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The present invention includes compositions and methods for binding Dectin-1 on immune cells with anti-Dectin-1-specific antibodies or fragment thereof capable of activating the immune cells.

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(54) Title: THERAPEUTIC APPLICATIONS OF ACTIVATION OF HUMAN ANTIGEN-PRESENTING CELLS THROUGH DECTIN-1

(57) Abstract: The present invention includes compositions and methods for binding Dectin-1 on immune cells with anti-Dectin-1-specific antibodies or fragment thereof capable of activating the immune cells.



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THERAPEUTIC APPLICATIONS OF ACTIVATION OF HUMAN ANTIGEN- PRESENTING CELLS THROUGH DECTIN-1

TECHNICAL FIELD OF THE INVENTION

The present invention relates in general to the field of antigen presentation and immune cell
5 activation, and more particularly, to compositions and methods for the activation of immune
cells through Dectin-1.

BACKGROUND OF THE INVENTION

Without limiting the scope of the invention, its background is described in connection with
dendritic cell activation.

10 Dendritic Cells play a pivotal role in controlling the interface of innate and acquired immunity
by providing soluble and intercellular signals, followed by recognition of pathogens. These
functions of DCs are largely dependent on the expression of specialized surface receptors,
'pattern recognition receptors' (PRRs), represented, most notably, by toll-like receptors (TLRs)
and C-type lectins or lectin-like receptors (LLRs) (1-3).

15 In the current paradigm, a major role of TLRs is to alert DCs to produce interleukin 12 (IL-12)
and other inflammatory cytokines for initiating immune responses. C-type LLRs operate as
constituents of the powerful antigen capture and uptake mechanism of macrophages and DCs
(1). Compared to TLRs, however, LLRs might have broader ranges of biological functions that
include cell migration (4) and intercellular interactions (5). These multiple functions of LLRs
20 might be due to the fact that LLRs, unlike TLRs, can recognize both self and non-self. However,
the complexity of LLRs, including the redundancy of a number of LLRs expressed in immune
cells, has been one of the major obstacles to understand the detailed functions of individual
LLRs. In addition, natural ligands for most of these receptors remain unidentified. Nonetheless,
evidence from recent studies suggests that LLRs, in collaboration with TLRs, may contribute to
25 the activation of immune cells during microbial infections (6-14). Compared to other LLRs,
Dectin-1 is known to have ITAM motif that delivers signals to activate cells expressing Dectin-
1. However, most of the studies have been performed in the mouse model and the biological
function of Dectin-1 expressed on human antigen presenting cells, including DCs, monocytes,
and B cells, has not been well characterized. This is particularly important since there is not
30 strict concordance between mouse and human for many of the LLRs.

SUMMARY OF THE INVENTION

The present invention include compositions and methods for making and using vaccines that specifically target (deliver) antigens to antigen-presenting cells for the purpose of eliciting potent and broad immune responses directed against the antigen. The purpose is primarily to evoke protective or therapeutic immune responses against the agent (pathogen or cancer) from which the antigen was derived. In addition the invention includes agents that are directly, or in concert with other agents, therapeutic through their specific engagement of a receptor called Dectin-1 that is expressed on antigen-presenting cells.

The present inventors show that Dectin-1 expression in human cells is restricted to antigen presenting cells, including DCs, Monocytes, and B cells. It is known that Dectin-1 expressed on mouse cells (macrophages) is downregulated by TLR4 ligand and IL-10, herein we show only TLR4 ligand can downregulate Dectin-1 expression on human DCs and IL-10 results in slightly increased expression of Dectin-1. More interestingly, Dectin-1 expressed on human DCs synergizes with TLR4 much more effectively than with TLR2, and the synergy between Dectin-1 and TLR4 results in dramatically increased production of cytokines and chemokines, particularly IL-12 that was not observed previously in mouse models. Human tonsil B cells can be divided into two groups: CD19⁺Dectin-1⁺ and CD19⁺Dectin-1⁻. These findings can also be used in therapeutic and preventive reagents based on anti-Dectin-1 agents.

Therefore, it was found herein that signaling through human Dectin-1 is a unique and functional, either alone or in collaboration with other cellular signals, in terms of cell (including DC) activation. Dectin-1-mediated cell activation is induced by particular anti-Dectin-1 mAbs, and therefore such anti-human Dectin-1 mAbs will be useful for developing reagents against diseases.

The present invention includes compositions and methods for increasing the effectiveness of antigen presentation by a Dectin-1-expressing antigen presenting cell by contacting the antigen presenting cell with an anti-Dectin-1-specific antibody or fragment thereof capable of activating the antigen presenting cell, wherein the antigen presenting cell is activated. Examples of antigen presenting cell include dendritic cells, peripheral blood mononuclear cells, monocytes, B cells, myeloid dendritic cells and combinations thereof. The antigen presenting cell may be cultured in vitro with GM-CSF and IL-4, interferon alpha, antigen and combinations thereof. Upon activation of the antigen presenting cells contacted with GM-CSF and IL-4 and a Dectin-1-specific antibody or fragment, an increase in the surface expression of CD86, CD80, and HLA-

DR on the antigen presenting cell is obtained. When activating the antigen presenting cells with Interferon alpha and the Dectin-1-specific antibody or fragment thereof, the cells increase the surface expression of CD86, CD83, CD80, and HLA-DR.

Yet another method of the present invention includes contacting dendritic cell that has been
5 contacted with GM-CSF and IL-4 or Interferon alpha to activate the dendritic cell, wherein the activated dendritic cells increases the surface expression of CD86, CD80, and HLA-DR. For dendritic cells that have been contacted with the anti-Dectin-1 antibody or fragments thereof and GM-CSF and IL-4 or Interferon alpha to activate the dendritic cell, the activated dendritic cells increases the secretion of IL-6, IL-8, IL-10, IL-12p40, IP-10, and MIP-1a and combinations
10 thereof. Yet another method of activating dendritic cell includes contacting with GM-CSF and IL-4 or Interferon alpha and the Dectin-1-specific antibody or fragment thereof increases the activation in conjunction with signaling through CD40. It has been found that the dendritic cell contacted with GM-CSF and IL-4 or Interferon alpha and the Dectin-1-specific antibody or fragment thereof have increased co-stimulatory activity by dendritic cells of B cells and T cells.

15 Yet another method include contacting an antigen presenting cell with the anti-Dectin-1 antibody and co-activating the antigen presenting cell the activating through the TLR4 receptor, wherein the cells increase cytokine and chemokine production. Co-activating the antigen presenting cell by activating through the TLR4 receptor, wherein the cells increase secretion of IL-10, IL-1b, TNF α , IL-12p40 and combinations thereof.

20 The method of claim 1, further comprising the step of co-activating the antigen presenting cell the activating through the TLR4 receptor using at least one of a TLR4 ligand, an anti-TLR4 antibody or fragments thereof, an anti-TLR4-anti-Dectin-1 hybrid antibody or fragment thereof, an anti-TLR4-anti-Dectin-1 ligand conjugate. The Dectin-1-specific antibody or fragment may be one or more of the clones selected from 15E2.5, 11B6.4, 15F4.7, 14D6.3 and 9H7.6 and
25 combinations thereof. The dendritic cells may be activated through the Dectin-1-receptor with the Dectin-1-specific antibody or fragment thereof to activate monocytes, dendritic cells, peripheral blood mononuclear cells, B cells and combinations thereof. The Dectin-1-specific antibody or fragment thereof may be bound to one half of a Cohesin/Dockerin pair. When the Dectin-1-specific antibody or fragment thereof is bound to one half of a Cohesin/Dockerin pair,
30 the other half of the pair may be bound to one or more antigens, cytokines selected from interleukins, transforming growth factors (TGFs), fibroblast growth factors (FGFs), platelet derived growth factors (PDGFs), epidermal growth factors (EGFs), connective tissue activated

peptides (CTAPs), osteogenic factors, and biologically active analogs, fragments, and derivatives of such growth factors, B/T-cell differentiation factors, B/T-cell growth factors, mitogenic cytokines, chemotactic cytokines and chemokines, colony stimulating factors, angiogenesis factors, IFN- α , IFN- β , IFN- γ , IL1, IL2, IL3, IL4, IL5, IL6, IL7, IL8, IL9, IL10, IL11, IL12, IL13, IL14, IL15, IL16, IL17, IL18, etc., leptin, myostatin, macrophage stimulating protein, platelet-derived growth factor, TNF- α , TNF- β , NGF, CD40L, CD137L/4-1BBL, human lymphotoxin- β , G-CSF, M-CSF, GM-CSF, PDGF, IL-1 α , IL1- β , IP-10, PF4, GRO, 9E3, erythropoietin, endostatin, angiostatin, VEGF, transforming growth factor (TGF) supergene family include the beta transforming growth factors (for example TGF- β 1, TGF- β 2, TGF- β 3); bone morphogenetic proteins (for example, BMP-1, BMP-2, BMP-3, BMP-4, BMP-5, BMP-6, BMP-7, BMP-8, BMP-9); heparin-binding growth factors (fibroblast growth factor (FGF), epidermal growth factor (EGF), platelet-derived growth factor (PDGF), insulin-like growth factor (IGF)); Inhibins (for example, Inhibin A, Inhibin B); growth differentiating factors (for example, GDF-1); and Activins (for example, Activin A, Activin B, Activin AB).

15 The present invention includes a hybridoma and antibodies isolated therefrom that expressed a Dectin-1-specific antibody or fragment thereof, wherein the Dectin-1-specific antibody or fragment thereof activates an antigen presenting cell to express new surface markers, secrete one or more cytokines or both. The hybridoma may be selected from clone PAB1, PAB4, PAB5, PAB8, PAB10 and combinations thereof.

20 A method for enhancing B cell immune responses that includes triggering a Dectin-1 receptor on a dendritic cell with a Dectin-1 specific antibody or fragment thereof in the presence of antigen and an activator of TLR9, wherein a B cell that is contacted with the Dectin-1/TLR9 activated dendritic cell increases antibody production, secretes cytokines, increase B cell activation surface marker expression and combinations thereof. B cells activated using these dendritic

25 cells secrete IL-8, MIP-1 α , IL-6, TNF α and combinations thereof. Examples of B cells include plasma cells, which may also express Dectin-1 and/or increases production of IgM.

The present invention also includes a method for enhancing B cell immune responses comprising triggering a Dectin-1 receptor on a B-cell with a Dectin-1 specific antibody or fragment thereof, wherein the B cell increases antibody production. B cells activated using the

30 present invention increase production of secreted IL-8, MIP-1 α , IL-6, TNF α and combinations thereof and/or increase production of IgG, IgM, IgA and combinations thereof.

The present invention also includes a method for enhancing T cell activation by triggering a Dectin-1 receptor on a dendritic cell with a Dectin-1 specific antibody or fragment thereof and TLR4 receptor and contacting a T cell to the Dectin-1/TLR4 activated dendritic cell, wherein T cell activation is enhanced. The dendritic cells used for activation may be contacted with GM-CSF and IL-4, interferon alpha, antigen and combinations thereof. The Dectin-1 specific antibody or fragment thereof increases the secretion of IL-10, IL-15 and combinations thereof by the T cells. The T cells activated by the dendritic cells may increase the surface expression of 4-1BBL and/or proliferate.

The present invention also includes an anti-Dectin-1 immunoglobulin or portion thereof that is secreted from mammalian cells and an antigen bound to the immunoglobulin, wherein the immunoglobulin targets the antigen to antigen presenting cells. The antigen specific domain includes a full length antibody, an antibody variable region domain, an Fab fragment, a Fab' fragment, an F(ab)₂ fragment, and Fv fragment, and Fabc fragment and/or a Fab fragment with portions of the Fc domain.

Yet another embodiment of the present invention includes a vaccine that includes a dendritic cell activated with a Dectin-1-specific antibody or fragment thereof. The present invention also includes B cells, T cells or other immune cells that are activated either directly by the Dectin-1-specific antibody or fragments thereof and/or by antigen presenting cells, such as dendritic cells, which have been activated with the Dectin-1-specific antibody or fragments thereof alone or in combination with the other immune cells. For example, a combination therapy may include an antigen loadable antigen presenting cells (e.g., a dendritic cell) that have been activated with the Dectin-1-specific antibody or fragments thereof, a B cell and/or a T cell that together form the vaccine.

The present invention also includes the use of agents that engage the Dectin-1 receptor on immune cells, alone or with co-activating agents, the combination activating antigen-presenting cells for therapeutic applications; use of a Dectin-1 binding agent linked to one or more antigens, with or without activating agents, on immune cells to make a vaccine; use of anti-Dectin-1 agents as co-activating agents of immune cells for the enhancement of immune responses directed through a cell surface receptor other than Dectin-1 expressed on immune cells; use of anti-Dectin-1 antibody V-region sequences capable of binding to and activating immune cells through the Dectin-1 receptor and/or use of Dectin-1 binding agents linked to one or more toxic agents for therapeutic purposes in the context of diseases known or suspected to result from

inappropriate activation of immune cells via Dectin-1 or in the context of pathogenic cells or tissues that express Dectin-1.

Yet another embodiment of the present invention includes a modular rAb carrier that includes a Dectin-1-specific antibody binding domain linked to one or more antigen carrier domains that
5 comprise one half of a cohesin-dockerin binding pair. The antigen-specific binding domain may be at least a portion of an antibody and/or at least a portion of an antibody in a fusion protein with the one half of the cohesin-dockerin binding pair. The rAb may also be a complementary half of the cohesin-dockerin binding pair bound to an antigen that forms a complex with the modular rAb carrier and/or a complementary half of the cohesin-dockerin binding pair that is a
10 fusion protein with an antigen. The antigen specific domain may be a full length antibody, an antibody variable region domain, an Fab fragment, a Fab' fragment, an F(ab)2 fragment, and Fv fragment, and Fabc fragment and/or a Fab fragment with portions of the Fc domain.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the features and advantages of the present invention,
15 reference is now made to the detailed description of the invention along with the accompanying figures and in which:

Figures 1A and 1B show the expression levels of Dectin-1 on PBMCs from normal donors;

Figure 2 shows the results from in vitro-cultured IL-4DCs were cultured in the presence of CD40L (50 ng/ml), TLR2 ligand (100 ng/ml), TLR3 ligand (100 nM), TLR4 ligand (20 ng/ml),
20 IL-10 (20 ng/ml), IL-15 (100 ng/ml), IFN α (500 U/ml), and IL-4 (50 ng/ml) for 24h;

Figure 3 demonstrates that anti-Dectin-1 mAbs activate DCs;

Figures 4A and 4B show that signaling through Dectin-1 can result in activation of both IL-4DCs and IFNDCs. Anti-Dectin-1 mAbs activate DCs. IFNDCs (Figure 4A) and IL-4DCs (Figure 4B) were stimulated with anti-Dectin-1 for 24 h, and then cells were stained with anti-
25 CD86, 80, 40, 83, CCR7, and HLA-DR;

Figure 5 shows that Dectin-1 and TLRs synergize to activate DCs. IL-4DCs (2×10^5 /200 ul/well) were cultured in 96-well plates coated with anti-Dectin-1 in the presence or absence of soluble TLR4 ligand (1.5 ng/ml) or TLR2 ligand (30 ng/ml) for 18 h. Control mAbs were also tested. After 18 h, culture supernatants were analyzed to measure cytokines and chemokines by
30 Luminex;

Figures 6A and 6B show the results for IFNDCs (5000 DCs/well/200 uL) loaded with 10 uM Mart-1 peptide and activated with anti-Dectin-1 mAbs, TLR4 ligand, or anti-Dectin-1 mAbs and TLR4 ligand for 18 h (Figure 6A). Purified autologous CD8 T cells (2×10^5 cells/well/200 uL) were co-cultured in the presence of 20U/ml IL-2 and 10ng/ml IL-7 for 10 days. Cells were stained with anti-CD8 and Mart-1-HLA-A2-tetramer. Figure 6B shows the results for IFNDCs (5000 DCs/well/200 uL) were loaded with 10 uM Mart-1 peptide and activated with anti-Dectin-1 mAbs, TLR2 ligand, or anti-Dectin-1 mAbs and TLR2 ligand for 18 h. Purified autologous CD8 T cells (2×10^5 cells/well/200 uL) were co-cultured in the presence of 20U/ml IL-2 and 10 ng/ml IL-7 for 10 days. Cells were stained with anti-CD8 and Mart-1-HLA-A2-tetramer;

Figure 7 shows the results for IFNDCs (5000 DCs/well/200 uL) loaded with 10 uM Mart-1 peptide and activated with anti-Dectin-1 mAbs, TLR4 ligand, or anti-Dectin-1 mAbs and TLR4 ligand, Zymosan for 18 h. anti-IL-10 neutralizing antibody (5 ug/ml) was added into the DCs stimulated with anti-Dectin-1 and TLR4 ligand and Zymosan. Control antibody to anti-IL-10 was also tested, but there was no significant difference observed (data not shown). Purified autologous CD8 T cells (2×10^5 cells/well/200 uL) were co-cultured in the presence of 20U/ml IL-2 and 10ng/ml IL-7 for 10 days. Cells were stained with anti-CD8 and Mart-1-HLA-A2-tetramer;

Figure 8 shows that DCs activated with anti-Dectin-1 mAbs express increased levels of IL-15 and 4-1BBL. IFNDCs (2×10^5 /200 ul/well) were cultured in the 96-well plates coated with anti-Dectin-1 or control Ig for 18 h. After 18 h, cells were stained with anti-IL-15 and anti-4-1BBL;

Figures 9A and 9B show that Dectin-1 expressed on DCs contributes to enhanced humoral immune responses. 6-day IL-4 DCs, 5×10^3 /well, were incubated in 96 well plates coated with anti-Dectin-1 or control mAbs for 16-18 h, and then 2×10^4 autologous CD19⁺ B cells stained with CFSE were co-cultured in the presence of 20 U/ml IL-2 and 50 ng/ml CD40L (Figure 9A) or 50 nM CpG (Figure 9B). On day six, cells were stained with fluorescently labeled anti-CD38 antibody. Culture supernatants on day thirteen were analyzed for total immunoglobulins by sandwich ELISA;

Figures 10A and 10B show that Dectin-1 expressed on B cells contributes to B cell activation and immunoglobulin production. Figure 10A. Purified CD19⁺ B cells (20000 cells/well/200ul) were cultured in plates coated with the mAbs, either anti-Dectin-1 or control Ig, in the presence of 50 nM CpG and 20U/ml IL-2 for 6 days. Cells were stained with anti-CD38 and cell

proliferation was measured by CFSE dilution. Figure 10B. On day 13 of the culture, culture supernatants were analyzed for measuring total immunoglobulins produced by ELISA;

Figures 11A to 11C show that Dectin-1 expressed on DCs contributes to enhanced cellular immune responses. Figure 11A. 5×10^3 of IFNDCs were cultured in plates coated with anti-Dectin-1 or control mAbs in the presence of 100 nM of recombinant Flu M1 protein for 16-18 h, and then purified autologous CD8 T cells were co-cultured in the presence of 20 U/ml IL-2 and 10ng/ml of IL-7 for 7 days. Cells were stained with anti-CD8 and tetramer for Flu M1 peptide epitope for HLA-A2. Figure 11B and Figure 11C. IFNDCs were loaded with 10 uM of Mart-1 peptide (Figure 11B) or 100 nM Coh-Mart-1 recombinant protein, and then stimulated with anti-Dectin-1 or control antibodies as described in Figure 11A. After 10-day culture, cells were stained with anti-CD8 and tetramer (HLA-A2-mart-1 peptide). Each line represents data generated from an individual donor. All cells used in this study were from HLA-A201 positive normal donors;

Figure 12 shows that anti-Dectin-1 mAbs in soluble form activate DCs to enhance Mart-1 specific CD8 T cell priming. 5×10^3 of IFNDCs were cultured in the presence of 0.5 ug/ml of anti-Dectin-1, anti-CD40, or control mAb for 16 h. Before purified autologous T cells (2×10^5 /well) were added into the culture, 20 uM Mart-1 peptide were added. After 10 days, cells were stained with anti-CD8 and tetramer (HLA-A2-mart-1 peptide). All cells used in this study were from HLA-A201 positive normal donors;

Figure 13 shows that tonsils from normal donors were acquired and a cell suspension was prepared using DNase-free Collagenase type III. Cells were washed vigorously with PBS containing 5% FCS, and then stained with anti-CD3 or anti-CD19 with anti-Dectin-1 mAbs. isotype-matched control mAbs were used;

Figures 14A and 14B show tissue sections of human skin (Figure 14A) and lymph node (Figure 14B) from normal donors were prepared and stained with DAPI (Blue) and anti-Dectin-1 (Red) prepared in this study;

Figure 15 shows that PBMC from non-human primates (Cynomolgus) were stained with anti-Dectin-1 mAb and antibodies to cell surface markers;

Figure 16 shows reduced SDS-PAGE analysis of typical rAb.antigen fusion proteins – bearing many of the antigens shown or mentioned above.

DETAILED DESCRIPTION OF THE INVENTION

While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific
5 embodiments discussed herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention.

To facilitate the understanding of this invention, a number of terms are defined below. Terms defined herein have meanings as commonly understood by a person of ordinary skill in the areas relevant to the present invention. Terms such as “a”, “an” and “the” are not intended to refer to
10 only a singular entity, but include the general class of which a specific example may be used for illustration. The terminology herein is used to describe specific embodiments of the invention, but their usage does not delimit the invention, except as outlined in the claims.

The present invention also includes a recombinant humanized mAb (directed to the specific human dendritic cell receptor Dectin-1) fused through the Ab heavy chain to antigens known or
15 suspected to encode protective antigens. These include as examples for vaccination against various agents - hemagglutinins from Influenza H5N1; HIV gag from attenuated toxins from Ricin, Anthrax toxin, and Staphylococcus B enterotoxin; 'strings' of antigenic peptides from melanoma antigens, etc. The present invention will find use in preventative or therapeutic
20 vaccination of at-risk or infected people. The invention has broad application for vaccination against many diseases and cancers, both for human and animal use.

As used herein, the term “modular rAb carrier” is used to describe a recombinant antibody system that has been engineered to provide the controlled modular addition of diverse antigens, activating proteins, or other antibodies to a single recombinant monoclonal antibody (mAb), in
25 this case, an anti-Dectin-1 monoclonal antibody. The rAb may be a monoclonal antibody made using standard hybridoma techniques, recombinant antibody display, humanized monoclonal antibodies and the like. The modular rAb carrier can be used to, e.g., target (via one primary recombinant antibody against an internalizing receptor, e.g., a human dendritic cell receptor) multiple antigens and/or antigens and an activating cytokine to dendritic cells (DC). The modular rAb carrier may also be used to join two different recombinant mAbs end-to-end in a
30 controlled and defined manner.

The antigen binding portion of the “modular rAb carrier” may be one or more variable domains, one or more variable and the first constant domain, an Fab fragment, a Fab' fragment, an F(ab)₂

fragment, and Fv fragment, and Fabc fragment and/or a Fab fragment with portions of the Fc domain to which the cognate modular binding portions are added to the amino acid sequence and/or bound. The antibody for use in the modular rAb carrier can be of any isotype or class, subclass or from any source (animal and/or recombinant).

- 5 In one non-limiting example, the modular rAb carrier is engineered to have one or more modular cohesin-dockerin protein domains for making specific and defined protein complexes in the context of engineered recombinant mAbs. The mAb is a portion of a fusion protein that includes one or more modular cohesin-dockerin protein domains carboxy from the antigen binding domains of the mAb. The cohesin-dockerin protein domains may even be attached post-translationally, e.g., by using chemical cross-linkers and/or disulfide bonding.

The term “antigen” as used herein refers to a molecule that can initiate a humoral and/or cellular immune response in a recipient of the antigen. Antigen may be used in two different contexts with the present invention: as a target for the antibody or other antigen recognition domain of the rAb or as the molecule that is carried to and/or into a cell or target by the rAb as part of a
15 dockerin/cohesin-molecule complement to the modular rAb carrier. The antigen is usually an agent that causes a disease for which a vaccination would be advantageous treatment. When the antigen is presented on MHC, the peptide is often about 8 to about 25 amino acids. Antigens include any type of biologic molecule, including, for example, simple intermediary metabolites, sugars, lipids and hormones as well as macromolecules such as complex carbohydrates, phospholipids, nucleic acids and proteins. Common categories of antigens include, but are not
20 limited to, viral antigens, bacterial antigens, fungal antigens, protozoal and other parasitic antigens, tumor antigens, antigens involved in autoimmune disease, allergy and graft rejection, and other miscellaneous antigens.

The modular rAb carrier is able to carry any number of active agents, e.g., antibiotics, anti-
25 infective agents, antiviral agents, anti-tumoral agents, antipyretics, analgesics, anti-inflammatory agents, therapeutic agents for osteoporosis, enzymes, cytokines, anticoagulants, polysaccharides, collagen, cells, and combinations of two or more of the foregoing active agents. Examples of antibiotics for delivery using the present invention include, without limitation, tetracycline, aminoglycosides, penicillins, cephalosporins, sulfonamide drugs, chloramphenicol sodium succinate, erythromycin, vancomycin, lincomycin, clindamycin, nystatin, amphotericin B,
30 amantidine, idoxuridine, p-amino salicylic acid, isoniazid, rifampin, antinomycin D,

mithramycin, daunomycin, adriamycin, bleomycin, vinblastine, vincristine, procarbazine, imidazole carboxamide, and the like.

Examples of anti-tumor agents for delivery using the present invention include, without limitation, doxorubicin, Daunorubicin, taxol, methotrexate, and the like. Examples of
5 antipyretics and analgesics include aspirin, Motrin®, Ibuprofen®, naprosyn, acetaminophen, and the like.

Examples of anti-inflammatory agents for delivery using the present invention include, without limitation, include NSAIDS, aspirin, steroids, dexamethasone, hydrocortisone, prednisolone, Diclofenac Na, and the like.

10 Examples of therapeutic agents for treating osteoporosis and other factors acting on bone and skeleton include for delivery using the present invention include, without limitation, calcium, alendronate, bone GLa peptide, parathyroid hormone and its active fragments, histone H4-related bone formation and proliferation peptide and mutations, derivatives and analogs thereof.

Examples of enzymes and enzyme cofactors for delivery using the present invention include,
15 without limitation, pancrease, L-asparaginase, hyaluronidase, chymotrypsin, trypsin, tPA, streptokinase, urokinase, pancreatin, collagenase, trypsinogen, chymotrypsinogen, plasminogen, streptokinase, adenyl cyclase, superoxide dismutase (SOD), and the like.

Examples of cytokines for delivery using the present invention include, without limitation, interleukins, transforming growth factors (TGFs), fibroblast growth factors (FGFs), platelet
20 derived growth factors (PDGFs), epidermal growth factors (EGFs), connective tissue activated peptides (CTAPs), osteogenic factors, and biologically active analogs, fragments, and derivatives of such growth factors. Cytokines may be B/T-cell differentiation factors, B/T-cell growth factors, mitogenic cytokines, chemotactic cytokines, colony stimulating factors, angiogenesis factors, IFN- α , IFN- β , IFN- γ , IL1, IL2, IL3, IL4, IL5, IL6, IL7, IL8, IL9, IL10,
25 IL11, IL12, IL13, IL14, IL15, IL16, IL17, IL18, etc., leptin, myostatin, macrophage stimulating protein, platelet-derived growth factor, TNF- α , TNF- β , NGF, CD40L, CD137L/4-1BBL, human lymphotoxin- β , G-CSF, M-CSF, GM-CSF, PDGF, IL-1 α , IL1- β , IP-10, PF4, GRO, 9E3, erythropoietin, endostatin, angiostatin, VEGF or any fragments or combinations thereof. Other cytokines include members of the transforming growth factor (TGF) supergene family include
30 the beta transforming growth factors (for example TGF- β 1, TGF- β 2, TGF- β 3); bone morphogenetic proteins (for example, BMP-1, BMP-2, BMP-3, BMP-4, BMP-5, BMP-6, BMP-7, BMP-8, BMP-9); heparin-binding growth factors (for example, fibroblast growth factor

(FGF), epidermal growth factor (EGF), platelet-derived growth factor (PDGF), insulin-like growth factor (IGF)); Inhibins (for example, Inhibin A, Inhibin B); growth differentiating factors (for example, GDF-1); and Activins (for example, Activin A, Activin B, Activin AB).

5 Examples of growth factors for delivery using the present invention include, without limitation, growth factors that can be isolated from native or natural sources, such as from mammalian cells, or can be prepared synthetically, such as by recombinant DNA techniques or by various chemical processes. In addition, analogs, fragments, or derivatives of these factors can be used, provided that they exhibit at least some of the biological activity of the native molecule. For example, analogs can be prepared by expression of genes altered by site-specific mutagenesis or
10 other genetic engineering techniques.

Examples of anticoagulants for delivery using the present invention include, without limitation, include warfarin, heparin, Hirudin, and the like. Examples of factors acting on the immune system include for delivery using the present invention include, without limitation, factors which control inflammation and malignant neoplasms and factors which attack infective
15 microorganisms, such as chemotactic peptides and bradykinins.

Examples of viral antigens include, but are not limited to, e.g., retroviral antigens such as retroviral antigens from the human immunodeficiency virus (HIV) antigens such as gene products of the gag, pol, and env genes, the Nef protein, reverse transcriptase, and other HIV components; hepatitis viral antigens such as the S, M, and L proteins of hepatitis B virus, the pre-S antigen of hepatitis B virus, and other hepatitis, e.g., hepatitis A, B, and C, viral components such as hepatitis C viral RNA; influenza viral antigens such as hemagglutinin and neuraminidase and other influenza viral components; measles viral antigens such as the measles virus fusion protein and other measles virus components; rubella viral antigens such as proteins E1 and E2 and other rubella virus components; rotaviral antigens such as VP7sc and other
20 rotaviral components; cytomegaloviral antigens such as envelope glycoprotein B and other cytomegaloviral antigen components; respiratory syncytial viral antigens such as the RSV fusion protein, the M2 protein and other respiratory syncytial viral antigen components; herpes simplex viral antigens such as immediate early proteins, glycoprotein D, and other herpes simplex viral antigen components; varicella zoster viral antigens such as gpI, gpII, and other varicella zoster viral antigen components; Japanese encephalitis viral antigens such as proteins E, M-E, M-E-NS1, NS1, NS1-NS2A, 80% E, and other Japanese encephalitis viral antigen components; rabies
25 viral antigens such as rabies glycoprotein, rabies nucleoprotein and other rabies viral antigen

components. See Fundamental Virology, Second Edition, eds. Fields, B. N. and Knipe, D. M. (Raven Press, New York, 1991) for additional examples of viral antigens.

Antigenic targets that may be delivered using the rAb-DC/DC-antigen vaccines of the present invention include genes encoding antigens such as viral antigens, bacterial antigens, fungal
5 antigens or parasitic antigens. Viruses include picornavirus, coronavirus, togavirus, flavivirus, rhabdovirus, paramyxovirus, orthomyxovirus, bunyavirus, arenavirus, reovirus, retrovirus, papillomavirus, parvovirus, herpesvirus, poxvirus, hepadnavirus, and spongiform virus. Other viral targets include influenza, herpes simplex virus 1 and 2, measles, dengue, smallpox, polio or HIV. Pathogens include trypanosomes, tapeworms, roundworms, helminthes, malaria. Tumor
10 markers, such as fetal antigen or prostate specific antigen, may be targeted in this manner. Other examples include: HIV env proteins and hepatitis B surface antigen. Administration of a vector according to the present invention for vaccination purposes would require that the vector-associated antigens be sufficiently non-immunogenic to enable long term expression of the transgene, for which a strong immune response would be desired. In some cases, vaccination of
15 an individual may only be required infrequently, such as yearly or biennially, and provide long term immunologic protection against the infectious agent. Specific examples of organisms, allergens and nucleic and amino sequences for use in vectors and ultimately as antigens with the present invention may be found in U.S. Patent No. 6,541,011, relevant portions incorporated herein by reference, in particular, the tables that match organisms and specific sequences that
20 may be used with the present invention.

Bacterial antigens for use with the rAb vaccine disclosed herein include, but are not limited to, e.g., bacterial antigens such as pertussis toxin, filamentous hemagglutinin, pertactin, FIM2, FIM3, adenylate cyclase and other pertussis bacterial antigen components; diphtheria bacterial
antigens such as diphtheria toxin or toxoid and other diphtheria bacterial antigen components;
25 tetanus bacterial antigens such as tetanus toxin or toxoid and other tetanus bacterial antigen components; streptococcal bacterial antigens such as M proteins and other streptococcal bacterial antigen components; gram-negative bacilli bacterial antigens such as lipopolysaccharides and other gram-negative bacterial antigen components, Mycobacterium tuberculosis bacterial antigens such as mycolic acid, heat shock protein 65 (HSP65), the 30 kDa
30 major secreted protein, antigen 85A and other mycobacterial antigen components; Helicobacter pylori bacterial antigen components; pneumococcal bacterial antigens such as pneumolysin, pneumococcal capsular polysaccharides and other pneumococcal bacterial antigen components; haemophilus influenza bacterial antigens such as capsular polysaccharides and other

haemophilus influenza bacterial antigen components; anthrax bacterial antigens such as anthrax protective antigen and other anthrax bacterial antigen components; rickettsiae bacterial antigens such as rompA and other rickettsiae bacterial antigen component. Also included with the bacterial antigens described herein are any other bacterial, mycobacterial, mycoplasmal, rickettsial, or chlamydial antigens. Partial or whole pathogens may also be: haemophilus influenza; Plasmodium falciparum; neisseria meningitidis; streptococcus pneumoniae; neisseria gonorrhoeae; salmonella serotype typhi; shigella; vibrio cholerae; Dengue Fever; Encephalitides; Japanese Encephalitis; lyme disease; Yersinia pestis; west nile virus; yellow fever; tularemia; hepatitis (viral; bacterial); RSV (respiratory syncytial virus); HPIV 1 and HPIV 3; adenovirus; small pox; allergies and cancers.

Fungal antigens for use with compositions and methods of the invention include, but are not limited to, e.g., candida fungal antigen components; histoplasma fungal antigens such as heat shock protein 60 (HSP60) and other histoplasma fungal antigen components; cryptococcal fungal antigens such as capsular polysaccharides and other cryptococcal fungal antigen components; coccidioides fungal antigens such as spherule antigens and other coccidioides fungal antigen components; and tinea fungal antigens such as trichophytin and other coccidioides fungal antigen components.

Examples of protozoal and other parasitic antigens include, but are not limited to, e.g., plasmodium falciparum antigens such as merozoite surface antigens, sporozoite surface antigens, circumsporozoite antigens, gametocyte/gamete surface antigens, blood-stage antigen pf 155/RESA and other plasmodial antigen components; toxoplasma antigens such as SAG-1, p30 and other toxoplasmal antigen components; schistosomae antigens such as glutathione-S-transferase, paramyosin, and other schistosomal antigen components; leishmania major and other leishmaniae antigens such as gp63, lipophosphoglycan and its associated protein and other leishmanial antigen components; and trypanosoma cruzi antigens such as the 75-77 kDa antigen, the 56 kDa antigen and other trypanosomal antigen components.

Antigen that can be targeted using the rAb of the present invention will generally be selected based on a number of factors, including: likelihood of internalization, level of immune cell specificity, type of immune cell targeted, level of immune cell maturity and/or activation and the like. Examples of cell surface markers for dendritic cells include, but are not limited to, MHC class I, MHC Class II, B7-2, CD18, CD29, CD31, CD43, CD44, CD45, CD54, CD58, CD83, CD86, CMRF-44, CMRF-56, DCIR and/or Dectin-1 and the like; while in some cases also

having the absence of CD2, CD3, CD4, CD8, CD14, CD15, CD16, CD 19, CD20, CD56, and/or CD57. Examples of cell surface markers for antigen presenting cells include, but are not limited to, MHC class I, MHC Class II, CD40, CD45, B7-1, B7-2, IFN- γ receptor and IL-2 receptor, ICAM-1 and/or Fc γ receptor. Examples of cell surface markers for T cells include, but are not
5 limited to, CD3, CD4, CD8, CD 14, CD20, CD11b, CD16, CD45 and HLA-DR.

Target antigens on cell surfaces for delivery includes those characteristic of tumor antigens typically will be derived from the cell surface, cytoplasm, nucleus, organelles and the like of cells of tumor tissue. Examples of tumor targets for the antibody portion of the present invention include, without limitation, hematological cancers such as leukemias and lymphomas,
10 neurological tumors such as astrocytomas or glioblastomas, melanoma, breast cancer, lung cancer, head and neck cancer, gastrointestinal tumors such as gastric or colon cancer, liver cancer, pancreatic cancer, genitourinary tumors such cervix, uterus, ovarian cancer, vaginal cancer, testicular cancer, prostate cancer or penile cancer, bone tumors, vascular tumors, or cancers of the lip, nasopharynx, pharynx and oral cavity, esophagus, rectum, gall bladder, biliary
15 tree, larynx, lung and bronchus, bladder, kidney, brain and other parts of the nervous system, thyroid, Hodgkin's disease, non-Hodgkin's lymphoma, multiple myeloma and leukemia.

Examples of antigens that may be delivered alone or in combination to immune cells for antigen presentation using the present invention includes tumor proteins, e.g., mutated oncogenes; viral proteins associated with tumors; and tumor mucins and glycolipids. The antigens may be viral
20 proteins associated with tumors would be those from the classes of viruses noted above. Certain antigens may be characteristic of tumors (one subset being proteins not usually expressed by a tumor precursor cell), or may be a protein which is normally expressed in a tumor precursor cell, but having a mutation characteristic of a tumor. Other antigens include mutant variant(s) of the normal protein having an altered activity or subcellular distribution, e.g., mutations of genes
25 giving rise to tumor antigens.

Specific non-limiting examples of tumor antigens include: CEA, prostate specific antigen (PSA), HER-2/neu, BAGE, GAGE, MAGE 1-4, 6 and 12, MUC (Mucin) (e.g., MUC-1, MUC-2, etc.), GM2 and GD2 gangliosides, ras, myc, tyrosinase, MART (melanoma antigen), Pmel 17(gp100), GnT-V intron V sequence (N-acetylglucoaminyltransferase V intron V sequence), Prostate Ca
30 psm, PRAME (melanoma antigen), β -catenin, MUM-1-B (melanoma ubiquitous mutated gene product), GAGE (melanoma antigen) 1, BAGE (melanoma antigen) 2-10, c-ERB2 (Her2/neu), EBNA (Epstein-Barr Virus nuclear antigen) 1-6, gp75, human papilloma virus (HPV) E6 and

E7, p53, lung resistance protein (LRP), Bcl-2, and Ki-67. In addition, the immunogenic molecule can be an autoantigen involved in the initiation and/or propagation of an autoimmune disease, the pathology of which is largely due to the activity of antibodies specific for a molecule expressed by the relevant target organ, tissue, or cells, e.g., SLE or MG. In such diseases, it can be desirable to direct an ongoing antibody-mediated (i.e., a Th2-type) immune response to the relevant autoantigen towards a cellular (i.e., a Th1-type) immune response. Alternatively, it can be desirable to prevent onset of or decrease the level of a Th2 response to the autoantigen in a subject not having, but who is suspected of being susceptible to, the relevant autoimmune disease by prophylactically inducing a Th1 response to the appropriate autoantigen.

Autoantigens of interest include, without limitation: (a) with respect to SLE, the Smith protein, RNP ribonucleoprotein, and the SS-A and SS-B proteins; and (b) with respect to MG, the acetylcholine receptor. Examples of other miscellaneous antigens involved in one or more types of autoimmune response include, e.g., endogenous hormones such as luteinizing hormone, follicular stimulating hormone, testosterone, growth hormone, prolactin, and other hormones.

Antigens involved in autoimmune diseases, allergy, and graft rejection can be used in the compositions and methods of the invention. For example, an antigen involved in any one or more of the following autoimmune diseases or disorders can be used in the present invention: diabetes, diabetes mellitus, arthritis (including rheumatoid arthritis, juvenile rheumatoid arthritis, osteoarthritis, psoriatic arthritis), multiple sclerosis, myasthenia gravis, systemic lupus erythematosus, autoimmune thyroiditis, dermatitis (including atopic dermatitis and eczematous dermatitis), psoriasis, Sjogren's Syndrome, including keratoconjunctivitis sicca secondary to Sjogren's Syndrome, alopecia areata, allergic responses due to arthropod bite reactions, Crohn's disease, aphthous ulcer, iritis, conjunctivitis, keratoconjunctivitis, ulcerative colitis, asthma, allergic asthma, cutaneous lupus erythematosus, scleroderma, vaginitis, proctitis, drug eruptions, leprosy reversal reactions, erythema nodosum leprosum, autoimmune uveitis, allergic encephalomyelitis, acute necrotizing hemorrhagic encephalopathy, idiopathic bilateral progressive sensorineural hearing loss, aplastic anemia, pure red cell anemia, idiopathic thrombocytopenia, polychondritis, Wegener's granulomatosis, chronic active hepatitis, Stevens-Johnson syndrome, idiopathic sprue, lichen planus, Crohn's disease, Graves ophthalmopathy, sarcoidosis, primary biliary cirrhosis, uveitis posterior, and interstitial lung fibrosis. Examples of antigens involved in autoimmune disease include glutamic acid decarboxylase 65 (GAD 65), native DNA, myelin basic protein, myelin proteolipid protein, acetylcholine receptor components, thyroglobulin, and the thyroid stimulating hormone (TSH) receptor. Examples of

antigens involved in allergy include pollen antigens such as Japanese cedar pollen antigens, ragweed pollen antigens, rye grass pollen antigens, animal derived antigens such as dust mite antigens and feline antigens, histocompatibility antigens, and penicillin and other therapeutic drugs. Examples of antigens involved in graft rejection include antigenic components of the graft to be transplanted into the graft recipient such as heart, lung, liver, pancreas, kidney, and neural graft components. The antigen may be an altered peptide ligand useful in treating an autoimmune disease.

As used herein, the term “epitope(s)” refer to a peptide or protein antigen that includes a primary, secondary or tertiary structure similar to an epitope located within any of a number of pathogen polypeptides encoded by the pathogen DNA or RNA. The level of similarity will generally be to such a degree that monoclonal or polyclonal antibodies directed against such polypeptides will also bind to, react with, or otherwise recognize, the peptide or protein antigen. Various immunoassay methods may be employed in conjunction with such antibodies, such as, for example, Western blotting, ELISA, RIA, and the like, all of which are known to those of skill in the art. The identification of pathogen epitopes, and/or their functional equivalents, suitable for use in vaccines is part of the present invention. Once isolated and identified, one may readily obtain functional equivalents. For example, one may employ the methods of Hopp, as taught in U.S. Pat. No. 4,554,101, incorporated herein by reference, which teaches the identification and preparation of epitopes from amino acid sequences on the basis of hydrophilicity. The methods described in several other papers, and software programs based thereon, can also be used to identify epitopic core sequences (see, for example, Jameson and Wolf, 1988; Wolf et al., 1988; U.S. Pat. No. 4,554,101). The amino acid sequence of these “epitopic core sequences” may then be readily incorporated into peptides, either through the application of peptide synthesis or recombinant technology.

The preparation of vaccine compositions that includes the nucleic acids that encode antigens of the invention as the active ingredient, may be prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid prior to infection can also be prepared. The preparation may be emulsified, encapsulated in liposomes. The active immunogenic ingredients are often mixed with carriers which are pharmaceutically acceptable and compatible with the active ingredient.

The term “pharmaceutically acceptable carrier” refers to a carrier that does not cause an allergic reaction or other untoward effect in subjects to whom it is administered. Suitable

pharmaceutically acceptable carriers include, for example, one or more of water, saline, phosphate buffered saline, dextrose, glycerol, ethanol, or the like and combinations thereof. In addition, if desired, the vaccine can contain minor amounts of auxiliary substances such as wetting or emulsifying agents, pH buffering agents, and/or adjuvants which enhance the effectiveness of the vaccine. Examples of adjuvants that may be effective include but are not limited to: aluminum hydroxide, N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-nor-muramyl-L-alanyl-D-isoglutamine, MTP-PE and RIBI, which contains three components extracted from bacteria, monophosphoryl lipid A, trehalose dimycolate and cell wall skeleton (MPL+TDM+CWS) in a 2% squalene/TweenTM 80 emulsion. Other examples of adjuvants include DDA (dimethyldioctadecylammonium bromide), Freund's complete and incomplete adjuvants and QuilA. In addition, immune modulating substances such as lymphokines (e.g., IFN- γ , IL-2 and IL-12) or synthetic IFN- γ inducers such as poly I:C can be used in combination with adjuvants described herein.

Pharmaceutical products that may include a naked polynucleotide with a single or multiple copies of the specific nucleotide sequences that bind to specific DNA-binding sites of the apolipoproteins present on plasma lipoproteins as described in the current invention. The polynucleotide may encode a biologically active peptide, antisense RNA, or ribozyme and will be provided in a physiologically acceptable administrable form. Another pharmaceutical product that may spring from the current invention may include a highly purified plasma lipoprotein fraction, isolated according to the methodology, described herein from either the patient's blood or other source, and a polynucleotide containing single or multiple copies of the specific nucleotide sequences that bind to specific DNA-binding sites of the apolipoproteins present on plasma lipoproteins, prebound to the purified lipoprotein fraction in a physiologically acceptable, administrable form.

Yet another pharmaceutical product may include a highly purified plasma lipoprotein fraction which contains recombinant apolipoprotein fragments containing single or multiple copies of specific DNA-binding motifs, prebound to a polynucleotide containing single or multiple copies of the specific nucleotide sequences, in a physiologically acceptable administrable form. Yet another pharmaceutical product may include a highly purified plasma lipoprotein fraction which contains recombinant apolipoprotein fragments containing single or multiple copies of specific DNA-binding motifs, prebound to a polynucleotide containing single or multiple copies of the specific nucleotide sequences, in a physiologically acceptable administrable form.

The dosage to be administered depends to a great extent on the body weight and physical condition of the subject being treated as well as the route of administration and frequency of treatment. A pharmaceutical composition that includes the naked polynucleotide prebound to a highly purified lipoprotein fraction may be administered in amounts ranging from 1 μ g to 1 mg polynucleotide and 1 μ g to 100 mg protein.

Administration of an rAb and rAb complexes a patient will follow general protocols for the administration of chemotherapeutics, taking into account the toxicity, if any, of the vector. It is anticipated that the treatment cycles would be repeated as necessary. It also is contemplated that various standard therapies, as well as surgical intervention, may be applied in combination with the described gene therapy.

Where clinical application of a gene therapy is contemplated, it will be necessary to prepare the complex as a pharmaceutical composition appropriate for the intended application. Generally this will entail preparing a pharmaceutical composition that is essentially free of pyrogens, as well as any other impurities that could be harmful to humans or animals. One also will generally desire to employ appropriate salts and buffers to render the complex stable and allow for complex uptake by target cells.

Aqueous compositions of the present invention may include an effective amount of the compound, dissolved or dispersed in a pharmaceutically acceptable carrier or aqueous medium. Such compositions can also be referred to as inocula. The use of such media and agents for pharmaceutical active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active ingredient, its use in the therapeutic compositions is contemplated. Supplementary active ingredients also can be incorporated into the compositions. The compositions of the present invention may include classic pharmaceutical preparations. Dispersions also can be prepared in glycerol, liquid polyethylene glycols, and mixtures thereof and in oils. Under ordinary conditions of storage and use, these preparations contain a preservative to prevent the growth of microorganisms.

Disease States. Depending on the particular disease to be treated, administration of therapeutic compositions according to the present invention will be via any common route so long as the target tissue is available via that route in order to maximize the delivery of antigen to a site for maximum (or in some cases minimum) immune response. Administration will generally be by orthotopic, intradermal, subcutaneous, intramuscular, intraperitoneal or intravenous injection. Other areas for delivery include: oral, nasal, buccal, rectal, vaginal or topical. Topical

administration would be particularly advantageous for treatment of skin cancers. Such compositions would normally be administered as pharmaceutically acceptable compositions that include physiologically acceptable carriers, buffers or other excipients.

Vaccine or treatment compositions of the invention may be administered parenterally, by
5 injection, for example, either subcutaneously or intramuscularly. Additional formulations which are suitable for other modes of administration include suppositories, and in some cases, oral formulations or formulations suitable for distribution as aerosols. In the case of the oral formulations, the manipulation of T-cell subsets employing adjuvants, antigen packaging, or the addition of individual cytokines to various formulation that result in improved oral vaccines with
10 optimized immune responses. For suppositories, traditional binders and carriers may include, for example, polyalkylene glycols or triglycerides; such suppositories may be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, preferably 1%-2%. Oral formulations include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch magnesium stearate, sodium saccharine, cellulose, magnesium
15 carbonate, and the like. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and contain 10%-95% of active ingredient, preferably 25-70%.

The antigen encoding nucleic acids of the invention may be formulated into the vaccine or treatment compositions as neutral or salt forms. Pharmaceutically acceptable salts include the
20 acid addition salts (formed with free amino groups of the peptide) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or with organic acids such as acetic, oxalic, tartaric, maleic, and the like. Salts formed with the free carboxyl groups can also be derived from inorganic bases such as, for example, sodium, potassium, ammonium, calcium, or ferric hydroxides, and such organic bases as isopropylamine, trimethylamine, 2-
25 ethylamino ethanol, histidine, procaine, and the like.

Vaccine or treatment compositions are administered in a manner compatible with the dosage formulation, and in such amount as will be prophylactically and/or therapeutically effective. The quantity to be administered depends on the subject to be treated, including, e.g., capacity of the subject's immune system to synthesize antibodies, and the degree of protection or treatment
30 desired. Suitable dosage ranges are of the order of several hundred micrograms active ingredient per vaccination with a range from about 0.1 mg to 1000 mg, such as in the range from about 1 mg to 300 mg, and preferably in the range from about 10 mg to 50 mg. Suitable regimens for

initial administration and booster shots are also variable but are typified by an initial administration followed by subsequent inoculations or other administrations. Precise amounts of active ingredient required to be administered depend on the judgment of the practitioner and may be peculiar to each subject. It will be apparent to those of skill in the art that the therapeutically effective amount of nucleic acid molecule or fusion polypeptides of this invention will depend, inter alia, upon the administration schedule, the unit dose of antigen administered, whether the nucleic acid molecule or fusion polypeptide is administered in combination with other therapeutic agents, the immune status and health of the recipient, and the therapeutic activity of the particular nucleic acid molecule or fusion polypeptide.

The compositions can be given in a single dose schedule or in a multiple dose schedule. A multiple dose schedule is one in which a primary course of vaccination may include, e.g., 1-10 separate doses, followed by other doses given at subsequent time intervals required to maintain and or reinforce the immune response, for example, at 1-4 months for a second dose, and if needed, a subsequent dose(s) after several months. Periodic boosters at intervals of 1-5 years, usually 3 years, are desirable to maintain the desired levels of protective immunity. The course of the immunization can be followed by in vitro proliferation assays of peripheral blood lymphocytes (PBLs) co-cultured with ESAT6 or ST-CF, and by measuring the levels of IFN- γ released from the primed lymphocytes. The assays may be performed using conventional labels, such as radionucleotides, enzymes, fluorescent labels and the like. These techniques are known to one skilled in the art and can be found in U.S. Pat. Nos. 3,791,932, 4,174,384 and 3,949,064, relevant portions incorporated by reference.

The modular rAb carrier and/or conjugated rAb carrier-(cohesion/dockerin and/or dockerin-cohesin)-antigen complex (rAb-DC/DC-antigen vaccine) may be provided in one or more "unit doses" depending on whether the nucleic acid vectors are used, the final purified proteins, or the final vaccine form is used. Unit dose is defined as containing a predetermined-quantity of the therapeutic composition calculated to produce the desired responses in association with its administration, i.e., the appropriate route and treatment regimen. The quantity to be administered, and the particular route and formulation, are within the skill of those in the clinical arts. The subject to be treated may also be evaluated, in particular, the state of the subject's immune system and the protection desired. A unit dose need not be administered as a single injection but may include continuous infusion over a set period of time. Unit dose of the present invention may conveniently may be described in terms of DNA/kg (or protein/Kg) body weight, with ranges between about 0.05, 0.10, 0.15, 0.20, 0.25, 0.5, 1, 10, 50, 100, 1,000 or more

mg/DNA or protein/kg body weight are administered. Likewise the amount of rAb-DC/DC-antigen vaccine delivered can vary from about 0.2 to about 8.0 mg/kg body weight. Thus, in particular embodiments, 0.4 mg, 0.5 mg, 0.8 mg, 1.0 mg, 1.5 mg, 2.0 mg, 2.5 mg, 3.0 mg, 4.0 mg, 5.0 mg, 5.5 mg, 6.0 mg, 6.5 mg, 7.0 mg and 7.5 mg of the vaccine may be delivered to an individual in vivo. The dosage of rAb-DC/DC-antigen vaccine to be administered depends to a great extent on the weight and physical condition of the subject being treated as well as the route of administration and the frequency of treatment. A pharmaceutical composition that includes a naked polynucleotide prebound to a liposomal or viral delivery vector may be administered in amounts ranging from 1 μ g to 1 mg polynucleotide to 1 μ g to 100 mg protein. Thus, particular compositions may include between about 1 μ g, 5 μ g, 10 μ g, 20 μ g, 30 μ g, 40 μ g, 50 μ g, 60 μ g, 70 μ g, 80 μ g, 100 μ g, 150 μ g, 200 μ g, 250 μ g, 500 μ g, 600 μ g, 700 μ g, 800 μ g, 900 μ g or 1,000 μ g polynucleotide or protein that is bound independently to 1 μ g, 5 μ g, 10 μ g, 20 μ g, 30 μ g, 40 μ g, 50 μ g, 60 μ g, 70 μ g, 80 μ g, 100 μ g, 150 μ g, 200 μ g, 250 μ g, 500 μ g, 600 μ g, 700 μ g, 800 μ g, 900 μ g, 1 mg, 1.5 mg, 5 mg, 10 mg, 20 mg, 30 mg, 40 mg, 50 mg, 60 mg, 70 mg, 80 mg, 90 mg or 100 mg vector.

The present invention was tested in an in vitro cellular system that measures immune stimulation of human Flu-specific T cells by dendritic cells to which Flu antigen has been targeted. The results shown herein demonstrate the specific expansion of such antigen specific cells at doses of the antigen which are by themselves ineffective in this system.

The present invention may also be used to make a modular rAb carrier that is, e.g., a recombinant humanized mAb (directed to a specific human dendritic cell receptor) complexed with protective antigens from Ricin, Anthrax toxin, and Staphylococcus B enterotoxin. The potential market for this entity is vaccination of all military personnel and stored vaccine held in reserve to administer to large population centers in response to any biothreat related to these agents. The invention has broad application to the design of vaccines in general, both for human and animal use. Industries of interest include the pharmaceutical and biotechnology industries.

The present invention includes compositions and methods, including vaccines, that specifically target (deliver) antigens to antigen-presenting cells (APCs) for the purpose of eliciting potent and broad immune responses directed against the antigen. These compositions evoke protective or therapeutic immune responses against the agent (pathogen or cancer) from which the antigen was derived. In addition the invention creates agents that are directly, or in concert with other

agents, therapeutic through their specific engagement of a receptor called DC-ASGPR that is expressed on antigen-presenting cells.

Dectin-1 (CLEC7A; G.D. Brown, *Nat Rev Immunol* 6 (2006), pp. 33–43.) was originally reported as a Dendritic Cell (DC)-specific molecule with a T cell costimulatory capacity (N. Kanazawa et al., *J Biol Chem* 278 (2003), pp. 32645–32652), but later its expression was found more strongly in monocytes, macrophages and neutrophils, and weakly in a subset of T cells, and, in humans, B cells and eosinophils. Most importantly, it was determined that Dectin-1 recognizes fungal β -glucan as the major nonopsonic receptor and is critical for the biological effects of β -glucan (G.D. Brown, *Nat Rev Immunol* 6 (2006), pp. 33–43.). Expression of Dectin-1 on macrophages is upregulated by IL-4 and IL-13, and downregulated by LPS as well as IL-10 and dexamethasone. Dectin-1 uniquely contains ITAM in its cytoplasmic region and actually works as an activating receptor in the absence of any adaptor molecule. The structure of its ITAM is also unique. Compared with the consensus sequence containing two repeats of YxxL/I (tyrosine-any-any-leucine or isoleucine) (S.J. van Vliet et al., *Int Immunol* 17 (2005), pp. 661–669, three amino acid residues are inserted between the first tyrosine and following leucine or isoleucine (YxxxL/I) in mouse or human Dectin-1, respectively. Actually, phosphorylation of only the second tyrosine was reportedly sufficient for the recruitment of Syk and various activatory effects of Dectin-1, such as induction of phagocytosis, production of reactive oxygen species (ROS) and cytokine production mediated by nuclear factor (NF)- κ B activation. However, Syk was required for only some of these effects in a certain cell type (macrophage or DCs). In addition, some of these effects required cooperation with MyD88-mediated TLR signaling. Notably, the Dectin-1 signal in DCs also induced IL-10 production in a Syk-dependent manner. Interestingly, β -glucan is exposed on the yeast cell surface only under some specific conditions and loss of the Dectin-1 signal might explain why some fungi escape the host immune surveillance (S.E. Heinsbroek et al., *Trends Immunol* 26 (2005), pp. 352–354). In addition, the Dectin-1-mediated signal was reported to promote induction of autoimmune arthritis in the genetically predisposed (ZAP-70-mutated) SKG mouse (H. Yoshitomi et al., *J Exp Med* 201 (2005), pp. 949–960). Considering that Candida antigens have widely been used for the induction of various autoimmune disease models (E.C. Keystone et al., *Arthritis Rheum* 20 (1977), pp. 1396–1401), Dectin-1 may have a role in breakage of self-tolerance. Its possible association with regulatory T cells, similar to that of Dectin-2 (E.P. McGreal, M. Rosas, G.D. Brown, S. Zamze, S.Y. Wong and S. Gordon et al., *Glycobiology* 16 (2006), pp. 422–430.), however, remains to be elucidated.

DCs can cross-present protein antigens (Rock KL Immunol Rev. 2005 Oct;207:166-83). In vivo, DCs take up antigens by the means of a number of receptors and present antigenic peptides in both class I and II. In this context, DC lectins, as pattern recognition receptors, contribute to the efficient uptake of antigens as well as cross-presentation of antigens.

- 5 The present invention includes the development, characterization and use of anti-human Dectin-1 monoclonal antibodies (mAbs) and characterized their biological functions leading to discovery of likely therapeutic applications of anti-Dectin-1 mAbs and their surrogates. The invention disclosure reveals means of developing unique agents capable of activating cells bearing Dectin-1, as well as the effect of the resulting changes in cells receiving these signals
10 regards action on other cells in the immune system. These effects [either alone, or in concert with other signals (i.e., co-stimulation)] are highly predictive of therapeutic outcomes for certain disease states or for augmenting protective outcomes in the context of vaccination.

Materials and Methods

- Antibodies and tetramers -Antibodies (Abs) for surface staining of DCs and B cells, including
15 isotype control Abs, were purchased from BD Biosciences (CA). Abs for ELISA were purchased from Bethyl (TX). Anti-BLyS and anti-APRIL were from PeproTech (NJ). Tetramers, HLA-A*0201-GILGFVFTL (Flu M1) and HLA-A*0201-ELAGIGILTV (Mart-1), were purchased from Beckman Coulter (CA).

- Cells and cultures - Monocytes (1×10^6 /ml) from normal donors were cultured in Cellgenics
20 (France) media containing GM-CSF (100 ng/ml) and IL-4 (50 ng/ml) (R&D, CA). For day three and day six, DCs, the same amounts of cytokines were supplemented into the media on day one and day three, respectively. B cells were purified with a negative isolation kit (BD). CD4 and CD8 T cells were purified with magnetic beads coated with anti-CD4 or CD8 (Milteniy, CA). PBMCs were isolated from Buffy coats using Percoll™ gradients (GE Healthcare UK Ltd,
25 Buckinghamshire, UK) by density gradient centrifugation. For DC activation, 1×10^5 DCs were cultured in the mAb-coated 96-well plate for 16-18 h. mAbs (1-2 ug/well) in carbonate buffer, pH 9.4, were incubated for at least 3h at 37°C. Culture supernatants were harvested and cytokines / chemokines were measured by Luminex (Biorad, CA). For gene analysis, DCs were cultured in the plates coated with mAbs for 8 h. In some studies, soluble 50 ng/ml of CD40L
30 (R&D, CA) or 50 nM CpG (InVivogen, CA) was added into the cultures. In the DCs and B cell co-cultures, 5×10^3 DCs resuspended in RPMI 1640 with 10% FCS and antibiotics (Biosource, CA) were first cultured in the plates coated with mAbs for at least 6 h, and then 1×10^5 purified

autologous B cells labeled with CFSE (Molecular Probes, OR) were added. In some studies, DCs were pulsed with 5 moi (multiplicity of infection) of heat-inactivated influenza virus (A/PR/8 H1N1) for 2 h, and then mixed with B cells. For the DCs and T cell co-cultures, 5×10^3 DCs were cultured with 1×10^5 purified autologous CD8 T cells or mixed allogeneic T cells. 5 Allogeneic T cells were pulsed with 1 uCi/well $^3\text{[H]}$ -thymidine for the final 18h of incubation, and then cpm were measured by a gamma-counter (Wallac, MN). 5×10^5 PBMCs /well were cultured in the plates coated with mAbs. The frequency of Mart-1 and Flu M1 specific CD8 T cells was measured by staining cells with anti-CD8 and tetramers on day ten and day seven of the cultures, respectively. 10 uM of Mart-1 peptide (ELAGIGILTV) and 20 nM of recombinant protein containing Mart-1 peptides (see below) were added to the DC and CD8 T cell cultures. 10 20 nM purified recombinant Flu M1 protein (see below) was add to the PBMC cultures.

Monoclonal antibodies - Mouse mAbs were generated by conventional technology. Briefly, six-week-old BALB/c mice were immunized i.p. with 20 μg of receptor ectodomain.hIgGFc fusion protein with Ribi adjuvant, then boosts with 20 μg antigen ten days and fifteen days later. After 15 three months, the mice were boosted again three days prior to taking the spleens. Alternately, mice were injected in the footpad with 1-10 μg antigen in Ribi adjuvant every three to four days over a thirty to forty day period. Three to four days after a final boost, draining lymph nodes were harvested. B cells from spleen or lymph node cells were fused with SP2/O-Ag 14 cells. Hybridoma supernatants were screened to analyze Abs to the receptor ectodomain fusion protein compared to the fusion partner alone, or the receptor ectodomain fused to alkaline phosphatase 20 (15). Positive wells were then screened in FACS using 293F cells transiently transfected with expression plasmids encoding full-length receptor cDNAs. Selected hybridomas were single cell cloned and expanded in CELLline flasks (Integra, CA). Hybridoma supernatants were mixed with an equal volume of 1.5 M glycine, 3 M NaCl, 1x PBS, pH 7.8 and tumbled with MabSelect 25 resin. The resin was washed with binding buffer and eluted with 0.1 M glycine, pH 2.7. Following neutralization with 2 M Tris, mAbs were dialyzed versus PBS.

ELISA - Sandwich ELISA was performed to measure total IgM, IgG, and IgA as well as flu-specific immunoglobulins (Igs). Standard human serum (Bethyl) containing known amounts of Igs and human AB serum were used as standard for total Igs and flu-specific Igs, respectively. 30 Flu specific Ab titers, units, in samples were defined as dilution factor of AB serum that shows an identical optical density. The amounts of BAFF and BLyS were measured by ELISA kits (Bender MedSystem, CA).

RNA purification and gene analysis - Total RNA extracted with RNeasy columns (Qiagen), and analyzed with the 2100 Bioanalyser (Agilent). Biotin-labeled cRNA targets were prepared using the Illumina totalprep labeling kit (Ambion) and hybridized to Sentrix Human6 BeadChips (46K transcripts). These microarrays consist of 50mer oligonucleotide probes attached to 3um beads which are lodged into microwells etched at the surface of a silicon wafer. After staining with Streptavidin-Cy3, the array surface is imaged using a sub-micron resolution scanner manufactured by Illumina (Beadstation 500X). A gene expression analysis software program, GeneSpring, Version 7.1 (Agilent), was used to perform data analysis.

Expression and purification of recombinant Flu M1 and MART-1 proteins - PCR was used to amplify the ORF of Influenza A/Puerto Rico/8/34/Mount Sinai (H1N1) M1 gene while incorporating an Nhe I site distal to the initiator codon and a Not I site distal to the stop codon. The digested fragment was cloned into pET28b(+) (Novagen), placing the M1 ORF in-frame with a His6 tag, thus encoding His.Flu M1 protein. A pET28b (+) derivative encoding an N-terminal 169 residue cohesin domain from *C. thermocellum* (unpublished) inserted between the Nco I and Nhe I sites expressed Coh.His. For expression of Cohesin-Flex-hMART-1-PeptideA-His, the sequence

GACACCACCGAGGCCCGCCACCCCCACCCCCCGTGACCACCCCCACCACCACCGA
CCGGAAGGGCACCACCGCCGAGGAGCTGGCCGGCATCGGCATCCTGACCGTGATCC
TGGGCGGCAAGCGGACCAACAACAGCACCCCCACCAAGGGCGAATTCTGCAGATAT
CCATCACACTGGCGGCCG (SEQ ID NO.: 1)(encoding
DTTEARHPHPVTTPTTDRKGTAEELAGIGILTVILGGKRTNNSTPTKGEFCRYPSHWR

P (SEQ ID NO.: 2)- the shaded residues are the immuno-dominant HLA-A2-restricted peptide and the underlined residues surrounding the peptide are from MART-1) was inserted between the Nhe I and Xho I sites of the above vector. The proteins were expressed in *E. coli* strain BL21 (DE3) (Novagen) or T7 Express (NEB), grown in LB at 37°C with selection for kanamycin resistance (40 µg/ml) and shaking at 200 rounds/min to mid log phase growth when 120 mg/L IPTG was added. After three hours, the cells were harvested by centrifugation and stored at -80°C. *E. coli* cells from each 1 L fermentation were resuspended in 30 ml ice-cold 50 mM Tris, 1 mM EDTA pH 8.0 (buffer B) with 0.1 ml of protease inhibitor Cocktail II (Calbiochem, CA).

The cells were sonicated on ice 2x 5 min at setting 18 (Fisher Sonic Dismembrator 60) with a 5 min rest period and then spun at 17,000 r.p.m. (Sorvall SA-600) for 20 min at 4°C. For His.Flu M1 purification the 50 ml cell lysate supernatant fraction was passed through 5 ml Q Sepharose beads and 6.25 ml 160 mM Tris, 40 mM imidazole, 4 M NaCl pH 7.9 was added to the Q

Sepharose flow through. This was loaded at 4 ml/min onto a 5 ml HiTrap chelating HP column charged with Ni⁺⁺. The column-bound protein was washed with 20 mM NaPO₄, 300 mM NaCl pH 7.6 (buffer D) followed by another wash with 100 mM H₃COONa pH 4.0. Bound protein was eluted with 100 mM H₃COONa pH 4.0. The peak fractions were pooled and loaded at 4 ml/min onto a 5 ml HiTrap S column equilibrated with 100 mM H₃COONa pH 5.5, and washed with the equilibration buffer followed by elution with a gradient from 0 - 1 M NaCl in 50 mM NaPO₄ pH 5.5. Peak fractions eluting at about 500 mM NaCl were pooled. For Coh.Flu M1.His purification, cells from 2 L of culture were lysed as above. After centrifugation, 2.5 ml of Triton X114 was added to the supernatant with incubation on ice for 5 min. After further incubation at 25°C for 5 min, the supernatant was separated from the Triton X114 following centrifugation at 25°C. The extraction was repeated and the supernatant was passed through 5 ml of Q Sepharose beads and 6.25 ml 160 mM Tris, 40 mM imidazole, 4 M NaCl pH 7.9 was added to the Q Sepharose flow through. The protein was then purified by Ni⁺⁺ chelating chromatography as described above and eluted with 0-500 mM imidazole in buffer D.

Anti-Dectin-1 mAbs – The invention encompasses particular amino acid sequences shown below corresponding to anti-LOX-1 monoclonal antibodies that are desirable components (in the context of e.g., humanized recombinant antibodies) of therapeutic or protective products. The following are such sequences in the context of chimeric mouse V region (underlined) – human C region (bold) recombinant antibodies. These mouse V regions can be readily ‘humanized, i.e., the LOX-1 combining regions grafted onto human V region framework sequences, by anyone well practiced in this art. Furthermore, the sequences can also be expressed in the context of fusion proteins that preserve antibody functionality, but add e.g., antigen, cytokine, or toxin for desired therapeutic applications.

rAB-pIRES2[manti-Dectin_1_11B6.4_H-V-hIgG4H-C]

25 QVQLKESGPGLVAPSQSLCSVSGFSLSNYDISWIRQPPGKGLEWLGVMWTGGGANYNSAFMSRLSINK
DNSKSQVFLKMNNLQTDDDTAIYYCVRDAVRYWNFDVWGAGTTVTVSSAKTKGPSVFPLAPCSRSTSEST
AALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVVTVPSSSLGTKTYTCNVDPHKPS
NTKVDKRVESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNW
YVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQP
30 REPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTPPVLDSDGSFFLYSRLT
VDKSRWQEGNVFSCSVMEALHNHYTQKSLSLSLGKAS (SEQ ID NO.: 3)

rAB-pIRES2[manti-Dectin_1_11B6.4_K-V-hIgGK-C]

35 QIVLSQSPAILSASPGEKVTMTCRASSSVSYIHWYQQKPGSSPKPWIYATSHLASGVPARFSGSGSGTSLT
ISRVEAEDTATYYCQQWSSNPFTFGSGTKLEIKRTVAAPSVFIFPPSDEQLKSGTASVVCLLNFPYPREA
KVQWKVDNALQSGNSQESVTEQDSKDSTYSLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNR
GEC (SEQ ID NO.: 4)

rAB-pIRES2[manti-Dectin_1_15E2.5_H-V-hIgG4H-C]

QVQLQQSGAELARPGASVKMSCKASGYTFTTYTMHWVKQRPGQGLEWIGYINPSSGYTNYNQKFKDKAT
LTADKSSSTASMQLSSTSEDSAVYYCARERAVLPYAMDYWGQGTSTVTVSSAKTKGPSVFPLAPCSRST
SESTAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTPSSSLGKTYTCNVD
HKPSNTKVDKRVERESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSDQEDPEVQ
5 FNWYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAK
GQPREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLY
SRLTVDKSRWQEGNVFSCSVMEALHNHYTQKSLSLGLGKAS (SEQ ID NO.: 5)

rAB-pIRES2[manti-Dectin_1_15E2.5_K-V-hIgGK-C]

QIVLTQSPAVMASAPGEKVTITCTASSSLSYMHWFOQKPGTSPKLWLYSTSILASGVPTRFSGSGSGTSYSLT
10 ISRMEAEDAATYYCQQRSSSPFTFGSGTKLEIKRTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREA
KVQWKVDNALQSGNSQESVTEQDSKDSTYLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNR
GEC (SEQ ID NO.: 6)

rAB-pIRES2[mAnti-Dectin_1_2D8.2D4H-V-hIgG4H-C]

EVQLQQSGPELEKPGASVKISCKASGYSFTGYNMNHWVKQSNQKSLWIGNIDPYYGDTNYNQKFKGKAT
15 LTVDKSSSTAYMHLKSLTSEDSAVYYCARPYGSEAYFAYWGQGLTVTVSAAKTKGPSVFPLAPCSRSTSE
STAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTPSSSLGKTYTCNVDHK
PSNTKVDKRVERESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSDQEDPEVQFN
WYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQ
20 PREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSRL
TVDKSRWQEGNVFSCSVMEALHNHYTQKSLSLGLGKAS (SEQ ID NO.: 7)

rAB-pIRES2[mAnti-Dectin_1_2D8.2D4K-V-hIgGK-C]

DIVMTQSPATLSVTPGDRVSLSCRASQISIDYLHWYQQKSHESPRLLIKYAAQSISGIPSRFSGSGSGSDFTLS
25 INGVEPEDVGVIYCYQNGHSFPYTFGGGTGLEIKRTVAAPSVFIFPPSDEQLKSGTASVVCLLNNFYPREA
KVQWKVDNALQSGNSQESVTEQDSKDSTYLSSTLTLSKADYEKHKVYACEVTHQGLSSPVTKSFNR
GEC (SEQ ID NO.: 8)

The V-region sequences and related sequences can be modified by those well versed in the art to, e.g., enhance affinity for Dectin-1 and/or integrated into human V-region framework sequences to be engineered into expression vectors to direct the expression of protein forms that can bind to Dectin-1 on antigen presenting cells. Furthermore, the other mAbs disclosed in the invention (or derived using similar methods and screens for the unique biology disclosed herein), can be via similar means (initially via PCR cloning and sequencing of mouse hybridoma V regions) be rendered into expression constructs encoding similar recombinant antibodies (rAbs). Such anti-Dectin-1 V regions can furthermore, by those well versed in the art, be 'humanized (i.e., mouse -specific combining sequences grafted onto human V region framework sequences) so as to minimize potential immune reactivity of the therapeutic rAb.

Engineered recombinant anti-Dectin-1 recombinant antibody - antigen fusion proteins (rAb.antigen) are efficacious prototype vaccines in vitro - Expression vectors can be constructed with diverse protein coding sequence e.g., fused in-frame to the H chain coding sequence. For example, antigens such as Influenza HA5, Influenza M1, HIV gag, or immuno-dominant peptides from cancer antigens, or cytokines, can be expressed subsequently as rAb.antigen or rAb.cytokine fusion proteins, which in the context of this invention, can have utility derived from using the anti-Dectin-1 V-region sequence to bring the antigen or cytokine (or toxin)

directly to the surface of the antigen presenting cell bearing Dectin-1. This permits internalization of e.g., antigen – sometimes associated with activation of the receptor and ensuing initiation of therapeutic or protective action (e.g., via initiation of a potent immune response, or via killing of the targeted cell. An exemplative prototype vaccine based on this concept could use a H chain vector such as rAB-pIRES2[manti-Dectin_1_11B6.4_H-LV-hIgG4H-C-Flex-FluHA1-1-6xHis] which directs the synthesis of a H chain mouse mAb V region (underlined) –human IgG4 C region (bold)–Flu HA1-1 (italicized) fusion protein. Co-expressed with the analogous light chain expression plasmid (encoding sequence shown above), this produces a multifunctional recombinant antibody (rAb) that binds Dectin-1 and delivers Flu HA1-1 antigen to the cell surface for DC activation, antigen internalization, antigen processing, antigen presentation, and education and expansion of specific anti-Flu HA1-1 B and T cells. Similar H chain constructs with fusions to FluHA5-1, HIV Viralgag p24, and PSA (prostate-specific antigen) are also shown below.

rAB-pIRES2[manti-Dectin_1_11B6.4_H-LV-hIgG4H-C-Flex-FluHA1-1-6xHis]

15 QVQLKESGPGLVAPSQSLCSITCSVSGFSLSNYDISWIRQPPGKGLEWLGVMWTGGGANYNSAFMSRLSINK
DNSKSQVFLKMNNLQTD DTAIYYCVRDAVRYWNFDVWGAGTTVTVSSAKTKGPSVFPLAPCSRSTSEST
AALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVPSSSLG**TKTYTCNV****DHKPS**
NTKVDKR**VESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNW**
YVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQP
20 **REPQVYTLPPS****QEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSRLT**
VDKSRWQEGNVFSCSV**MHEALHNHYTQKSLSL****SLGKASDTTEPATPTTPVTTDTICIGYHANNSTD****TVDT**
VLEKNVTVT**HSVNLL****EDSHNGKLCRLKGIAPLQLGKCNIAGWLLGNPECDPLLPVRSWSYIVETP****NSENGICYPGD**
FIDYEELREQLSSVSSFERFEIFPKESSWP**NHNTNGVTAACSHEGKSSFYRNLLWLTEKEGSYPKLKNSYVNKKGK**
EVLVLWGIHHPNSKEQQNLYQNENAYVSVVTSNYNRRFTPEIAERP**KVRDQAGRMNYYWTLLKPGD****TIIFEANG**
25 **NLIAPMYAFALSRGFGSGHITSNASMHECNTKCQTPLGAINSSLPYQNIHPVTIGECLKYVRS****AKLRMVH****HHHHH**
 (SEQ ID NO.: 9)

rAB-pIRES2[manti-Dectin_1_11B6.4_H-LV-hIgG4H-C-Flex-FluHA5-1-6xHis]

30 QVQLKESGPGLVAPSQSLCSITCSVSGFSLSNYDISWIRQPPGKGLEWLGVMWTGGGANYNSAFMSRLSINK
DNSKSQVFLKMNNLQTD DTAIYYCVRDAVRYWNFDVWGAGTTVTVSSAKTKGPSVFPLAPCSRSTSEST
AALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVPSSSLG**TKTYTCNV****DHKPS**
NTKVDKR**VESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNW**
YVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQP
REPQVYTLPPS**QEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTTPVLDSDGSFFLYSRLT**
35 **VDKSRWQEGNVFSCSV****MHEALHNHYTQKSLSL****SLGKASDTTEPATPTTPVTTDQICIGYHANNSTEQVDT**
IMEKNVTVT**HAQDILEKKHNGKLC****DL****DGVKPLILRDCSVAGWLLGNPMCDEFINVP****EW****SYIVEKANPVNDLCYP**
GDFNDYEELKHLLSRINHFEKIQIIPKSSWSSHEASLG**VSSACPYQGKSSFFRN****VVWLIKKNSTYPTIKRSYNNTNQ**
EDLLVLWGIHHPNDAAEQTKLYQNPTTYISVGTSTLNQRLVPRIATRSK**VNGQSGRMEFFWTILKPNDAINFESNGN**
FIAPEYAYKIVKKGDSTIMKSELEYGNCNTKCQTPMGAINSSMPFHNIHPLTIGEC**PKYVKS****NRLVLA****HHHHH**
 (SEQ ID NO.: 10)

40 rAB-pIRES2[mAnti-Dectin_1_2D8.2D4H-LV-hIgG4H-Viralgag]

EVQLQQSGPELEKPGASVKISCKASGYSFTGYNMNWWVKQSNGKSLEWIGNIDPYYGDTNYNQKFKGKAT
LTVDKSSSTAYMHLKSLTSEDSAVYYCARPYGSEAYFAYWGQGLTVTVSAAKTKGPSVFPLAPCSRSTSE
STAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVPSSSLG**TKTYTCNV****DHK**
PSNTKVDKR**VESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFN**

WYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQ
 PREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSRL
 TVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLGLKASDMAKKETVWRLEEFGRPIVQNIQGQMVH
 QAISPRTLNAWVKVVEEKAFSPEVPMFSALSEGATPQDLNTMLNTVGGHQAAMQMLKETINEEAAEWDRVHPV
 5 HAGPIAPGQMREPRGSDIAGTTSTLQEIQGWMTNPNPIPVG EIIYKRWIILGLNKIVRMYSPTSILDIRQGPKEPFRD
 YVDRFYKTLRAEQASQEVKNWMTETLLVQNANPDCKTILKALGPAATLEEMMTACQGVGGPGHKARVL (SEQ
 ID NO.: 11)

rAB-pIRES2[mAnti-Dectin_1_2D8.2D4H-V-hIgG4H-C-hPSA]

EVQLQQSGPELEKPGASVKISCKASGYSFTGYNMNWWVKQSNNGKSLEWIGNIDPYYGDTNYNQKFKGKAT
 10 LTVDKSSSTAYMHLKSLTSEDSAVYYCARPYGSEAYFAYWGQGLTVTVSAAKTKGPSVFPLAPCSRSTSE
 STAALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTPSSSLGTKTYTCNVDPHK
 PSNTKVDKRVERESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFN
 WYVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQ
 15 PREPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSRL
 TVDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLGLKASDTTEPATPTTPVTPTPTTTLLAPLILSRIVGG
 WECEKHSQPWQVLVASRGRAVCGGVLVHPQWVLTAAHCIRNKSIVLLGRHSLFHPEDTGQVFQVSHSFPHPLYD
 MSLKKNRFLRPGDDSSHDLMLRLSEPAELTDAVKVMDLPTQEPALGTTTCYASGWGSIEPEEFLLTPKKLQCVDL
 HVISNDVCAQVHPQKVTKFMLCAGRWTGGKSTCSGDSGGPLVCNGVLQGITSWGSEPCALPERPSLYTKVVHYR
 KWIKDTIVANP (SEQ ID NO.: 12)

20 Similarly, rAB-pIRES2[manti-Dectin_1_11B6.4_H-LV-hIgG4H-C-Dockerin] shown below
 encodes an anti-Dectin-1 H chain fused to dockerin (sequence shown below). The dockerin
 allows for strong specific non-covalent interaction with cohesin-antigen (coh.antigen) fusion
 proteins – providing an alternate means of delivering antigen to DC and other antigen presenting
 cells.

25 rAB-pIRES2[manti-Dectin_1_11B6.4_H-LV-hIgG4H-C-Dockerin]

QVQLKESGPGLVAPSQSLITCSVSGFSLSNYDISWIRQPPGKGLEWLGVMTGTTGGGANYNSAFMSRLSINK
 DNSKSQVFLKMNNLQTDITAIYYCVRDAVRYWNFDVWGAGTTVTVSSAKTKGPSVFPLAPCSRSTSEST
 AALGCLVKDYFPEPVTVSWNSGALTSGVHTFPAVLQSSGLYSLSSVTVTPSSSLGTKTYTCNVDPHKPS
 NTKVDKRVERESKYGPPCPPCPAPEFEGGPSVFLFPPKPKDTLMISRTPEVTCVVVDVSQEDPEVQFNW
 30 YVDGVEVHNAKTKPREEQFNSTYRVVSVLTVLHQDWLNGKEYKCKVSNKGLPSSIEKTISKAKGQP
 REPQVYTLPPSQEEMTKNQVSLTCLVKGFYPSDIAVEWESNGQPENNYKTTPPVLDSDGSFFLYSRLT
 VDKSRWQEGNVFSCSVMHEALHNHYTQKSLSLGLKASNSPQNEVLYGDVNDGKVNSTDLTLLKRYVL
 KAVSTLPSSKA EKNADVNRDGRVNSSDVTILSRYLIRVIEKLPI (SEQ ID NO.: 13)

[0100] Methods relating to cloning and expression of recombinant antibodies (rAbs) and rAb.antigens

35 cDNA cloning and expression of chimeric mouse/human mAbs – Total RNA was prepared from
 hybridoma cells (RNeasy kit, Qiagen) and used for cDNA synthesis and PCR (SMART RACE
 kit, BD Biosciences) using supplied 5' primers and gene specific 3' primers

(mIgGκ, 5'ggatggtgggaagatggatacagttggtgcagcatc3' (SEQ ID NO.: 14);

mIgGλ, 5'ctaggaacagtcagcacgggacaaactcttctccacagtgtagccttc3'(SEQ ID NO.: 15);

40 mIgG1, 5'gtcactggctcagggaaatagcccttgaccaggcatc3' (SEQ ID NO.: 16);

mIgG2a, 5'ccaggcatcctagagtcaccgaggagccagt3'(SEQ ID NO.: 17); and

mIgG2b, 5'ggtgctggaggggacagtcactgagctgctcatagtgt3'(SEQ ID NO.: 18)).

PCR products were cloned (pCR2.1 TA kit, Invitrogen) and characterized by DNA sequencing. Using the derived sequences for the mouse H and L chain V-region cDNAs, specific primers were used to PCR amplify the signal peptide and V-regions while incorporating flanking restriction sites for cloning into expression vectors encoding downstream human IgGκ or IgG4H regions. The vector for expression of chimeric mVκ-hIgκ was built by amplifying residues 401-731 (gi|63101937|) flanked by *Xho* I and *Not* I sites and inserting this into the *Xho* I – *Not* I interval of pIRES2-DsRed2 (BD Biosciences). PCR was used to amplify the mAb Vκ region from the initiator codon, appending a *Nhe* I or *Spe* I site then CACC, to the region encoding (e.g., residue 126 of gi|76779294|), appending a *Xho* I site. The PCR fragment was then cloned into the *Nhe* I – *Not* I interval of the above vector. The vector for chimeric mVκ-hIgκ using the mSLAM leader was built by inserting the sequence 5'ctagttgctggctaattggaccccaaaggctccctttcctggagaatacttctgtttctctccctggcttttgagttgtcgtacggattaattaaggcccactcgag3' (SEQ ID NO.: 19) into the *Nhe* I – *Xho* I interval of the above vector. PCR was used to amplify the interval between the predicted mature N-terminal codon (defined using the SignalP 3.0 Server) (16) and the end of the mVκ region (as defined above) while appending 5'tcgtacgga3'. The fragment digested with *Bsi* WI and *Xho* I was inserted into the corresponding sites of the above vector. The control hIgκ sequence corresponds to gi|49257887| residues 26-85 and gi|21669402| residues 67-709. The control hIgG4H vector corresponds to residues 12-1473 of gi|19684072| with S229P and L236E substitutions, which stabilize a disulphide bond and abrogate residual FcR binding (27), inserted between the pIRES2-DsRed2 vector *Bgl* II and *Not* I sites while adding the sequence 5'gctagctgattaattaa3' (SEQ ID NO.: 20) instead of the stop codon. PCR was used to amplify the mAb VH region from the initiator codon, appending CACC then a *Bgl* II site, to the region encoding residue 473 of gi|19684072|. The PCR fragment was then cloned into the *Bgl* II – *Apa* I interval of the above vector. The vector for chimeric mVH-hIgG4 sequence using the mSLAM leader was built by inserting the sequence 5'ctagttgctggctaattggaccccaaaggctccctttcctggagaatacttctgtttctctccctggcttttgagttgtcgtacggattaattaaggccc3' (SEQ ID NO.: 22) into the *Nhe* I – *Apa* I interval of the above vector. PCR was used to amplify the interval between the predicted mature N-terminal codon and the end of the mVH region while appending 5'tcgtacgga3'. The fragment digested with *Bsi* WI and *Apa* I was inserted into the corresponding sites of the above vector. Appendix 2 details the nucleotide sequences of the various mVκ and mVH regions used in this study.

Various antigen coding sequences flanked by a proximal *Nhe* I site and a distal *Not* I site following the stop codon were inserted into the *Nhe* I - *Pac* I - *Not* I interval of the H chain

vectors. Flu HA1-1 was encoded by Influenza A virus (A/Puerto Rico/8/34(H1N1)) hemagglutinin gi|21693168| residues 82-1025 (with a C982T change) with proximal 5'gctagcgataacaacagaacctgcaacacctacaacacctgtaacaa3' (SEQ ID NO.: 23) sequence (a *Nhe* I site followed by sequence encoding *cipA* cohesin-cohesin linker residues) and distal
5 5'caccatcaccatcaccattgagcgccgc3' (SEQ ID NO.: 24) sequence (encoding His6, a stop codon, and a *Not* I site). Flu HA5-1 was encoded by gi|50296052| Influenza A virus (A/Viet Nam/1203/2004(H5N1)) hemagglutinin residues 49-990 bound by the same sequences as Flu HA1-1. Doc was encoded by gi|40671| *celD* residues 1923-2150 with proximal *Nhe* I and distal *Not* I sites. PSA was encoded by gi|34784812| prostate specific antigen residues 101-832 with
10 proximal sequence
5'gctagcgataacaacagaacctgcaacacctacaacacctgtaacaacaccgacaacaacacttctagcg3' (SEQ ID NO.: 25) (*Nhe* I site and *cipA* spacer) and a distal *Not* I site. Flu M1-PEP was encoded by 5'gctagcccccattctgagccccctgaccaaaggcattctgggctttgtgtttaccctgaccgtgcccgagcaacgcaagggtatacttgat
15 tcgttttcacacttacttaagcgccgc3' (SEQ ID NO.: 26). This and all other peptide-encoding sequences were created via mixtures of complimentary synthetic DNA fragments with ends compatible for cloning into *Nhe* I and *Not* I-restricted H chain vectors, or *Nhe* I – *Xho* I-restricted Coh.His vector. Preferred human codons were always used, except where restriction sites needed to be incorporated or in *CipA* spacer sequences.

Production levels of rAb expression constructs were tested in 5 ml transient transfections using
20 ~2.5 µg each of the L chain and H chain construct and the protocol described above. Supernatants were analyzed by anti-hIgG ELISA (AffiniPure Goat anti-human IgG (H+L), Jackson ImmunoResearch). In tests of this protocol, production of secreted rAb was independent of H chain and L chain vectors concentration over a ~2-fold range of each DNA concentration (i.e., the system was DNA saturated).

25 Novel anti-Dectin-1 monoclonal antibodies (mAbs) were developed and used to uncover previously unknown biology associated with this cell surface receptor that is found on antigen-presenting cells. This novel biology is highly predictive of the application of anti-Dectin-1 agents that activate this receptor for diverse therapeutic and protective applications. Data presented below strongly support the initial predictions and demonstrated the pathway to
30 reducing the discoveries herein to clinical application.

Development of high affinity monoclonal antibodies against human Dectin-1: Receptor ectodomain.hIgG (human IgG1Fc) and AP (human placental alkaline phosphatase) fusion

proteins were produced for immunization of mice and screening of mAbs, respectively. An expression construct for DCIR ectodomain.IgG was described previously (15) and used the mouse SLAM (mSLAM) signal peptide to direct secretion (16). An expression vector for DCIR ectodomain.AP was also generated using PCR to amplify AP residues 133-1581 (gb|BC009647|) while adding a proximal in-frame *Xho* I site and a distal TGA stop codon and Not I site. This *Xho* I – Not I fragment replaced the IgG coding sequence in the above DCIR ectodomain.IgG vector. Dectin-1 ectodomain constructs in the same Ig and AP vector series contained inserts encoding (bp 397-603, gi|88999591|. Dectin-1 fusion proteins were produced using the FreeStyle™ 293 Expression System (Invitrogen) according to the manufacturer's protocol (1 mg total plasmid DNA with 1.3 ml 293 Fectin reagent /L of transfection). For rAb production, equal amounts of vector encoding the H and L chain were co-transfected. Transfected cells are cultured for 3 days, the culture supernatant was harvested and fresh media added with continued incubation for two days. The pooled supernatants were clarified by filtration. Receptor ectodomain.hIgG was purified by HiTrap protein A affinity chromatography with elution by 0.1 M glycine pH 2.7 and then dialyzed versus PBS. rAbs (recombinant antibodies described later) were purified similarly, by using HiTrap MabSelect™ columns. Mouse mAbs were generated by conventional cell fusion technology. Briefly, 6-week-old BALB/c mice were immunized intraperitoneally with 20 µg of receptor ectodomain.hIgGFc fusion protein with Ribi adjuvant, then boosts with 20 µg antigen 10 days and 15 days later. After 3 months, the mice were boosted again three days prior to taking the spleens. Alternately, mice were injected in the footpad with 1-10 µg antigen in Ribi adjuvant every 3-4 days over a 30-40 day period. 3-4 days after a final boost, draining lymph nodes were harvested. B cells from spleen or lymph node cells were fused with SP2/O-Ag 14 cells (17) using conventional techniques. ELISA was used to screen hybridoma supernatants against the receptor ectodomain fusion protein compared to the fusion partner alone, or versus the receptor ectodomain fused to AP (15). Positive wells were then screened in FACS using 293F cells transiently transfected with expression plasmids encoding full-length receptor cDNAs. Selected hybridomas were single cell cloned, adapted to serum-free media, and expanded in CELLline flasks (Intergra). Hybridoma supernatants were mixed with an equal volume of 1.5 M glycine, 3 M NaCl, 1x PBS, pH 7.8 and tumbled with MabSelect resin. The resin was washed with binding buffer and eluted with 0.1 M glycine, pH 2.7. Following neutralization with 2 M Tris, mAbs were dialyzed versus PBS.

Characterization of purified anti-Dectin-1 monoclonal antibodies by direct ELISA. The relative affinities of several anti-Dectin-1 mAbs by ELISA (i.e., Dectin-1.Ig protein is immobilized on

the microtiter plate surface and the antibodies are tested in a dose titration series for their ability to bind to Dectin-1.Ig (as detected by an anti-mouse IgG-HRP conjugate reagent). The panels are (left) mAb reactivity to Dectin-1.Ig protein; and (right) mAb reactivity to hIgGFc protein. The panels show that the anti-Dectin-1 mAbs react specifically to the Dectin-1. Variations in binding were noted for the various antibodies.

Both in vivo DCs and in vitro-cultured DCs express Dectin-1: Figures 1A and 1B show the expression levels of Dectin-1 on PBMCs from normal donors. As shown in Fig. 1A below, antigen presenting cells, including CD11c+ DCs, CD14+ monocytes, and CD19+B cells express Dectin-1. CD3+ T cells do not express detectable surface Dectin-1. Expression levels of Dectin-1 on in vitro-cultured DCs, IFNDCs and IL-4DCs, are shown in Fig. 1b. Both IL-4 and IFNDCs were stained with all three anti-Dectin-1 made in this study.

Both in vivo and in vitro-cultured DCs express Dectin-1. Figure 1A. PBMCs from normal donors were stained with anti-CD11c, CD14, CD19, and CD3 with anti-Dectin-1 mAb. Cells stained with individual antibodies were gated to measure the expression levels of Dectin-1. Figure 1B. Monocytes from normal donors were cultured in the presence of GM-CSF with IL-4 (IL-4DCs) or IFNa (IFNDCs), and cells were stained with anti-Dectin-1 mAb. Cells were also stained with control antibodies and goat anti-mouse antibody labeled with FITC.

Expression levels of Dectin-1 on DCs are modulated with TLR ligands and cytokines: The expression levels of DC surface molecules can be modulated with various stimulators. To see whether Dectin-1 expression is controlled by the activation of DCs, IL-4DCs were stimulated with TLR ligands and cytokines. Data in Fig. 2 show that TLR4 ligand (LPS from *E. coli*) reduced the expression levels of Dectin-1, but IL-10 slightly enhanced Dectin-1 expression on IL-4DCs. In a repeat study, IL-15 slightly downregulated Dectin-1. Other stimulators, including IFNa and TLR3 ligand did not alter the expression levels of Dectin-1 on IL-4DCs.

Figure 2. In vitro-cultured IL-4DCs were cultured in the presence of CD40L (50 ng/ml), TLR2 ligand (100 ng/ml), TLR3 ligand (100 nM), TLR4 ligand (20 ng/ml), IL-10 (20 ng/ml), IL-15 (100 ng/ml), IFNa (500 U/ml), and IL-4 (50 ng/ml) for 24h. Cells were stained with anti-Dectin-1 or control mAbs. Dotted lines indicate cells stained with isotype control antibody. Gray and opened histograms represent cells cultured in the media without any stimulator and with stimulators, respectively.

Signaling through Dectin-1 stimulates DCs to produce cytokines and chemokines: Dendritic cells are the primary immune cells that determine the results of immune responses, either

induction or tolerance, depending on their activation (18). The role of Dectin-1 in human DC activation has not been thoroughly studied. We generated 8 different hybridoma clones that produce mouse anti-hDectin-1 mAbs, and we tested whether individual mAbs activate DCs by measuring cytokines and chemokines secreted from DCs. Data in Fig. 3 show that especially
5 PAB47 and PAB49 could activate DCs to produce significant amounts of IL-6, IL-8, IL-10, IL-12p40, IP-10, and MIP-1a. PAB187 is an anti-CD40 mAb that is known to activate DCs. PAB85 is a control antibody.

Figure 3 shows that anti-Dectin-1 mAbs activate DCs. $1 \times 10^5/200$ ul IFNDCs were cultured in the plates coated with different clones of mAbs for 18 h. A. Culture supernatants were analyzed
10 to measure cytokines and chemokines by Luminex.

Figure 4 shows that signaling through Dectin-1 can result in the activation of both IL-4DCs and IFNDCs. For IFNDCs, anti-Dectin-1 mAbs stimulate DCs to express significantly increased levels of CD86, CD83, CD80, and HLA-DR (Fig. 4A). Anti-Dectin-1 mAb also activated IL-4DCs to express increased levels of CD86, CD80, and HLA-DR (Fig. 4B).

15 Signaling through Dectin-1 augments signaling through TLRs: Signals through Dectin-1 can synergize with signals through TLRs for enhanced activation of DCs (Fig. 5). It has been known that Dectin-1 synergizes with TLR2. In this study, however, we show that synergy between Dectin-1 and TLR4 is stronger than synergy between Dectin-1 and TLR2 for the activation of DCs. This synergy, Dectin-1 and TLR4, resulted in dramatically increased production of IL-10,
20 IL-1b, $\text{TNF}\alpha$, and IL-12p40 from DCs. We have also stained cells with anti-costimulatory molecules, including CD86, CD80, CD83 and CD40; this synergy did not result in increased expression of costimulatory molecules tested.

Synergy between Dectin-1 and TLR4 resulted in the enhanced antigen specific CD8 T cell responses: To test whether the synergy between Dectin-1 and TLR-mediated signaling results in
25 enhanced immune responses, the capacity of DC to prime Mart-1 specific CD8 T cells was tested (Fig. 6). As shown in Fig. 6A, synergy between Dectin-1 and TLR4L resulted in more than 5 fold increased number of Mart-1 specific CD8 T cell responses. We could also see the synergy between Dectin-1 and TLR2 resulted in enhanced Mart-1 specific CD8 T cell priming. Data in Fig. 6 will be useful for future vaccine development.

30 IL-10 produced from DCs stimulated through Dectin-1 contributes to the enhanced Mart-1 specific CD8 T cell priming: As shown in Fig. 3 and Fig. 5, signaling through Dectin-1 resulted in significant amounts of IL-10, an inhibitory cytokine for CD8 T cell responses, from DCs. The

amount of IL-10 were significantly increased when Dectin-1 synergize with TLR ligands. Regardless of the IL-10 produced by DCs, however, DCs stimulated with either anti-Dectin-1 alone or anti-Dectin-1 and TLR ligands resulted in the enhanced priming of Mart-1 specific CD8 T cells (Fig. 6). Therefore, it is likely that IL-10 during priming may contribute to antigen specific CD8 T cell priming. To test this hypothesis, we added anti-IL-10 antibody in the culture, and data in Fig. 7 indicate that IL-10 from DCs stimulated with anti-Dectin-1 and TLR ligands enhance Mart-1 specific CD8 T cell priming. Similar result was observed when DCs were stimulated with Zymosan. When same DCs were stimulated with Zymosan, DCs produced significant amount of IL-10 (more than 1000 pg/ml from 1×10^5 DCs) (data not shown). Since DCs stimulated with anti-Dectin-1 mAbs produce significant amounts of IL-10, this IL-10 mediated enhanced priming of antigen specific CD8 T cells will be useful for future vaccine development.

DCs activated with anti-Dectin-1 express increased levels of IL-15 and 4-1BBL: To further analyze the role of anti-Dectin-1 in DC activation, IFN DCs were stimulated with anti-Dectin-1, and then cells were stained with anti-IL-15 and 4-1BBL. Data in Fig. 8 show that signaling through Dectin-1 induces increased expression of both IL-15 and 4-1BBL that may contribute to enhanced humoral and cellular immune responses. IL-15 is known to playing an important role in CD8 T cell responses and B cell proliferation and antibody production. 4-1-BBL is a costimulatory molecule that contributes to DC-mediated CD8 T cell responses - human 4-1BBL signals through both CD137/4-1BB and itself. Its cytoplasmic tail participates in reverse signaling that induces apoptosis in T cells and cytokine secretion (IL-6; TNF- α) by monocytes. 4-1BBL binding to CD137/4-1BB produces a number of effects and plays a key role in the T cell recall response. It maintains T cell numbers at the end of a primary response, and induces CD4+ and CD8+ T cells to proliferate and secrete cytokines such as IL-2 and IFN- γ in CD4+ cells, and IFN- γ in CD8+ cells.

DCs stimulated through Dectin-1 induce potent humoral immune responses:-DCs play an important role in humoral immune responses by providing signals for both T-dependent and T-independent B cell responses (19-22) and by transferring antigens to B cells (23, 24). In addition to DCs, signaling through TLR9 as a third signal is necessary for efficient B cell responses (25, 26). Dectin-1 can affect DCs-mediated humoral immune responses in the presence of TLR9 ligand, CpG. Six day IL-4 DCs were stimulated with anti- Dectin-1 mAb, and then purified B cells were co-cultured in the presence of CD40L or CpG. As shown in Fig. 9a and 9b, DCs activated with anti-Dectin-1 mAb result in the enhanced B cell proliferation (seen via CFSE

dilution) and plasma cell differentiation (increase in CD38⁺), compared to DCs stimulated with control mAb.

The amounts of total immunoglobulins (Igs) produced were measured by ELISA (Fig. 9a and b). Consistent with the B cell proliferation and plasma cell differentiation, B cells cultured with anti-Dectin-1 mAb-stimulated DCs result in significantly increased production of total immunoglobulins in presence of CD40L or CpG.

The present invention may be used for the therapeutic application of agents that activate specifically through Dectin-1, e.g., as adjuvant in vaccination, or as immune system stimulants for immune compromised individuals. Also, the discovery predicts that blocking natural or abnormally regulated activation via Dectin-1 can have applications (e.g., for evoking tolerance in a transplantation setting, or ameliorating autoimmune diseases).

Anti-Dectin-1 mAbs activate B cells: CD19⁺ B cells express Dectin-1 (Fig. 1) and this predicts a possible role for Dectin-1 expressed on B cells. Data in Fig. 10A show that triggering Dectin-1 on B cells results in the enhanced B cell proliferation and plasma cell differentiation in the presence of CpG. Consistently, Fig. 10B shows that B cells activated with anti-Dectin-1 mAb secrete increased amounts of total IgM, but not IgG and IgA.

The above discovery of direct effects on B cells through engagement of Dectin-1 reinforces the scope of therapeutic application outlined above for agents acting through or against Dectin-1.

Role of Dectin-1 in T cell responses: DCs stimulated through Dectin-1 express enhanced levels of co-stimulatory molecules and produce increased amounts of cytokines and chemokines (Fig. 3 and 4), suggesting that Dectin-1 contributes to enhanced cellular immune responses as well as humoral immune responses. This was tested by measuring antigen specific CD8 T cell responses (Fig. 11). Data in Fig. 11 show that DCs activated through Dectin-1 result in enhanced memory CD8 T cell responses specific to Flu M1 protein (Fig. 11a). More importantly, signaling through Dectin-1 permits DCs to prime and cross-prime Mart-1 peptides to CD8 T cells (Fig. 11b and c). This indicates that Dectin-1 plays an important role in enhancing DC function, resulting in improved priming and cross-priming of antigens to CD8 T cells. Therefore, anti-Dectin-1 mAb and antigen fusion proteins will induce robust antigen specific CD8 T cell responses, suggesting that reagents composed of anti-Dectin-1 mAbs will be useful for developing vaccine against cancers and infections.

Soluble form of anti-Dectin-1 mAbs activate DCs to result in enhanced priming of Mart-1 specific CD8 T cells from normal donors. We have shown that soluble anti-Dectin-1 mAbs can

activate DCs, and therefore we have tested whether DCs stimulated with soluble anti-Dectin-1 could enhance antigen specific CD8 T cell responses. Data in Fig. 12 show that DCs activated with soluble anti-Dectin-1 resulted in the enhanced priming of Mart-1 specific CD8 T cells from normal donors. Soluble form of anti-CD40 made in this study also resulted in the enhanced CD8 T cell priming.

Human tonsil B cells divided into two groups based on Dectin-1 expression: Cells from human tonsils were stained with anti-Dectin-1 and other antibodies. As shown in Fig. 13, CD3⁺ T cells do not express Dectin-1 (left panel). However, there were two groups of CD19⁺ B cells; one does not express Dectin-1 and the other group of CD19⁺B cells expresses Dectin-1 similarly to CD19⁺B cells from PBMC from normal donors. This may likely have implications for developing new anti-Dectin-1-based therapeutic reagents for cancers and vaccines.

Cells in human skins and lymph nodes express Dectin-1: Cells expressing Dectin-1 are detectable in human skins and Lymph nodes by IHC. Tissue sections were stained with the nuclear stain DAPI (Blue) and Anti-Dectin-1 (Red). Fig. 14 shows that both human skin and lymph nodes contain cells express significant levels of Dectin-1. This is an important observation since it reveals that cells in vivo express Dectin-1 – in exactly the location (skin) that would be a preferred site for administration of e.g., anti-Dectin-1-targeted antigen.

In vivo DCs in non-human primate express Dectin-1- Blood DCs in non-human primates (Cynomolgus), monkey PBMC were stained with anti-Dectin-1 mAbs and antibodies to other cellular markers, CD3, CD14, CD11c, CD27, CD56, and CD16. Data in Fig. 15 show that both CD14 and CD11c⁺ cells were stained with anti-human Dectin-1 mAbs. Unlike CD14⁺ and CD11c⁺ cells, CD3⁺, CD16⁺, CD27⁺, and CD56⁺ cells did not express Dectin-1 (data not shown). This data demonstrates the cross-reactivity of certain anti-human Dectin-1-1 mAbs against monkey antigen presenting cells. This greatly facilitates reducing the inventions described herein to practice, since monkey can be used as a valid model for both efficacy and safely studies of envisioned human therapies.

The discoveries shown above both enhance and broaden the scope of therapeutic application for agents acting through Dectin-1. Dectin-1 activation of DCs influences neighboring T cells directing them to increase proliferation. Furthermore, when antigen is present during this interaction, Dectin-1 activated DCs result in enhance expansion of antigen-specific T cells. This shows that Dectin-1 activation, e.g., in a vaccine setting, can direct selective expansion of antigen-specific naïve T cells – this together with the above direct and indirect effects of Dectin-

1 activation on B cells, clearly predicts the expansion of antigen-specific B cells, and therefore production of antigen-specific antibody.

It is contemplated that any embodiment discussed in this specification can be implemented with respect to any method, kit, reagent, or composition of the invention, and vice versa.

5 Furthermore, compositions of the invention can be used to achieve methods of the invention.

It will be understood that particular embodiments described herein are shown by way of illustration and not as limitations of the invention. The principal features of this invention can be employed in various embodiments without departing from the scope of the invention. Those skilled in the art will recognize, or be able to ascertain using no more than routine
10 experimentation, numerous equivalents to the specific procedures described herein. Such equivalents are considered to be within the scope of this invention and are covered by the claims.

All publications and patent applications mentioned in the specification are indicative of the level of skill of those skilled in the art to which this invention pertains. All publications and patent applications are herein incorporated by reference to the same extent as if each individual
15 publication or patent application was specifically and individually indicated to be incorporated by reference.

The use of the word “a” or “an” when used in conjunction with the term “comprising” in the claims and/or the specification may mean “one,” but it is also consistent with the meaning of “one or more,” “at least one,” and “one or more than one.” The use of the term “or” in the
20 claims is used to mean “and/or” unless explicitly indicated to refer to alternatives only or the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and “and/or.” Throughout this application, the term “about” is used to indicate that a value includes the inherent variation of error for the device, the method being employed to determine the value, or the variation that exists among the study subjects.

25 As used in this specification and claim(s), the words “comprising” (and any form of comprising, such as “comprise” and “comprises”), “having” (and any form of having, such as “have” and “has”), “including” (and any form of including, such as “includes” and “include”) or “containing” (and any form of containing, such as “contains” and “contain”) are inclusive or open-ended and do not exclude additional, unrecited elements or method steps.

30 The term “or combinations thereof” as used herein refers to all permutations and combinations of the listed items preceding the term. For example, “A, B, C, or combinations thereof” is intended to include at least one of: A, B, C, AB, AC, BC, or ABC, and if order is important in a

particular context, also BA, CA, CB, CBA, BCA, ACB, BAC, or CAB. Continuing with this example, expressly included are combinations that contain repeats of one or more item or term, such as BB, AAA, MB, BBC, AAABCCCC, CBBAAA, CABABB, and so forth. The skilled artisan will understand that typically there is no limit on the number of items or terms in any combination, unless otherwise apparent from the context.

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WHAT IS CLAIMED IS:

1. Use of a composition comprising an anti-Dectin-1 receptor antibody for increasing the proliferation of T cells, wherein the anti-Dectin-1 receptor antibody activates the Dectin-1 receptor on antigen presenting cells (APCs).
2. Use of a composition comprising an anti-Dectin-1 receptor antibody in the manufacture of a medicament for increasing the proliferation of T cells in a subject, wherein the anti-Dectin-1 receptor antibody activates the Dectin-1 receptor on antigen presenting cells (APCs).
3. The use of claim 1 or 2, wherein the anti-Dectin-1 receptor antibody is fused to an antigen.
4. The use of any one of claims 1-3, wherein the composition further comprises a TLR ligand.
5. The use of claim 4, wherein the TLR ligand is selected from a TLR2 ligand, a TLR3 ligand, and a TLR4 ligand.
6. The use of claim 5, wherein the TLR ligand is a TLR2 ligand.
7. The use of any one of claims 1-6, wherein the composition is formulated for an administration by orthotopic, intradermal, intraperitoneal, or intravenous injection.
8. The use of any one of claims 1-6, wherein the composition is formulated for parenteral administration.
9. The use of claim 8, wherein the composition is formulated for subcutaneous or intramuscular administration.

10. The use of any one of claims 1-9, wherein the composition is formulated for an biennially administration.
11. The use of any one of claims 1-9, wherein the composition is formulated for a yearly administration.
12. The use of any one of claims 1-11, wherein the composition further comprises a pharmaceutically acceptable carrier.
13. The use of any one of claims 1-12, wherein the composition is in an amount effective for the increase of antigen-specific cells in a subject.
14. The use of claim 13, wherein the antigen-specific cells comprise CD8+ T cells.
15. The use of claim 13, wherein the antigen-specific cells comprise B cells.
16. The use of any one of claims 1-12, wherein the composition is in an amount effective for the increase of IL-10 in a subject.
17. An antibody comprising any one of SEQ ID NOS:3-8: or a Dectin-1 receptor binding fragment thereof.
18. The antibody of claim 17, wherein the antibody comprises a Dectin-1 receptor binding fragment of any one of SEQ ID NOS:3-8.
19. The antibody of claim 18, wherein the Dectin-1 receptor binding fragment is a V-region fragment binding to an activating immune cells through the Dectin-1 receptor.
20. The antibody of claim 18, wherein the fragment comprises an antibody variable region domain, an Fab fragment, a Fab' fragment, an F(ab)₂ fragment, an Fv fragment, an Fabc fragment and/or an Fab fragment with portions of the Fc domain.

21. The antibody of any one of claims 17-20, wherein the antibody is humanized.
22. The antibody of any one of claims 17-21, wherein the antibody is chimeric.
23. The antibody of any one of claims 17-22, wherein the antibody comprises SEQ ID NOs:3 and 4 or Dectin-1 receptor binding fragments thereof.
24. The antibody of any one of claims 17-22, wherein the antibody comprises SEQ ID NOs:5 and 6 or Dectin-1 receptor binding fragments thereof.
25. The antibody of any one of claims 21-22, wherein the antibody comprises SEQ ID NOs:7 and 8 or Dectin-1 receptor binding fragments thereof.

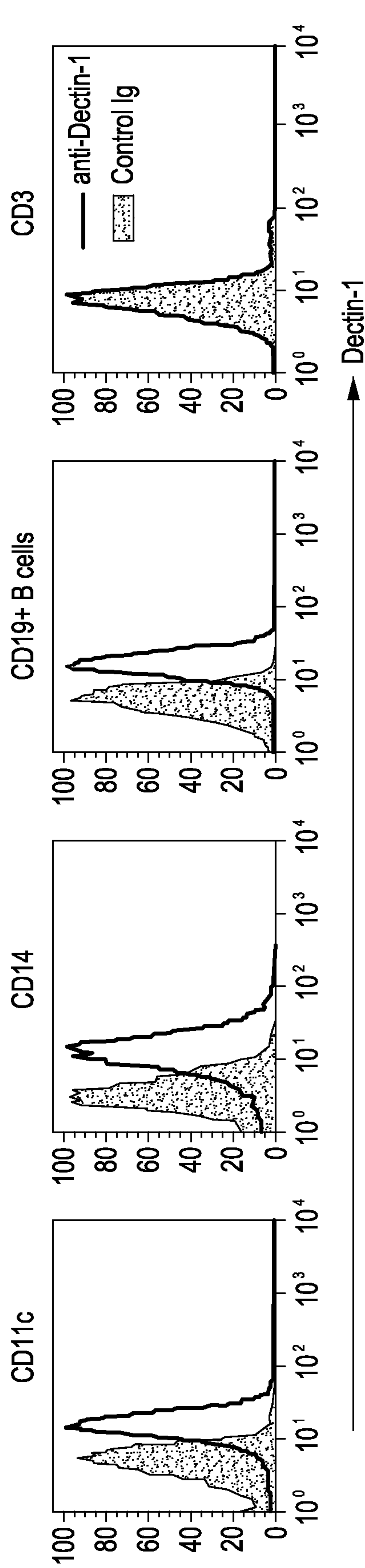


FIG. 1A

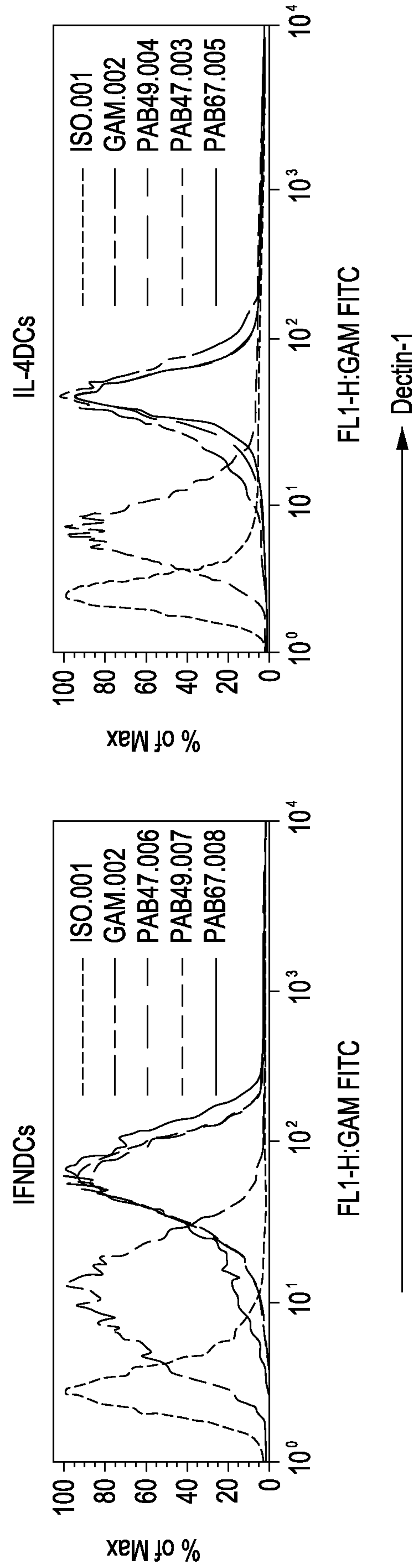
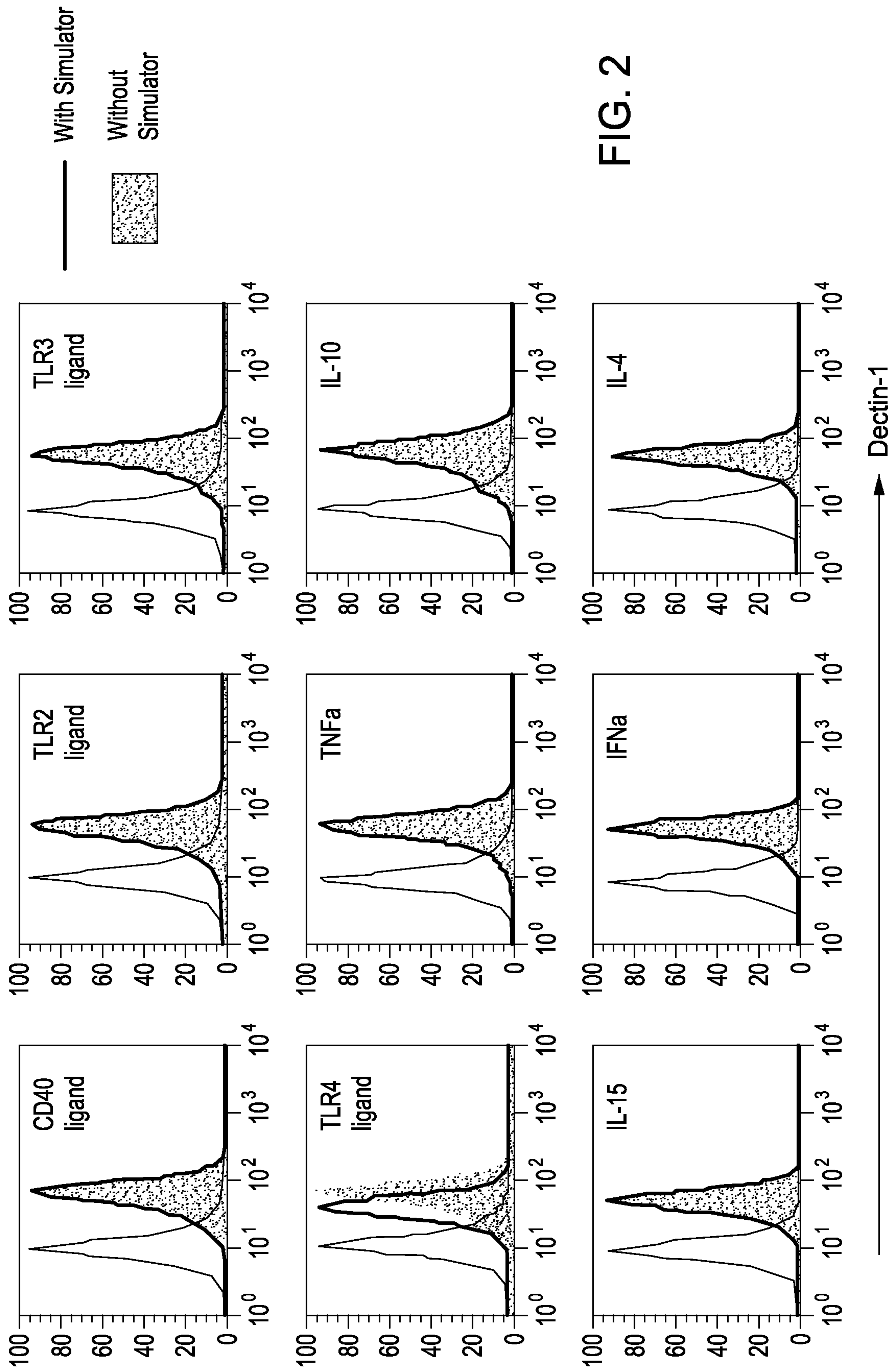


FIG. 1B



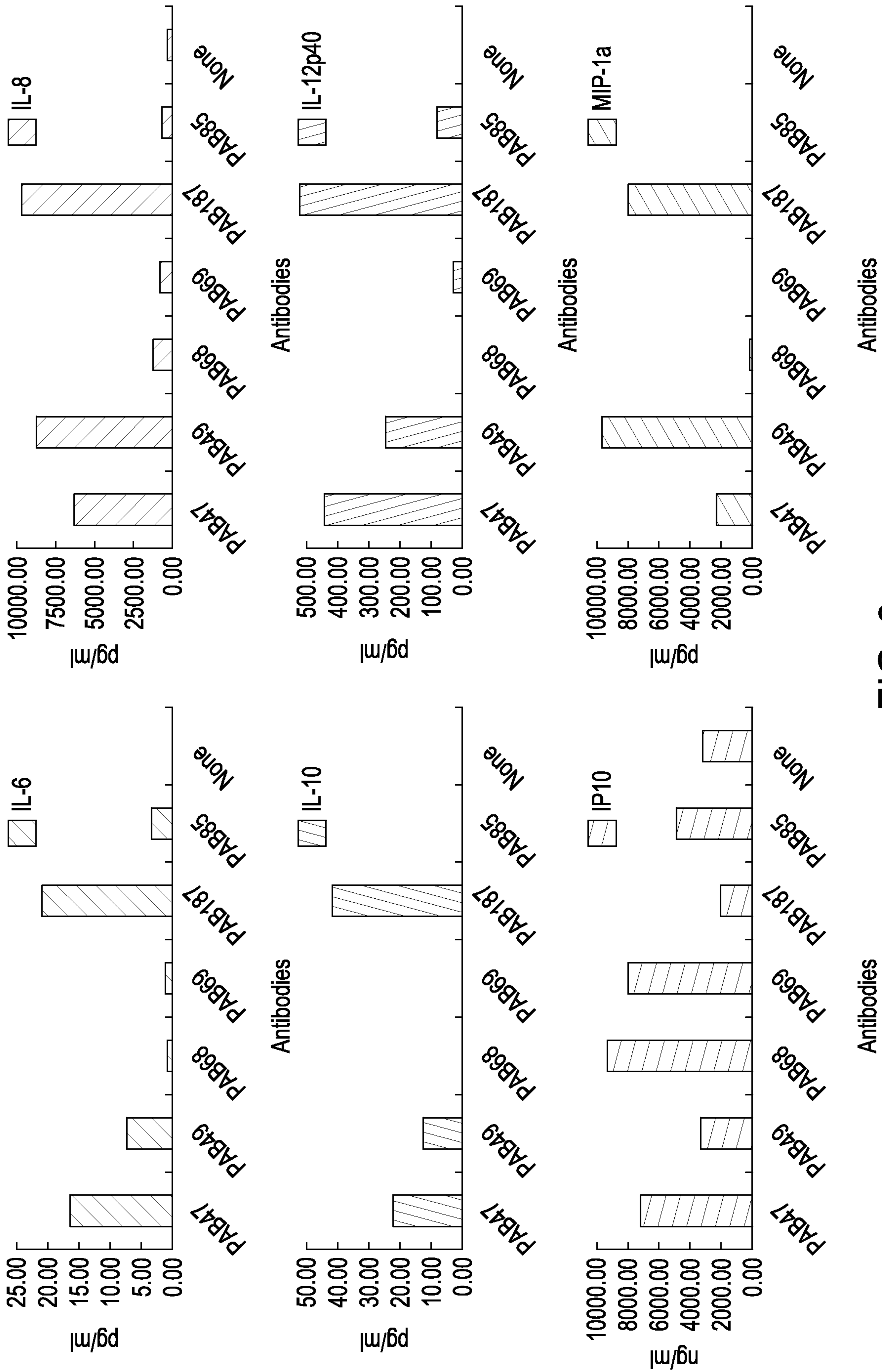
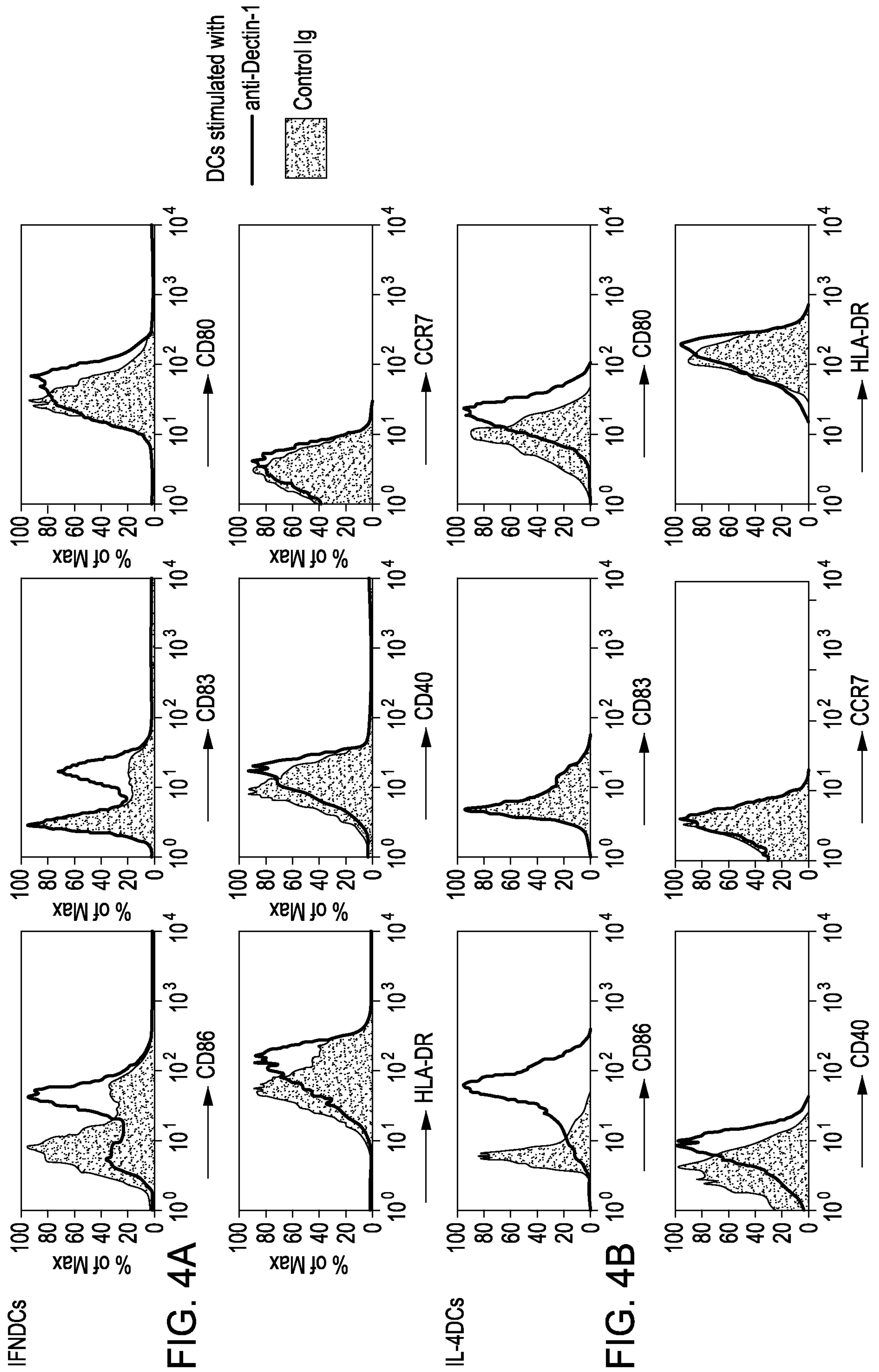


FIG. 3

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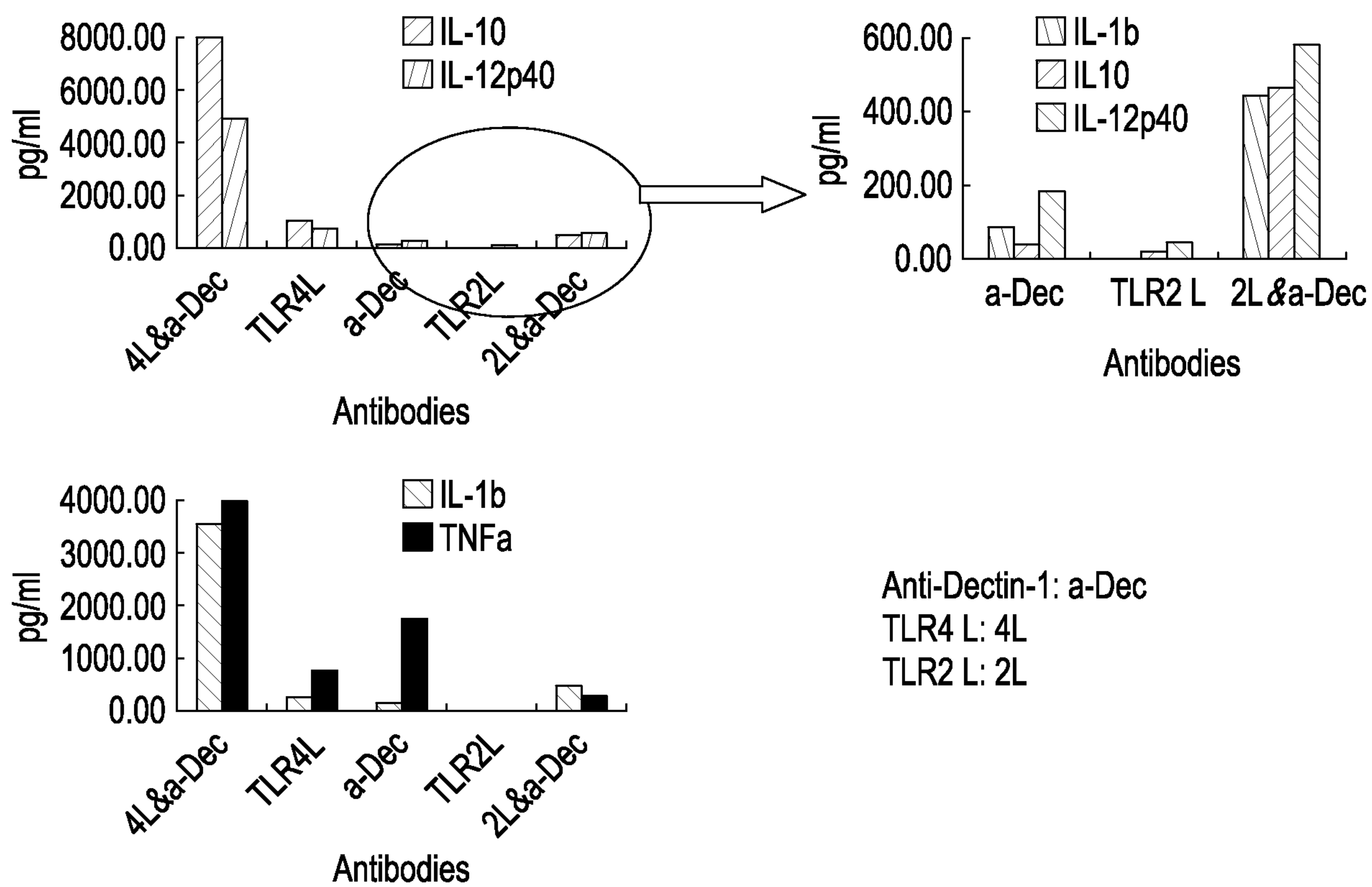
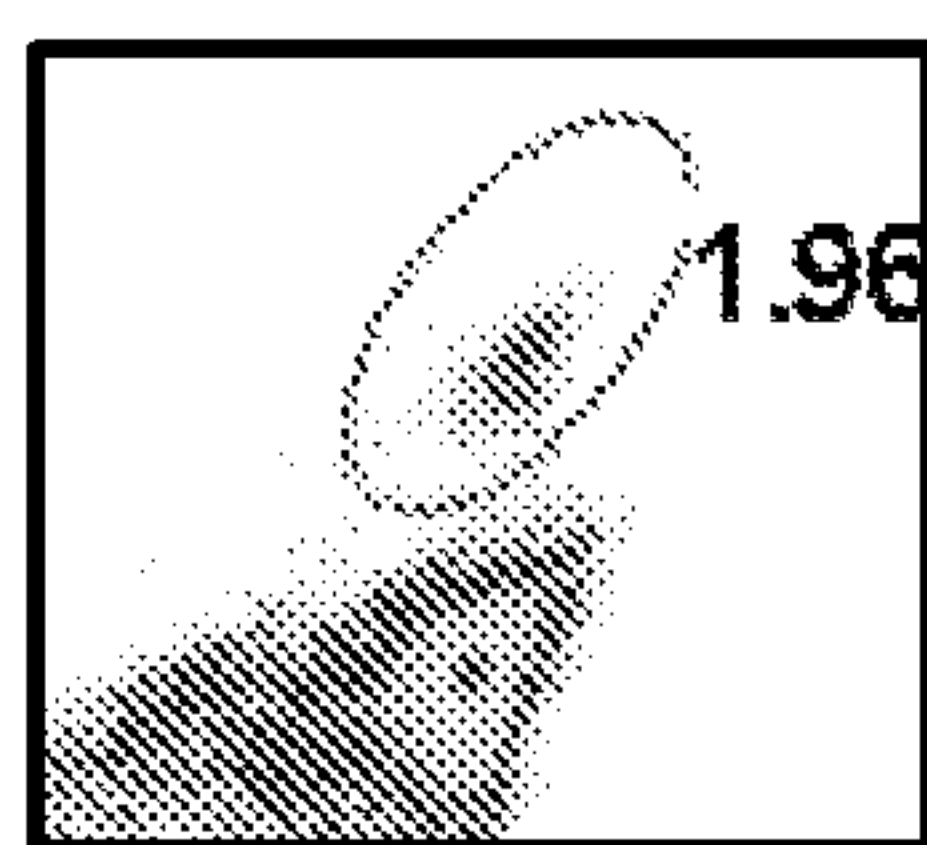


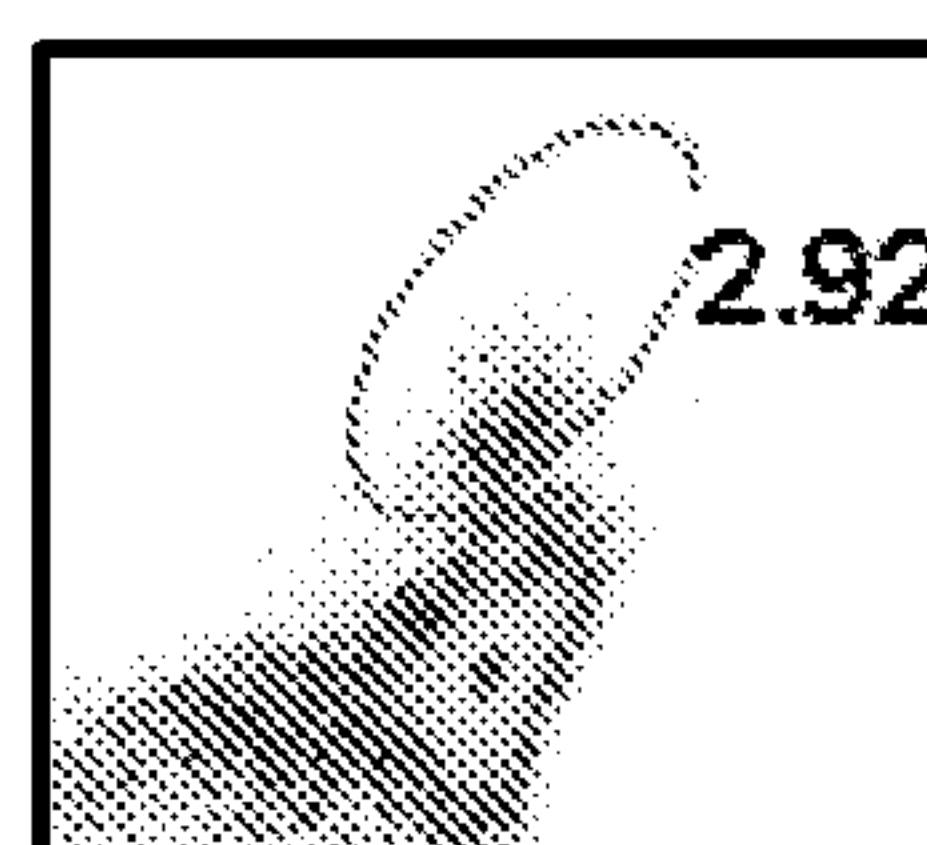
FIG. 5

Synergy with TLR4L

Anti-Dectin-1



TLR4 L



Anti-Dec&TLR4 L

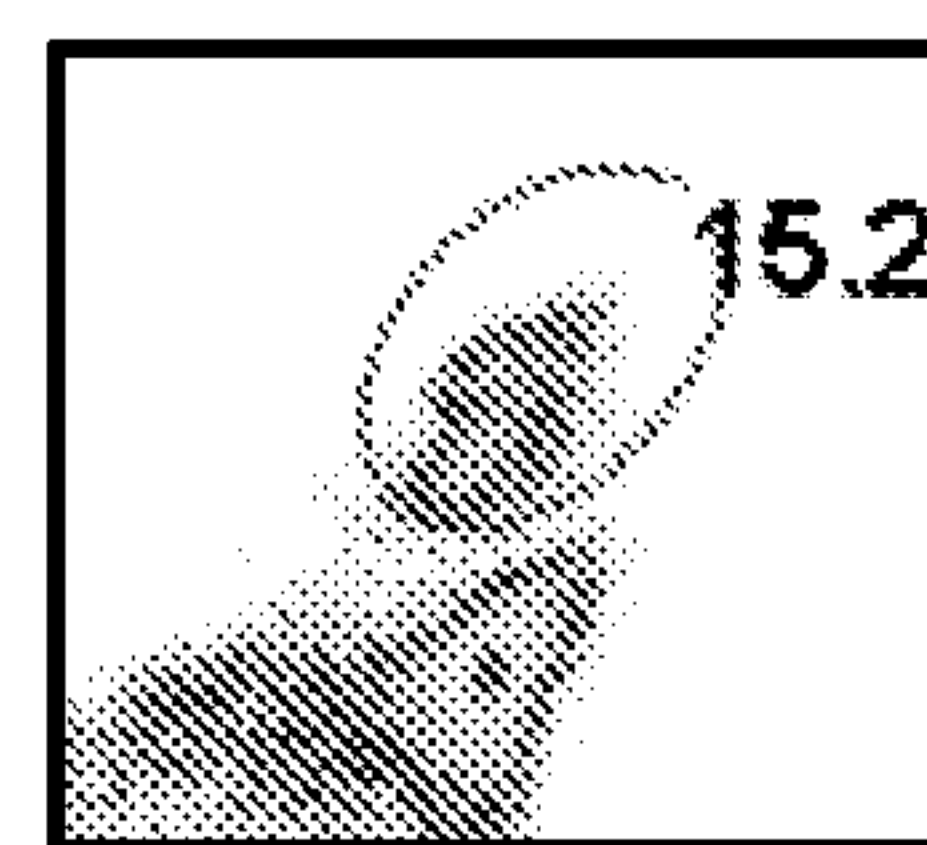
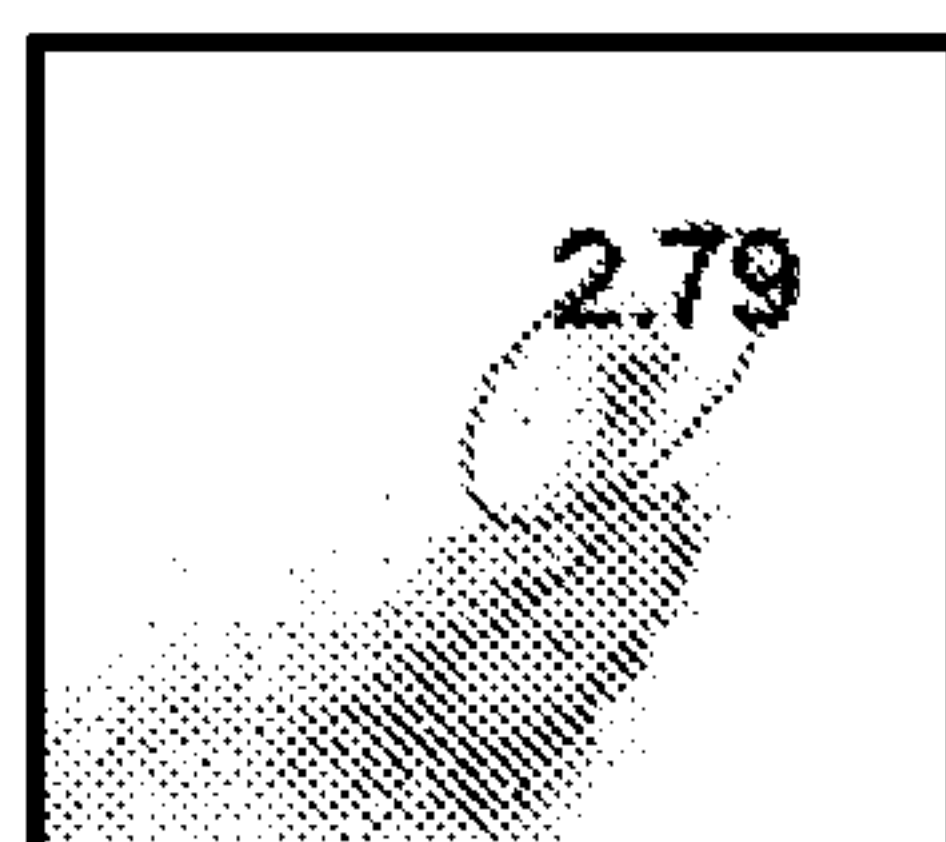


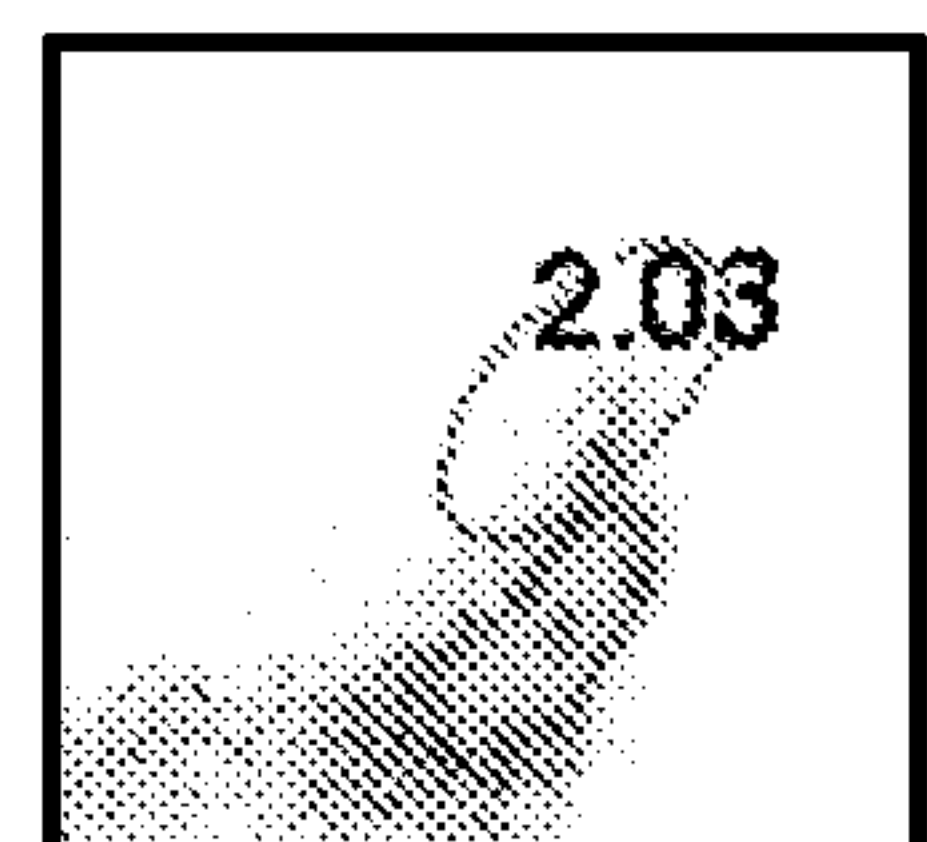
FIG. 6A

Synergy with TLR2L

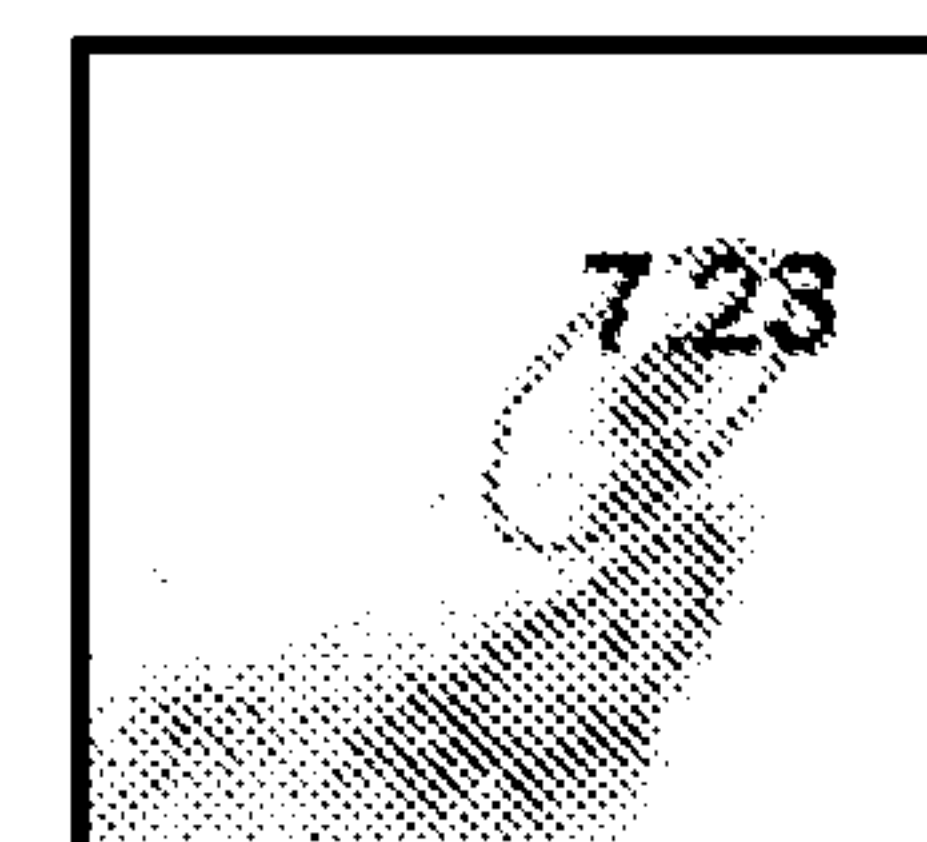
A-Dectin-1



TLR2 L



Anti-Dec&TLR2 L



Mart-1 tetramer

CD8

FIG. 6B

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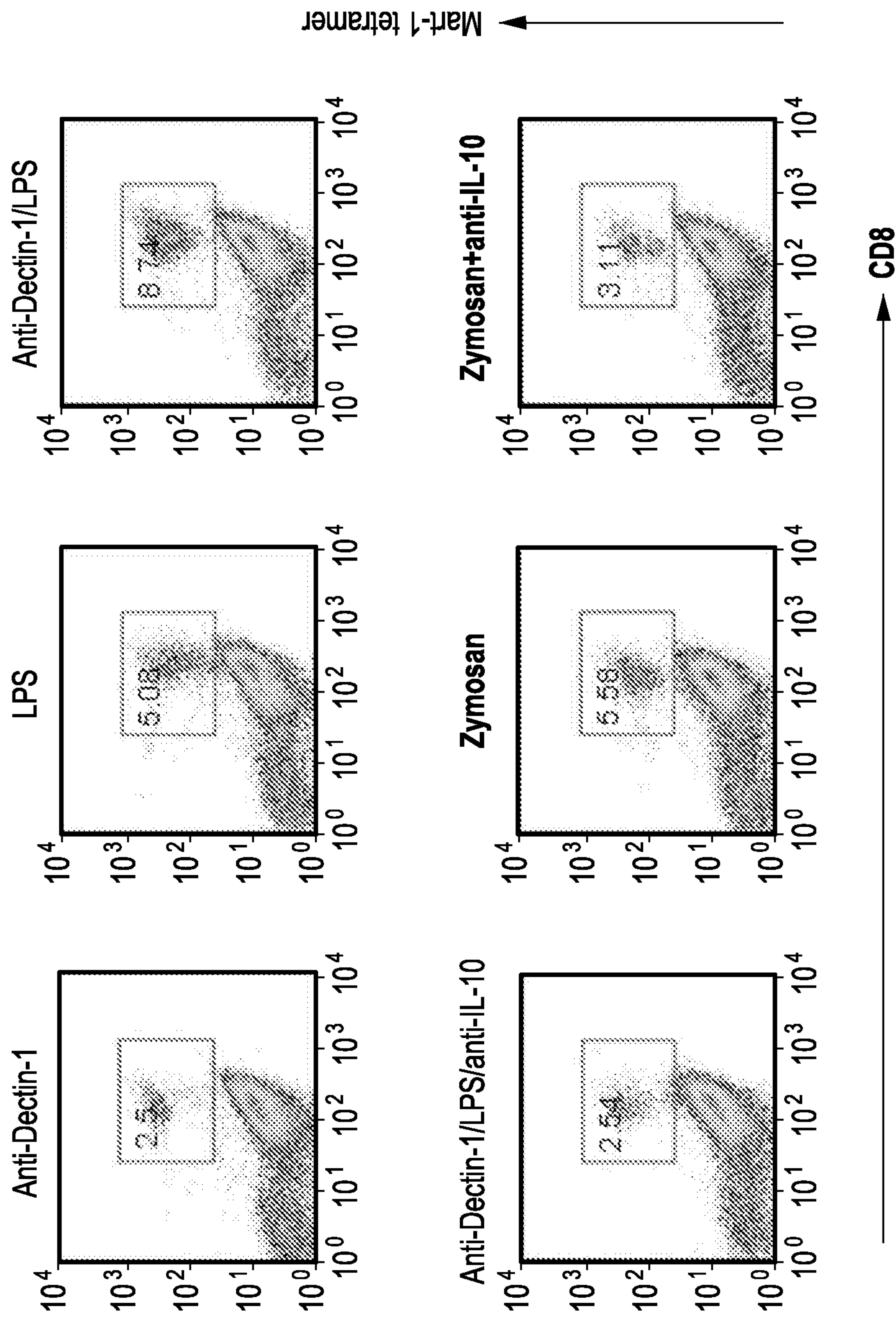


FIG. 7

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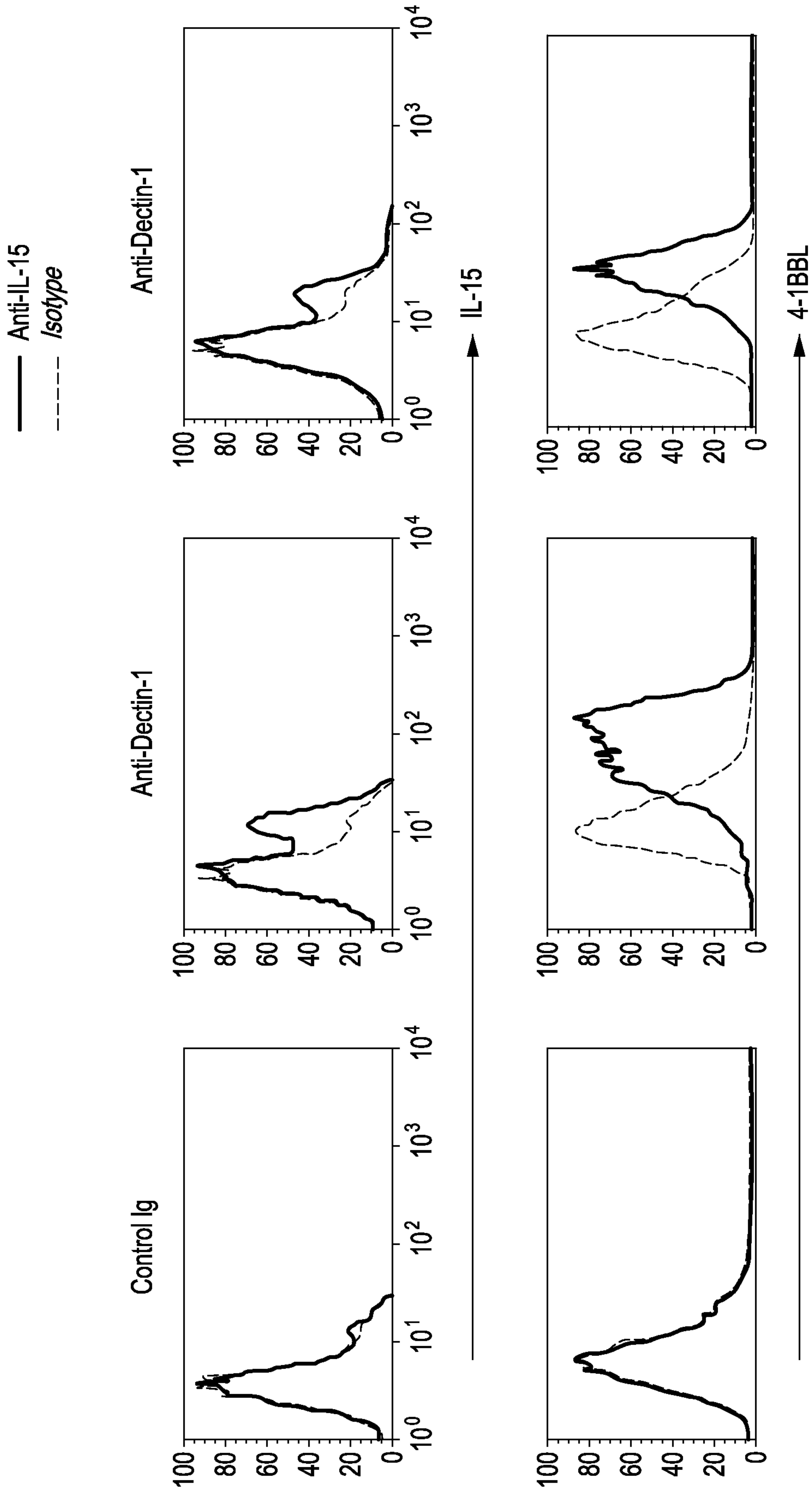


FIG. 8

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With CD40L (50 ng/ml)

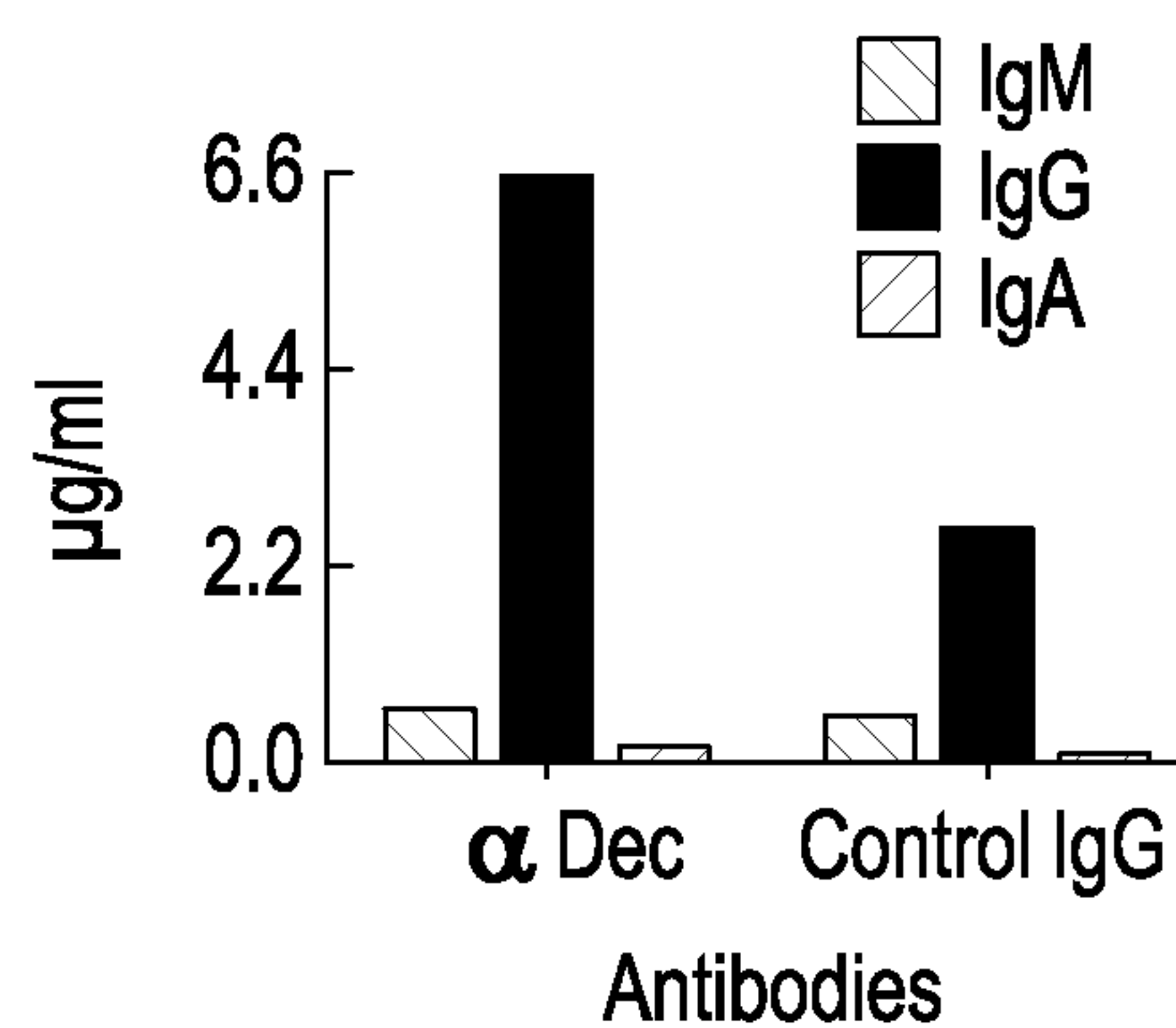
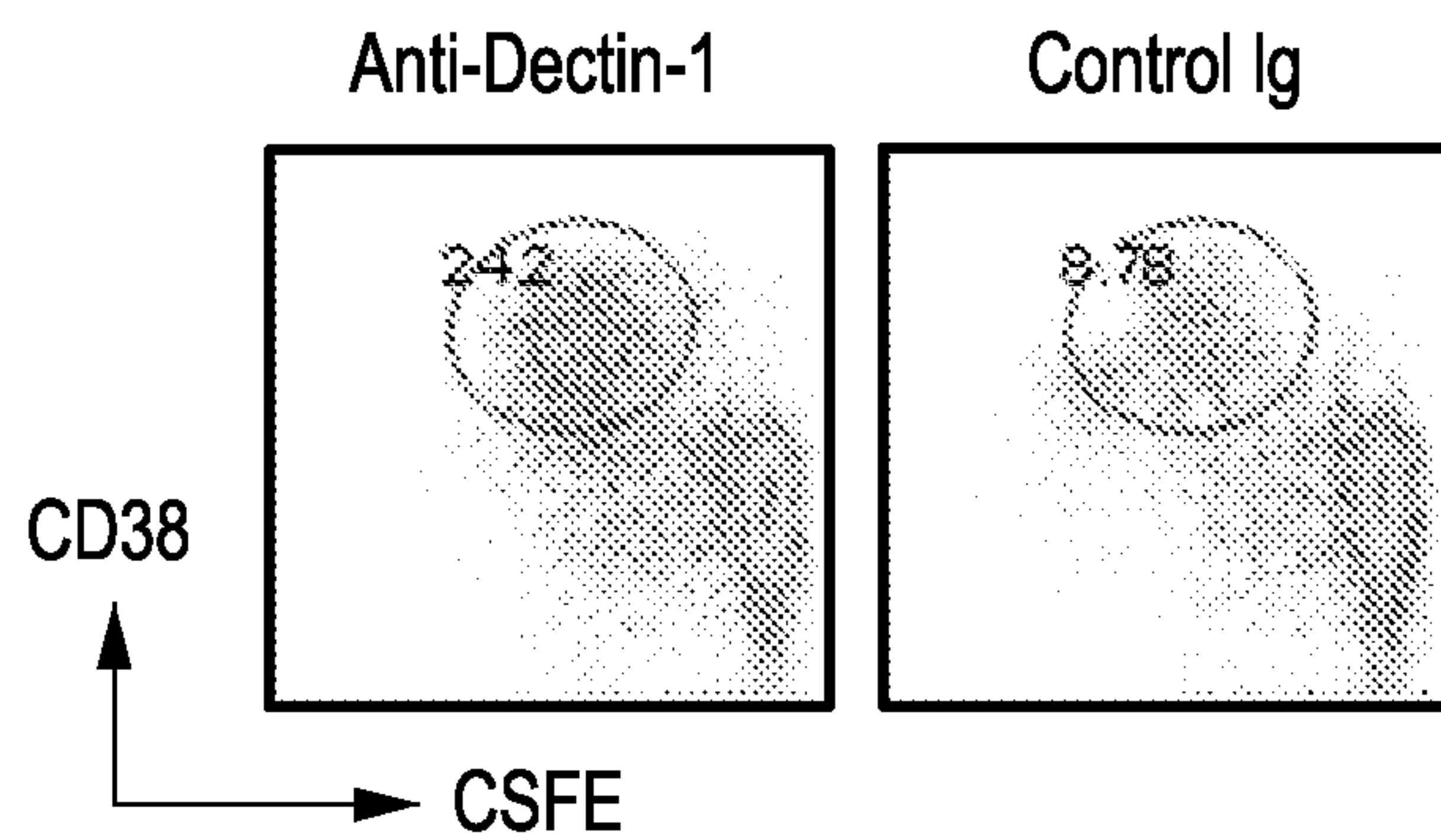


FIG. 9A

With CpG (50 nM)

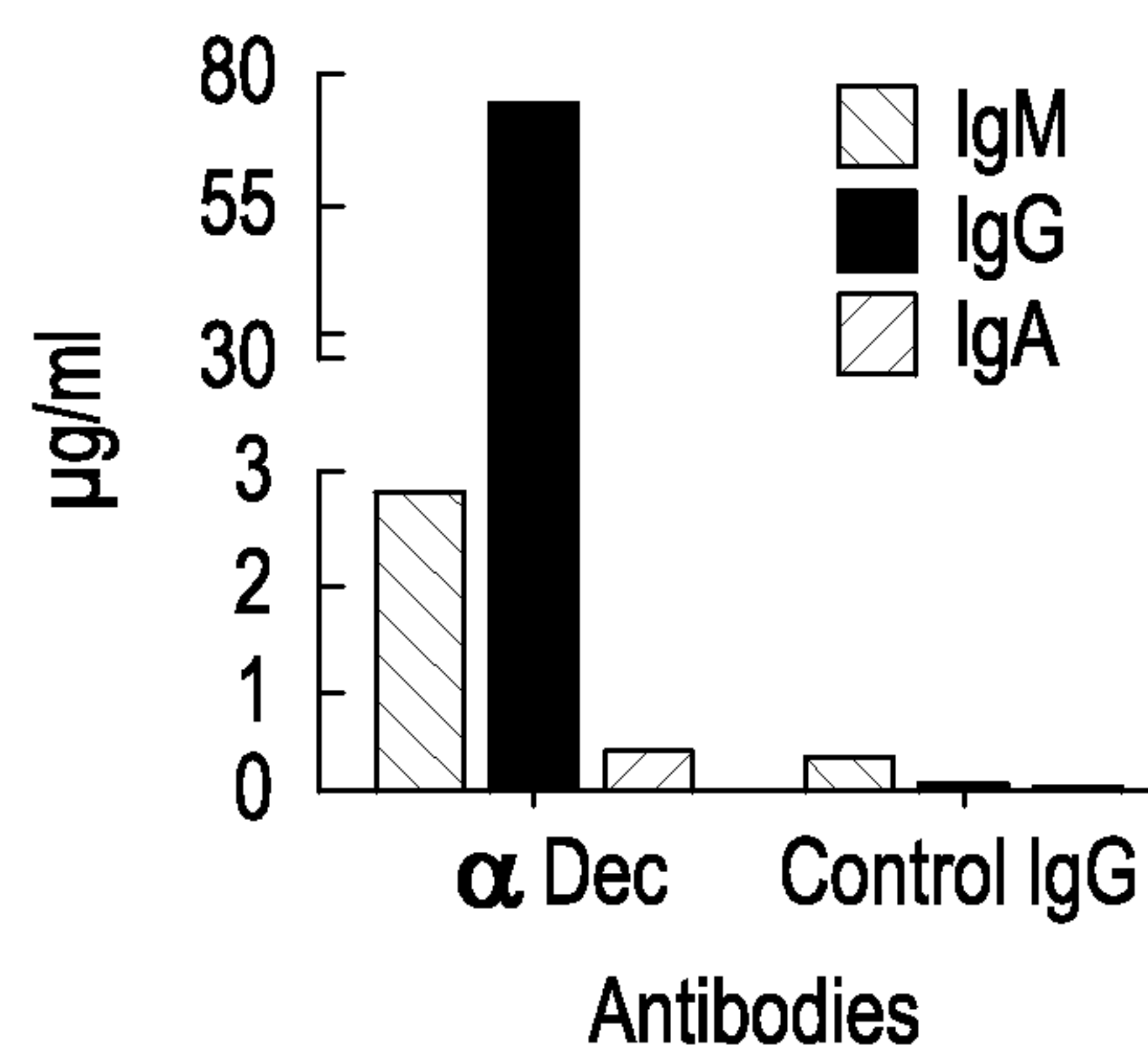
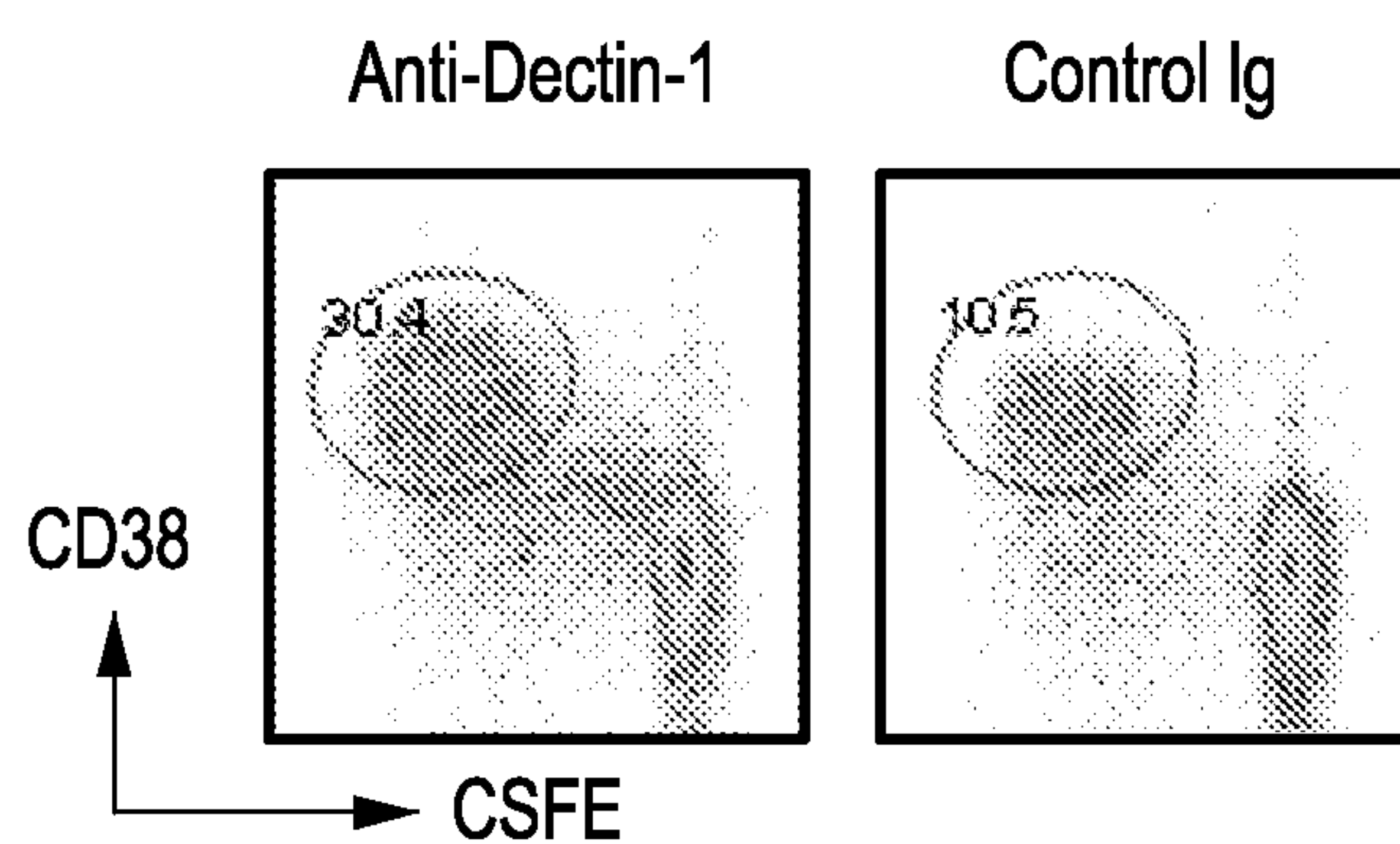


FIG. 9B

FIG. 10A

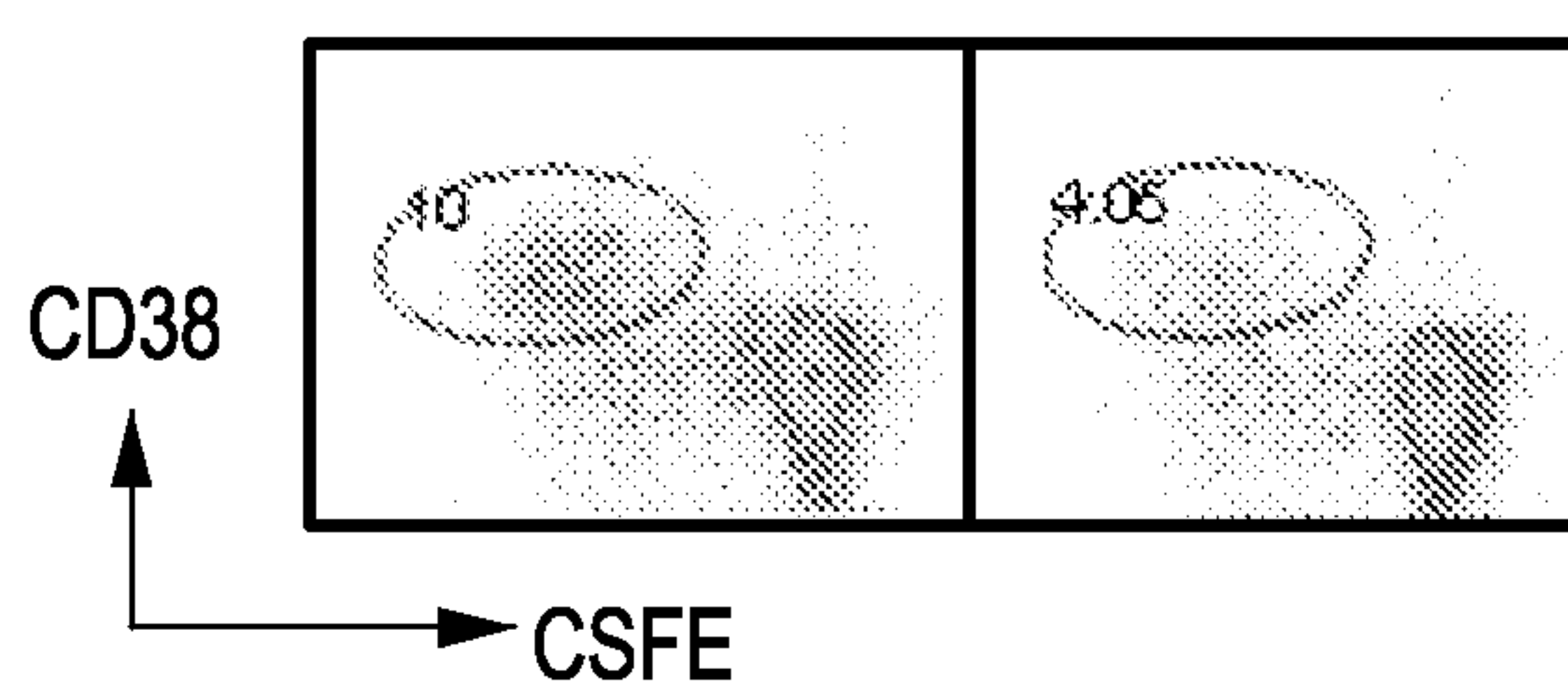
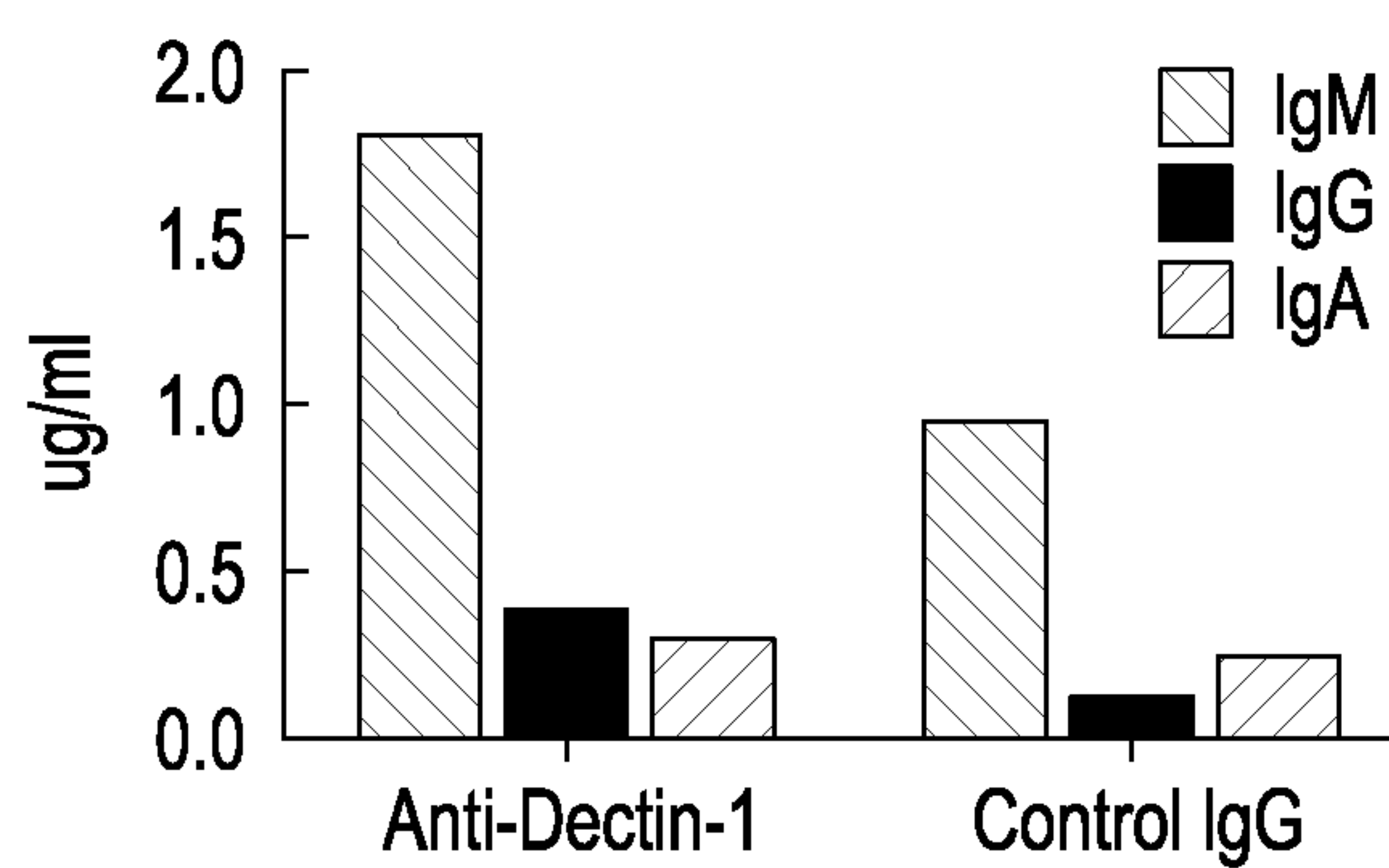
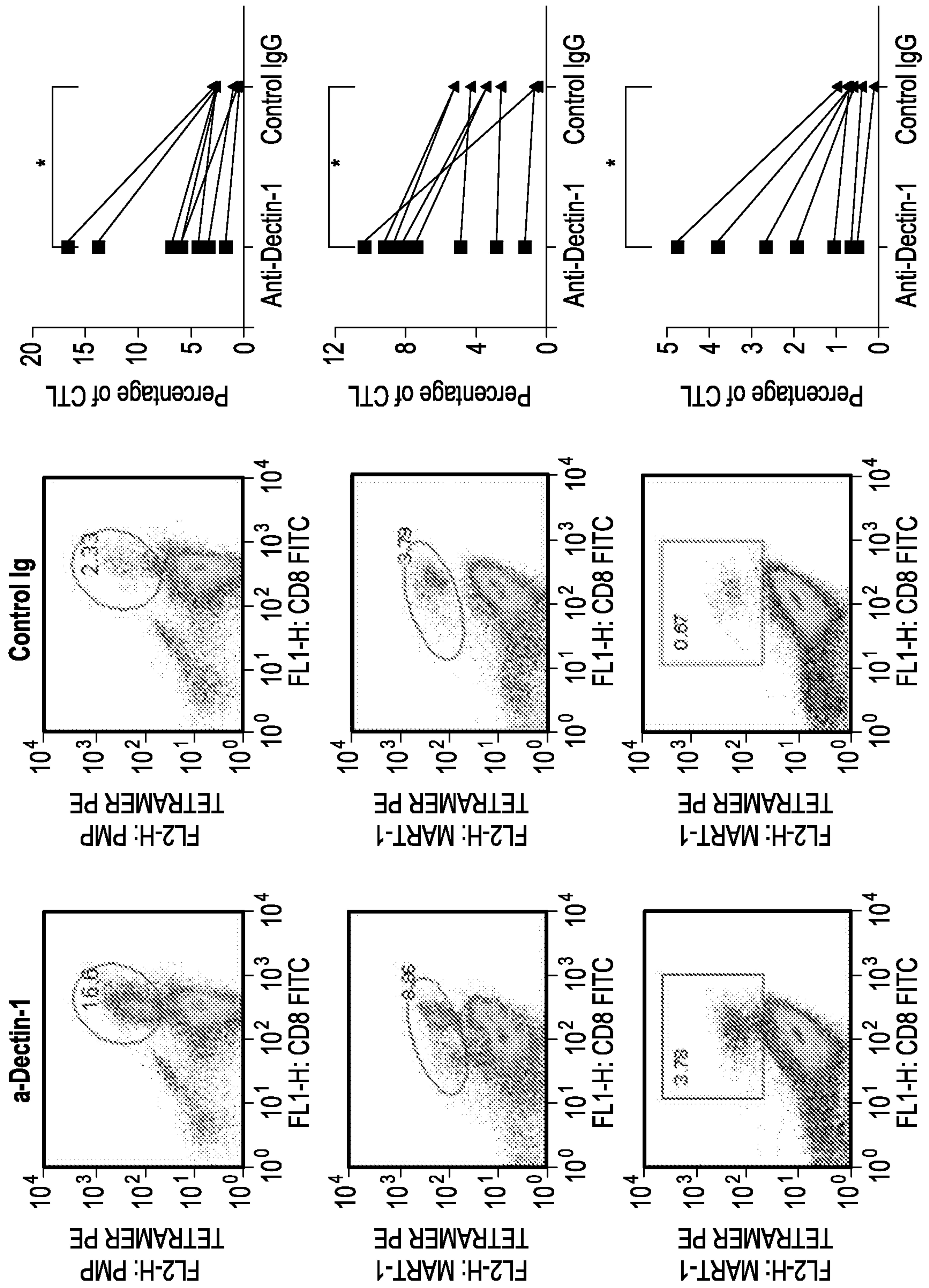


FIG. 10B



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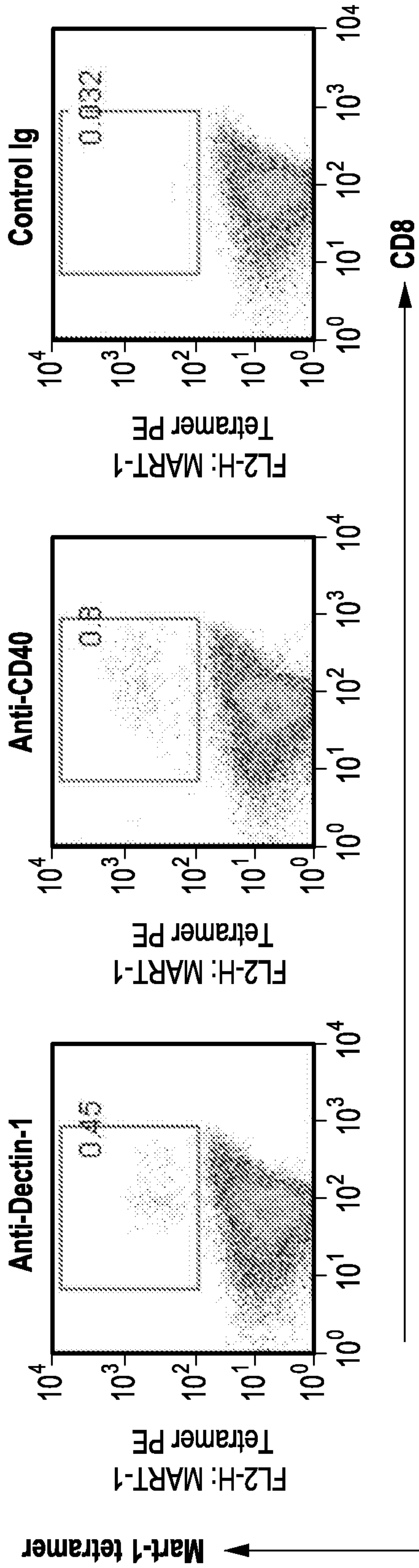


FIG. 12

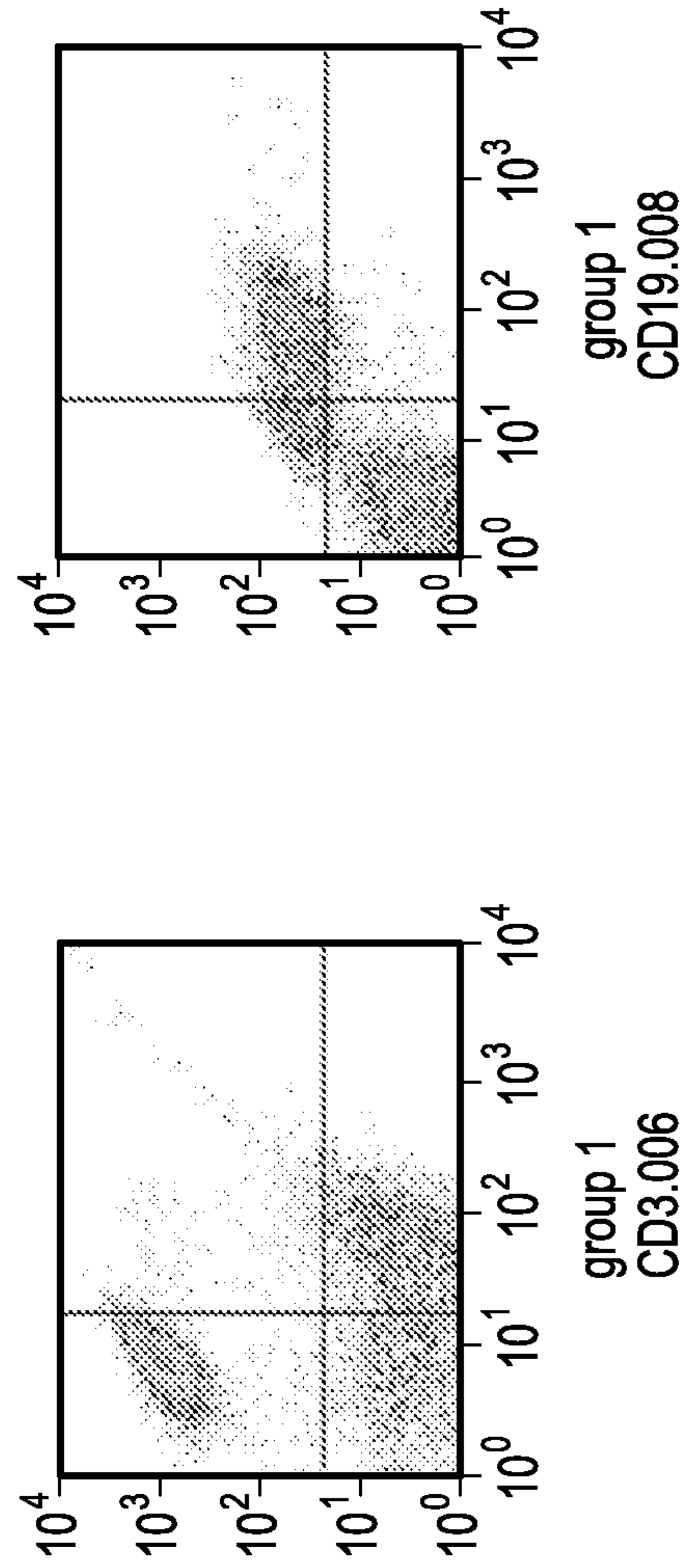


FIG. 13

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Human Skin Cross-section

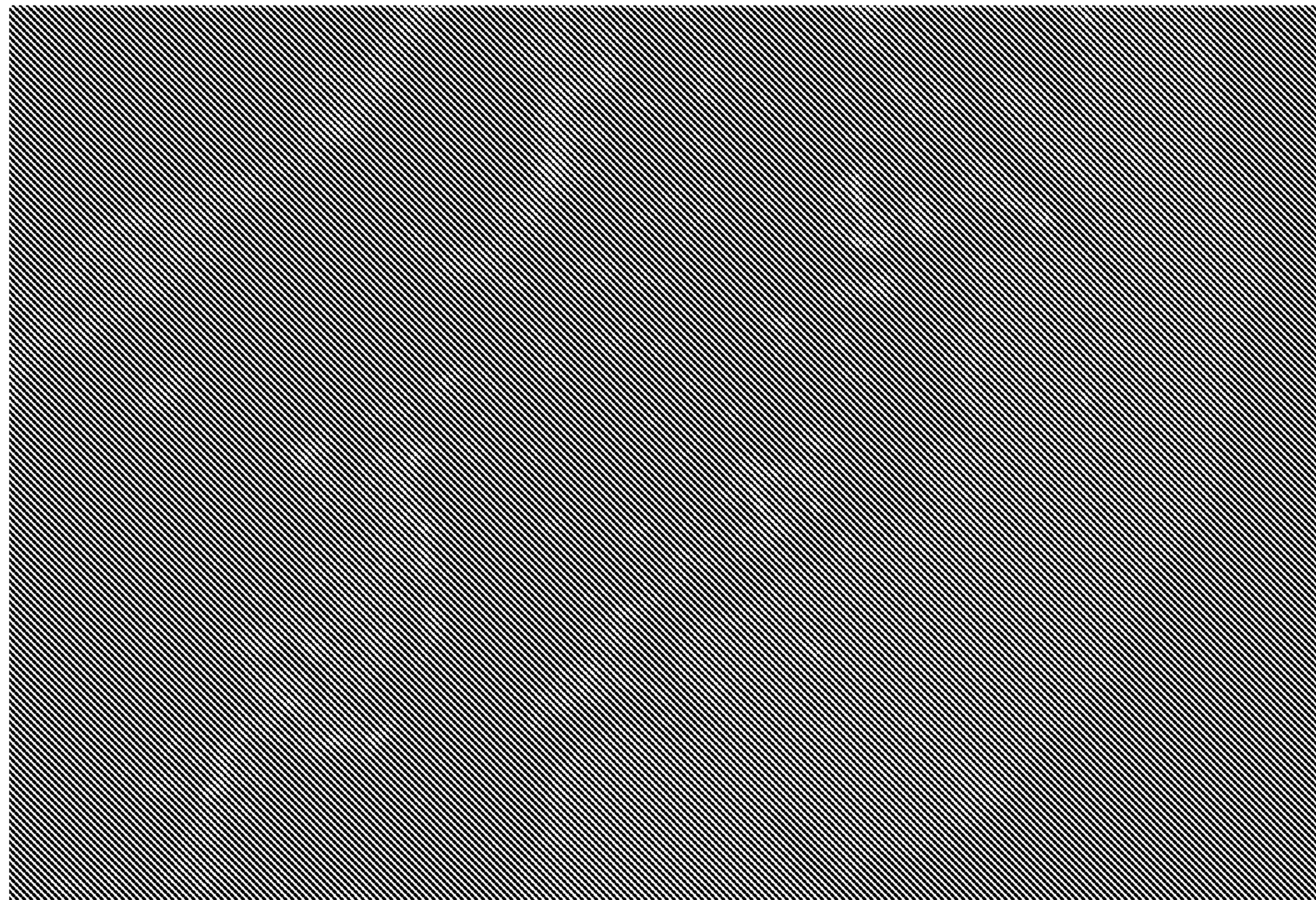


FIG. 14A

Human Lymph Node

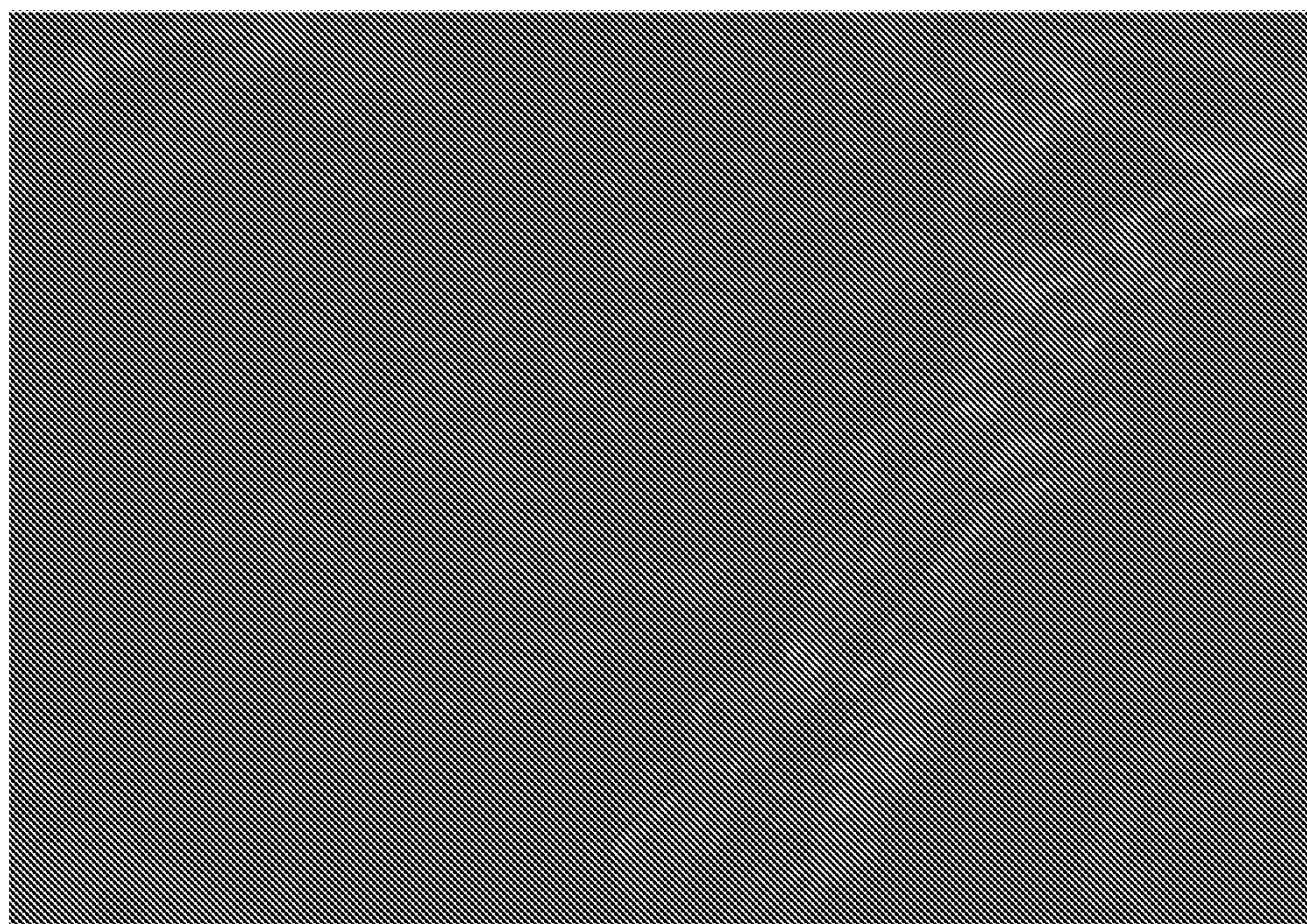


FIG. 14B

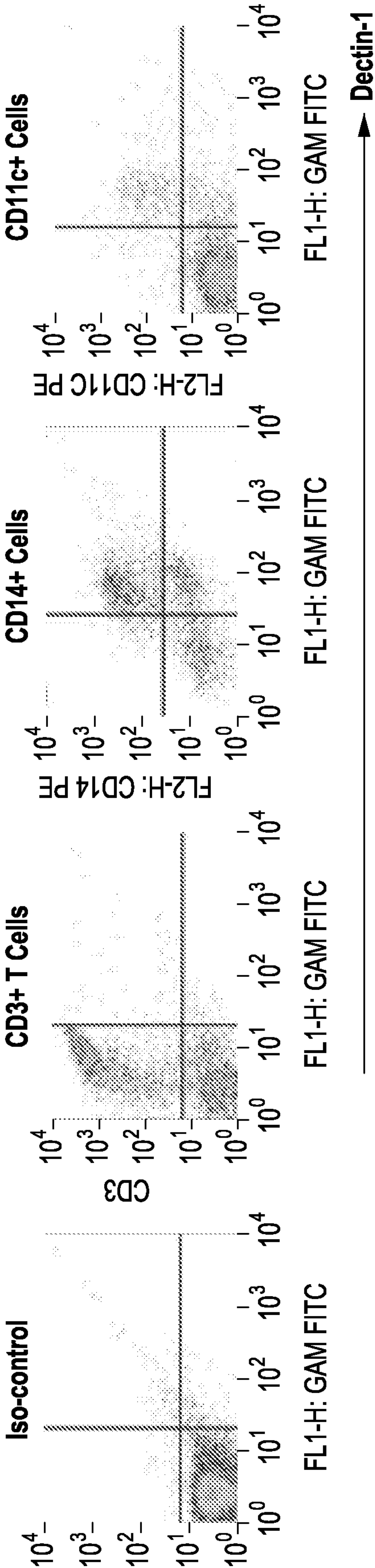


FIG. 15

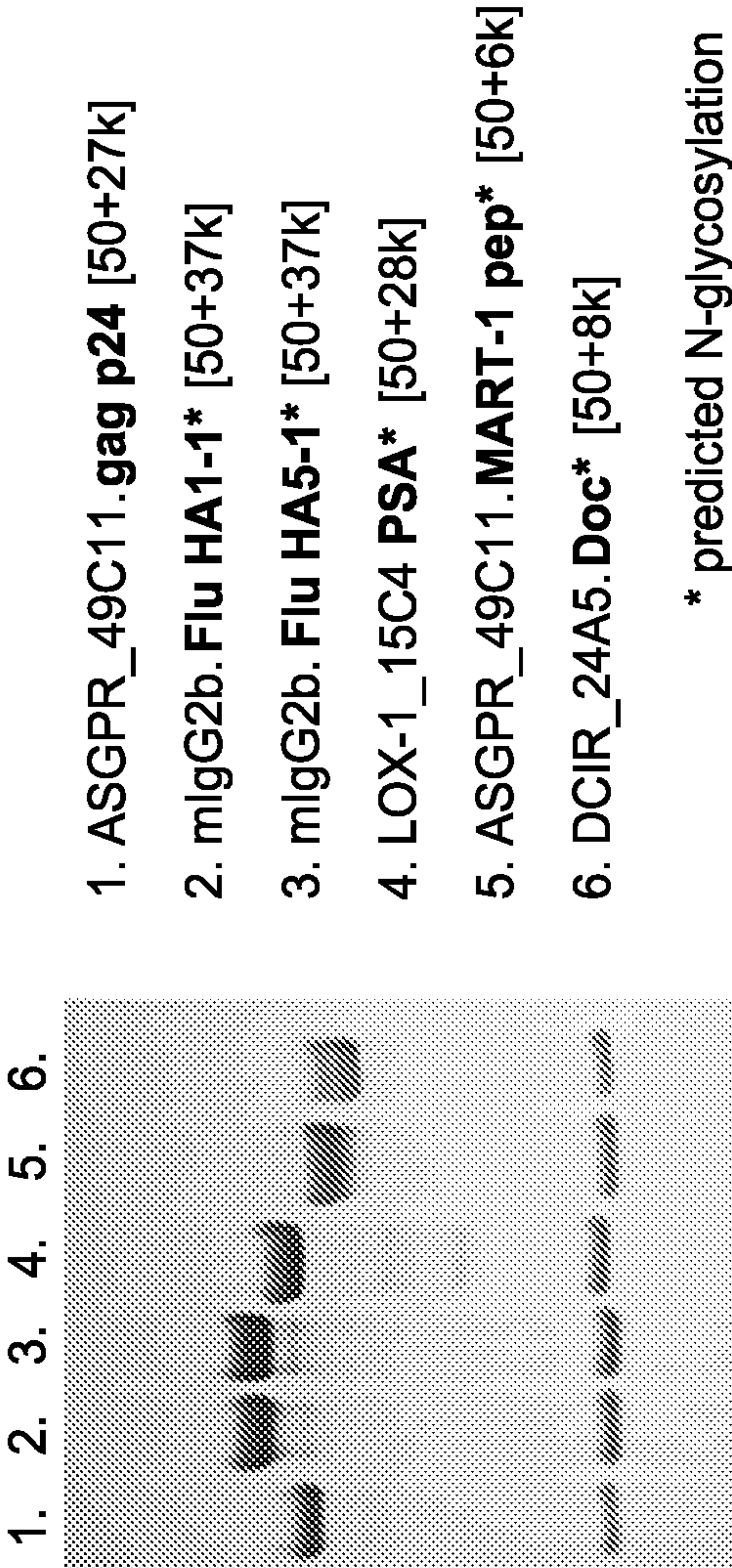


FIG. 16