limited to, promoters from the following genes ADH1, GAL1, GAL4, CUP1, PHO5, nmt, RPR1, or TEF1.

In a further example, the CD83 binding protein is expressed in an insect cell. Typical promoters suitable for expression in insect cells, or in insects, include, but are not limited to, the OPEI2 promoter, the insect actin promoter isolated from *Bombyx mori*, the *Drosophila sp.* dsh promoter (Marsh *et al.*, Hum. Mol. Genet. 9:, 13-25, 5 2000).

A CD83 binding protein of the disclosure can also be expressed in plant cells. Promoters for expressing peptides in plant cells are known in the art, and include, but are not limited to, the *Hordeum vulgare* amylase gene promoter, the cauliflower mosaic virus 35S promoter, the nopaline synthase (NOS) gene promoter, and the auxin 10 inducible plant promoters P1 and P2.

In one example, a CD83 binding protein of the disclosure is expressed in a mammalian cell or in a mammal. Typical promoters suitable for expression in a mammalian cell include, for example a promoter selected from the group consisting of, retroviral LTR elements, the SV40 early promoter, the SV40 late promoter, the CMV 15 IE (cytomegalovirus immediate early) promoter, the EF1 promoter (from human elongation factor 1), the EM7 promoter, the UbC promoter (from human ubiquitin C). Examples of useful mammalian host cell lines include monkey kidney CV1 line transformed by SV40 (COS-7); human embryonic kidney line (HEK-293 cells); baby hamster kidney cells (BHK); Chinese hamster ovary cells (CHO); African green 20 monkey kidney cells (VERO-76); or myeloma cells (e.g., NS/0 cells).

Exemplary cells used for expressing a CD83 binding protein of the disclosure are CHO cells, myeloma cells or HEK cells. The cell may further comprise one or more genetic mutations and/or deletions that facilitate expression of a modified antibody. One non-limiting example is a deletion of a gene encoding an enzyme 25 required for fucosylation of an expressed immunoglobulin or antibody. For example, the deleted gene encodes FUT8. A commercially available source of FUT8-deleted CHO cells is Biowa (Potelligent™ cells). For example, the cells used for expression of an defucosylated immunoglobulin or antibody are FUT8-deleted CHO cells, such as, Biowa's Potelligent™ cells.

30 Other elements of expression constructs/vectors are known in the art and include, for example, enhancers, transcriptional terminators, polyadenylation sequences, nucleic acids encoding selectable or detectable markers and origins of replication.

In one example, an expression construct is a bicistronic expression construct. 35 By "bicistronic" is meant a single nucleic acid molecule that is capable of encoding two distinct polypeptides from different regions of the nucleic acid, for example, a single

nucleic acid capable of encoding a  $V_H$  containing polypeptide and a  $V_L$  containing polypeptide as distinct polypeptides. Generally, the regions encoding each distinct polypeptide are separated by an internal ribosome entry site (IRES) and the region 5' of the IRES does not comprise a transcription termination sequence. Exemplary IRESs  
5 are described, for example, in US20090247455.

Following production of a suitable expression construct, it is introduced into a suitable cell using any method known in the art. Exemplary methods include microinjection, transfection mediated by DEAE-dextran, transfection mediated by liposomes such as by using lipofectamine (Gibco, MD, USA) and/or cellfectin (Gibco,  
10 MD, USA), PEG-mediated DNA uptake, electroporation and microparticle bombardment such as by using DNA-coated tungsten or gold particles (Agracetus Inc., WI, USA) amongst others.

The cells used to produce the CD83 binding proteins of this disclosure are then cultured under conditions known in the art to produce the CD83 binding protein of the  
15 disclosure.

Cell free expression systems are also contemplated by the present disclosure, for example, the TNT T7 and TNT T3 systems (Promega), the pEXP1-DEST and pEXP2-DEST vectors (Invitrogen).

## 20 Protein Purification

Following production/expression, a CD83 binding protein of the disclosure is purified using a method known in the art. Such purification provides the protein of the disclosure substantially free of nonspecific protein, acids, lipids, carbohydrates, and the like. In one example, the protein will be in a preparation wherein more than about 90%  
25 (e.g., 95%, 98% or 99%) of the protein in the preparation is a CD83 binding protein of the disclosure.

Standard methods of peptide purification are employed to obtain an isolated CD83 binding protein of the disclosure, including but not limited to various high-pressure (or performance) liquid chromatography (HPLC) and non-HPLC polypeptide  
30 isolation protocols, such as size exclusion chromatography, ion exchange chromatography, hydrophobic interaction chromatography, mixed mode chromatography, phase separation methods, electrophoretic separations, precipitation methods, salting in/out methods, immunochromatography, and/or other methods.

In one example, affinity purification is useful for isolating a fusion protein  
35 comprising a label. Methods for isolating a protein using affinity chromatography are known in the art and described, for example, in Scopes (In: Protein purification:

principles and practice, Third Edition, Springer Verlag, 1994). For example, an antibody or compound that binds to the label (in the case of a polyhistidine tag this may be, for example, nickel-NTA) is immobilized on a solid support. A sample comprising a protein is then contacted to the immobilized antibody or compound for a time and  
5 under conditions sufficient for binding to occur. Following washing to remove any unbound or non-specifically bound protein, the protein is eluted.

In the case of a CD83 binding protein comprising a Fc region of an antibody, protein A or protein G or modified forms thereof can be used for affinity purification. Protein A is useful for isolating purified proteins comprising a human  $\gamma 1$ ,  $\gamma 2$ , or  $\gamma 4$   
10 heavy chain Fc region. Protein G is recommended for all mouse Fc isotypes and for human  $\gamma 3$ .

### Conjugates

In one example, a CD83 binding protein of the present disclosure is conjugated  
15 to a compound. For example, the compound is selected from the group consisting of a radioisotope, a detectable label, a therapeutic compound, a colloid, a toxin, a nucleic acid, a peptide, a protein, a compound that increases the half life of the CD83 binding protein in a subject and mixtures thereof.

The compound can be directly or indirectly bound to the CD83 binding protein  
20 (e.g., can comprise a linker in the case of indirect binding). Examples of compounds include, a radioisotope (e.g., iodine-131, yttrium-90 or indium-111), a detectable label (e.g., a fluorophore or a fluorescent nanocrystal), a therapeutic compound (e.g., a chemotherapeutic or an anti-inflammatory), a colloid (e.g., gold), a toxin (e.g., ricin or tetanus toxoid), a nucleic acid, a peptide (e.g., a serum albumin binding peptide), a  
25 protein (e.g., a protein comprising an antigen binding domain of an antibody or serum albumin), a compound that increases the half life of the CD83 binding protein in a subject (e.g., polyethylene glycol or other water soluble polymer having this activity) and mixtures thereof. Exemplary compounds that can be conjugated to a CD83 binding protein of the disclosure and methods for such conjugation are known in the art and  
30 described, for example, in US2010221262.

Some exemplary compounds that can be conjugated to a CD83 binding protein of the present disclosure are listed in Table 3.

**Table 3:** Compounds useful in conjugation.

<b>Group</b>	<b>Detail</b>
<b>Radioisotopes (either directly or indirectly)</b>	<ul style="list-style-type: none"> <li>• <math>^{123}\text{I}</math>, <math>^{125}\text{I}</math>, <math>^{130}\text{I}</math>, <math>^{133}\text{I}</math>, <math>^{135}\text{I}</math>, <math>^{47}\text{Sc}</math>, <math>^{72}\text{As}</math>, <math>^{72}\text{Sc}</math>, <math>^{90}\text{Y}</math>, <math>^{88}\text{Y}</math>, <math>^{97}\text{Ru}</math>, <math>^{100}\text{Pd}</math>, <math>^{101\text{m}}\text{Rh}</math>, <math>^{101\text{m}}\text{Rh}</math>, <math>^{119}\text{Sb}</math>, <math>^{128}\text{Ba}</math>, <math>^{197}\text{Hg}</math>, <math>^{211}\text{At}</math>, <math>^{212}\text{Bi}</math>, <math>^{153}\text{Sm}</math>, <math>^{169}\text{Eu}</math>, <math>^{212}\text{Pb}</math>, <math>^{109}\text{Pd}</math>, <math>^{111}\text{In}</math>, <math>^{67}\text{Ga}</math>, <math>^{68}\text{Ga}</math>, <math>^{67}\text{Cu}</math>, <math>^{75}\text{Br}</math>, <math>^{76}\text{Br}</math>, <math>^{77}\text{Br}</math>, <math>^{99\text{m}}\text{Tc}</math>, <math>^{11}\text{C}</math>, <math>^{13}\text{N}</math>, <math>^{15}\text{O}</math>, <math>^{18}\text{F}</math>, <math>^{188}\text{Re}</math>, <math>^{203}\text{Pb}</math>, <math>^{64}\text{Cu}</math>, <math>^{105}\text{Rh}</math>, <math>^{198}\text{Au}</math>, <math>^{199}\text{Ag}</math> or <math>^{177}\text{Lu}</math></li> </ul>
<b>Half life extenders</b>	<ul style="list-style-type: none"> <li>• Polyethylene glycol</li> <li>• Glycerol</li> <li>• Glucose</li> </ul>
<b>Fluorescent probes</b>	<ul style="list-style-type: none"> <li>• Phycoerythrin (PE)</li> <li>• Allophycocyanin (APC)</li> <li>• Alexa Fluor 488</li> <li>• Cy5.5</li> </ul>
<b>Biologics</b>	<ul style="list-style-type: none"> <li>• fluorescent proteins such as Renilla luciferase, GFP</li> <li>• immune modulators, such as cytokines</li> <li>• toxins</li> <li>• an immunoglobulin or antibody or antibody variable region</li> <li>• half life extenders such as albumin or antibody variable regions or peptides that bind to albumin</li> </ul>
<b>Chemotherapeutics</b>	<ul style="list-style-type: none"> <li>• Taxol</li> <li>• 5-FU</li> <li>• Doxorubicin</li> <li>• Idarubicin</li> </ul>

### Screening Assays

CD83 binding proteins of the present disclosure are readily screened for biological activity, for example, as described below.

#### 5 Binding Assays

One form of assay is an antigen binding assay, for example, as described in Scopes (In: Protein purification: principles and practice, Third Edition, Springer Verlag, 1994). Such a method generally involves labeling the CD83 binding protein and contacting it with immobilized antigen. Following washing to remove non-specific  
10 bound protein, the amount of label and, as a consequence, bound protein is detected. Of course, the CD83 binding protein can be immobilized and the antigen labeled. Panning-type assays, for example, as described or exemplified herein can also be used. Alternatively, or additionally, surface plasmon resonance assays can be used.

In one example, a binding assay is performed with peptide comprising an  
15 epitope of CD83. In this way, CD83 binding proteins that bind to a specific region of CD83 are selected.

#### In Vivo Assays

CD83 binding proteins of the present disclosure can also be assessed for  
20 therapeutic efficacy in an animal model of a condition, for example, a CD83 mediated condition. For example, the CD83 binding protein is administered to a model of inflammatory bowel disease or colitis (e.g., dextran sodium sulphate (DSS)-induced colitis or CD45Rb adoptive transfer model of colitis (e.g., Kanai *et al.*, *Inflamm. Bowel Dis.* 12: 89-99, 2006). In another example, a CD83 binding protein is administered to a  
25 model of multiple sclerosis, for example, EAE models in which a mouse or rat is immunized with a myelin sheath protein or peptide derived therefrom (e.g., MOG, MBP or PLP) and an immune response is generated against the protein thereby inducing a model of multiple sclerosis. Exemplary EAE models are reviewed in, for example Tsunoda and Fujinami, *J. Neuropathol. Exp. Neurol.* 55: 673-686, 1996. The  
30 CD83 binding protein can also or alternatively be tested in a model of arthritis, for example, a SKG strain of mouse (Sakaguchi *et al.*, *Nature* 426: 454-460, 1995), rat type II collagen arthritis model, mouse type II collagen arthritis model or antigen induced arthritis models (Bendele *J. Musculoskel. Neuron. Interact.* 1: 377-385, 2001) and/or a  
35 model of inflammatory airway disease (for example, OVA challenge or cockroach antigen challenge).

The therapeutic efficacy of a CD83 binding protein of the present disclosure can also or alternatively be assessed in a model of graft-versus-host-response, for example, in which splenocytes from one animal are injected into a allogeneic animal (e.g., a MHC or HLA unmatched animal). In one example, human peripheral blood mononuclear cells (PBMCs) are transplanted into a xenogeneic SCID mouse model via, for example, intraperitoneal injection after sub lethal total body irradiation inducing a fatal human CD4<sup>+</sup> T cell mediated graft versus host response that requires human DCs. Treatment with a CD83 binding protein of the disclosure can be administered to mice, by, for example, intraperitoneal injection on the day of PBMC transplant (day 0) and mice scored for clinical manifestations of GVDH.

#### Competitive Binding Assays

Assays for determining a CD83 binding protein that competitively inhibits binding of an antibody of the disclosure will be apparent to the skilled artisan. For example, the antibody of the disclosure is conjugated to a detectable label, for example, a fluorescent label or a radioactive label. The labeled antibody and the test CD83 binding protein are then mixed and contacted with CD83 or a peptide comprising an epitope thereof. The level of labeled antibody is then determined and compared to the level determined when the labeled antibody is contacted with the CD83 or the peptide comprising an epitope thereof in the absence of the CD83 binding protein. If the level of labeled antibody is reduced in the presence of the CD83 binding protein compared to the absence of the CD83 binding protein, the CD83 binding protein competitively inhibits binding of the antibody.

Optionally, the CD83 binding protein is conjugated to a different label than the antibody. This permits detection of the level of binding of the CD83 binding protein to CD83 or epitope bearing peptide.

In another example, the CD83 binding protein is permitted to bind to CD83 or a peptide comprising an epitope thereof prior to contacting the CD83 or peptide with an antibody described herein. A reduction in the amount of bound antibody in the presence of the CD83 binding protein compared to in the absence of the CD83 binding protein indicates that the CD83 binding protein competitively inhibits binding of the antibody to CD83. A reciprocal assay can also be performed using labeled CD83 binding protein and first allowing the antibody to bind to CD83 or the peptide. In this case, a reduced amount of labeled CD83 binding protein bound to CD83 or the peptide in the presence of the antibody compared to in the absence of antibody indicates that the CD83 binding protein competitively inhibits binding of the antibody to CD83.

### Epitope Mapping Assays

In another example, the epitope bound by a protein described herein is mapped. Epitope mapping methods will be apparent to the skilled artisan. For example, a series of overlapping peptides spanning the CD83 sequence or a region thereof comprising an epitope of interest, for example, peptides comprising 10 to 15 amino acids are produced. The CD83 binding protein is then contacted to each peptide or a combination thereof and the peptide(s) to which it binds determined. This permits determination of peptide(s) comprising the epitope to which the CD83 binding protein binds. If multiple non-contiguous peptides are bound by the protein, the protein may bind a conformational epitope.

Alternatively, or in addition, amino acid residues within CD83 are mutated, for example, by alanine scanning mutagenesis, and mutations that reduce or prevent protein binding are determined. Any mutation that reduces or prevents binding of the CD83 binding protein is likely to be within the epitope bound by the protein.

A further method involves binding CD83 or a region thereof to an immobilized CD83 binding protein of the present disclosure and digesting the resulting complex with proteases. Peptide that remains bound to the immobilized protein are then isolated and analyzed, for example, using mass spectrometry, to determine their sequence.

A further method involves converting hydrogens in CD83 or a region thereof to deuterium atoms and binding the resulting protein to an immobilized CD83 binding protein of the present disclosure. The deuterium atoms are then converted back to hydrogen, the CD83 or region thereof isolated, digested with enzymes and analyzed, for example, using mass spectrometry to identify those regions comprising deuterium, which would have been protected from conversion to hydrogen by the binding of a CD83 binding protein described herein.

### Half Life Assays

Some CD83 binding proteins encompassed by the present disclosure have an improved half-life, for example, are modified to extend their half-life compared to CD83 binding proteins that are unmodified. Methods for determining a CD83 binding protein with an improved half-life will be apparent to the skilled person. For example, the ability of a CD83 binding protein to bind to a neonatal Fc receptor (FcRn) is assessed. In this regard, increased binding affinity for FcRn increased the serum half-life of the CD83 binding protein (see for example, Kim *et al.*, Eur. J. Immunol., 24: 2429, 1994).

The half-life of a CD83 binding protein of the disclosure can also be measured by pharmacokinetic studies, for example, according to the method described by Kim *et al.*, Eur. J. of Immunol. 24: 542, 1994. According to this method, radiolabeled CD83 binding protein is injected intravenously into mice and its plasma concentration is periodically measured as a function of time, for example at 3 minutes to 72 hours after the injection. The clearance curve thus obtained should be biphasic, that is, an alpha phase and beta phase. For the determination of the *in vivo* half-life of the CD83 binding protein, the clearance rate in beta-phase is calculated and compared with that of the wild type or unmodified CD83 binding protein.

10

#### Stability Assays

Stability of a CD83 binding protein of the disclosure can be assessed by any of a variety of assays. For example, the CD83 binding protein is exposed to a condition, for example, heat or acid or stored for a period of time (e.g., 1 month) at room temperature. Aggregation of the CD83 binding protein can then be assessed by determining turbidity (with an increase in turbidity following exposure to the condition indicating instability), size exclusion chromatography, non-reducing gel electrophoresis or a binding or neutralization study described herein.

#### 20 **Pharmaceutical Compositions and Methods of Treatment**

The CD83 binding protein of the present disclosure or nucleic acid encoding same or cell expressing same (*syn.* active ingredient) is useful for parenteral, topical, oral, or local administration, aerosol administration, or transdermal administration, for prophylactic or for therapeutic treatment.

25 Formulation of a CD83 binding protein or nucleic acid encoding same or cell expressing same to be administered will vary according to the route of administration and formulation (e.g., solution, emulsion, capsule) selected. An appropriate pharmaceutical composition comprising CD83 binding protein or nucleic acid encoding same or cell expressing same to be administered can be prepared in a physiologically acceptable carrier. A mixture of CD83 binding proteins can also be used. For solutions or emulsions, suitable carriers include, for example, aqueous or alcoholic/aqueous solutions, emulsions or suspensions, including saline and buffered media. Parenteral vehicles can include sodium chloride solution, Ringer's dextrose, dextrose and sodium chloride, lactated Ringer's or fixed oils. A variety of appropriate aqueous carriers are known to the skilled artisan, including water, buffered water, buffered saline, polyols (e.g., glycerol, propylene glycol, liquid polyethylene glycol), dextrose solution and

glycine. Intravenous vehicles can include various additives, preservatives, or fluid, nutrient or electrolyte replenishers (See, generally, Remington's Pharmaceutical Science, 16th Edition, Mack, Ed. 1980). The compositions can optionally contain pharmaceutically acceptable auxiliary substances as required to approximate  
5 physiological conditions such as pH adjusting and buffering agents and toxicity adjusting agents, for example, sodium acetate, sodium chloride, potassium chloride, calcium chloride and sodium lactate. The CD83 binding protein of this disclosure can be lyophilized for storage and reconstituted in a suitable carrier prior to use according to art-known lyophilization and reconstitution techniques.

10 The optimum concentration of the active ingredient(s) in the chosen medium can be determined empirically, according to procedures well known to the skilled artisan, and will depend on the ultimate pharmaceutical formulation desired.

The dosage ranges for the administration of the CD83 binding protein of the disclosure are those large enough to produce the desired effect. For example, the  
15 composition comprises a therapeutically or prophylactically effective amount of the CD83 binding protein or nucleic acid encoding same or cell expressing same.

As used herein, the term "effective amount" shall be taken to mean a sufficient quantity of the CD83 binding protein, nucleic acid, or cells to induce/increase or inhibit/reduce/prevent CD83 activity in a subject. The skilled artisan will be aware that  
20 such an amount will vary depending on, for example, the CD83 binding protein, nucleic acid, or cells and/or the particular subject and/or the type or severity of a condition being treated. Accordingly, this term is not to be construed to limit the disclosure to a specific quantity, for example, weight or number of CD83 binding proteins, nucleic acids, or cells.

25 As used herein, the term "therapeutically effective amount" shall be taken to mean a sufficient quantity of CD83 binding protein, nucleic acid, or cells to reduce or inhibit one or more symptoms of a condition.

As used herein, the term "prophylactically effective amount" shall be taken to mean a sufficient quantity of CD83 binding protein, nucleic acid or cells to prevent or  
30 inhibit or delay the onset of one or more detectable symptoms of a condition.

The dosage should not be so large as to cause adverse side effects, such as hyper viscosity syndromes, pulmonary edema, congestive heart failure, and the like. Generally, the dosage will vary with the age, condition, sex and extent of the disease in the patient and can be determined by one of skill in the art. The dosage can be adjusted  
35 by the individual physician in the event of any complication. Dosage can vary from about 0.1 mg/kg to about 300 mg/kg, for example, from about 0.2 mg/kg to about 200

mg/kg, such as, from about 0.5 mg/kg to about 20 mg/kg, in one or more dose administrations daily, for one or several days.

In one example, the CD83 binding protein is administered subcutaneously or intravenously.

5 In some examples, the CD83 binding protein or other active ingredient is administered at an initial (or loading) dose which is higher than subsequent (maintenance doses). For example, the binding molecule is administered at an initial dose of between about 1 mg/kg to about 30 mg/kg. The binding molecule is then administered at a maintenance dose of between about 0.0001 mg/kg to about 1 mg/kg.  
10 The maintenance doses may be administered every 7 to 35 days, such as, every 14 or 21 or 28 days.

In some examples, a dose escalation regime is used, in which a CD83 binding protein or other active ingredient is initially administered at a lower dose than used in subsequent doses. This dosage regime is useful in the case of subject's initially  
15 suffering adverse events

In the case of a subject that is not adequately responding to treatment, multiple doses in a week may be administered. Alternatively, or in addition, increasing doses may be administered.

One or more CD83 binding proteins of the present disclosure can be  
20 administered to an individual by an appropriate route, either alone or in combination with (before, simultaneous with, or after) another drug or agent. For example, the CD83 binding protein of the present disclosure can also be used in combination with proteins, for example, a TNF antagonist, an anti-IL-12/23 antibody, an anti-inflammatory, a corticosteroid, methotrexate or a painkiller. The CD83 binding protein  
25 of the present disclosure can be used as separately administered compositions given in conjunction with antibiotics and/or antimicrobial agents.

It will be appreciated by those skilled in the art that the CD83 binding proteins of the present disclosure may be introduced into a subject by administering an expression construct of the disclosure or a cell expressing a CD83 binding protein of  
30 the disclosure. A variety of methods can be used for introducing a nucleic acid encoding the antibody into a target cell *in vivo*. For example, the naked nucleic acid may be injected at the target site, may be encapsulated into liposomes, or may be introduced by way of a viral vector.

### CD83 Detection Assays

The following assays can be performed with a CD83 binding protein of the disclosure, for example, a CD83 binding protein conjugated to a detectable label as discussed herein. Detection of CD83 with an assay described herein is useful for  
5 diagnosing or prognosing a condition.

An immunoassay is an exemplary assay format for diagnosing a condition in a subject or detecting CD83 in a sample. The present disclosure contemplates any form of immunoassay, including Western blotting, enzyme-linked immunosorbent assay (ELISA), fluorescence-linked immunosorbent assay (FLISA), competition assay,  
10 radioimmunoassay, lateral flow immunoassay, flow-through immunoassay, electrochemiluminescent assay, nephelometric-based assays, turbidometric-based assay, and fluorescence activated cell sorting (FACS)-based assays.

One form of a suitable immunoassay is, for example, an ELISA or FLISA.

In one form, such an assay involves immobilizing a CD83 binding protein of the  
15 disclosure onto a solid matrix, such as, for example a polystyrene or polycarbonate microwell or dipstick, a membrane, or a glass support (e.g., a glass slide). A test sample is then brought into direct contact with the CD83 binding protein and CD83 in the sample is bound or captured. Following washing to remove any unbound protein in the sample, a protein that binds to CD83 at a distinct epitope is brought into direct  
20 contact with the captured CD83. This detector protein is generally labeled with a detectable reporter molecule, such as, for example, an enzyme (e.g. horseradish peroxidase (HRP)), alkaline phosphatase (AP) or  $\beta$ -galactosidase) in the case of an ELISA or a fluorophore in the case of a FLISA. Alternatively, a second labeled protein can be used that binds to the detector protein. Following washing to remove any  
25 unbound protein the detectable reporter molecule is detected by the addition of a substrate in the case of an ELISA, such as, for example, hydrogen peroxide, TMB, or toluidine, or 5-bromo-4-chloro-3-indol-beta-D-galactopyranoside (x-gal). Of course, the immobilized (capture) protein and the detector protein may be used in the opposite manner.

30 The level of the antigen in the sample is then determined using a standard curve that has been produced using known quantities of the marker or by comparison to a control sample.

The assays described above are readily modified to use chemiluminescence or electrochemiluminescence as the basis for detection.

35 As will be apparent to the skilled artisan, other detection methods based on an immunosorbent assay are useful in the performance of the present disclosure. For

example, an immunosorbent method based on the description *supra* using a radiolabel for detection, or a gold label (e.g., colloidal gold) for detection, or a liposome, for example, encapsulating NAD<sup>+</sup> for detection or an acridinium linked immunosorbent assay.

5 In some examples of the disclosure, the level of CD83 is determined using a surface plasmon resonance detector (e.g., BIAcore™, GE Healthcare, Piscataway, N.J.), a flow through device, for example, as described in US7205159, a micro- or nano-immunoassay device (e.g., as described in US7271007), a lateral flow device (e.g., as described in US20040228761 or US20040265926), a fluorescence polarization  
10 immunoassay (FPIA e.g., as described in US4593089 or US4751190), or an immunoturbidimetric assay (e.g., as described in US5571728 or US6248597).

#### **Conditions or Disease**

The CD83 binding proteins of the disclosure can be used for the treatment,  
15 prevention, diagnosis or prophylaxis of a CD83 associated condition or disease.

Exemplary conditions or disease that can be treated, prevented, diagnosed, or prognosed by performing a method of the disclosure include inflammatory or autoimmune conditions or diseases.

Exemplary conditions and diseases include allergies, asthma, graft rejection,  
20 autoimmune conditions such as myasthenia gravis, multiple sclerosis, vasculitis, chronic inflammatory bowel diseases such as Morbus Crohn or colitis ulcerosa, HLA B27-associated autoimmunopathis such as Morbus Bechterew, and systemic lupus erythematosus, skin diseases such as psoriasis, rheumatoid arthritis, insulin-dependent diabetes mellitus and AIDS.

25 In one example, the CD83 binding protein of the disclosure depletes immune cells such as antigen presenting cells (APC) (e.g., dendritic cells (DCs)) and/or lymphocytes (e.g., T cells) to modulate aberrant or unwanted immune responses in, for example, inflammatory and/or autoimmune conditions or diseases. In one example, the CD83 binding protein is an antibody which specifically binds to the surface of an APC  
30 and/or lymphocyte and depletes the APC and/or lymphocyte via antibody dependent mediated cytotoxicity (ADCC). In one example, ADCC is mediated by natural killer (NK) cells.

### Graft Rejection

In one example, the CD83 binding proteins of the disclosure can be used to deplete immune cells such as APCs and/or lymphocytes to modulate immune responses associated with, for example, rejection of a graft by, for example, graft versus host  
5 disease or host versus graft disease. In one example, the graft is an organ or tissue or cell graft. In one example, the graft is an allograft. In one example, the graft is an hematopoietic stem cell graft.

Graft versus host disease may result where an immunocompetant graft, for example, an allogeneic hematopoietic stem cell graft, is administered with viable and  
10 functional immune cells to a recipient, for example, an histo-incompatible recipient, and the immune cells present in the graft, for example, T cells, attack tissues of the transplant recipient.

Host versus graft disease may result where antigens derived from the allogeneic graft are presented by either donor or recipient APCs to immune cells of the recipient,  
15 for example, T cells, which are in turn activated to become effector immune cells, for example, cytotoxic T lymphocytes (CTLs) that then attack the transplant.

An "allogeneic graft" is a graft from a genetically non-identical donor (e.g., histo-incompatible donor) of the same species.

### 20 *Hematopoietic Stem Cell Transplantation (HSCT)*

An "hematopoietic stem cell transplantation (HSCT)" is a graft comprising multipotent hematopoietic stem cells which can be derived, for example, from bone marrow or peripheral blood. The transplant may include some non-stem cells, for example, APCs including DCs and/or lymphocytes.

25 "Hematopoietic stem cells" can self renew and differentiate to give rise to all the blood cell types including myeloid (monocytes and macrophages, neutrophils, basophils, eosinophils, dendritic cells), erythroid (erythrocytes), megakaryocytic (platelets) and lymphoid lineages (T-cells, B-cells, NK-cells). Throughout differentiation, the hematopoietic stem cell first loses its self-renewal capacity, then  
30 loses lineage potential step by step as it commits to becoming a mature effector cell. Typically a Lin-, CD34+, CD38-, CD90+, CD45RA- human cell is a hematopoietic stem cell. In one example, expression of CD34 is used to identify hematopoietic stem cells in peripheral blood isolated from human donors.

HSCT can be used in the treatment of diseases and conditions which require  
35 stem cell transplants. For example, the stem cells can be used for the treatment of failure or dysfunction of normal blood cell production and maturation, hematopoietic

malignancy, autoimmune disease, liver disease, or immunodeficiency (by reason of for example, irradiation, chemotherapy or infection with a pathogen).

The stem cells may be expanded or differentiated *ex vivo* prior to administration to a subject.

5 Allogeneic hematopoietic stem-cell transplantation may be used to treat one or more of the following conditions: acute myeloid leukemia, acute lymphoblastic leukemia, chronic myeloid leukemia, chronic lymphocytic leukemia, myeloproliferative disorders, myelodysplastic syndromes, multiple myeloma, non-Hodgkin lymphoma, Hodgkin disease, aplastic anemia, pure red cell aplasia,  
10 paroxysmal nocturnal hemoglobinuria, Fanconi anemia, Thalassemia major, sickle cell anemia, Severe combined immunodeficiency (SCID), Wiskott-Aldrich syndrome, hemophagocytic lymphohistiocytosis (HLH), inborn errors of metabolism (e.g., mucopolysaccharidosis,, Gaucher disease, metachromatic leukodystrophies and adrenoleukodystrophies).

15

#### **Kits**

The present disclosure additionally comprises a kit comprising one or more of the following:

- 20 (i) a CD83 binding protein of the disclosure or expression construct(s) encoding same;
- (ii) a cell of the disclosure; or
- (iii) a pharmaceutical composition of the disclosure.

In the case of a kit for detecting CD83, the kit can additionally comprise a detection means, for example, linked to a CD83 binding protein of the disclosure.

25 In the case of a kit for therapeutic/prophylactic use, the kit can additionally comprise a pharmaceutically acceptable carrier.

Optionally a kit of the disclosure is packaged with instructions for use in a method described herein according to any example.

30 The present disclosure includes the following non-limiting Examples.

## EXAMPLES

### Example 1 Materials and Methods

#### Expression Vector Design

mAbXpress vectors were assembled using publicly available human constant  
 5 region heavy chain (IgG1 and IgG4 subtypes) and  $\kappa$  light chain sequences. Required  
 DNA was synthesized and codon-optimized for mammalian expression by Genent AG  
 (Germany). These cassettes were then placed into mammalian expression vectors  
 containing sequences for expression, selection and amplification in mammalian cells  
 (Acyte Biotech, Australia). A single *SacI* site was included in the expression vector to  
 10 facilitate linearization and In Fusion™ (ClonTech) cloning of the variable region.

#### Phage Display Panning against CD83 and Ligation-Independent, In Fusion™ Cloning of scFvs

The extracellular domain of human CD83 was expressed in CHO cells and  
 15 purified by IMAC. This preparation was used to isolate binders from a published  
 human scFv phage display library (Sheets *et al.*, Proc. Natl. Acad. Sci. U.S.A 95(11):  
 6157-62, 1998). Several unique binders to recombinant CD83 were isolated and clone  
 3C12 was selected for cloning and expression. Variable regions for both the heavy and  
 light chains were PCR amplified from the phagemid vectors using primers against the  
 20 5' and 3' framework regions of each chain. An additional 15 bp was included on each  
 primer corresponding to upstream and downstream bases of the destination vector to  
 enable ligation-independent In Fusion™ cloning (Clontech). Example primers for the  
 heavy chain were: 3C12\_VhFor 5'-  
 CAGGTGTCCACTCCGAGGTGCAGCTGCAGGAG-3' (SEQ ID NO:50) and  
 25 3C12\_VhRev 5'-GCGGAGGACACGGTGAGCGTGGTCCCTTGGCCC-3' (SEQ ID  
 NO:51), and for the light chain the primers were: 3C12\_VkFor 5'-  
 CCGGCGTGCCTCCGAGATCGTGATGACCCAG-3' (SEQ ID NO:52) and  
 3C12\_VkRev 5'-GCCACGGTCCGCTTGAGTTCAGCTTGGTCCC-3' (SEQ ID  
 NO:53). Underlined regions represent the scFv-specific sequence, which varies from  
 30 clone to clone. The unpurified PCR products were inserted into the mAbXpress IgG1  
 heavy and  $\kappa$  light chain vectors using the In Fusion™ system (Clontech), as per the  
 manufacturer's instructions. Transfection and purification of antibodies was performed  
 as described below.

### Mammalian Cell Expression

For antibody expression, mAbXpress plasmids harbouring heavy chain and light chain sequences were co-transfected using Polyethylenimine (PEI)-Max prepared in water (Polysciences Inc). Transfection complexes were prepared at a ratio of PEI:DNA of 3.5:1. Transient transfections of suspension-adapted CHO were performed using a 0.75:0.25 v/v ratio of cells : transfection complex, meaning each 750  $\mu\text{L}$  cells (at  $1.5 \times 10^6$  cells.mL<sup>-1</sup>) in CD-CHO media is transfected with 1.6  $\mu\text{g}$  DNA and 5.6  $\mu\text{g}$  PEI in 250  $\mu\text{L}$  of OptiPro SFM medium (Invitrogen). The complex was incubated for 15 mins at room temperature without disruption before addition to the cell suspension. At 4 hours post-transfection, cells were diluted by doubling the total volume with CD-CHO and Insulin-like Growth Factor 1 (IGF-1) at 0.1 mg.L<sup>-1</sup> before transferring cultures to humidified incubators at 32°C and 7.5% CO<sub>2</sub> for 7-14 days with shaking (160-250 rpm, depending of the vessel and the shaker throw ratio). Expression studies were typically performed at small (2 mL), medium (30 mL) or large (400 mL) scale. Cellular debris was removed by centrifugation and secreted antibody purified with Protein-A chromatography.

### Protein A Purification of Immunoglobulins and Ig-Fusion Proteins

A 1 mL Protein A HiTrap column (GE Healthcare) was pump washed with 20 Column Volumes (CV) of PBS. Supernatant containing human IgG1 or CD83-Fc fusion protein, ranging from volumes of 20 mL – 1.2 L, were applied at a flow rate of 1 mL per minute. The column was washed with 20-50 CV PBS prior to applying 10 CV of Protein A Elution Buffer with each 1 mL fraction eluted into 40  $\mu\text{L}$  Neutralization Buffer to restore the pH to 7.0.

### Analytical Size Exclusion Chromatography (SEC) of Antibodies expressed in mAbXpress

For SEC, a TSK-GEL G3000SWxl 30 cm x 7.8 mm column (Tosoh Bioscience) was used on an Agilent 1200 series LC with a mobile phase of 100 mM Phosphate pH 6.7, 200 mM NaCl, filtered through a 0.22  $\mu\text{m}$  filter. Flow rate was 0.8 mL.min<sup>-1</sup>. Calibration was performed using gel filtration standards (Bio-Rad). Typical yields from transient transfection experiments using this system ranged from 20-60 mg.L<sup>-1</sup>.

### CD83 Western Blot

To assess whether anti-CD83 mAbs recognise linear or conformational epitopes, recombinant hCD83<sub>ECD</sub>-His protein was prepared for SDS-PAGE. Non-denatured samples (i.e., not denatured by boiling in mercaptoethanol) containing 5 µg hCD83<sub>ECD</sub>-His were loaded directly to wells, whereas denatured samples included 2.5% β-mercaptoethanol and were heated at 95°C for 10 mins prior to loading. Proteins were separated on 12% NuPAGE gels (Invitrogen) by running at 200 volts for 50 mins prior to transfer to nitrocellulose membrane for 45 mins at 100 volts using the Transblot System (BioRad). Odyssey Blocking buffer (Li-Cor Biosciences) was applied for 1 hour prior to addition of primary antibody. Primary antibody was composed of either 5 µg.mL<sup>-1</sup> 3C12 IgG or a 1:2,000 dilution of anti-human CD83 reagent, HB15e-PE, each prepared in PBS with 0.5% Tween-20 (PBST) for 1 hour. After washing twice with PBST, an infrared IRD800 anti-human or mouse Fc antibody (Li-Cor) was applied at 1:10,000 dilution for 45 mins prior to washing and visualisation on Odyssey Infrared Imaging System (Li-Cor).

### Quantification of Cell Membrane CD83

The number of cell surface CD83 molecules present on cell lines and blood DCs from human PBMC was estimated using standard QIFIKIT (Dako) protocol (Serke S *et al.*, Cytometry 33(2): 179-87, 1998). In the case of cell lines and transfected cells, 0.5x10<sup>6</sup> cells were stained with 20 µg.mL<sup>-1</sup> of unconjugated anti-CD83 mAb, HB15a (Immunotech) for 45 mins at 4°C and 1:50 dilution of either the kit provided anti-mouse IgG-FITC or anti-mouse IgG-PE (Chemicon). For the quantification of CD83 levels on activated DCs, 1x10<sup>6</sup> PBMC were cultured overnight to up-regulate CD83 (Zhou *et al.*, J. Immunol. 154(8): 3821-35, 1995). Cells were then stained with 20 µg.mL<sup>-1</sup> HB15a followed by detection as stated above. To block any remaining unbound anti-mouse FITC, 50 µL of 10% mouse serum was added and incubated at 4°C for 20 mins. A lineage mix consisting of CD3, CD14, CD19, CD20 and CD56 antibodies conjugated to PE and applied at manufacturer's recommendation were added, along with HLA-DR-*apc*-Cy7 and 150 µg.mL<sup>-1</sup> biotinylated CMRF-44, subsequently detected with 1:50 dilution of Streptavidin-Pacific Blue. Cells were washed between each step with 2 mL MACS Buffer and centrifuged at 1000 x g for 2 mins, as described below. Activated human DCs were gated as lineage-HLA-DR<sup>+</sup>CMRF-44<sup>+</sup>HB15a<sup>+</sup>. A standard curve was prepared to estimate CD83 surface densities as outlined in the QIFIKIT provided protocol.

### Flow Cytometry

Cells for flow cytometric analysis were washed in cold Magnetic-Activated Cell Sorting (MACS) Buffer comprised of 0.5% bovine serum albumin (BSA; Invitrogen) with 2 mM EDTA in PBS pH7.2, or Fluorescence-Activated Cell Sorting (FACS) Buffer containing 0.5% FCS, 0.05% Sodium azide (Ajax Finechem) in PBS. Washed cells were counted and  $2 \times 10^5$  –  $2 \times 10^6$  cells were distributed to 5 mL Polystyrene Round-bottom Tubes (BD Biosciences). All steps involving centrifugation of cell pellets were performed in a DiaCent-12 Benchtop centrifuge (DiaMed) at 1000 x g for 2 mins. Cells were stained for 30-60 mins on ice unless otherwise stated in a 50  $\mu$ L final volume with fluorescent primary or secondary antibody conjugates. Cells were washed with 3 mL FACS or MACS Buffer and pelleted. This step was repeated for multiple step-staining procedures. Cells were either analysed within 3 hours of stain completion or else were fixed by application of 200  $\mu$ L 1% paraformaldehyde (PFA) for 30 mins, before washing and resuspending in 200  $\mu$ L FACS Buffer. In cases where dead cells were assessed by 7-AAD staining, cells were left on ice a maximum of 2 hours prior to analysis. Cells were analysed using either FACS Calibur 4-colour flow cytometer using CellQuest software to acquire data, or an LSRII Flow Cytometer System using FACSDiva Version 6.1 software (all BD Biosciences). Data analysis was performed on FlowJo Version 8.8.6 or FCS Express 3 Software (DeNovo Software).

20

### Chemical Conjugation of mAb to R-Phycoerythrin (RPE)

Purified 3C12 or human IgG1 isotype control mAb, Herceptin (60 $\mu$ g) in PBS were covalently coupled to 100  $\mu$ g RPE with Lynx Rapid RPE Antibody Conjugation (AbDSerotec) as per manufacturer's specifications. Prior to use in flow cytometry experiments, the antibody was titrated from 0.5-50  $\mu$ g.mL<sup>-1</sup>, with 5  $\mu$ g.mL<sup>-1</sup> determined as an optimal working concentration for staining CD83 on KM-H2 cells.

### Preparation of Defucosylated IgG

Non-fucosylated antibody was obtained by adding 2  $\mu$ g.mL<sup>-1</sup> kifunensine (GlycoFineChem, New Zealand) to CHO cells transfected as per the standard protocol outlined above, approximately 4-6 hours after addition of the transformation complex. Cultures were harvested after 6-7 days of standard culture and purified using Protein-A affinity chromatography as described above. To validate the content of antibody-associated oligosaccharide, purified protein was concentrated to 2 mg.mL<sup>-1</sup> using Ultra-4 Centrifugal Filter Device (Amicon) in a fixed angle centrifuge as per manufacturer's instruction. A sample of 50  $\mu$ L was reduced with 0.25% 2-mercaptoethanol in 50 mM

ammonium bicarbonate, 0.25% SDS at 100°C for 20 mins. Triton-X-100 was added to 0.5% to complex with SDS and subsequently 1U of N-glycosidase F (Roche) was added. Samples were digested for 4 mins in an inverter microwave prior to dilution and acidification with 0.5% trifluoroacetic acid (TFA), and purified by graphitised carbon solid phase extraction (SPE) chromatography. Purified samples were freeze dried, resuspended in 50 mM NaCl and analysed in super-2,5-dihydroxybenzoic acid (sDHB; Sigma) MALDI-MS matrix on positive reflectron model in the Bruker Ultraflex. Validation of defucosylated IgG by mass spectrometry was subsequently performed.

#### 10 Construction of V<sub>L</sub> Shuffled Library for Affinity Maturation

Heavy chain (V<sub>H</sub>) DNA of 3C12 scFv was amplified from pHEN1 phagemid vector (Hoogenboom *et al.*, Nucleic Acids Res. 19(15): 4133-7, 1991) with 2.5 U of high fidelity Pfu polymerase (Stratagene) using the kit provided protocol, and the primers with restriction sites (underlined) and the additional 5' sequences overlapping with the vector to allow Gap Repair cloning (Orr-Weaver and Szostack, 1983; Gietz and Schiestl 1991):

3C12VH5' 5'-

GACTATGCAGCTAGCGGTGCCATGGCAGAGGTGCAGCTGCAGGAGTCGGG-3'

(SEQ ID NO:54)

Mod3C12VH3' 5'-

20 GTTGAGCCTCCGGACTTAAGGTCGACTGAGGACACGGTGAGCGTGGTCC-3'

(SEQ ID NO:55)

at a final concentration of 0.5 μM. The 3C12-V<sub>L</sub> shuffled library was constructed using *in vivo* homologous recombination, based on a previously described method (Zhou *et al.*, J. Mol. Biol. 404(1): 88-99, 2010) with modification as follows. Briefly, 10 μg of gel purified (GeneClean Turbo, Qbiogene) 3C12 V<sub>H</sub> fragment DNA was used in standard lithium acetate transformation of EBY100 yeast cells (Antibody Epitope Mapping using Yeast Display (Garcia-Rodriguez C, Zhou Y, Marks JD, eds, 2010), Springer) together with 50 μg of *NcoI-SalI* digested pYD4 vector containing a library of approximately 10<sup>7</sup> human V<sub>L</sub> gene sequences. The transformed yeast library was cultured in 500 mL yeast minimal media, Selective growth Dextrose Casamino Acid media (SD-CAA), as defined elsewhere (Antibody Epitope Mapping using Yeast Display (Garcia-Rodriguez C, Zhou Y, Marks JD, eds, 2010), Springer). Culture conditions were at 30°C with 250 rpm shaking unless otherwise stated. The size of the library was estimated by plating serial dilutions of transformed yeast on SD-CAA plates. At 48 hours post-transformation, a sample representing a ten-fold excess of maximum library diversity (i.e., 10<sup>8</sup>) was induced in Selective growth Galactose Casamino Acid media (SG-CAA) at 18°C for 48 hours.

### Sorting of V<sub>L</sub> Shuffled Library by Yeast Display using FACS

The displayed 3C12 V<sub>L</sub> shuffled library was subjected to three rounds of cell sorting. Each round involved incubation with soluble hCD83<sub>ECD</sub>-His for 1 hour at 4°C. The concentration of antigen used to bind to displayed antibody clones in the various rounds of selection was 20 nM, 2.5 nM and 0.5 nM of hCD83<sub>ECD</sub>-His diluted in FACS buffer, for the first through to the third rounds, respectively. The third and final round of sorting also incorporated an overnight wash step in FACS buffer after staining with hCD83<sub>ECD</sub>-His antigen in order to select clones with slower off rates. Antigen binding was detected in each selection step using an anti-CD83 antibody (either 100 µg.mL<sup>-1</sup> mouse monoclonal antibody, mB4 or 1 µg.mL<sup>-1</sup> polyclonal antibody, RA83) captured by 1:500 dilution of respectively, anti-mouse IgG1 Fc specific-FITC or anti-rabbit Fc specific-FITC (both Jackson Immunoresearch). The expression of scFv on the surface of the yeast was assessed during each round using an anti-SV5-Alexa 647. Cells diluted to 1-5x10<sup>7</sup> cells.mL<sup>-1</sup> in cold FACS buffer were analysed on a FACSAriaII instrument (BD Biosciences) and sorted into P2 and P3 collection gates, shown in Figure 6A. The outputs from the collection gates were cultured at 1x10<sup>4</sup>-1x10<sup>5</sup> cells.mL<sup>-1</sup> in SD-CAA liquid media (Antibody Epitope Mapping using Yeast Display (Garcia-Rodriguez C, Zhou Y, Marks JD, eds, 2010), Springer) for 48 hours prior to inducing surface display with galactose-containing SG-CAA liquid media (Antibody Epitope Mapping using Yeast Display (Garcia-Rodriguez C, Zhou Y, Marks JD, eds, 2010), Springer) for the next round of sorting. The output of third round sorted clones was plated on SD-CAA. A total of 90 individual clones were cultured in SD-CAA overnight prior to induction in SG-CAA media for a further 18 hours. Amplified yeast displaying scFv were stained with 0.2 nM hCD83<sub>ECD</sub>-His and compared to yeast-displayed wildtype 3C12 scFv. From this FACS analysis, 20 individual clones with apparent increases in antigen binding intensity were selected for sequencing. DNA sequencing revealed four dominant V<sub>L</sub> chain sequences (3C12.B, 3C12.C, 3C12.D and 3C12.E), which were reformatted as human IgG1κ (mAbXpress vectors, ACYTE Biotech) as described above.

### 30 Generation of Stable Transfectants with Varying Levels of CD83 Expression

Full length cDNA (Genbank accession NM\_004233.3) was cloned into a bi-cistronic Internal Ribosome Entry Site (IRES)-Green Fluorescent Protein (GFP) expression vector, pMXIE.2. Plasmid DNA (10 µg) was used to transfect confluent GP+E86 retroviral packaging cells in a T25 flask using lipofectamine (Invitrogen) as per manufacturer's protocol. When stably transfected GP+E86 packaging cells had reached 80% confluence, the packaging cells were irradiated with 2000cGy to inhibit expansion, and 5 x 10<sup>5</sup>

cells.mL<sup>-1</sup> of BB88 suspension cell line were added for co-culture, along with 2-4 µg.mL<sup>-1</sup> hexadimethrine bromide (Sigma) as an enhancer of viral infection. After 48 hours culture at 37°C, 5% CO<sub>2</sub>, BB88 suspension cells were removed and were sorted for GFP expression using a FACSAriaII instrument. Subsequent sorting rounds were conducted, selecting for transformants with enhanced GFP/CD83 expression. CD83 expression was confirmed by flow cytometric staining of sorted cells. Monoclonal cultures of cells were cloned by limiting dilution.

#### Depletion of Activated Dendritic Cells with CD83 mAb

Cryopreserved PBMC were thawed and cultured overnight in RPMI-10 to induce up-regulation of CD83 (Zhou and Tedder, J. Immunol. 154(8): 3821-35, 1995). Cells at 2x10<sup>6</sup> cells.mL<sup>-1</sup> were cultured in a final volume of 1 mL in sterile capped 5mL FACS tubes (BD Biosciences) in the presence of 6,000 IU.mL<sup>-1</sup> recombinant IL-2 (Boehringer Mannheim) to activate NK cells and either 5 µg.mL<sup>-1</sup> 3C12.C IgG or human IgG1κ isotype control. Cells were incubated for 3-4 days prior to flow cytometric staining and analysis to assess the activated DC population.

#### Xenogeneic SCID Mouse Model of GVHD

All animal work was approved by the University of Queensland Animal Ethics Committee. Five-week old SCID mice were obtained from the Animal Resources Centre (Western Australia) and were housed in pathogen-free conditions for a week prior to experimental work. The xenogeneic model used has been previously described (Wilson *et al.*, J. Exp. Med. 206(2): 387-98, 2009). Briefly, mice conditioned on Day -1 with 325cGy radiation were dosed with antibody against asialoGM1 (ASGM-1), which depletes NK cells and other leukocytes to facilitate engraftment of an intraperitoneal injection of 50x10<sup>6</sup> human PBMC on Day 0. Antibody treatments were administered to mice, also via intraperitoneal injection, on the day of PBMC transplant (Day 0) at the dose specified in figure legends. Mice were given scores daily on a metric range from 0.0 (healthy) to 2.0 (poor condition) with 0.5 minimal increments for each clinical manifestation of GVHD for 30 days post-transplant without knowledge of the treatment group to eliminate bias. Scoring criteria were weight loss, posture, activity, fur texture, skin and eye integrity and diarrhoea. Animals scoring 2.0 for any one criteria or possessing a cumulative score >5.0 were sacrificed by cervical dislocation. Animals surviving past Day 20 had spleen, bone marrow and peritoneal cavity washouts collected and assessed for flow cytometric staining with anti-human and anti-mouse CD45 antibodies to confirm the presence of engrafted

human cells. Survival curve comparisons were performed in GraphPad Prism Version 5.01 using the Log-rank (Mantel-Cox) test.

#### Fab Preparation and Affinity Analysis

5 Fab fragments were generated by papain digestion with Pierce Fab MicroFab Preparation Kit, as per the manufacturer's instructions except that the kit-provided Protein A resin was replaced with MAbSelect SuRE resin (Seldon *et al.*, J. Biomol. Tech. 22: 50-2, 2011). Fab were diluted in HBS-EP buffer consisting of 10 mM Hepes, 150 mM Sodium Chloride, 3 mM EDTA, and 0.005% Polysorbate 20 (GE Healthcare).  
10 Diluted Fab were assessed for affinity using a BiaCore3000 (GE Healthcare) instrument equipped with a CM5 chip coupled with 100 Resonance Units (RU) of hCD83ECD-His protein, using the Kinetic Analysis wizard protocol. Kinetic rates were estimated using BiaEvaluation Software (GE Healthcare) using the inbuilt 1:1 binding model with mass transfer limitations.

15

#### Cells

Lymphoma cell lines, KM-H2 and L428, and cell lines amenable to transfection including suspension Chinese Hamster Ovary (CHO-S) and mouse cell lines BB88 and FDCP1 were obtained from the Mater Medical Research Institute stocks. Human  
20 peripheral blood mononuclear cells (PBMC) were obtained from healthy volunteers donating blood or aphaeresis product, as recruited in accordance with the Mater Health Services Human Research Ethics Committee. All human healthy donor samples were screened for Human Immunodeficiency Virus, Hepatitis B and C, Human T-lymphotropic Virus and Syphilis.

25

#### Cell Culture Media and Solutions

Human cell lines and human PBMC were cultured in Roswell Part Memorial Institute (RPMI) medium supplemented with 1x Penicillin-Streptomycin, 2 mM GlutaMAX, 25 mM HEPES and 10% Foetal Calf Serum (FCS) that had been heat-  
30 inactivated at 56°C for 30 minutes prior to use (RPMI-10, all components from Invitrogen). Mouse cell lines BB88 and FDCP1 cells were cultured in Dulbecco's Modified Eagle Medium (Invitrogen) supplemented with Penicillin-Streptomycin, GlutaMAX, HEPES and 10% FCS (DMEM-10). FDCP1 cells transfected with full length human CD83 were additionally cultured in the presence of 100 µg.mL<sup>-1</sup> G418  
35 Geneticin selective antibiotic. All cells were cultured in a humidified 37°C, 5% CO<sub>2</sub> incubator and passaged as appropriate.

### Ficoll Preparation of PBMC from Peripheral Blood and Apheresis Products

Density gradient centrifugation was utilized in the purification of PBMC from blood products. Briefly, a 400 mL sample of peripheral blood was diluted 1:1 with sterile room temperature PBS, whilst concentrated aphaeresis products were diluted  
5 1:20 with PBS. In sterile 50 mL tubes, 35 mL of diluted blood product was under-  
laid with 15 mL of Ficoll-Paque PLUS (GE Healthcare) prior to centrifugation at 600  
x g for 20 mins with the centrifuge brake switched off. Using a Pasteur pipette, cells at  
the Ficoll interface were collected and washed 3-5 times with PBS to remove  
contaminating platelets. Cells were counted using a haemocytometer and either  
10 cultured, cryopreserved or used in functional assays.

### Cryopreservation and Reviving of Mammalian Cells

PBMC were prepared for cryopreservation by centrifugation at 300 x g for 5  
mins and resuspending at a final density of  $50 \times 10^6$  cells.mL<sup>-1</sup> in a solution comprised of  
15 10% dimethyl sulfoxide (DMSO; Sigma) and 90% FCS. All other cells were typically  
resuspended in a solution containing 8% DMSO, 50% conditioned media and 42%  
fresh media. Cells were aliquoted into 1 mL sterile cryovials, placed in Cryo 1°C  
Freezing Containers (Nalgene) and immediately transferred into temporary storage at -  
80°C with relocation into liquid nitrogen storage (-196°C) occurring within 24-48  
20 hours. As required, cells were thawed in 37°C water bath and immediately diluted in  
15 mL pre-warmed media. Cells were centrifuged at 300 x g for 5 mins and  
resuspended in 10 mL media for further use or culture.

### Generation of Lymphokine Activated Killer (LAK) Cells

25 Fresh or thawed PBMC ( $< 2 \times 10^9$  cells) were washed and resuspended in cold  
MACS Buffer comprised of 0.5% bovine serum albumin (BSA; Invitrogen) with 2 mM  
EDTA in PBS pH7.2. Human CD56 MicroBeads were added as per manufacturer's  
recommendations and cells were positively selected on a VarioMACS Separator  
equipped with an LS column (all Miltenyi). To confirm the purity of the NK cells, both  
30 positive and negative fractions were stained with a CD56 fluorescent antibody  
conjugate (BD Biosciences) and analysed by flow cytometry. LAK cells were cultured  
in the presence of 6000IU.mL<sup>-1</sup> human IL-2 (Boehringer Mannheim) at 37°C, 5% CO<sub>2</sub>  
for 2-7 days. Cells were harvested by incubation for 30 mins on ice before supernatant  
removal, followed by 30 mins on ice in cold PBS containing 2% EDTA; all harvested  
35 cells were washed twice before addition before resuspending in RPMI-10.

### Chromium Release Assay

To determine the ability of mAbs to elicit ADCC with LAK effector cells, chromium release assays were performed using KM-H2 cell line or BB88 cell lines stably transfected with human CD83 as the chromium-labelled targets. A maximum of  
5  $1 \times 10^6$  cells  $\text{mL}^{-1}$  were labelled with 100  $\mu\text{Ci}$   $^{51}\text{Cr}$  in TD Buffer for 45 mins at  $37^\circ\text{C}$ ,  
5%  $\text{CO}_2$  with gentle agitation every 10 mins. Cells were washed twice with RPMI-10.  
LAK effector cells and  $1-5 \times 10^3$   $^{51}\text{Cr}$ -labelled target cells were plated in V-bottom 96  
well plates (Nunc) at the Effector : Target (E:T) ratio specified in Figure legends.  
Antibody treatments were added as specified. For blocking experiments,  $15 \mu\text{g} \cdot \text{mL}^{-1}$   
10 unconjugated anti-human CD16 clone 3G8 or mouse IgG1k isotype control were added  
to a final volume of 150  $\mu\text{L}$ . Additional wells containing target cells in either RPMI-10  
(i.e. spontaneous release) or 1.67% Triton-X-100 (total release) were prepared. Each  
condition was run with five replicates. Plated cells were incubated for 4 hours prior to  
centrifugation at  $300 \times g$  for 5 mins at room temperature. Supernatant (50  $\mu\text{L}$ ) from  
15 each well was mixed with 150  $\mu\text{L}$  OptiPhase "SuperMix" and assayed for  $^{51}\text{Cr}$  counts  
per minute (cpm) with a Trilux 1450-MicroBeta scintillation counter (both from  
Wallac). Specific cell lysis was calculated using the standard formula: % lysis = [(test  
sample cpm – spontaneous cpm)/(total cpm – spontaneous cpm)\* 100]. GraphPad  
Prism Version 5.01 software was used to graph data and standard error of the mean.

20

### Mixed lymphocyte reaction (MLR)

Cyropreserved PBMC from two human donors were thawed and  $20 \mu\text{g} \cdot \text{mL}^{-1}$   
DNAaseI (Roche) was added to prevent cellular aggregation. For a one-way MLR,  
cells from one donor selected to serve as the MLR "stimulator" were irradiated with  
25 3000cGy. Stimulator cells ( $1 \times 10^5$  cells) were added to an equivalent number of the  
non-irradiated "responder" cells in 96-well U-bottom plates (Nunc), along with the  
antibody to be tested in a final volume of 180  $\mu\text{L}$  with five replicates per condition. For  
a two-way MLR, cells from both donors are non-irradiated and participate in allogeneic  
activation. Following four days incubation at  $37^\circ\text{C}$ , 5%  $\text{CO}_2$ , 1  $\mu\text{Ci}$  of tritiated  
30 thymidine (Perkin Elmer) in a volume of 20  $\mu\text{L}$  was added. The cells were incubated a  
further 16 hours and then transferred to a filtermat using FilterMate Harvester  
(PerkinElmer). Filtermats were dried completely before applying 5mL Betaplate Scint  
(Wallac) and reading with Trilux 1450 Microbeta counter. Raw data was standardized  
against the nil antibody control wells and reported as the percentage of maximal  
35 proliferation.

### Example 2 Generation and Characterization of 3C12 mAb

An scFv phage clone was obtained by biopanning a large human naïve scFv immunoglobulin gene library (Sheets *et al.*, Proc. Natl. Acad. Sci. U.S.A 95(11): 6157-62, 1998) by three rounds of selection against recombinant hCD83<sub>ECD</sub>-His. Using  
 5 primers that bind the semi-conserved flanking framework region for each variable region, and which also contain the required vector overlap, this clone was amplified by PCR and cloned into the mAbXpress vectors using the In Fusion™ system. The reformatted IgG1 mAb was expressed in CHO cells, followed by protein-A based purification. Analysis by SDS-PAGE and SEC (Figure 1) showed that the molecule  
 10 was expressed well in this transient expression system, with no observable degradation or aggregation. The reformatted antibody demonstrated specific binding to cell surface CD83 expressed by the human Hodgkin's Lymphoma derived cell line, KM-H2 (Figure 2).

The anti-CD83 scFv was reformatted as an IgG1  $\kappa$  specifically to provide an  
 15 ADCC response. In order to show the resulting antibody was functional, purified recombinant anti-CD83 antibody (i.e., 3C12 mAb) was used in flow cytometry to demonstrate binding to CD83<sup>+</sup> human cell lines and hCD83-transfected cells (Figure 2A). Additionally, in a chromium release functional assay, 3C12 mAb induced significant cytolysis of KM-H2 cells in the presence of activated natural killer (NK)  
 20 effector cells (Figure 2B). This antibody-induced lysis, however, was abrogated upon blockade of Fc $\gamma$ IIIIRa (CD16) with anti-CD16 mAb, 3G8, demonstrating the necessity for CD16 in the *in vitro* mechanism of action of 3C12 in the chromium release assay.

### Example 3 Characterization of anti-CD83 mAb, 3C12

25 Anti-human CD83 mAb, 3C12, was characterized to assess binding affinity and specificity (Table 4). 3C12 bound to CD83<sup>+</sup> cell line, KM-H2 and suppressed allogeneic T cell stimulation in an MLR.

**Table 4: Binding affinity and specificity for 3C12**

30

Parent scFv library origin	Naïve human
hCD83 Peptide <sub>AA61-78</sub> reactivity	-
<b>BiaCore Fab Affinity</b>	
$K_{on}$ ( $M^{-1}s^{-1}$ )	$9.5 \times 10^5$
$K_{off}$ ( $s^{-1}$ )	$1.2 \times 10^{-1}$
$K_D$ (M)	$1.3 \times 10^{-7}$

Under non-reducing conditions, 3C12 detects recombinant human CD83<sub>ECD</sub>-His on a western blot, yet 3C12 binding is abolished when CD83 has been denatured by heat and disulphide bond reduction. This observation also holds for commercial antibody HB15e (Figure 3A). Consequently, both 3C12 and HB15e appear to bind to conformational epitopes which are destroyed by heat and disulphide reduction. To determine whether CD83 mAbs bound competitively or independently of other anti-CD83 reagents, 3C12 IgG was conjugated to RPE and competitively assayed with FITC-conjugated commercial antibodies HB15a and HB15e, and RA83 polyclonal antibody detected with anti-rabbit-Ig. Competitive blocking with 3C12 was evident upon simultaneous addition of the antibodies, as full inhibition of HB15e, and partial inhibition of HB15a and RA83 binding was observed in the presence of 3C12 (Figure 3 inset table). This indicates the 3C12 epitope is shared or overlapping with that of other antibodies. Under the conditions examined, 3C12 binding was minimally altered by addition of any of the anti-CD83 reagents, with only a marginal decrease in 3C12 signal observed in competition with RA83. This finding demonstrates that 3C12 antibody competes with other anti-CD83 reagents for antigen binding and that the 3C12 epitope is similar to that of antibodies derived from traditional approaches to antibody generation.

#### 20 **Example 4 *In vivo* Evaluation of 3C12 mAb**

To assess the ability of the 3C12 mAb to prevent GVHD *in vivo*, the antibody was administered to SCID mice receiving a xenogeneic transplant of human PBMC. Dosing of the 3C12 antibody was varied three-fold above and below the optimal dose of 0.125 mg previously determined for the rabbit polyclonal antibody RA83 (Wilson *et al.*, Med. 206(2): 387-98, 2009). As observed for RA83, administration of 0.125 mg 3C12 significantly improves survival in the xenogeneic GVHD model, relative to its isotype control (Figure 4A). Increasing the dose of 3C12 IgG to 0.375 mg resulted in decreased treatment efficacy, although this trend was not significant. In comparison to the standard 0.125 mg dose of rabbit polyclonal RA83 antibody, which produced 61% survival, 3C12 IgG at the equivalent dose was less potent, protecting 39% of mice from succumbing to GVHD (Figure 4B). Increasing the dose of RA83 to 1 mg resulted in 100% survival, yet the same increase to 3C12 antibody abolished efficacy of the monoclonal antibody (Figure 4C). Co-treatment of animals with the standard dose (0.125 mg) of RA83 with 1 mg of 3C12 IgG was also ineffective. This indicates the effect of RA83 was inhibited by the presence of a high dose of 3C12. As the standard and lower doses of 3C12 were effective, but less potent than RA83 *in vivo*, the 3C12

antibody was subjected to further antibody engineering designed to improve mAb potency.

#### **Example 5 Glyco-engineering of a CD83 mAb**

5 To produce an afucosylated antibody for the purpose of improving the potential for ADCC, kifunensine, a potent glycosidase inhibitor, was added during CHO cell transfection with 3C12-encoding cDNA. Figure 5 demonstrates that the presence of kifunensine during the transfection effectively blocks fucose addition of the 3C12 antibody (i.e., 3C12.Kif), as assessed by mass spectrometry. Glycans released from the  
10 3C12.Kif sample by N-glycosidase F digestion produced a predominant signal at approximately 1905 m/z, corresponding to GlcNAc2Man9, as expected if there is no processing of high mannose glycans. There were also smaller signals at 1742 m/z and 1580 m/z corresponding to GlcNAc2Man8 and GlcNAc2Man7 respectively. In comparison, wildtype 3C12 produces a dominant signal at 1485m/z, corresponding to  
15 fucose-containing carbohydrate. The glyco-modification was made without discernibly altering molecular weight, specificity and functional affinity of wildtype 3C12 (Figure 5B, C).

#### **Example 6 Affinity-engineering of a CD83 mAb by Light Chain Shuffling**

20 Affinity maturation by light chain shuffling was utilized to improve the strength of the antigen-antibody interaction as a strategy for enhancing functionality. Here, the 3C12 V<sub>H</sub> DNA sequence was cloned into a cDNA library of human V<sub>L</sub> sequences, and the resulting library of approximately 10<sup>7</sup> unique V<sub>H</sub>-V<sub>L</sub> pairings displayed on the surface of yeast cells to allow affinity driven selections. At the protein level, many of  
25 these pairings are detrimental to the ability of 3C12 to bind to CD83 antigen, as <1% of displayed scFv remained positive for antigen binding in the first round of yeast sorting (Figure 6A). Clones with improved affinity for recombinant CD83 antigen were selected by enriching for yeast, displaying scFv that strongly bound hCD83<sub>ECD</sub>-His relative to the level of scFv expression on the surface of the yeast, determined by  
30 detecting the fluorescence intensity of an SV5 tag expressed at the C-terminal of each scFv. Selection of scFv clones by this method produced four new 3C12 scFv variants with distinct VL sequences and enhanced binding properties relative to the wildtype scFv (Figure 6B, C).

Whole human IgG1 reformatted affinity matured 3C12 mAbs, when prepared as  
35 Fab binders using papain digestion were estimated to have 3-20 fold affinity improvements relative to the wildtype (3C12.WT), as determined by Biacore SPR

(Table 5). The greatest improvements to antibody binding are attributable to slower kinetic off-rates, with clones demonstrating 8 to 15-fold improvements to the observed koff. Antibody on-rate remained similar to that of 3C12 wildtype ( $K_{on} = 9.0 \times 10^5 M^{-1}s^{-1}$ ), with most clones exhibiting <1.4-fold improvements and one clone (3C12.B) had approximately 3-fold reduction in on-rate ( $K_{on} = 3.2 \times 10^5 M^{-1}s^{-1}$ ). In terms of overall affinity improvement, variant 3C12.C had the highest observed affinity for CD83 ( $KD = 6.1 \times 10^{-9} M$ ) including the best (i.e., slowest) off-rate ( $K_{off} = 7.8 \times 10^{-3} s^{-1}$ ) and was further characterized. Figure 7A graphically highlights these improvements of 3C12.C binding relative to 3C12.WT, as higher binding signal intensity (i.e., RU) is achieved using reduced concentrations of the  $V_L$  shuffled variant during the  $K_{off}$  and  $K_{on}$ -dependent Association Phase. Similarly, a slower off-rate is observed for 3C12.C Fab during the  $K_{off}$ -dependent dissociation phase. As a whole IgG molecule, the affinity improved 3C12.C IgG also demonstrated superior binding to KM-H2 cells relative to 3C12.WT IgG (Figure 7B).

15

**Table 5: Affinity of wildtype 3C12 (3C12.WT) and  $V_L$  shuffled variant Fab fragments**

<i>Clone</i>	<i>Fab <math>K_{on}</math></i> ( $1/Ms$ )	<i>Fab <math>K_{off}</math></i> ( $1/s$ )	<i>Fab <math>K_D</math></i> ( $M$ )
3C12.WT	$9.0 \times 10^5$	$1.2 \times 10^{-1}$	$1.3 \times 10^{-7}$
3C12.B	$3.2 \times 10^5$	$1.4 \times 10^{-2}$	$4.3 \times 10^{-8}$
3C12.C	$1.3 \times 10^6$	$7.8 \times 10^{-3}$	$6.1 \times 10^{-9}$
3C12.D	$1.1 \times 10^6$	$2.7 \times 10^{-2}$	$2.5 \times 10^{-8}$
3C12.E	$1.2 \times 10^6$	$5.0 \times 10^{-2}$	$4.2 \times 10^{-8}$

20 **Example 7: Glyco- and Affinity Engineered 3C12 Variants Improve *in vitro* Efficacy**

Improvements to functional activity of glyco-engineered 3C12.kif and affinity enhanced 3C12.C antibodies were assessed by ADCC assay and within a MLR. Both 3C12.C and 3C12.Kif produce >10% increased maximal NK-mediated ADCC in a chromium release assay, and had >25-fold potency than 3C12.WT (Figure 8A). Likewise, cellular proliferation as a result of allogeneic stimulation within an MLR was inhibited by 3C12.C and 3C12.Kif IgG with >5-fold increased potency than 3C12.WT

(Figure 8B). Superior activity was observed for 3C12.C, which demonstrated comparable potency to polyclonal antibody, RA83.

**Example 8: *In vitro* Mechanisms of Action of an Engineered anti-CD83 mAb**

5 To determine the effect of anti-CD83 mAb on primary blood DCs, 3C12.C antibody was applied to cultured PBMC in the presence of IL-2 to activate NK cells. Cells cultured in the presence of 3C12.C IgG had reduced percentages of activated DCs (58%) as opposed to nil or isotype control treated cells (>80%), as assessed by activation markers CMRF-44 and CD83 (detected by unconjugated 3C12.C and  
10 secondary anti-human Fc-FITC, rather than FITC-conjugated 3C12.C, so as to remove the potential for any reduction in detection signal intensity due to competition with the treatment antibody; Figure 9). Also, the population of CD83<sup>bright</sup> expressing DCs present in both nil and isotype-treated controls was absent after 3C12.C treatment, whereas only CD83<sup>dim</sup> populations of DCs were observed. To determine whether the  
15 level of cell surface CD83 expression is a contributing factor to the ability of 3C12.C to induce ADCC, stably transfected BB88 cells with varying levels of CD83 expression were used. The number of CD83 molecules on these cells, and other CD83-expressing cell lines was quantified using an indirect immunofluorescence flow cytometry assay, which showed that the BB88 transfectants express from 5,400 molecules per cell  
20 (MPC) to <2,300 MPC of CD83 antigen (Table 6). Thus, the transfectants possess much lower levels of CD83 in comparison to expression levels on immortalized cell lines and primary blood DCs (10,000-50,000MPC). Each of the BB88 CD83 transfected cell lines were specifically lysed by engineered 3C12 variants, demonstrating only low levels of cell surface CD83 are required to trigger ADCC.  
25 Furthermore, the extent of lysis induced by 3C12 mAb variants is sensitive to the number of the CD83 molecules expressed on the cell surface. This is exemplified in Figure 10, where increasing antigen density from <2,300 to 3,600 and 5,400 correlated with increased 5-25-fold increased specific lysis.

**Table 6: QIFIKit quantification of CD83 antigen density**

Cell type	CD83 Molecules per cell (MPC)	Independent replicates
BB88-CD83-TF.5K	5,400	2
BB88-CD83-TF.3K	3,600	1
BB88-CD83-TF.2K	<2,300*	2
KM-H2	55,000	6
Raji	49,000	1
L428	11,000	1
Activated blood DC <sup>bright**</sup>	49,000	2
Activated blood DC <sup>mid**</sup>	20,000	1
Activated blood DC <sup>dim**</sup>	<2,300	1

\* Below limits of QIFI kit standards

TF = transfected cells

\*\*See Appendix 6 for gating

**Example 9 Affinity Matured anti-CD83 mAb, 3C12.C is Efficacious in a 5 Xenogeneic GVHD Model**

To assess the affinity enhanced 3C12.C mAb to prevent GVHD *in vivo*, the V<sub>L</sub> shuffled 3C12 variant was administered at the standard 0.125mg dose to conditioned SCID mice transplanted with human PBMC. In comparison to the polyclonal reagent, RA83 which protected 45% (5/11) of mice, 3C12.C IgG demonstrated equivalent 10 potency, preventing GVHD in 54% (6/11) of mice, and higher potency than 3C12.WT which had 27% (4/15) survival (Figure 11). The efficacy of all cohorts appeared reduced in comparison to previous findings (Wilson *et al.*, J. Exp. Med. 206(2): 387-98., 2009) as RA83 and 3C12.WT typically provide >60% and 40% survival 15 respectively. Under these experimental conditions only 3C12.C was significantly different to the isotype control.

**CLAIMS:**

1. An isolated or recombinant CD83 binding protein comprising an antigen binding domain which specifically binds to CD83, wherein the binding protein  
5 comprises a heavy chain variable region ( $V_H$ ) which comprises:
  - (i) a sequence which is at least 90% identical to the amino acid sequence shown in SEQ ID NO:1; or
  - (ii) three complementarity determining regions (CDRs) of the amino acid sequence shown in SEQ ID NO:1.
- 10 2. The CD83 binding protein of claim 1, wherein the binding protein further comprises a light chain variable region ( $V_L$ ) which comprises:
  - (i) a sequence which is at least 90% identical to any one of the amino acid sequences shown in SEQ ID NO:5, 6, 7, 8, or 9; or
  - 15 (ii) three complementarity determining regions (CDRs) of any one of the amino acid sequences shown in SEQ ID NO:5, 6, 7, 8, or 9; or
  - (iii) a consensus sequence as shown in SEQ ID NO:10 or
  - (iv) three CDRs, wherein the amino acid sequence of CDR1, CDR2, or CDR3 is a consensus sequence shown in SEQ ID NO:26, 27, or 28.
- 20 3. The CD83 binding protein of claim 1, wherein the binding protein further comprises a  $V_L$  sequence as shown in SEQ ID NO:7.
4. The CD83 binding protein of claim 2 or claim 3, wherein the  $V_L$  and  $V_H$  are in a  
25 single polypeptide chain.
5. The CD83 binding protein of claim 4, which is:
  - (i) a single chain Fv fragment (scFv); or
  - (ii) a dimeric scFv (di-scFv); or
  - 30 (iii) (i) or (ii) linked to a Fc or a heavy chain constant domain ( $C_H$ ) 2 and/or  $C_H3$ ; or
  - (iv) (i) or (ii) linked to a protein that binds to an immune effector cell.
6. The CD83 binding protein of 2 or claim 3, wherein the  $V_L$  and  $V_H$  are in  
35 separate polypeptide chains.

7. The CD83 binding protein of claim 6, which is:
- (i) a diabody; or
  - (ii) a triabody; or
  - (iii) a tetrabody; or
  - 5 (iv) a Fab; or
  - (v) a F(ab')<sub>2</sub>; or
  - (vi) a Fv; or
  - (vii) one of (i) to (vi) linked to a Fc or a C<sub>H</sub>2 and/or C<sub>H</sub>3; or
  - (viii) one of (i) to (vi) linked to a protein that binds to an immune effector cell.
- 10
8. The CD83 binding protein of claim 7, which is an antibody.
9. The CD83 binding protein of claim 8, wherein the antibody comprises:
- (i) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in
  - 15 SEQ ID NO:5; or
  - (ii) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:6;
  - (iii) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:7; or
  - 20 (iv) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:8; or
  - (v) a V<sub>H</sub> sequence as shown in SEQ ID NO:1 and a V<sub>L</sub> sequence as shown in SEQ ID NO:9; or
  - (vi) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain
  - 25 sequence as shown in SEQ ID NO:30; or
  - (vii) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:31; or
  - (viii) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:32; or
  - 30 (ix) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:33; or
  - (x) a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:34.
- 35 10. The CD83 binding protein of any one of claims 1 to 9 which is chimeric, de-immunized, humanized, synhumanized, human, primatized, or a composite protein.

11. The CD83 binding protein of any one of claims 1 to 10, comprising an Fc region capable of inducing an enhanced level of effector function compared to a human IgG1 Fc region and/or conferring an extended half life compared to a human IgG1 Fc region.
- 5 12. The CD83 binding protein of any one of claims 1 to 11, which competitively inhibits binding of an antibody comprising a heavy chain sequence as shown in SEQ ID NO:29 and a light chain sequence as shown in SEQ ID NO:30 to CD83 or which binds to the same epitope in CD83 as said antibody.
- 10 13. The CD83 binding protein of any one of claims 1 to 12 conjugated to a compound.
14. The CD83 binding protein of any one of claims 1 to 12 which is a naked binding protein.
- 15 15. An isolated or recombinant nucleic acid encoding the CD83 binding protein of any one of claims 1 to 12 or encoding a polypeptide thereof.
16. The nucleic acid of claim 15 comprising a nucleotide sequence as shown in any one of SEQ ID NOs:35 to 46, or a nucleic acid that hybridizes under moderate to high stringency hybridization conditions.
- 20 17. An expression construct comprising the nucleic acid of claim 16 operably linked to a promoter.
- 25 18. An isolated cell expressing the CD83 binding protein of any one of claims 1 to 12, or a recombinant cell genetically-modified to express the CD83 binding protein of any one of claims 1 to 12.
- 30 19. The cell of claim 18 comprising the nucleic acid of claim 15 or 16, or the expression construct of claim 17.
20. A composition comprising the CD83 binding protein of any one of claims 1 to 13, and a suitable carrier.

21. The composition of claim 20 in which the carrier is pharmaceutically acceptable.
22. A method for treating or preventing a disease or condition caused by the  
5 dysfunction or undesired function of a cellular immune response involving T cells and/or dendritic cells in a subject, the method comprising administering the CD83 binding protein of any one of claims 1 to 14 or the composition of claim 21 to the subject.
- 10 23. A method for treating or preventing allergies, asthma, rejection of a tissue or organ graft, autoimmune conditions such as myasthenia gravis, multiple sclerosis, vasculitis, chronic inflammatory bowel diseases such as Morbus Crohn or colitis ulcerosa, HLA B27-associated autoimmunopathies such as Morbus Bechterew, and systemic  
15 lupus erythematosus, skin diseases such as psoriasis, rheumatoid arthritis, insulin-dependent diabetes mellitus and AIDS in a subject, the method comprising administering the CD83 binding protein of any one of claims 1 to 14 or the composition of claim 21 to the subject.
24. The method of claim 23, wherein the rejection of a tissue or organ transplant  
20 occurs as a result of graft versus host disease.
25. A method for downregulating the immunoactivity of an allogeneic graft, the method comprising contacting the graft with the CD83 binding protein of any one of claims 1 to 14 or the composition of claim 21.  
25
26. Use of the CD83 binding protein of any one of claims 1 to 14, or the nucleic acid of claim 15 or 16, or the expression construct of claim 17, or the cell of 18 or 19, or the composition of claim 20 or 21, in medicine.
- 30 27. Use of the CD83 binding protein of any one of claims 1 to 14, or the nucleic acid of claim 15 or 16, or the expression construct of claim 17, or the cell of 18 or 19, or the composition of claim 20 or 21, in the manufacture of a medicament for the treatment or prevention of allergies, asthma, rejection of a tissue or organ graft, autoimmune conditions such as myasthenia gravis, multiple sclerosis, vasculitis, chronic  
35 inflammatory bowel diseases such as Morbus Crohn or colitis ulcerosa, HLA B27-associated autoimmunopathies such as Morbus Bechterew, and systemic lupus

erythematosis, skin diseases such as psoriasis, rheumatoid arthritis, insulin-dependent diabetes mellitus and AIDS.

28. The CD83 binding protein of any one of claims 1 to 14, or the nucleic acid of  
5 claim 15 or 16, or the expression construct of claim 17, or the cell of 18 or 19, or the  
composition of claim 20 or 21, for use in the treatment or prevention of allergies,  
asthma, rejection of a tissue or organ graft, autoimmune conditions such as myasthenia  
gravis, multiple sclerosis, vasculitis, chronic inflammatory bowel diseases such as  
Morbus Crohn or colitis ulcerosa, HLA B27-associated autoimmunopathis such as  
10 Morbus Bechterew, and systemic lupus erythematosus, skin diseases such as psoriasis,  
rheumatoid arthritis, insulin-dependent diabetes mellitus and AIDS.

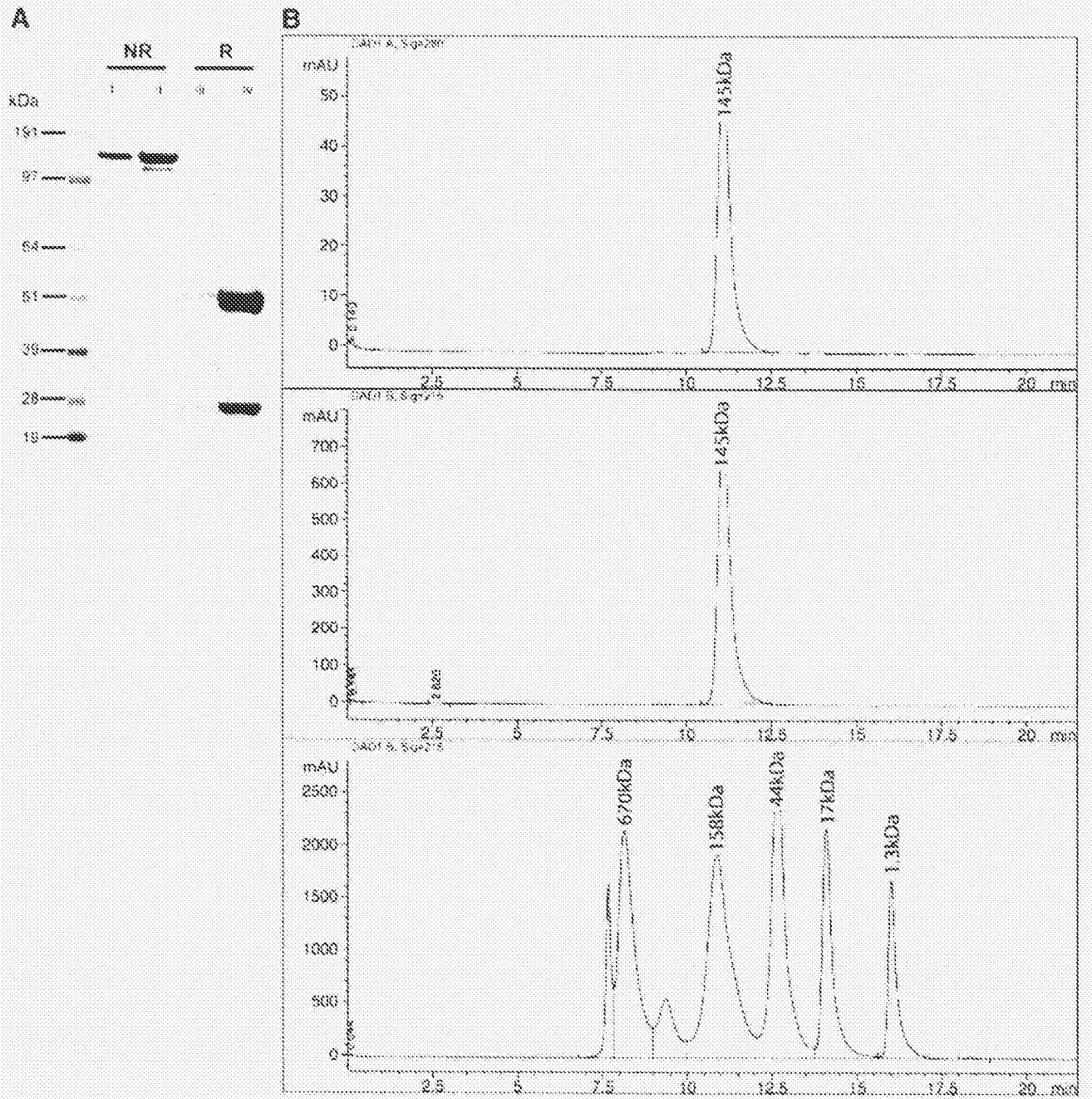


Figure 1

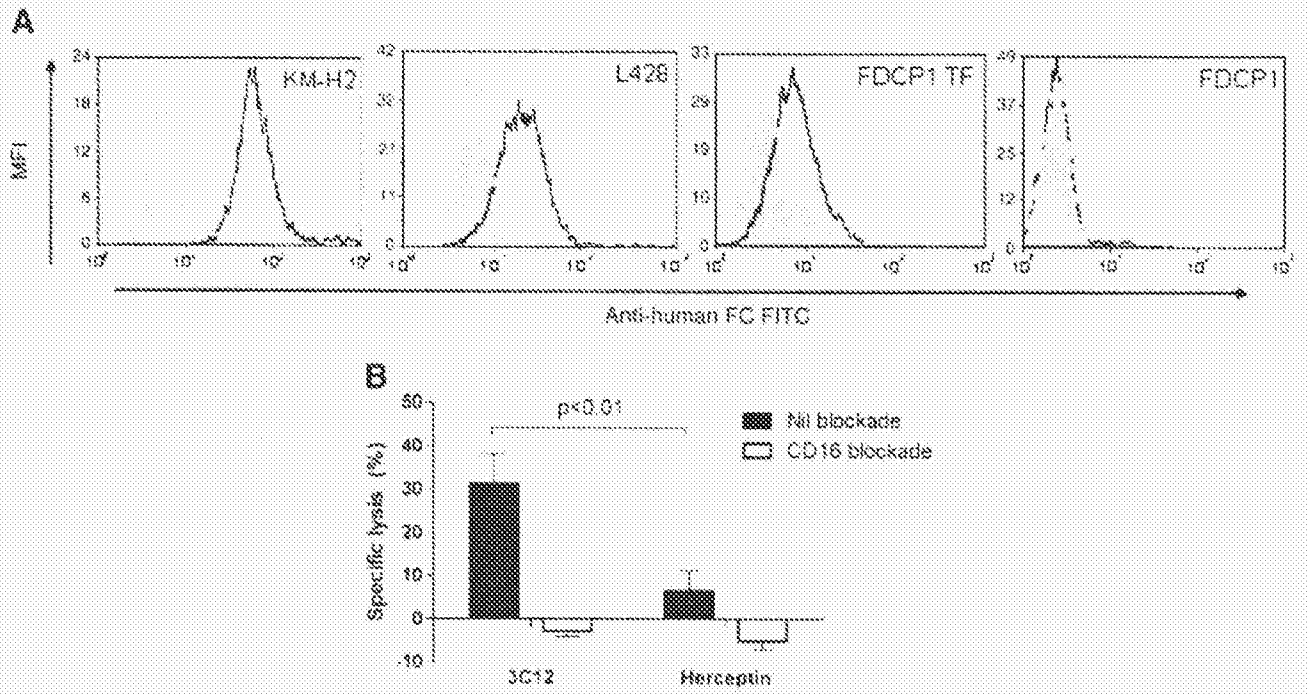


Figure 2

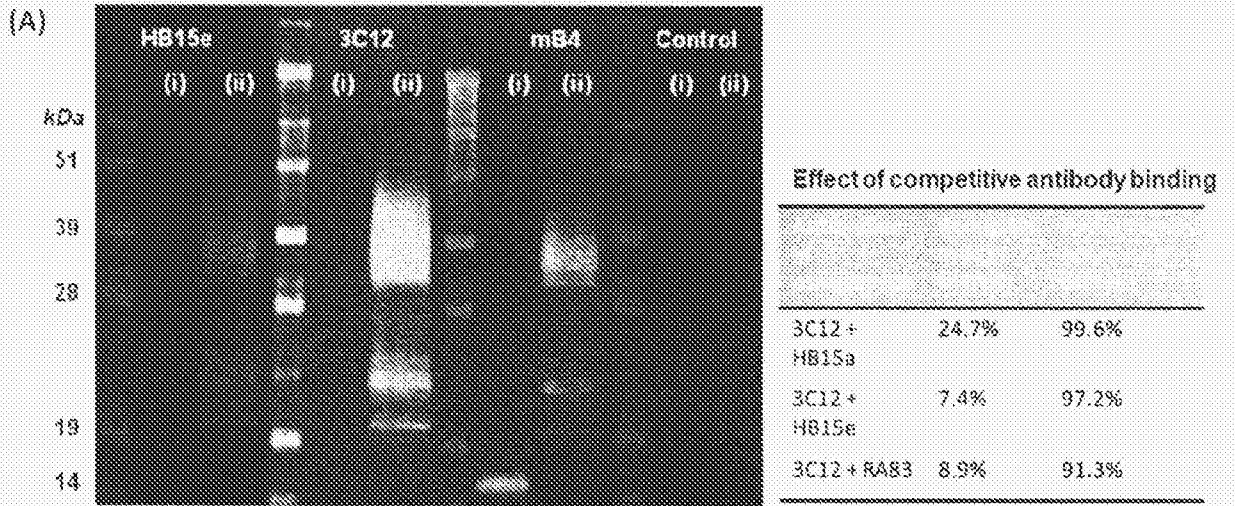


Figure 3

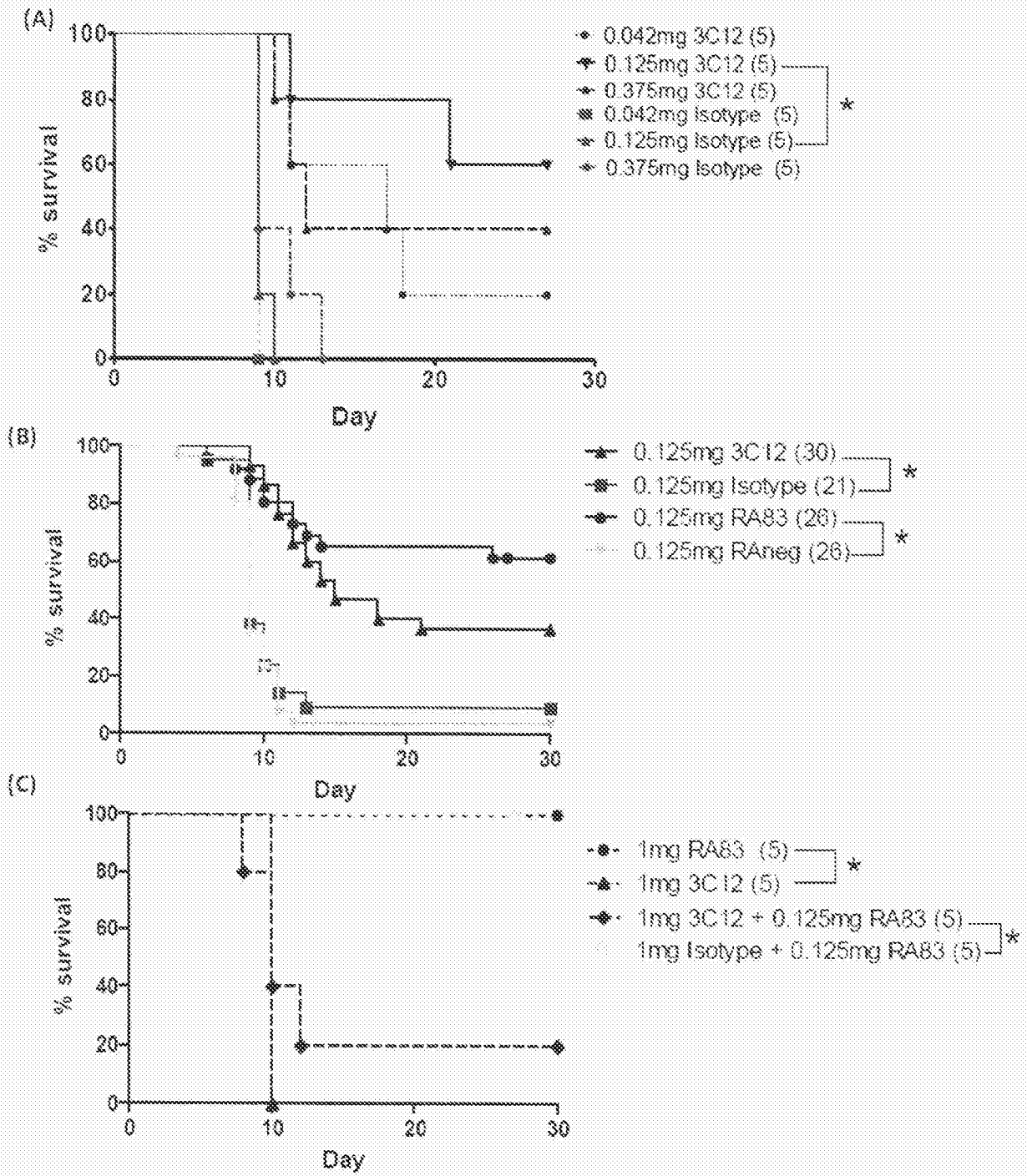


Figure 4

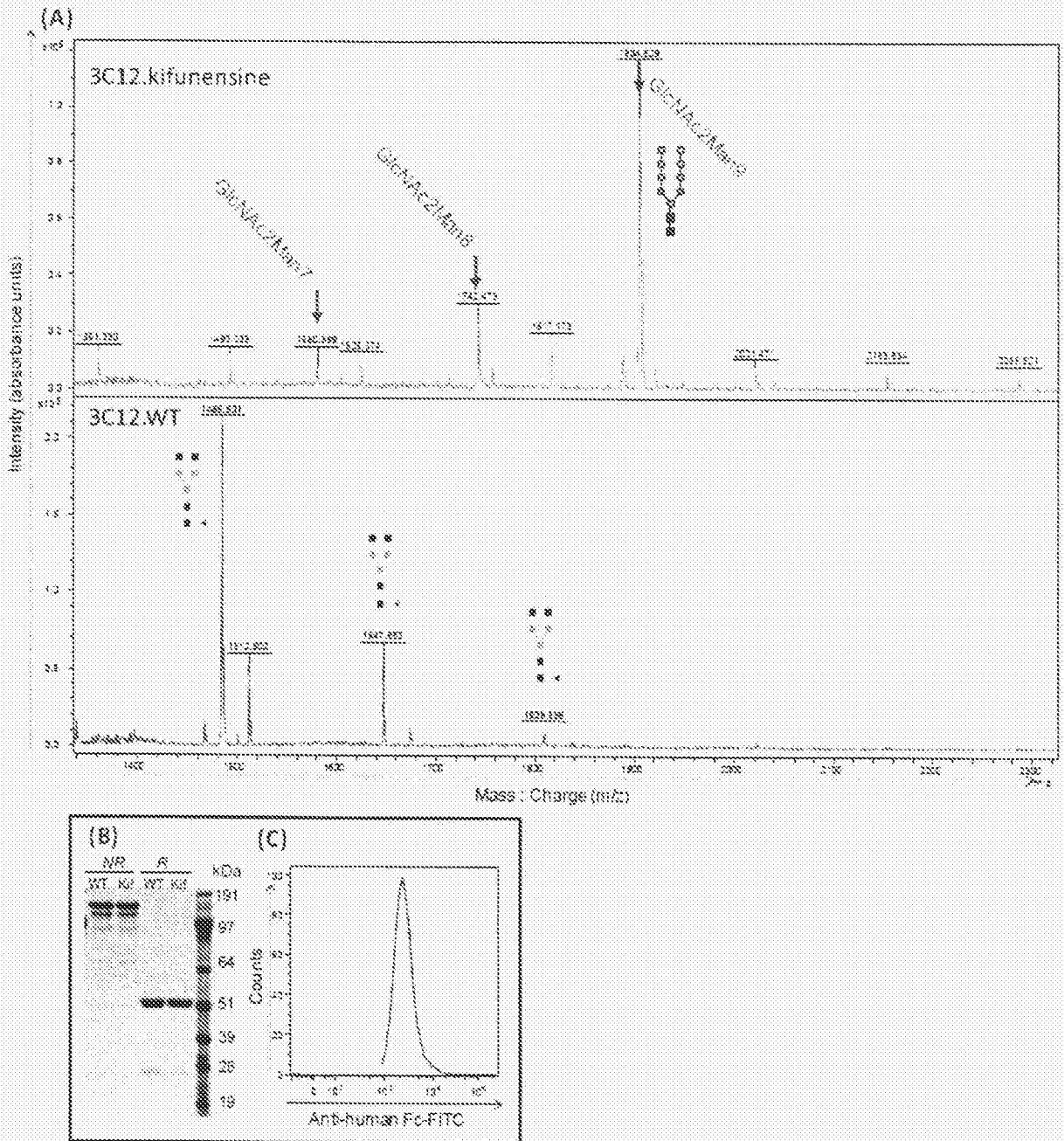


Figure 5

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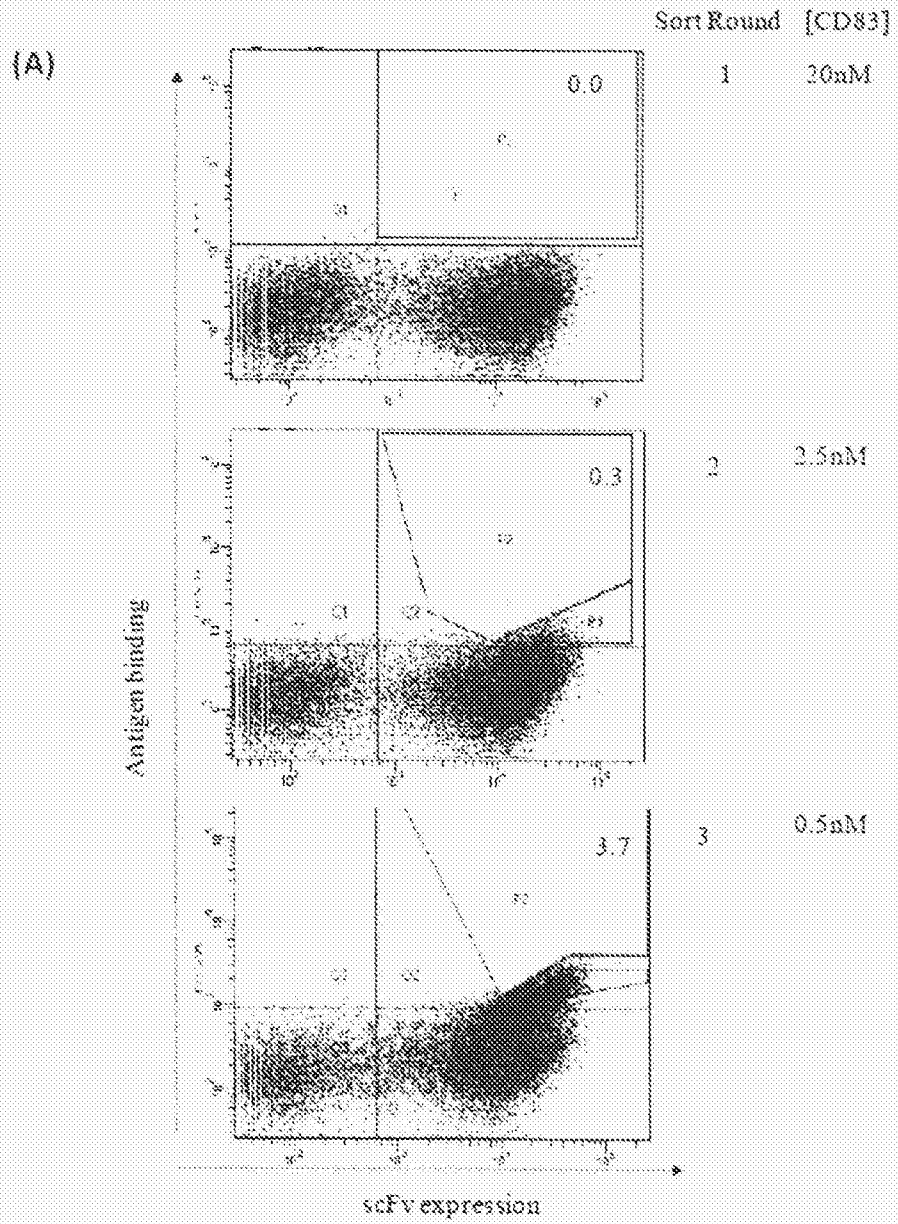


Figure 6

(B)

Clone	FR1	CDR1	FR2	CDR2	FR3	CDR3	FR4
3C12.WT	33 EIVNLSFSLISASLGGKRVIIIC	32 EASQSKKXYS	40 WYQKRFQKAPKLLIV	52 KISHLQS	63 GYPFRFSGSSSTETITISLQEDFAFYIC	80 CCCLAYFLI	102 FSGGTRLEIK
3C12.B	V.M...F...I...S...	I...S...EL...	K...K...K...K...K...	A.S...A.S...A.S...	D...D...D...D...D...	IATVIC...VNS...Y...G...R...	
3C12.C	L...S...V...V...V...	R...L...S...L...S...	K...V...K...V...K...V...	T...T...T...T...T...	R...R...R...R...R...	VERFY...VERFY...Q...V...	
3C12.D	Q...S...V...V...V...	S...L...S...L...S...	K...V...K...V...K...V...	A.S...A.S...A.S...	D...D...D...D...D...	K...SS...Y...G...V...	
3C12.E	L...S...V...V...V...	S...L...S...L...S...	K...V...K...V...K...V...	A.T...A.T...A.T...	E...E...E...E...E...	KNSA...Y...Q...V...	
consensus	X...X...X...X...X...	X...X...X...X...X...	X...X...X...X...X...	X...X...X...X...X...	X...X...X...X...X...	X...X...X...X...X...	X...X...X...X...X...

(C)

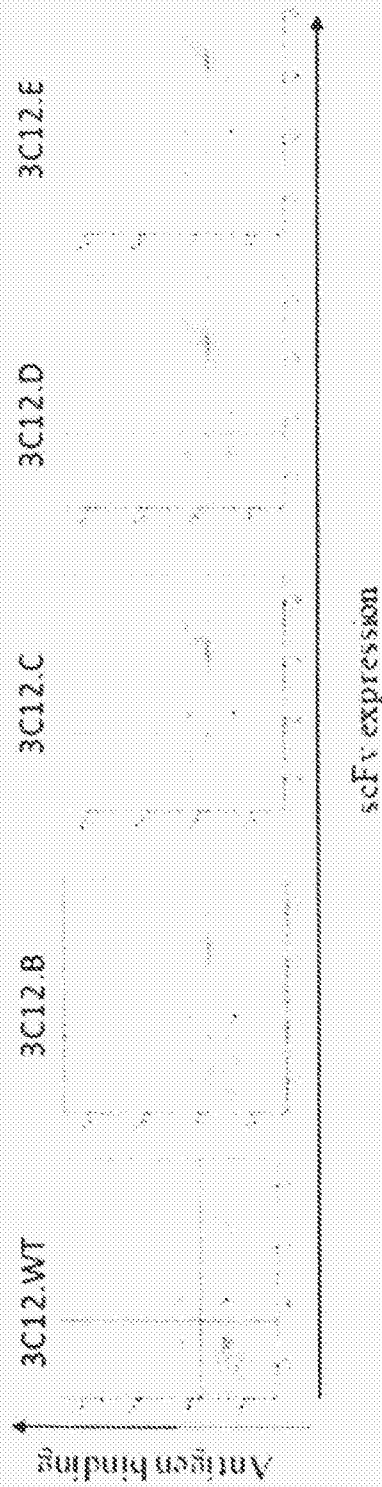


Figure 6 continued

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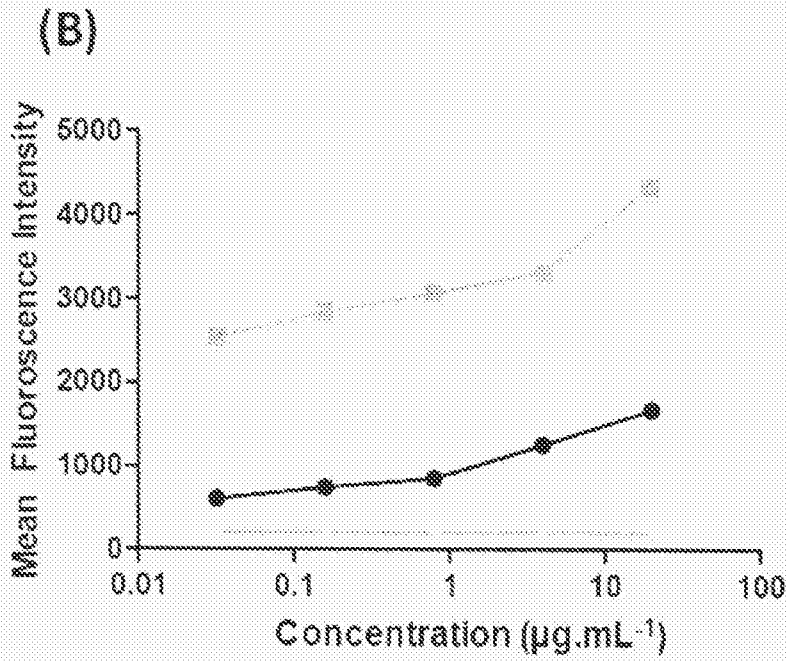
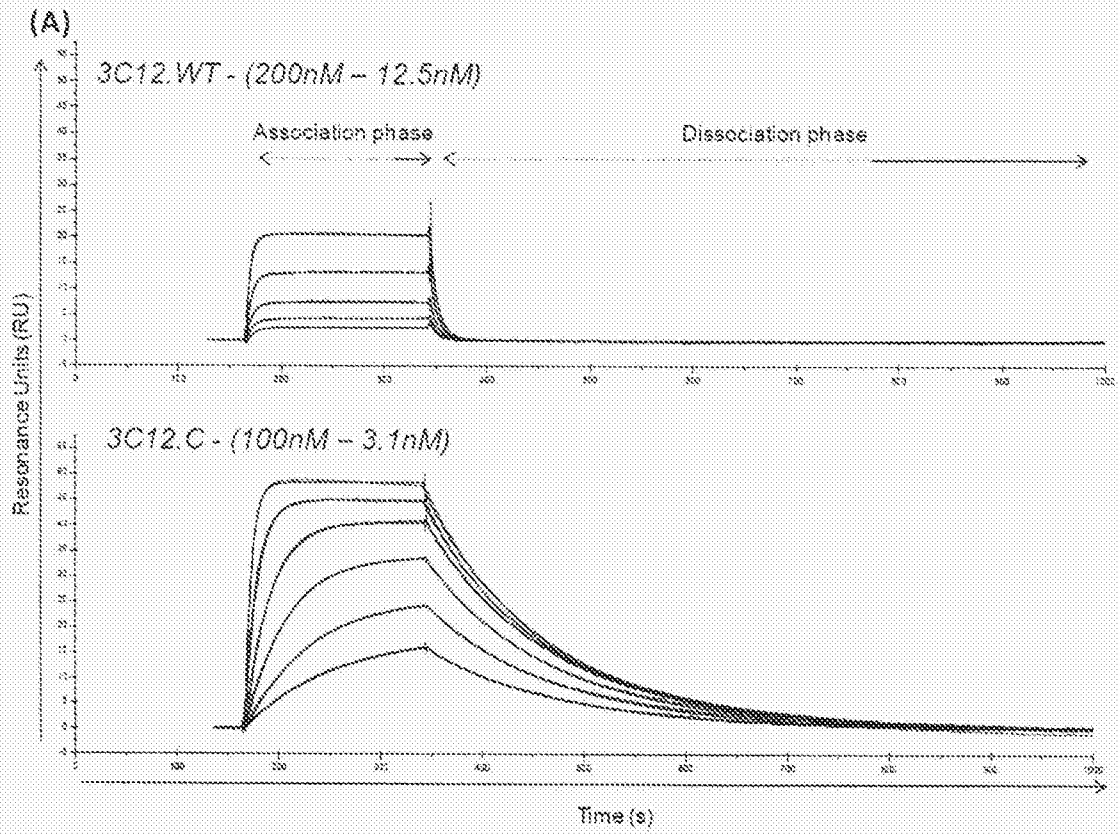


Figure 7

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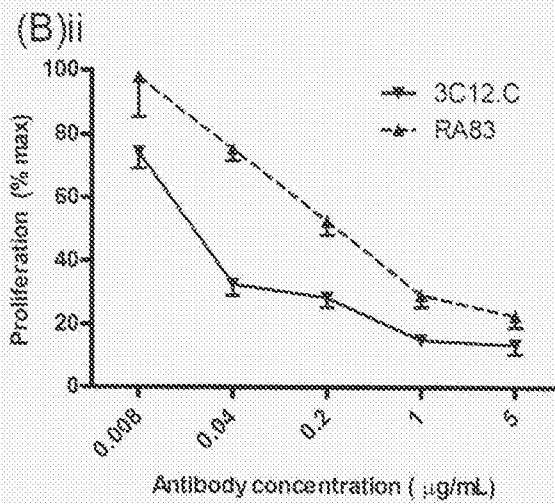
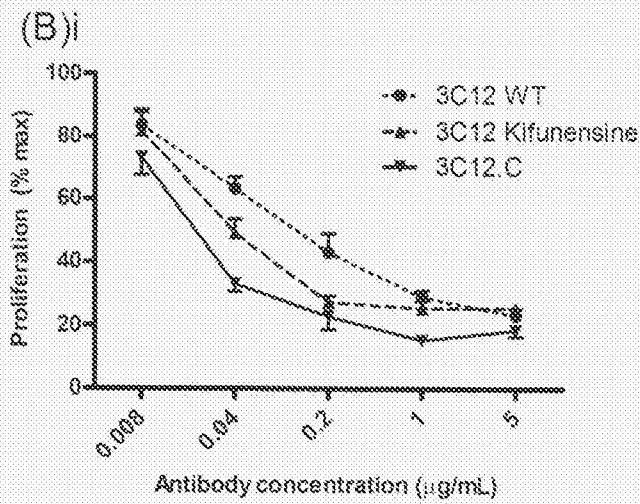
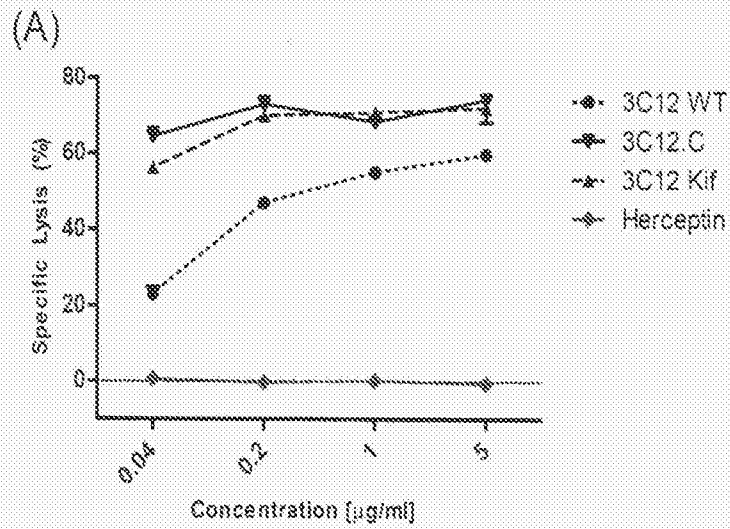


Figure 8

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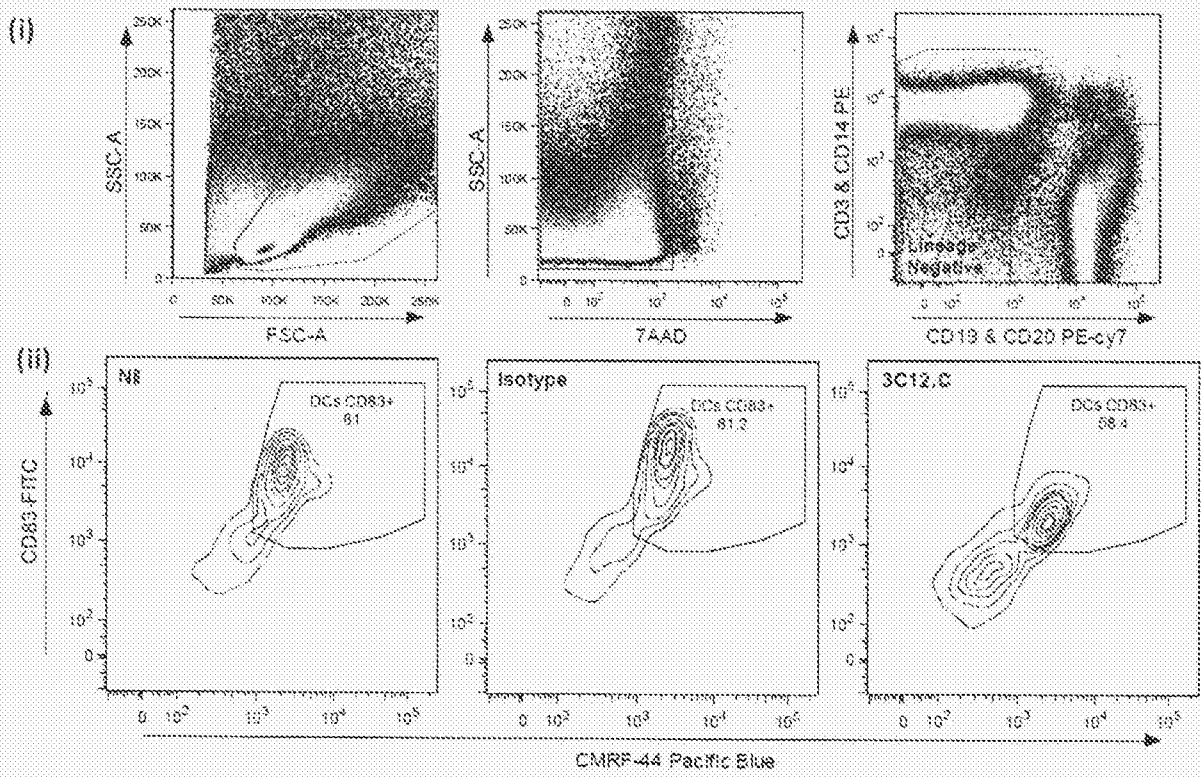


Figure 9

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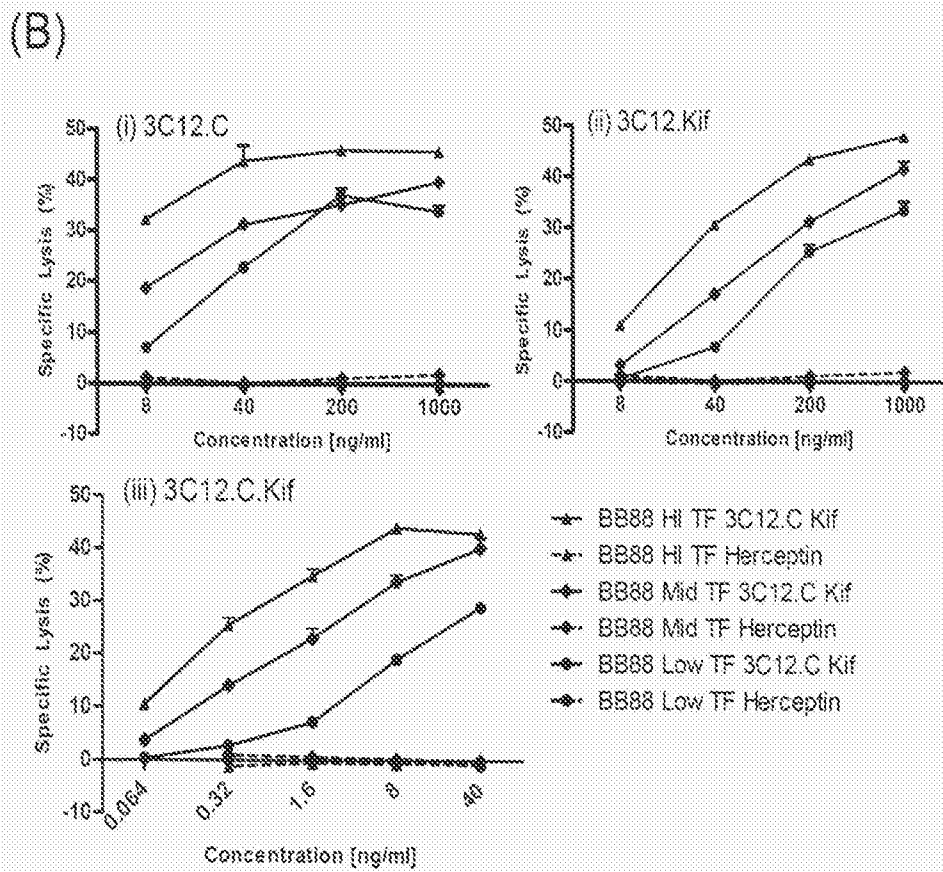
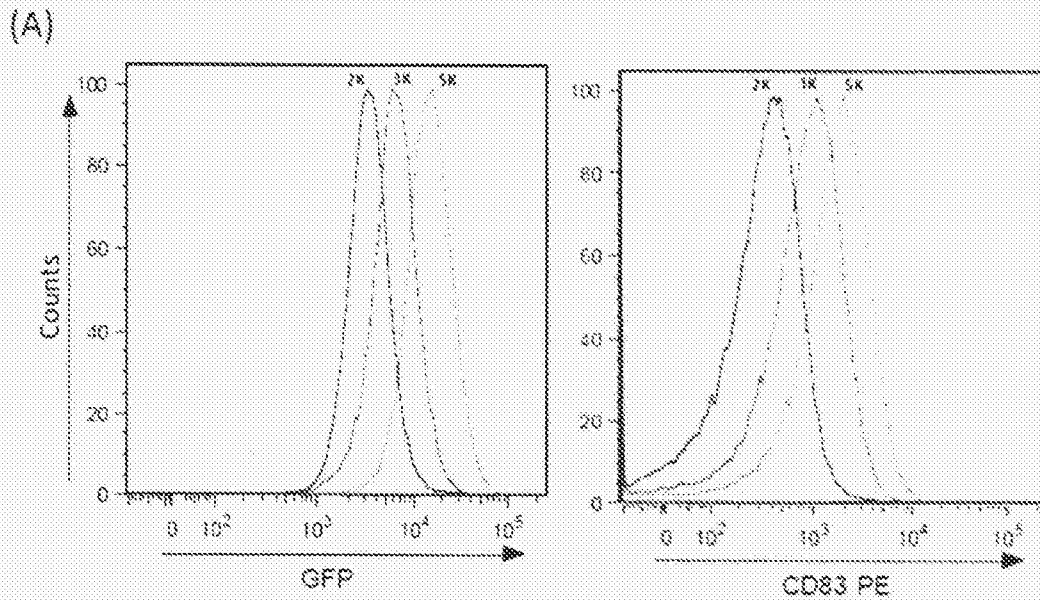


Figure 10

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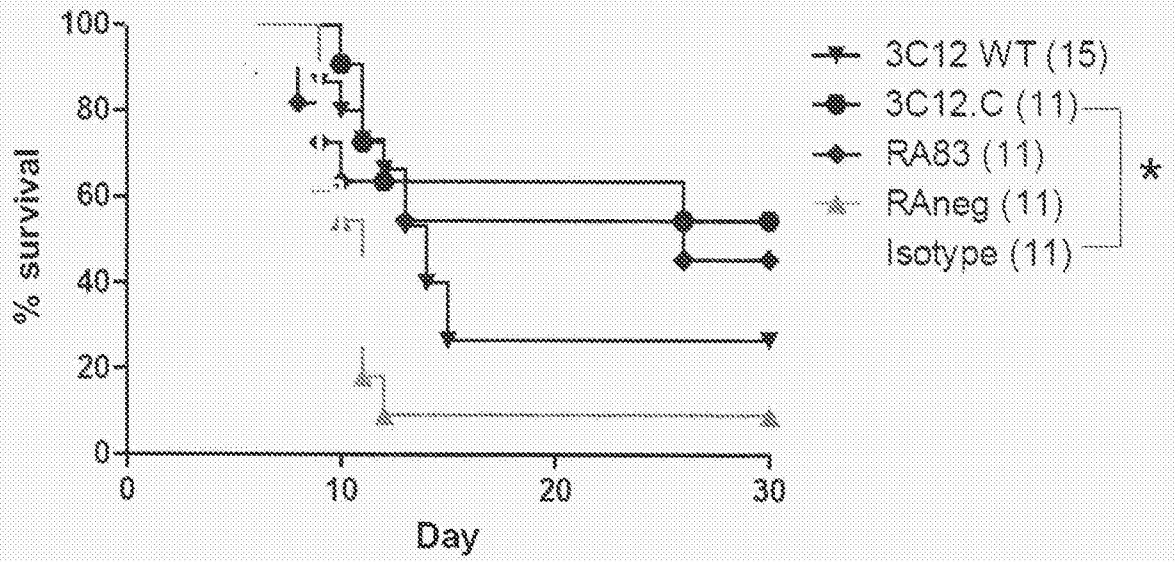


Figure 11

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2014/000066

## A. CLASSIFICATION OF SUBJECT MATTER

*C07K 16/28 (2006.01) C12N 15/13 (2006.01) A61K 39/395 (2006.01) A61K 39/44 (2006.01) A61P 37/08 (2006.01)*  
*A61P 37/02 (2006.01) A61P 1/00 (2006.01) A61P 25/28 (2006.01) A61P 9/00 (2006.01) A61P 17/00 (2006.01)*  
*A61P 17/06 (2006.01) A61P 3/10 (2006.01) A61P 31/14 (2006.01)*

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

GeneomeQuest Search (Databases: GQ-Pat; Protein Data Bank; Genpept; ENSEMBL; Swiss-Prot; Ref Seq; Translated EMBL) of SEQ ID Nos. 1-9, 26-28, 35-46

Applicant and inventor search on AusPat, Patentscope, Espacenet, PAMS

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search  
11 April 2014

Date of mailing of the international search report  
11 April 2014

## Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE  
PO BOX 200, WODEN ACT 2606, AUSTRALIA  
Email address: pct@ipaustralia.gov.au  
Facsimile No.: +61 2 6283 7999

## Authorised officer

Scott Makin  
AUSTRALIAN PATENT OFFICE  
(ISO 9001 Quality Certified Service)  
Telephone No. +61 2 6283 7971

<b>INTERNATIONAL SEARCH REPORT</b>		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		<b>PCT/AU2014/000066</b>
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/0190051 A1 (BEDIAN et al) 16 August 2007 Abstract; Claims; Paragraphs [0232] to [0248], pp. 25-26; Paragraph [0099] and Table A, p. 8; SEQ ID NOs: 73, 74, 77, 78, 91, 92, 105, 106, 107, 115, 116 and 117; Paragraphs [0222] to [0231], pp. 24-25	1-28
A	WO 2012/088290 A2 (ABBOTT LABORATORIES) 28 June 2012 Abstract; Claims; pp. 13-17; SEQ ID NO: 73	1-28
A	Genbank Accession No. ABI35683, 30 December 2007 Sequence comprises CDRs of SEQ ID NO:1	1-28
A	Genbank Accession No. ACF37389, 31 March 2009 Sequence comprises CDRs of SEQ ID NO:1	1-28
A	US 2011/0195027 A1 (PARK et al) 11 August 2011 Abstract; Claims; SEQ ID NO:57	1-28

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2014/000066	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 2007/0190051 A1	16 Aug 2007	US 7563442 B2	21 Jul 2009
		AP 1918 A	13 Nov 2008
		AR 039067 A1	09 Feb 2005
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		CR 7343 A	28 Oct 2004
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		KR 20050063749 A	28 Jun 2005
		KR 100830086 B1	20 May 2008
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		NO 334339 B1	10 Feb 2014

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.  
Form PCT/ISA/210 (Family Annex)(July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		<b>PCT/AU2014/000066</b>	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
		NZ 533180 A	28 Mar 2008
		OA 12725 A	28 Jun 2006
		PA 8557701 A1	19 Dec 2003
		PE 08462003 A1	11 Oct 2003
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