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(71) Applicant: **MASSACHUSETTS INSTITUTE OF TECHNOLOGY** [US/US]; 77 Massachusetts Avenue, Cambridge, MA 02139 (US).

(72) Inventors: **IRVINE, Darrell, J.**; 17 Gray Street, Arlington, MA 02476 (US). **ZHENG, Yiran**; 143 Albany Street, Apt. 201A, Cambridge, MA 02139 (US).

(74) Agent: **DIPIETRANTONIO, Heather, J.**; Wolf, Greenfield & Sacks, P.C., 600 Atlantic Avenue, Boston, MA 02210-2206 (US).

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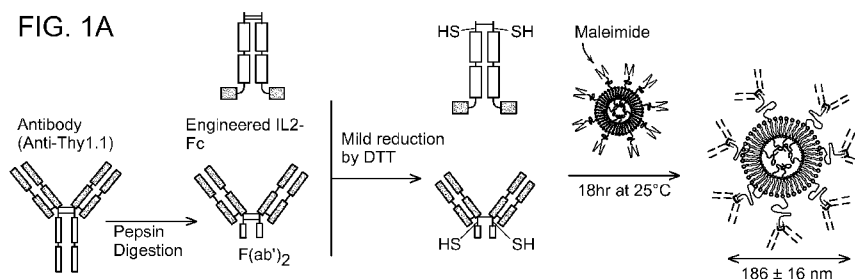
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(54) Title: *IN VIVO* TARGETING OF CELLS WITH LIGAND-CONJUGATED PARTICLES

FIG. 1A



(57) Abstract: The invention provides compositions and methods for, *inter alia*, augmenting cell-based therapies *in vivo* by repeatedly stimulating target cells of interest over a period of time.

***IN VIVO* TARGETING OF CELLS WITH LIGAND-CONJUGATED PARTICLES**

RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. § 119(e) of U.S. provisional
5 application number 61/837,137, filed June 19, 2013, which is incorporated by reference herein in its entirety.

FEDERALLY SPONSORED RESEARCH

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BACKGROUND OF INVENTION

15 Immunotherapy treatments stimulating a patient's own immune system to attack tumors are beginning to show signs of clinical efficacy, demonstrating that the immune system can be harnessed for cancer therapy even in patients with advanced disease [1-3]. Among many immunotherapy strategies in development, adoptive cell therapy (ACT) with autologous tumor-specific T-cells has shown particularly striking results in recent phase I clinical trials [3, 4]. In
20 this approach, autologous T-cells isolated from tumor biopsies or peripheral blood are treated with cytokine/stimulatory cocktails ex vivo to promote expansion of large numbers of tumor-reactive cells that can be re-infused into the patient, following which the transferred cells can home to disseminated tumor sites and destroy metastatic tumors. ACT therapy using completely autologous patient-derived tumor-infiltrating lymphocytes [4, 5] or patient T-cells transduced
25 with genetically engineered T-cell receptors [3, 6] (TCRs, either exogenous TCR chains or chimeric antigen receptors comprised of synthetic antigen-binding Ig domains fused with TCR signaling components) have been demonstrated to elicit objective response rates in up to 70% of patients with advanced metastatic melanoma [4-7] and dramatic cures in chronic lymphoblastic leukemia [3].

SUMMARY OF INVENTION

Aspects of the invention provide compositions and methods for enhancing endogenous or adoptively-transferred T-cell responses and include repeated (*e.g.*, at least 2 times, at least 3 times, at least 4 times, at least 5 times, or more) *in vivo* delivery (*e.g.*, systemic/intravenous delivery) of agents to tumor- or pathogen-reactive T-cells. Methods of the present disclosure, in some embodiments, employ particles to deliver agents to target cells of interest. For example, methods of the present disclosure may be used to target agents to T cells or other leukocytes, including endogenous T cells and adoptively-transferred T cells. In the context of adoptive cell therapy, adoptively-transferred leukocytes (*e.g.*, lymphocytes such as T cells) can be repeatedly stimulated with, for example, supporting adjuvants or other agents, thereby providing continuous supporting signals over prolonged durations that might be necessary for elimination of large tumor or pathogen burdens. Such “re-arming” of leukocytes (*e.g.*, lymphocytes such as T-cells) with supporting agents can be achieved by repeated administration of targeting particles. In this manner, adoptively-transferred or endogenous leukocytes (*e.g.*, lymphocytes such as T-cells) can be re-stimulated multiple times directly *in vivo*. Particles may target, or may be targeted to, particular cell types (*e.g.*, T cells) using cell-specific targeting molecules, such as, for example, ligands or receptors such as antibodies or antibody fragments. In some embodiments, further use of internalizing targeting ligands minimizes the likelihood of immune responses against the particle carrier.

Surprisingly, compositions and methods of the present disclosure permit, in some embodiments, *in vivo* administration of a targeting molecule and/or an agent at a dose higher than otherwise possible if the same targeting molecule and/or an agent were administered in soluble form. For example, as shown in Figures 6A-6C, co-administration of a mixture of soluble forms of anti-CD137 antibody and IL-2-Fc fusion protein to tumor-bearing subjects resulted in a decrease in tumor volume (FIG. 6A), but the percent survival of the subjects (an indication of toxicity) decreased to about 50% (FIG. 6C). By contrast, co-administration of a mixture of liposomal-conjugated anti-CD137 antibody and liposomal-conjugated IL-2-Fc fusion protein to tumor-bearing subjects, at a dose comparable to the soluble forms (*e.g.*, 100 µg anti-CD137, 20 µg IL-2-Fc), resulted in a decrease in tumor volume (FIG. 6A), and a percent survival rate of 100% (FIG. 6C).

Compositions and methods of the present disclosure, in some embodiments, employ particles having on their surface targeting molecules (e.g., ligands and/or antibodies or antibody fragments) that are specific for markers on the surface of target cells and, thus, bind to (or are bound by) the target cells. In some embodiments, target cells are leukocytes such as, for
5 example, lymphocytes, including T cells, B cells and NK cells. In some embodiments, target cells are tumor-reactive cells, such as tumor-reactive T cells. In some embodiments, target cells are pathogen-reactive cells.

Targeting molecules (e.g., ligands and antibodies, or antibody fragments), in some embodiments, function solely to target the particle to a particular cell. In other embodiments,
10 targeting molecules function solely to stimulate the target cell. In some embodiments, targeting molecules function to target the particle to the cell and to stimulate the cell. An example of such a targeting molecule is the ligand IL-2. Another example of a suitable targeting molecule is an antibody or antibody fragment that binds to Thy1 or CD137. An example of an antibody or antibody fragment that can function to stimulate the target cells is an anti-CTLA4 or an anti-PD-
15 1 antibody or antibody fragment.

Targeting particles (e.g., lymphocyte-targeting particles) of the present disclosure may further comprise active agents that act upon the target cells. The nature of the active agent may vary depending on the ultimate outcome that is sought. An example of a class of active agents is inhibitors of immunosuppression. In the context of adoptive cell therapy, such active agents can
20 reduce or eliminate the immunosuppression occurring in or around a tumor, thereby increasing the anti-tumor immune response.

Aspects of the invention provide methods that comprise repeated systemic administration of a population of lymphocyte-targeting particles to a subject, wherein the lymphocyte-targeting particles comprise on their surface at least one lymphocyte-targeting molecule that binds to a
25 lymphocyte cell surface marker. The present disclosure also contemplates, more generally, methods that comprise repeated systemic administration of a population of leukocyte-targeting particles to a subject, wherein the leukocyte-targeting particles comprise on their surface at least one leukocyte-targeting molecule that binds to a leukocyte cell surface marker.

In some embodiments, the at least one lymphocyte-targeting molecule stimulates
30 lymphocytes.

In some embodiments, the at least one lymphocyte-targeting molecule is a lymphocyte-specific ligand that binds to a receptor on the surface of a lymphocyte. In some embodiments, the at least one lymphocyte-targeting molecule is an antibody or an antibody fragment that binds to a cell surface molecule on the surface of a lymphocyte.

5 In some embodiments, the lymphocyte-targeting particles further comprise an active agent. The active agent may be encapsulated in the lymphocyte-targeting particles, or the active agent may be bound to a surface of the lymphocyte-targeting particles.

In some embodiments, the population comprises (a) lymphocyte-targeting particles comprising a first lymphocyte-targeting molecule and (b) lymphocyte-targeting particles
10 comprising a second lymphocyte-targeting molecule, wherein the second lymphocyte-targeting molecule is different from the first lymphocyte-targeting molecule.

In some embodiments, individual lymphocyte-targeting particles of the population comprise at least two lymphocyte-targeting molecules that are different from each other.

In some embodiments, the lymphocyte-targeting particles target endogenous T cells.

15 In some embodiments, the lymphocyte-targeting particles comprise an active agent that stimulates activity and/or proliferation of endogenous T cells.

In some embodiments, the lymphocyte-targeting particles target adoptively-transferred T-cells or T cells engineered to express a T cell receptor.

In some embodiments, the lymphocyte cell surface marker is ART2, CD1a, CD1d, CD2,
20 CD3, CD4, CD5, CD7, CD8, CD11b, CD25, CD28, CD38, CD45RO, CD72, CD134, CD137, CD150, CD154, CRTAM, FOXP3, FT2, GPCA, HLA-DR, HML-1, HT23A, LEU-22, LFA-1, LY-2, LY-M22, MICG, MRC-OX-8, MRC-OX-22, OX-40, PD-1, RT-6, TCR, THY-1 (CD90), TIM-3, CTLA-4 or TSA-2, or any combination thereof

In some embodiments, the lymphocyte-specific ligand is a cytokine, interleukin,
25 chemokine or growth factor. In some embodiments, the lymphocyte-specific ligand is a cytokine.

In some embodiments, the cytokine is IL-2, IL-7, IL-15, CXCL10, CXCL5, MIP-1a, MIP-1b, or an Fc-fusion protein of any one of the foregoing cytokines.

In some embodiments, the antibody is anti-Thy1 (*e.g.*, anti-Thy1.1), anti-CD137, anti-
30 CTLA-4, anti-PD-1, or an antibody fragment of any one of the foregoing antibodies.

In some embodiments, the active agent is a chemical entity, a protein, a polypeptide, a peptide, a nucleic acid, a virus-like particle, a steroid, a proteoglycan, a lipid or a carbohydrate.

In some embodiments, the active agent is a therapeutic agent.

In some embodiments, the active agent is an agent that inhibits immunosuppression. For example, the active agent that inhibits immunosuppression may be a Shp1/2 protein tyrosine phosphatase (PTPase) inhibitor.

In some embodiments, the lymphocyte-targeting particles are lymphocyte-targeting liposomes. For example, the lymphocyte-targeting liposomes may be PEGylated lymphocyte-targeting liposomes.

In some embodiments, the lymphocyte-targeting particles are polymer-based lymphocyte-targeting particles.

In some embodiments, repeated administration comprises daily, weekly or biweekly administration.

In some embodiments, the subject has cancer.

In some embodiments, the subject has an infection.

In some embodiments, the lymphocyte-targeting particles are administered parenterally to the subject.

In some embodiments, the subject is undergoing or has undergone adoptive cell therapy.

In some embodiments, the targeting molecule and/or active agent is administered at a dose that is greater than the maximum tolerated dose of a soluble form of the active agent.

Aspects of the invention provide a method comprising repeated administration of lymphocyte-targeting particles to a subject undergoing adoptive cell therapy, wherein the lymphocyte-targeting particles comprise

(a) on their surface, at least one of

(i) a lymphocyte specific ligand and

(ii) an antibody or antibody fragment that binds to a lymphocyte cell surface marker, and

(b) internally, an active agent.

In another aspect, the invention provides a method comprising repeated administration of particles to a subject undergoing adoptive cell therapy, wherein the particles comprise IL-2 or an IL-2-Fc fusion protein on their surface.

In some embodiments, the administration is not local administration. In some
5 embodiments, the administration is systemic administration.

In some embodiments, the particles internally comprise an active agent. In some
embodiments, the active agent is an agent that inhibits immunosuppression. In some
embodiments, the agent that inhibits immunosuppression is a Shp1/2 protein tyrosine
phosphatase (PTPase) inhibitor.

10 In some embodiments, the lymphocyte specific ligand is a cytokine. In some
embodiments, the lymphocyte specific ligand is IL-2 or an IL-2-Fc fusion protein.

In some embodiments, the lymphocyte cell surface marker is Thy1 (*e.g.*, anti-Thy1.1). In
some embodiments, the lymphocyte cell surface marker is CD137. In some embodiments, the
lymphocyte cell surface marker is CTLA-4. In some embodiments, the lymphocyte cell surface
15 marker is PD-1.

In some embodiments, repeated administration comprises daily, weekly, or biweekly
administration. In some embodiments, repeated administration comprises administration
substantially simultaneously with the administration of tumor-reactive lymphocytes cells, and at
least one administration after administration of tumor-reactive lymphocytes. In some
20 embodiments, the tumor-reactive lymphocytes are tumor-reactive T cells. In some embodiments,
the tumor-reactive T cells are tumor-reactive CD8+ T cells.

In some embodiments, the adoptive cell therapy comprises administration of tumor-
reactive CD8+ T cells.

In another aspect, the invention provides a method comprising repeated administration of
25 lymphocyte-targeting particles to a subject, wherein the lymphocyte-targeting particles comprise

(a) on their surface, at least one of

(i) a lymphocyte-specific ligand and

(ii) an antibody or antibody fragment that binds to a lymphocyte cell surface
marker, and

30 (b) internally, an active agent.

In another aspect, the invention provides a method comprising repeated administration of particles to a subject, wherein the particles comprise IL-2 or an IL-2-Fc fusion protein on their surface.

In some embodiments, the particles internally comprise an active agent. In some
5 embodiments, the active agent is an agent that inhibits immunosuppression. In some
embodiments, the agent that inhibits immunosuppression is a Shp1/2 protein tyrosine
phosphatase (PTPase) inhibitor.

In some embodiments, the lymphocyte specific ligand is a cytokine. In some
embodiments, the lymphocyte specific ligand is IL-2 or an IL-2-Fc fusion protein.

10 In some embodiments, the lymphocyte cell surface marker is Thy1 (*e.g.*, anti-Thy1.1). In
some embodiments, the lymphocyte cell surface marker is CD137, CTLA-4 or PD-1.

In some embodiments, the particles are liposomes, including PEGylated liposomes,
having on their surface either IL-2 (*e.g.*, in the form of an IL-2-Fc fusion) or anti-Thy1 (*e.g.*,
anti-Thy1.1) antibodies or antibody fragments, and optionally comprising Shp1/2 PTPase
15 inhibitor.

In some embodiments, repeated administration comprises daily, weekly or biweekly
administration.

In some embodiments, the particles target endogenous T cells. In some embodiments, the
particles comprise an agent that stimulates activity and/or proliferation of endogenous T cells.

20 In some embodiments, the subject has an infection. In some embodiments, the subject
has a cancer.

In some embodiments, the particles are liposomes. In some embodiments, the liposomes
are PEGylated liposomes. In some embodiments, the particles are polymer-based particles.

In some embodiments, the particles are administered parenterally. The particles are
25 typically formulated and thereby administered without cells (*e.g.*, such formulations do not
contain cells that act as carriers for the particles).

It should be appreciated that all combinations of the foregoing concepts and additional
concepts discussed in greater detail below (provided such concepts are not mutually inconsistent)
are contemplated as being part of the inventive subject matter disclosed herein. In particular, all

combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter disclosed herein.

BRIEF DESCRIPTION OF DRAWINGS

5 FIGs. 1A-1C show T-cell-targeted liposome synthesis and characterization. (A) Schematic of immunoliposome preparation. (B) Typical particle size distributions for liposomes before antibody conjugation (open bars) and after conjugation (black filled bars) determined by dynamic light scattering. (C) Quantification of ligand (IL-2 cytokine equivalent or anti-Thy1.1) coupled to liposomes incorporating different mole fractions of maleimide-PEG lipid: 2.5% (black filled bar), 1% (open bar) or 0% (striped bar), assessed by IL-2 ELISA and measuring
10 FITC-labeled anti-Thy1.1 incorporation respectively.

 FIGs. 2A-2F show *in vitro* binding of IL-2-Fc-Lip and anti-Thy1.1 F(ab')₂-Lip to primary T-cells. (A) Flow cytometry analysis of cell surface expression of CD25 and Thy1.1 on naïve C57BL/6/J (Thy1.1⁻) splenocytes vs. activated pmel-1 Thy1.1+CD8⁺ T-cells. (B, C) Pmel-
15 1 CD8⁺ Thy1.1⁺ T-cells were incubated with 0.7 mg/ml (per 15×10⁶ cells) DiD-labeled liposomes (IL-2-Fc or anti-Thy1.1 F(ab')₂ conjugated) for 30 min at 37 °C in complete RPMI, then analyzed by flow cytometry for liposome binding. Shown are representative flow cytometry scatter plots (B) and quantification of Mean Fluorescence Intensity (MFI) of pmel-1 T-cells as a function of mol% of mal-PEG-DSPE included in the vesicles (C). (D, E) Activated
20 pmel-1 CD8⁺ T-cells were mixed with naïve C57BL/6 splenocytes in a 1:1 ratio and incubated with 0.07 mg/ml IL-2-Fc-Lip or 0.15 mg/ml anti-Thy1.1-Lip for 30 min at 37 °C, then analyzed by flow cytometry. (D) Shown are scatter plots representing liposome fluorescence on naïve C57BL/6 CD8⁺ T cells (Thy1.1⁻) and activated pmel-1 CD8⁺ T-cells (Thy1.1⁺) with/without 0.24 mg/ml soluble IL-2-Fc or 1.34 mg/ml anti-Thy1.1 antibody added for 30 min prior to
25 addition of liposomes. Cells incubated with 0.15 mg/ml IgG2a-lipo are also shown. (E) Quantification of the MFI of Pmel-1 CD8⁺ T cells when bound with respective liposomes or pre-blocked by free Ab/IL-2. (F) Titrated concentrations of fluorescent liposomes were added to 5 ×10⁶ activated pmel-1 T-cells and incubated at 37°C for 30 min, then analyzed by flow cytometry for MFI of T-cell-associated liposomes. *, p<0.05; **, p<0.01; ***, p<0.001.

FIG. 3 shows internalization of Thy1.1-targeted liposomes. Carboxy-fluorescein (CF)-labeled anti-Thy1.1-Lip (1.4 mg/ml) were incubated with 12×10^6 activated pmel-1 CD8+ T-cells in 500 μ l RPMI containing 10% FCS for 1 hr at 4°C, washed, then incubated in RPMI at 37°C until analysis by flow cytometry 2 hr, 4 hr or 6 hrs later. (A) MFI of T-cell-associated CF
 5 fluorescence. (B) Confocal images of cells at time zero or after 6 hr at 37°C. Scale bar= 20 μ m.

FIGs. 4A-4F show that IL-2-Fc- and anti-Thy1.1-Liposomes target transferred T-cells *in vivo*. C57Bl/6 mice received i.v. adoptive transfer of 15×10^6 pmel-1 CD8+Thy1.1+ T-cells, followed by i.v. injection of 1.4 mg IL-2-Fc-Lip, anti-Thy1.1-Lip, or isotype control IgG2a-Lip either immediately after the T-cells or 3 days after the T-cells. Liposome binding to cells
 10 recovered from lymphoid organs and blood was analyzed 24 hr after liposome injections by flow cytometry. (A) Timeline of injections and analysis. (B) Representative flow cytometry plots illustrating gating strategy for analysis of liposome binding to transferred pmel-1 T-cells or endogenous CD8+ T-cells. (C) Representative histograms of pmel-1 T-cell or endogenous CD8+ T-cell labeling following day 0 liposome injections. (D-F) Quantification of percentages
 15 of endogenous or transferred T-cells labeled by day 0 or day 3 liposome injections in the blood (D), lymph nodes (E), and spleen (F). n=5 animals/group for IgG2a-Lip and anti-Thy1.1-Lip and n=3 for IL-2-Fc-Lip. *, p<0.05; **, p<0.01; ***, p<0.001.

FIGs. 5A-5E show that IL-2-Fc-liposomes allow repeated expansion of target ACT T-cells *in vivo* in tumor-bearing animals. (A-C) B16F10 tumor cells (1×10^6) were injected i.v. into
 20 albino C57Bl/6 mice and allowed to establish lung metastases for 7 days. Animals were then sublethally lymphodepleted by irradiation and received i.v. adoptive transfer of 12×10^6 luciferase-expressing pmel-1 CD8+ T-cells the next day. One group of mice additionally received injections of IL-2-Fc-Lip (1 mg, carrying 60 μ g IL-2-Fc or 20 μ g IL-2 cytokine equivalent) i.v. immediately after T-cell transfer and again on day 6. (A) Timelines of
 25 cell/liposome injections and bioluminescence imaging of T-cells. (B) Representative bioluminescent images of ACT T-cells over time. (C) Quantification of average whole-body T-cell bioluminescence over time. (D-E) Groups of C57B/6 mice with established lung metastases were left untreated or were treated with T-cells as in A, then received either IL-2-Fc-Lip or equivalent total doses of systemic free IL-2 (10 μ g day 0, 20 μ g day 6) injected i.v. on day 0 and
 30 day 6. (D) Sample flow cytometry analyses showing percentages of tumor-specific ($\nu\beta 13$

TCR+) CD8+ T-cells among T-cells in inguinal lymph nodes on day 12 after adoptive transfer.

(E) Quantification of average frequency of tumor-specific ($\nu\beta 13$ TCR+) CD8+ T-cells in inguinal lymph nodes 12 days after adoptive transfer. n=3-4 animals/group. *, $p < 0.05$; **, $p < 0.01$.

FIG. 6A shows a graph representative of particle size of liposomes measured by dynamic light scattering. Medium gray: liposome-Maleimide; Dark gray: liposome-CD137; Light gray: liposome-IL-2-Fc. FIG. 6B shows a cryo-transmission electron microscopy (TEM) image of antibody-conjugated liposomes.

FIGs. 7A-7C show graphs representative of tumor growth inhibition (FIG. 7A), relative body weight changes (normalized to day 0) (FIG. 7B) and a survival curve of the treatment (FIG. 7C) from B16-OVA tumor bearing mice that were given intravenous injections on day 0, 2 and 4 with a 100 $\mu\text{g}/\text{dose}$ of CD137 and a 20 $\mu\text{g}/\text{dose}$ of IL-2-Fc (untreated, soluble CD137/IL-2-Fc, liposome-conjugated CD137 and liposome-conjugated IL-2-Fc, or liposome-conjugated IgG).

FIG. 8 shows a graph representative of CD8⁺ T cell enrichment in peripheral blood mononucleated cells (PBMCs) on day 6 post injection. CD8+ T cell numbers were analyzed by flow cytometry.

FIGs. 9A-9B show graphs representative of intracellular cytokine staining of IFN γ (FIG. 9A) and TNF α (FIG. 9B) in CD8+ T cells from PBMC. Lymphocytes from PBMC (day 6 post injection) were pulsed with 10 μm OVA protein before analyzed by flow cytometry.

FIGs. 10A-10C show graphs representative of tumor growth inhibition (FIG. 10A), relative body weight changes (normalized to day 0) (FIG. 10B) and survival curve of the treatment (FIG. 10C) obtained from B16F10 tumor bearing mice that were given intravenous injections on day 0, 3 and 6 with a 100 $\mu\text{g}/\text{dose}$ of CD137 and a 60 $\mu\text{g}/\text{dose}$ of IL-2-Fc.

FIG. 11 shows graphs representative of serum cytokine levels obtained from mice after systemic delivery of lipo-CD137/IL-2-Fc, showing prevention of lethal systemic inflammatory toxicity. Two days after single intravenous injection on B16F10 tumor bearing mice, blood serums were collected and serum cytokine levels were measured by LUMINEX[®] cytokine bead assay.

DETAILED DESCRIPTION OF INVENTION

Aspects of the invention provide methods for augmenting lymphocyte function *in vivo* by repeated stimulation of lymphocytes *in vivo* using particles that comprise stimulatory agents and/or inhibitors of immunosuppression. In some embodiments, the lymphocytes are adoptively-
5 transferred lymphocytes, such as those used in adoptive cell therapy, which has been used in the treatment of cancer. In some embodiments, the lymphocytes may be endogenous lymphocytes. Aspects of the invention are premised, in part, on the unexpected and, thus, surprising finding that repeated administration of particles comprising stimulatory agents and/or inhibitors of immunosuppression augments the activity of target cells *in vivo* more efficiently than systemic
10 administration of stimulatory agents (see for example FIG. 5E). It is therefore contemplated by the invention that the beneficial effects of adoptive cell therapy may be extended in time and augmented in efficacy by boosting the activity and/or proliferation of transferred cells at various times post-transfer. Each administration of particles of the invention to a subject may be regarded as a “boost” since it will result in proliferation of the target cells of interest (and thus
15 expansion of such cell populations), increased longevity of the target cells of interest, and/or increased activity of the target cells of interest.

Provided herein are experimental results evidencing specific targeting of adoptive cell therapy (ACT) T-cells (also referred to herein as adoptively-transferred T cells) *in vivo* using particles in the form of liposomes. Surprisingly, repeated systemic administration to tumor-
20 bearing subjects did not lead to a toxic proinflammatory response, and subjects survived and cleared tumors, indicating that the easier route of administration (systemic, instead of intratumoral) is effective. In these illustrative examples, PEGylated liposomes were conjugated with two types of targeting molecules. The first type of targeting molecule is an antibody against a cell surface antigen expressed by the ACT T-cells. The cell surface antigen may be one that
25 the target cell normally expresses or it may one that the target cell is made to express, for example, through genetic engineering strategies. An example of a cell surface antigen is Thy1.1. The second type of targeting molecule is a ligand, the receptor for which is found on ACT T cells. One such ligand is interleukin-2 (IL-2). IL-2 binds the trimeric IL-2 receptor (IL-2R) expressed by activated T cells. These targeting molecules provide contrasting targeting
30 strategies: anti-Thy1.1 provides highly specific targeting without overt stimulation of target cells,

while IL-2 provides potentially less specific targeting (since IL-2R can be expressed by some endogenous T-cells) but also delivers a direct stimulatory signal to T cells.

Targeting liposomes were shown to label T cells in multiple systemic compartments *in vivo*, with anti-Thy1.1 liposomes binding to >90% of transferred cells following a single systemic injection. Additionally, multiple periodic administrations of targeted stimulatory IL-2-conjugated liposomes resulted in repeated expansion of ACT T-cells *in vivo*.

Accordingly, the aspects of the invention contemplate that these targeted particle strategies can be used to safely amplify the efficacy of ACT while avoiding systemic toxicity associated with many adjuvant drug treatments. Aspects of the invention further contemplate that the strategies are amenable and translatable to other immunotherapy settings, such as enhancement of cancer vaccines and therapeutic interventions in infectious diseases such as human immunodeficiency virus (HIV), which may rely on transferred cells and/or on endogenous cells.

It was also found, surprisingly, that administration of IL-2 conjugated to particles of the invention, and lacking another active agent, resulted in greater expansion of tumor-reactive CD8+ T cells as compared to the same dose of soluble IL-2. As described in greater detail in the Examples, administration of soluble IL-2 at the same dose provided no enhancement in T cell expansion. Accordingly, aspects of the invention also contemplate the use of particles having surface-conjugated IL-2 in expanding T cell populations *in vivo*, including but not limited to tumor-reactive T cells used in adoptive cell therapy (referred to as adoptively-transferred T cells).

Applications

Methods of the present disclosure embrace the unexpected findings that repeat systemic administration of agents, including targeting molecules, is therapeutically effective when the agents are delivered conjugated to a particle (*e.g.*, liposome) and that in so doing, it is possible to administer the agents in a dose that would otherwise be toxic if administered in soluble form. It is to be understood that methods of the invention may be used in a variety of applications in which it is desirable to deliver agents specifically to a target cell population (*e.g.*, endogenous T cells and/or adoptively-transferred T cells), and where it is desirable to continually and

repeatedly boost an immune response (*e.g.*, multiple boosts over the course of several days or weeks). One advantage of the methods of the invention is the ability to deliver active agents to particular cells of interest (*e.g.*, lymphocytes), potentially at particular regions of the interest in the body, thereby avoiding the adverse effects associated with simple systemic administration of a soluble active agent.

Methods of the present disclosure may, therefore, be used in subjects undergoing or who have undergone adoptive cell therapy. Typically, such subjects have cancer or are at risk of developing cancer (*e.g.*, they may be in remission or may be genetically or environmentally predisposed to developing cancer).

Methods of the present disclosure, however, may also be used in other applications that require enhanced immune responses, including prolonged enhanced immune responses over a period of time. Non-limiting examples include vaccine-based methods and cell-based methods.

Target cells

Cells that may be targeted using particles of the invention may be those occurring endogenously in a subject, or those that are transferred (*e.g.*, administered) to a subject, for example, for therapeutic or prophylactic benefit. A cell is considered “endogenous” in a subject if it originates from within the subject and has never been removed from the subject. A cell is considered an “adoptively-transferred cell” if it is obtained from a subject and then transferred back into the same subject or if it is obtained from a subject and transferred into a new subject. Adoptively-transferred cells include, for example, autologous subject-derived (*e.g.*, human patient-derived) tumor-infiltrating lymphocytes as well as subject T cells transduced with engineered (*e.g.*, genetically engineered) T cell receptors (TCRs). T cell receptors may be, for example, exogenous T cell chains or chimeric antigen receptors composed of synthetic antigen-binding Ig domains fused with TCR signaling components. A cell is considered to be “subject-derived” if it is obtained from (*e.g.*, isolated from) the subject.

In the context of adoptive cell therapy, the target cells and the transferred cells are typically one and the same in the context of the invention. For example, tumor-reactive CD8⁺ T cells may be transferred to a subject in need of such therapy, and may also be targeted by particles of the invention. The target cells are typically immune cells such as, but not limited, to

lymphocytes. Lymphocytes of the present disclosure may be T cells, such as CD8⁺ T cells, B cells or natural killer (NK) cells. In the context of adoptive cell therapy in subjects having cancer, the target cells are tumor-reactive (or tumor-specific) T cells. Transferred cells may be autologous to the subject being treated, or they may be allogeneic.

5 It is to be understood that any immune cell-based therapy may benefit from methods of the invention, including therapies that involve transfer of dendritic cells, cell-based vaccines, and the like and therapies that involve stimulation of endogenous lymphocytes.

Target cells may be tumor-reactive cells. This means that they recognize and/or bind to tumor cells and/or are involved in an immune response directed against the tumor.

10 Target cells may be pathogen-reactive cells. This means that they recognize and/or bind to pathogens or pathogen-infected cells and/or are involved in an immune response directed against the pathogen or pathogen-infected cells.

Target cells (*e.g.*, lymphocytes) of the present disclosure have cell surface markers that bind to (or are bound by) cognate recognition molecules (*e.g.*, lymphocyte-targeting molecules) present on the surface of targeting particles (*e.g.*, lymphocyte-targeting particles). A “cell surface marker” refers to a moiety present on the surface of cells that serves as a marker of specific cell types. Cell surface moieties include, without limitation, those used for immunophenotyping cells, such as CD (Classification Determinant) proteins. Other cell surface moieties are contemplated herein. It should be understood that cell-specific targeting molecules present on particles of the present disclosure typically confer cell-specific targeting of the particles. Thus, for example, a liposome conjugated to an anti-CD137 antibody is considered a lymphocyte-targeting particle (and more specifically, a T cell-targeting particle) because anti-CD137 antibody is a lymphocyte-targeting molecule that specifically recognizes and binds to CD137, which is expressed on T cells, thereby targeting the particle to the T cells.

25 Examples of lymphocyte cell surface markers include, without limitation, ART2, CD1a, CD1d, CD2, CD3, CD4, CD5, CD7, CD8, CD11b, CD25, CD28, CD38, CD45RO, CD72, CD134, CD137, CD150, CD154, CRTAM, FOXP3, FT2, GPCA, HLA-DR, HML-1, HT23A, LEU-22, LFA-1, LY-2, LY-M22, MICG, MRC-OX-8, MRC-OX-22, OX-40, PD-1, RT-6, TCR, THY-1 (CD90), TIM-3, CTLA-4 and TSA-2. Other cell-type specific (*e.g.*, lymphocyte specific) surface markers are contemplated herein.

30

Targeting Molecules

“Targeting molecules” refers to molecules (*e.g.*, ligands, receptors and/or antibodies/antibody fragments) that bind to (*e.g.*, bind specifically to) target cells of interest (*e.g.*, lymphocytes). A targeting molecule is considered to bind to a target cell if it binds to a cell surface marker (*e.g.*, antigen, ligand, receptor) of the target cell. In some embodiments, targeting molecules bind specifically to particular target cells – that is, they bind to cell surface markers that are present only on the particular target cells. Thus, a targeting molecule is considered to bind specifically to a T cell if it binds a cell surface marker that is expressed only on T cells.

In the context of adoptive cell therapy, for example, adoptively-transferred T cells in a subject may uniquely express a cell surface marker (*e.g.*, Thy1.1), which itself may be considered, for example, a ligand or a receptor. A cell surface marker that is “uniquely expressed” by a particular cell type is expressed by no other cell types. Thus, “specific binding” occurs, for example, when an anti-Thy1.1 antibody that is conjugated to a T cell-targeting particle binds to Thy1.1 on the surface of T cells. Adoptively-transferred cells may naturally express a unique marker or they may be modified to express a unique marker. Such modification may include, without limitation, genetic engineering of the adoptively-transferred cells.

Targeting molecules (*e.g.*, ligands or antibodies) that are bound by (or bind to) lymphocytes are referred to herein as “lymphocyte-targeting molecules.” Lymphocyte-targeting molecules include lymphocyte-targeting ligands and lymphocyte-targeting antibodies and antibody fragments such as a Fab fragment.

Ligands that are bound by (or that bind to) lymphocytes may be referred to herein as “lymphocyte-targeting ligands” or “lymphocyte-specific ligands.” Examples of lymphocyte-targeting ligands include, without limitation, cytokines, which as used generally herein encompass cytokines, interleukins, chemokines and growth factors. Non-limiting examples of cytokines include IL-2, IL-7, IL-15, CXCL10, CXCL5, MIP-1a and MIP-1b. In some embodiments, the cytokine is IL-2. In some embodiments, a ligand may be in the form of an Fc fusion protein. For example, an IL-2 ligand may be an IL-2-Fc fusion protein. Other non-limiting examples of Fc fusion proteins include IL-7, IL-15, CXCL10, CXCL5, MIP-1a and MIP-1b Fc fusion proteins. Other ligands and Fc fusion proteins are contemplated herein.

Antibodies that are bound by (or that bind to) lymphocytes may be referred to herein as “lymphocyte-targeting antibodies” or “lymphocyte-specific antibodies.” Antibody fragments that are bound by (or that bind to) lymphocytes may be referred to herein as “lymphocyte-targeting antibody fragments” or “lymphocyte-specific antibody fragments.” Examples of lymphocyte-targeting antibodies include, without limitation, antibodies that bind specifically to ART2, CD1a, CD1d, CD2, CD3, CD4, CD5, CD7, CD8, CD11b, CD25, CD28, CD38, CD45RO, CD72, CD134, CD137, CD150, CD154, CRTAM, FOXP3, FT2, GPCA, HLA-DR, HML-1, HT23A, LEU-22, LFA-1, LY-2, LY-M22, MICG, MRC-OX-8, MRC-OX-22, OX-40, PD-1, RT-6, TCR, THY-1 (CD90), TIM-3, CTLA-4 or TSA-2. Also contemplated herein are immunostimulatory antibodies including, without limitation, anti-PD-1, anti-CTLA4, anti-PDL1 and anti-LaG3 antibodies. Antibody fragments of any of the foregoing antibodies are also contemplated herein. Other antibodies and antibody fragments are contemplated herein. In some embodiments, antibodies used in accordance with the present disclosure are monoclonal antibodies. In some embodiments, antibodies used in accordance with the present disclosure are chimeric antibodies.

It should be understood that a targeting particle of the present invention may comprise at least one (*e.g.*, two or more) targeting molecules that are the same as each other (*e.g.*, targeting ligands) or different from each other (*e.g.*, targeting ligands and targeting antibodies). For example, a lymphocyte-targeting particle may comprise an anti-CD137 antibody and IL-2. Alternatively, a population of lymphocyte-targeting particles may comprise a portion of lymphocyte-targeting particles (*e.g.*, half) that comprise one type of lymphocyte-targeting molecule (*e.g.*, anti-CD137 antibody), and another portion of lymphocyte-targeting particles that comprise another, different, type of lymphocyte-targeting molecule (*e.g.*, IL-2). Thus, mixtures of different targeting particles are contemplated herein. In some embodiments, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% or 90% of a mixture comprises one type of lymphocyte-targeting molecule, while the remaining portion or portions of the mixture comprise(s) another type(s) of lymphocyte-targeting molecule(s).

Targeting Particles

Compositions and methods of the invention involve targeting particles (also referred to as targeted particles). “Targeting particles” refers to particles that comprise on their surface targeting molecules (*e.g.*, ligands, receptors and/or antibodies/antibody fragments) that bind to (or are bound by) cell surface markers on target cells of interest, such as lymphocytes (*e.g.*, T cells). A targeting particle is considered to comprise a targeting molecule on its surface if the targeting molecule is associated with or interacts with (*e.g.*, is covalently or non-covalently conjugated to/bound to) the surface of the targeting particle.

“Particles,” as used herein, refer to particulate carriers (*e.g.*, are capable of transporting molecules), optionally with active agent encapsulated in or bound to (*e.g.*, covalently or non-covalently conjugated to) the particle surface. Examples of particles of the present disclosure include, without limitation, liposomes and polymeric particles, described in greater detail below.

Targeting particles that are bound by (or bind to) targeting molecules that bind to (*e.g.*, bind specifically to) lymphocytes (*e.g.*, bind to lymphocyte cell surface markers) are referred to as “lymphocyte-targeting particles.”

Particles of the present disclosure may be of any suitable size. As used herein, nanoparticles are particles of approximate nanometer dimensions. As used herein, microparticles are particles of approximate micrometer dimensions. The invention contemplates the use of nanoparticles and/or microparticles.

The diameter of a particle may range from 1-1000 nanometers (nm). In some embodiments, the diameter ranges in size from 20 to 750 nm, from 20 to 500 nm, or from 20 to 250 nm. In some embodiments, the diameter ranges in size from 50 to 750 nm, from 50 to 500 nm, from 50 to 250 nm, or from 100-300 nm. In some embodiments, the diameter is 100, 150, 200 nm, 250 nm or 300 nm. In some embodiments, the diameter ranges in size from about 20 to 750 nm, from about 20 to 500 nm, or from about 20 to 250 nm. In some embodiments, the diameter ranges in size from about 50 to 750 nm, from about 50 to 500 nm, from about 50 to 250 nm, or from about 100-300 nm. In some embodiments, the diameter is about 100, about 150, about 200 nm, about 250 nm or about 300 nm.

In some embodiments, the diameter of a microparticle may range from 0.1 μm to 100 μm (or about 0.1 μm to about 100 μm), 0.1 μm to 90 μm , 0.1 μm to 80 μm , 0.1 μm to 70 μm , 0.1 μm

to 60 μm , 0.1 μm to 50 μm , 0.1 μm to 40 μm , 0.1 μm to 30 μm , 0.1 μm to 20 μm , 0.1 μm to 10 μm , 0.1 μm to 5 μm , 0.1 μm to 4 μm , 0.1 μm to 3 μm , 0.1 μm to 2 μm or 0.1 μm to 1 μm .

As used in the context of particle sizes and diameters, the term “about” means $\pm 5\%$ of the absolute value stated.

5 In some embodiments, particles of the present disclosure comprise an active agent and release the active agent over a period of time, ranging from hours to days. The particles may gradually degrade in an aqueous environment, such as occurs *in vivo*. If active agents are dispersed throughout the particles, then release of the active agents will occur as the outermost layers of the particle degrade or as pores within the particle enlarge.

10 In some embodiments, particles of the present disclosure comprise an active agent and release the active agent all at once as the particle “bursts.”

Particles of the present disclosure are administered in a cell-free formulation. This means that they are not bound to cells and are not formulated with cells prior to administration. As described above, particles of the present disclosure may be referred to herein as “lymphocyte-
15 targeting particle.” Lymphocyte-targeting particles are able to target lymphocytes *in vivo* without the assistance of carrier cells or other carrier vehicles.

Particles of the present disclosure may be endocytosed when used *in vivo*, although methods of the invention are not dependent upon endocytosis of the particles.

In some embodiments, particles are porous particles. In some embodiments, particles are
20 hollow core particles. Particles of the present disclosure are not viruses or particles thereof (*e.g.*, virus-like particles (VLPs)). Particles of the present disclosure, in some embodiments, are biodegradable and, thus, typically are not magnetic. Biodegradable particles may be synthesized using methods known in the art including, without limitation, solvent evaporation, hot melt microencapsulation, solvent removal and spray drying. Exemplary methods for synthesizing
25 particles are described in Bershteyn *et al.*, *Soft Matter* 4:1787-1787, 2008 and in US 2008/0014144 A1, the specific teachings of which relating to particle synthesis are incorporated herein by reference.

Particles of the present disclosure may be natural particles or synthetic polymer-based particles (including nucleic acid-based particles) or they may be lipid-based particles, such as
30 liposomes. They may be natural or synthetic polymer-based particles having a lipid coating. In

some embodiments, particles of the invention are multilamellar lipid vesicles (*e.g.*, interbilayer-crosslinked multilamellar lipid vesicles) (*e.g.*, Moon *et al.*, *Nature Materials* 10, 243–251 (2011)).

5 ***Natural or synthetic polymer based particles***

In some embodiments, particles of the present disclosure are formed from polymers including, without limitation, aliphatic polyesters, poly (lactic acid) (PLA), poly (glycolic acid) (PGA), co-polymers of lactic acid and glycolic acid (PLGA), polycaprolactone (PCL), polyanhydrides, poly(ortho)esters, polyurethanes, poly(butyric acid), poly(valeric acid), and
10 poly(lactide-co-caprolactone), and natural polymers such as alginate and other polysaccharides including dextran and cellulose, collagen, chemical derivatives thereof, including substitutions, additions of chemical groups such as for example alkyl, alkylene, hydroxylations, oxidations, and other modifications routinely made by those skilled in the art), albumin and other hydrophilic proteins, zein and other prolamines and hydrophobic proteins, copolymers and
15 mixtures thereof. In some embodiments, the particles may be biodegradable particles such as, for example, particles having a biodegradable polymer core. Such particles are described in greater detail in U.S. application number US 2008/0014144 A1, Bershteyn *et al.*, *Soft Matter*, 4:1787-1787, 2008, published international application number WO 2010/059253, and published U.S. application number 2011/0229556 A1, each of which is incorporated by reference herein.

20 In some embodiments, the particles may comprise a nucleic acid core, optionally with a lipid coating. Such “DNA particles” or “DNA-hydrogel particles” are described in greater detail in published U.S. application number US 2007/0148246, the teachings of which are incorporated by reference herein.

In some embodiments, the particles may comprise a lipid bilayer on their outermost
25 surface. This bilayer may be comprised of one or more lipids of the same or different type. Examples include, without limitation, phospholipids such as phosphocholines and phosphoinositols. Specific examples include, without limitation, DMPC, DOPC, DSPC, DOPG and various other lipids.

Lipid based particles

In some embodiments, particles are liposomes. Liposomes are vesicles comprising at least one lipid bilayer and an internal typically aqueous compartment. Liposomes may be anionic, neutral or cationic. Liposomes may comprise, without limitation, DOPC, DOPG, DOTMA, DOTAP, DOTIM, DDAB, alone or together with cholesterol, to yield DOTMA and cholesterol, DOTAP and cholesterol, DOTIM and cholesterol, and DDAB and cholesterol. In some embodiments, the particles of the invention may be unilamellar liposomal vesicles. In some embodiments, the particles of the invention may be multilamellar liposomal vesicles. In some embodiments, the particles may be interbilayer crosslinked multilamellar vesicles (ICMVs), which are multilamellar lipid vesicles having crosslinked lipid bilayers. Such particles are described in greater detail in U.S. application numbers US 2011/0229529 A1 and US 2012/0177724 A1, each of which is incorporated by reference herein.

Particle conjugation

In some embodiments, particles comprise antibodies or antibody fragments on their surface. In some embodiments, the particles comprise non-antibody-based ligands on their surface. Non-antibody based ligands include, but are not limited, to cytokines, a term used generically to embrace cytokines, interleukins, and growth factors generally.

In some embodiments, the antibodies are designed to bind to target cells without triggering their elimination by complement or other antibody effector mechanisms. This is achieved either by using antibody fragments or antibodies with mutations that abrogate Fc receptor binding or other effector mechanisms.

These antibody and non-antibody based ligands may be conjugated (or attached or bound, as the terms are used interchangeably herein) to the particle surface covalently or non-covalently.

The particles may be synthesized or modified post-synthesis to comprise one or more reactive groups on their exterior surface that can be used to conjugate the antibody and non-antibody based ligands. These particle reactive groups include without limitation thiol-reactive maleimide head groups, haloacetyl (*e.g.*, iodoacetyl) groups, imidoester groups, N-hydroxysuccinimide esters, pyridyl disulfide groups, and the like. As an example, particles may be synthesized to include maleimide conjugated phospholipids such as, without limitation, DSPE-MaL-PEG2000.

It will be understood that when surface modified in this manner, the particles are intended for use with ligands having “complementary” reactive groups (i.e., reactive groups that react with those of the particles).

Methods for conjugating ligands or receptors such as antibodies to particle surfaces are described by Kwong et al. Cancer Research, 2013, 73:1547-1558, the entire contents of which are incorporated by reference herein.

Agents

The invention contemplates the delivery of agents to particular cells, and thus potentially to localized regions or tissues *in vivo*. As used herein, an agent is any atom or molecule or compound that can be used to provide benefit to a subject (including without limitation prophylactic or therapeutic benefit). The agents of particular interest, in some embodiments, are those that exert an effect on target cells, whether directly or indirectly. Some agents may exert their effects on tumor cells, pathogens, or pathogen-infected cells. The nature of the agent will depend on the particular application, as should be apparent.

The particles may carry the agent internally including for example in pores or in a hollow core. The particles may carry the agent on its surface. The particles may carry the agent internally and on its surface.

The invention further contemplates that one or more agents may be used alongside of the particles of the invention, although not conjugated to or encapsulated within. For example, the particles of the invention may be formulated together with one or more agents.

The agent may be without limitation a chemical entity, a protein, a polypeptide, a peptide, a nucleic acid, a virus-like particle, a steroid, a proteoglycan, a lipid, a carbohydrate, and analogs, derivatives, mixtures, fusions, combinations or conjugates thereof. The agent may be a pro-drug that is metabolized and thus converted *in vivo* to its active (and/or stable) form.

The agents may be naturally occurring or non-naturally occurring. Naturally occurring agents include those capable of being synthesized by the subjects to whom the particles are administered. Non-naturally occurring are those that do not exist in nature normally, whether produced by plant, animal, microbe or other living organism.

One class of agents that can be delivered in a localized manner using the particles of the invention includes chemical compounds that are non-naturally occurring, or chemical compounds that are not naturally synthesized by mammalian (and in particular human) cells.

A variety of agents that are currently used for therapeutic purposes can be delivered according to the invention and these include without limitation immunomodulatory agents such as immunostimulatory agents, antigens, adjuvants, imaging agents, anti-cancer agents, anti-infective agents, and the like.

One particular class of agents is inhibitors of immunosuppression. Examples include Shp1/2 protein tyrosine phosphatase (PTPase) inhibitor (NSC-87877; CAS 56932-43-5), sunitinib, or other inhibitors of receptor tyrosine kinases, or p38 MAPK inhibitors including MAPK pathway inhibitors.

The p38 MAPK pathway inhibitor may be a RAF inhibitor such as a pan-RAF inhibitor or a selective RAF inhibitor. Examples of RAF inhibitors include RAF265, sorafenib, dabrafenib (GSK2118436), SB590885, PLX 4720, PLX4032, GDC-0879 and ZM 336372.

The p38 MAPK pathway inhibitor may be a MEK inhibitor. Examples of MEK inhibitors include CI-1040/PD184352, AZD6244, PD318088, PD98059, PD334581, RDEA119, 6-Methoxy-7-(3-morpholin-4-yl-propoxy)-4-(4-phenoxy-phenylamino)-quinoline-3-carbonitrile and 4-[3-Chloro-4-(1-methyl-1H-imidazol-2-ylsulfanyl)-phenylamino]-6-methoxy-7-(3-morpholin-4-yl-propoxy)-quinoline-3-carbonitrile, trametinib (GSK1120212), and ARRY-438162.

The p38 MAPK pathway inhibitor may be an ERK inhibitor. Examples of ERK inhibitors include VTX11e, AEZS-131, PD98059, FR180204, and FR148083.

Still other p38 MAPK inhibitors are Tocriset, SB239063, SB203580, pamapimod,, dilmapimod, and PH797804.

Imaging Agents. As used herein, an imaging agent is an agent that emits signal directly or indirectly thereby allowing its detection *in vivo*. Imaging agents such as contrast agents and radioactive agents that can be detected using medical imaging techniques such as nuclear medicine scans and magnetic resonance imaging (MRI). Imaging agents for magnetic resonance imaging (MRI) include Gd(DOTA), iron oxide or gold nanoparticles; imaging agents for nuclear medicine include ²⁰¹Tl, gamma-emitting radionuclide ^{99m}Tc; imaging agents for positron-

emission tomography (PET) include positron-emitting isotopes, (18)F-fluorodeoxyglucose ((18)FDG), (18)F-fluoride, copper-64, gadoamide, and radioisotopes of Pb(II) such as 203 Pb, and 11In; imaging agents for *in vivo* fluorescence imaging such as fluorescent dyes or dye-conjugated nanoparticles. In other embodiments, the agent to be delivered is conjugated, or fused to, or mixed or combined with an imaging agent.

Immunostimulatory Agents. As used herein, an immunostimulatory agent is an agent that stimulates an immune response (including enhancing a pre-existing immune response) in a subject to whom it is administered, whether alone or in combination with another agent. Examples include antigens, adjuvants (*e.g.*, TLR ligands such as imiquimod, imidazoquinoline, nucleic acids comprising an unmethylated CpG dinucleotide, monophosphoryl lipid A or other lipopolysaccharide derivatives, single-stranded or double-stranded RNA, flagellin, muramyl dipeptide), cytokines including interleukins (*e.g.*, IL-2, IL-7, IL-15 (or superagonist/mutant forms of these cytokines), IL-12, IFN-gamma, IFN-alpha, GM-CSF, FLT3-ligand, etc.), immunostimulatory antibodies (*e.g.*, anti-CTLA-4, anti-CD28, anti-CD3, or single chain/antibody fragments of these molecules), and the like.

Adjuvants. The adjuvant may be without limitation alum (*e.g.*, aluminum hydroxide, aluminum phosphate); saponins purified from the bark of the *Q. saponaria* tree such as QS21 (a glycolipid that elutes in the 21st peak with HPLC fractionation; Antigenics, Inc., Worcester, Mass.); poly[di(carboxylatophenoxy)phosphazene (PCPP polymer; Virus Research Institute, USA), Flt3 ligand, *Leishmania* elongation factor (a purified *Leishmania* protein; Corixa Corporation, Seattle, Wash.), ISCOMS (immunostimulating complexes which contain mixed saponins, lipids and form virus-sized particles with pores that can hold antigen; CSL, Melbourne, Australia), Pam3Cys, SB-AS4 (SmithKline Beecham adjuvant system #4 which contains alum and MPL; SBB, Belgium), non-ionic block copolymers that form micelles such as CRL 1005 (these contain a linear chain of hydrophobic polyoxypropylene flanked by chains of polyoxyethylene, Vaxcel, Inc., Norcross, Ga.), and Montanide IMS (*e.g.*, IMS 1312, water-based nanoparticles combined with a soluble immunostimulant, Seppic)

Adjuvants may be TLR ligands. Adjuvants that act through TLR3 include without limitation double-stranded RNA. Adjuvants that act through TLR4 include without limitation derivatives of lipopolysaccharides such as monophosphoryl lipid A (MPLA; Ribi ImmunoChem

Research, Inc., Hamilton, Mont.) and muramyl dipeptide (MDP; Ribi) and threonyl-muramyl dipeptide (t-MDP; Ribi); OM-174 (a glucosamine disaccharide related to lipid A; OM Pharma SA, Meyrin, Switzerland). Adjuvants that act through TLR5 include without limitation flagellin. Adjuvants that act through TLR7 and/or TLR8 include single-stranded RNA,
5 oligoribonucleotides (ORN), synthetic low molecular weight compounds such as imidazoquinolinamines (*e.g.*, imiquimod, resiquimod). Adjuvants acting through TLR9 include DNA of viral or bacterial origin, or synthetic oligodeoxynucleotides (ODN), such as CpG ODN. Another adjuvant class is phosphorothioate containing molecules such as phosphorothioate nucleotide analogs and nucleic acids containing phosphorothioate backbone linkages.

10 *Immunoinhibitory Agents.* As used herein, an immunoinhibitory agent is an agent that inhibits an immune response in a subject to whom it is administered, whether alone or in combination with another agent. Examples include steroids, retinoic acid, dexamethasone, cyclophosphamide, anti-CD3 antibody or antibody fragment, and other immunosuppressants.

Anti-Cancer Agents. As used herein, an anti-cancer agent is an agent that at least
15 partially inhibits the development or progression of a cancer, including inhibiting in whole or in part symptoms associated with the cancer even if only for the short term. Several anti-cancer agents can be categorized as DNA damaging agents and these include topoisomerase inhibitors (*e.g.*, etoposide, irinotecan, topotecan, teniposide, mitoxantrone), DNA alkylating agents (*e.g.*, cisplatin, mechlorethamine, cyclophosphamide, ifosfamide, melphalan, chlorambucil,
20 busulfan, thiotepa, carmustine, lomustine, carboplatin, dacarbazine, procarbazine), DNA strand break inducing agents (*e.g.*, bleomycin, doxorubicin, daunorubicin, idarubicin, mitomycin C), anti-microtubule agents (*e.g.*, vincristine, vinblastine), anti-metabolic agents (*e.g.*, cytarabine, methotrexate, hydroxyurea, 5-fluorouracil, floxuridine, 6-thioguanine, 6-mercaptopurine, fludarabine, pentostatin, chlorodeoxyadenosine), anthracyclines, vinca alkaloids. or
25 epipodophyllotoxins.

Examples of anti-cancer agents include without limitation Acivicin; Aclarubicin; Acodazole Hydrochloride; Acronine; Adozelesin; Aldesleukin; Altretamine; Ambomycin; Ametantrone Acetate; Aminoglutethimide; Amsacrine; Anastrozole; Anthramycin; Asparaginase; Asperlin; Azacitidine; Azetepa; Azotomycin; Batimastat; Benzodepa;
30 Bicalutamide; Bisantrene Hydrochloride; Bisnafide Dimesylate; Bizelesin; Bleomycin Sulfate;

Bortezomib (VELCADE); Brequinar Sodium; Bropirimine; Busulfan; Cactinomycin;
Calusterone; Caracemide; Carbetimer; Carboplatin (a platinum-containing regimen);
Carmustine; Carubicin Hydrochloride; Carzelesin; Cedefingol; Chlorambucil; Cirolemycin;
Cisplatin (a platinum-containing regimen); Cladribine; Crisnatol Mesylate; Cyclophosphamide;
5 Cytarabine; Dacarbazine; Dactinomycin; Daunorubicin; Decitabine; Dexormaplatin;
Dezaguanine; Diaziquone; Docetaxel (TAXOTERE); Doxorubicin; Droloxifene;
Dromostanolone; Duazomycin; Edatrexate; Eflornithine; Elsamitrucin; Enloplatin; Enpromate;
Epipropidine; Epirubicin; Erbulozole; Erlotinib (TARCEVA), Esorubicin; Estramustine;
Etanidazole; Etoposide; Etoprine; Fadrozole; Fazarabine; Fenretinide; Floxuridine; Fludarabine;
10 5-Fluorouracil; Flurocitabine; Fosquidone; Fostriecin; Gefitinib (IRESSA), Gemcitabine;
Hydroxyurea; Idarubicin; Ifosfamide; Ilmofofosine; Imatinib mesylate (GLEEVAC); Interferon
alpha-2a; Interferon alpha-2b; Interferon alpha-n1; Interferon alpha-n3; Interferon beta-I a;
Interferon gamma-I b; Iproplatin; Irinotecan; Lanreotide; Lenalidomide (REVLIMID,
REVIMID); Letrozole; Leuprolide; Liarozole; Lometrexol; Lomustine; Losoxantrone;
15 Masoprocol; Maytansine; Mechlorethamine; Megestrol; Melengestrol; Melphalan; Menogaril;
Mercaptopurine; Methotrexate; Metoprine; Meturedopa; Mitindomide; Mitocarcin; Mitocromin;
Mitogillin; Mitomalcin; Mitomycin; Mitosper; Mitotane; Mitoxantrone; Mycophenolic Acid;
Nocodazole; Nogalamycin; Ormaplatin; Oxisuran; Paclitaxel; Pemetrexed (ALIMTA),
Pegaspargase; Peliomycin; Pentamustine; Pentomone; Peplomycin; Perfosfamide; Pipobroman;
20 Pipsulfan; Piritrexim Isethionate; Piroxantrone; Plicamycin; Plomestane; Porfimer;
Porfiromycin; Prednimustine; Procarbazine; Puromycin; Pyrazofurin; Riboprine; Rogletimide;
Safingol; Semustine; Simtrazene; Sitogluside; Sparfosate; Sparsomycin; Spirogermanium;
Spiromustine; Spiroplatin; Streptonigrin; Streptozocin; Sulofenur; Talisomycin; Tamsulosin;
Taxol; Taxotere; Tecogalan; Tegafur; Teloxantrone; Temoporfin; Temozolomide (TEMODAR);
25 Teniposide; Teroxirone; Testolactone; Thalidomide (THALOMID) and derivatives thereof;
Thiamiprine; Thioguanine; Thiotepa; Tiazofurin; Tirapazamine; Topotecan; Toremifene;
Trestolone; Triciribine; Trimetrexate; Triptorelin; Tubulozole; Uracil Mustard; Uredopa;
Vapreotide; Verteporfin; Vinblastine; Vincristine; Vindesine; Vinepidine; Vinglycinate;
Vinleurosine; Vinorelbine; Vinrosidine; Vinzolidine; Vorozole; Zeniplatin; Zinostatin;
30 Zorubicin.

The anti-cancer agent may be an enzyme inhibitor including without limitation tyrosine kinase inhibitor, a CDK inhibitor, a MAP kinase inhibitor, or an EGFR inhibitor. The tyrosine kinase inhibitor may be without limitation Genistein (4',5,7-trihydroxyisoflavone), Tyrphostin 25 (3,4,5-trihydroxyphenyl), methylene]-propanedinitrile, Herbimycin A, Daidzein (4',7-
5 dihydroxyisoflavone), AG-126, trans-1-(3'-carboxy-4'-hydroxyphenyl)-2-(2'',5''-dihydroxy-phenyl)ethane, or HDBA (2-Hydroxy5-(2,5-Dihydroxybenzylamino)-2-hydroxybenzoic acid. The CDK inhibitor may be without limitation p21, p27, p57, p15, p16, p18, or p19. The MAP kinase inhibitor may be without limitation KY12420 (C₂₃H₂₄O₈), CNI-1493, PD98059, or 4-(4-Fluorophenyl)-2-(4-methylsulfinyl phenyl)-5-(4-pyridyl) 1H-imidazole. The EGFR inhibitor
10 may be without limitation erlotinib (TARCEVA), gefitinib (IRESSA), WHI-P97 (quinazoline derivative), LFM-A12 (leflunomide metabolite analog), ABX-EGF, lapatinib, canertinib, ZD-6474 (ZACTIMA), AEE788, and AG1458.

The anti-cancer agent may be a VEGF inhibitor including without limitation bevacizumab (AVASTIN), ranibizumab (LUCENTIS), pegaptanib (MACUGEN), sorafenib,
15 sunitinib (SUTENT), vatalanib, ZD-6474 (ZACTIMA), anecortave (RETAANE), squalamine lactate, and semaphorin.

The anti-cancer agent may be an antibody or an antibody fragment including without limitation an antibody or an antibody fragment including but not limited to bevacizumab (AVASTIN), trastuzumab (HERCEPTIN), alemtuzumab (CAMPATH, indicated for B cell
20 chronic lymphocytic leukemia,), gemtuzumab (MYLOTARG, hP67.6, anti-CD33, indicated for leukemia such as acute myeloid leukemia), rituximab (RITUXAN), tositumomab (BEXXAR, anti-CD20, indicated for B cell malignancy), MDX-210 (bispecific antibody that binds simultaneously to HER-2/neu oncogene protein product and type I Fc receptors for immunoglobulin G (IgG) (Fc gamma RI)), oregovomab (OVAREX, indicated for ovarian
25 cancer), edrecolomab (PANOREX), daclizumab (ZENAPAX), palivizumab (SYNAGIS, indicated for respiratory conditions such as RSV infection), ibritumomab tiuxetan (ZEVALIN, indicated for Non-Hodgkin's lymphoma), cetuximab (ERBITUX), MDX-447, MDX-22, MDX-220 (anti-TAG-72), IOR-C5, IOR-T6 (anti-CD1), IOR EGF/R3, celogovab (ONCOSCINT OV103), epratuzumab (LYMPHOCIDE), pentumomab (THERAGYN), and Gliomab-H
30 (indicated for brain cancer, melanoma).

Anti-Infective Agents. The agent may be an anti-infective agent including without limitation an anti-bacterial agent, an anti-viral agent, an anti-parasitic agent, an anti-fungal agent, and an anti-mycobacterial agent.

Anti-bacterial agents may be without limitation β -lactam antibiotics, penicillins (such as
5 natural penicillins, aminopenicillins, penicillinase-resistant penicillins, carboxy penicillins, ureido penicillins), cephalosporins (first generation, second generation, and third generation cephalosporins), other β -lactams (such as imipenem, monobactams), β -lactamase inhibitors, vancomycin, aminoglycosides and spectinomycin, tetracyclines, chloramphenicol, erythromycin, lincomycin, clindamycin, rifampin, metronidazole, polymyxins, sulfonamides and trimethoprim,
10 or quinolines.

Other anti-bacterials may be without limitation Acedapsone; Acetosulfone Sodium; Alamecin; Alexidine; Amdinocillin; Amdinocillin Pivoxil; Amicycline; Amifloxacin; Amifloxacin Mesylate; Amikacin; Amikacin Sulfate; Aminosalicyclic acid; Aminosalicylate sodium; Amoxicillin; Amphomycin; Ampicillin; Ampicillin Sodium; Apalcillin Sodium;
15 Apramycin; Aspartocin; Astromicin Sulfate; Avilamycin; Avoparcin; Azithromycin; Azlocillin; Azlocillin Sodium; Bacampicillin Hydrochloride; Bacitracin; Bacitracin Methylene Disalicylate; Bacitracin Zinc; Bambermycins; Benzoylpas Calcium; Berythromycin; Betamicin Sulfate; Biapenem; Biniramycin; Biphenamine Hydrochloride; Bispyrithione Magsulfex; Butikacin; Butirosin Sulfate; Capreomycin Sulfate; Carbadox; Carbenicillin Disodium; Carbenicillin
20 Indanyl Sodium; Carbenicillin Phenyl Sodium; Carbenicillin Potassium; Carumonam Sodium; Cefaclor; Cefadroxil; Cefamandole; Cefamandole Nafate; Cefamandole Sodium; Cefaparolet; Cefatrizine; Cefazaflur Sodium; Cefazolin; Cefazolin Sodium; Cefbuperazone; Cefdinir; Cefepime; Cefepime Hydrochloride; Cefetecol; Cefixime; Cefmenoxime Hydrochloride; Cefmetazole; Cefmetazole Sodium; Cefonicid Monosodium; Cefonicid Sodium; Cefoperazone
25 Sodium; Ceforanide; Cefotaxime Sodium; Cefotetan; Cefotetan Disodium; Cefotiam Hydrochloride; Cefoxitin; Cefoxitin Sodium; Cefpimizole; Cefpimizole Sodium; Cefpiramide; Cefpiramide Sodium; Cefpirome Sulfate; Cefpodoxime Proxetil; Cefprozil; Cefroxadine; Cefsulodin Sodium; Ceftazidime; Ceftibuten; Ceftizoxime Sodium; Ceftriaxone Sodium; Cefuroxime; Cefuroxime Axetil; Cefuroxime Pivoxetil; Cefuroxime Sodium; Cephacetrile
30 Sodium; Cephalexin; Cephalexin Hydrochloride; Cephaloglycin; Cephaloridine; Cephalothin

Sodium; Cephapirin Sodium; Cephradine; Cetocycline Hydrochloride; Cetophenicol;
Chloramphenicol; Chloramphenicol Palmitate; Chloramphenicol Pantothenate Complex;
Chloramphenicol Sodium Succinate; Chlorhexidine Phosphanilate; Chloroxylenol;
Chlortetracycline Bisulfate; Chlortetracycline Hydrochloride; Cinoxacin; Ciprofloxacin;
5 Ciprofloxacin Hydrochloride; Cirolemycin; Clarithromycin; Clinafloxacin Hydrochloride;
Clindamycin; Clindamycin Hydrochloride; Clindamycin Palmitate Hydrochloride; Clindamycin
Phosphate; Clofazimine; Cloxacillin Benzathine; Cloxacillin Sodium; Cloxyquin; Colistimethate
Sodium; Colistin Sulfate; Coumermycin; Coumermycin Sodium; Cyclacillin; Cycloserine;
Dalfopristin; Dapsone; Daptomycin; Demeclocycline; Demeclocycline Hydrochloride;
10 Demecycline; Denofungin; Diaveridine; Dicloxacillin; Dicloxacillin Sodium;
Dihydrostreptomycin Sulfate; Dipyrithione; Dirithromycin; Doxycycline; Doxycycline Calcium;
Doxycycline Fosfatex; Doxycycline Hyclate; Droxacin Sodium; Enoxacin; Epicillin;
Epitetracycline Hydrochloride; Erythromycin; Erythromycin Acistrate; Erythromycin Estolate;
Erythromycin Ethylsuccinate; Erythromycin Gluceptate; Erythromycin Lactobionate;
15 Erythromycin Propionate; Erythromycin Stearate; Ethambutol Hydrochloride; Ethionamide;
Fleroxacin; Floxacillin; Fludalanine; Flumequine; Fosfomycin; Fosfomycin Tromethamine;
Fumoxicillin; Furazolium Chloride; Furazolium Tartrate; Fusidate Sodium; Fusidic Acid;
Gentamicin Sulfate; Gloximonam; Gramicidin; Haloprogin; Hetacillin; Hetacillin Potassium;
Hexedine; Ibafloxacin; Imipenem; Isoconazole; Isepamicin; Isoniazid; Josamycin; Kanamycin
20 Sulfate; KITASAMYCIN; Levofuraltadone; Levopropylcillin Potassium; Lexithromycin;
Lincomycin; Lincomycin Hydrochloride; Lomefloxacin; Lomefloxacin Hydrochloride;
Lomefloxacin Mesylate; Loracarbef; Mafenide; Meclocycline; Meclocycline Sulfosalicylate;
Megalomicin Potassium Phosphate; Mequidox; Meropenem; Methacycline; Methacycline
Hydrochloride; Methenamine; Methenamine Hippurate; Methenamine Mandelate; Methicillin
25 Sodium; Metioprime; Metronidazole Hydrochloride; Metronidazole Phosphate; Mezlocillin;
Mezlocillin Sodium; Minocycline; Minocycline Hydrochloride; Mirincamycin Hydrochloride;
Monensin; Monensin Sodium; Nafcillin Sodium; Nalidixate Sodium; Nalidixic Acid;
Natamycin; Nebramycin; Neomycin Palmitate; Neomycin Sulfate; Neomycin Undecylenate;
Netilmicin Sulfate; Neutramycin; Nifuradene; Nifuraldezone; Nifuratel; Nifuratrone; Nifurdazil;
30 Nifurimide; Nifurpirinol; Nifurquinazol; Nifurthiazole; Nitrocyline; Nitrofurantoin; Nitromide;

Norfloxacin; Novobiocin Sodium; Ofloxacin; Ormetoprim; Oxacillin Sodium; Oximonam;
 Oximonam Sodium; Oxolinic Acid; Oxytetracycline; Oxytetracycline Calcium; Oxytetracycline
 Hydrochloride; Paldimycin; Parachlorophenol; Paulomycin; Pefloxacin; Pefloxacin Mesylate;
 Penamecillin; Penicillin G Benzathine; Penicillin G Potassium; Penicillin G Procaine; Penicillin
 5 G Sodium; Penicillin V; Penicillin V Benzathine; Penicillin V Hydrabamine; Penicillin V
 Potassium; Pentizidone Sodium; Phenyl Aminosalicylate; Piperacillin Sodium; Pirbenicillin
 Sodium; Piridicillin Sodium; Pirlimycin Hydrochloride; Pivampicillin Hydrochloride;
 Pivampicillin Pamoate; Pivampicillin Probenate; Polymyxin B Sulfate; Porfiromycin;
 Propikacin; Pyrazinamide; Pyrithione Zinc; Quindecamine Acetate; Quinupristin; Racephenicol;
 10 Ramoplanin; Ranimycin; Relomycin; Repromicin; Rifabutin; Rifametane; Rifamexil; Rifamide;
 Rifampin; Rifapentine; Rifaximin; Rolitetracycline; Rolitetracycline Nitrate; Rosaramicin;
 Rosaramicin Butyrate; Rosaramicin Propionate; Rosaramicin Sodium Phosphate; Rosaramicin
 Stearate; Rosoxacin; Roxarsone; Roxithromycin; Sancycline; Sanfetrinem Sodium;
 Sarmoxicillin; Sarpicillin; Scopafungin; Sisomicin; Sisomicin Sulfate; Sparfloxacin;
 15 Spectinomycin Hydrochloride; Spiramycin; Stallimycin Hydrochloride; Steffimycin;
 Streptomycin Sulfate; Streptonicozid; Sulfabenz; Sulfabenzamide; Sulfacetamide; Sulfacetamide
 Sodium; Sulfacytine; Sulfadiazine; Sulfadiazine Sodium; Sulfadoxine; Sulfalene; Sulfamerazine;
 Sulfameter; Sulfamethazine; Sulfamethizole; Sulfamethoxazole; Sulfamonomethoxine;
 Sulfamoxole; Sulfanilate Zinc; Sulfanitran; Sulfasalazine; Sulfasomizole; Sulfathiazole;
 20 Sulfazamet; Sulfisoxazole; Sulfisoxazole Acetyl; Sulfisoxazole Diolamine; Sulfomyxin;
 Sulopenem; Sultamicillin; Suncillin Sodium; Talampicillin Hydrochloride; Teicoplanin;
 Temafloxacin Hydrochloride; Temocillin; Tetracycline; Tetracycline Hydrochloride;
 Tetracycline Phosphate Complex; Tetroxoprim; Thiamphenicol; Thiphencillin Potassium;
 Ticarcillin Cresyl Sodium; Ticarcillin Disodium; Ticarcillin Monosodium; Ticlatone; Tiodonium
 25 Chloride; Tobramycin; Tobramycin Sulfate; Tosufloxacin; Trimethoprim; Trimethoprim Sulfate;
 Trisulfapyrimidines; Troleandomycin; Trospectomycin Sulfate; Tyrothricin; Vancomycin;
 Vancomycin Hydrochloride; Virginiamycin; or Zorbamycin.

Anti-mycobacterial agents may be without limitation Myambutol (Ethambutol
 Hydrochloride), Dapsone (4,4'-diaminodiphenylsulfone), Paser Granules (aminosalicylic acid
 30 granules), Priftin (rifapentine), Pyrazinamide, Isoniazid, Rifadin (Rifampin), Rifadin IV,

Rifamate (Rifampin and Isoniazid), Rifater (Rifampin, Isoniazid, and Pyrazinamide), Streptomycin Sulfate or Treacator-SC (Ethionamide).

Anti-viral agents may be without limitation amantidine and rimantadine, ribivarin, acyclovir, vidarabine, trifluorothymidine, ganciclovir, zidovudine, retinovir, and interferons.

5 Anti-viral agents may be without limitation further include Acemannan; Acyclovir; Acyclovir Sodium; Adefovir; Alovudine; Alvircept Sudotox; Amantadine Hydrochloride; Aranotin; Arildone; Ateviridine Mesylate; Avridine; Cidofovir; Cipamfylline; Cytarabine Hydrochloride; Delavirdine Mesylate; Desciclovir; Didanosine; Disoxaril; Edoxudine; Enviroxime; Famciclovir; Famotone Hydrochloride; Fiacitabine; Fialuridine; Fosarilate; Foscarnet Sodium; Fosfonet Sodium; Ganciclovir; Ganciclovir Sodium; Idoxuridine; Kethoxal; Lamivudine; Lobucavir; Memotone Hydrochloride; Methisazone; Nevirapine; Penciclovir; Pirodavis; Ribavirin; Rimantadine Hydrochloride; Saquinavir Mesylate; Somantadine Hydrochloride; Sorivudine; Statolon; Stavudine; Tilorone Hydrochloride; Trifluridine; Valacyclovir Hydrochloride; Vidarabine; Vidarabine Phosphate; Vidarabine Sodium Phosphate; Viroxime; Zalcitabine; Zidovudine; Zinviroxime or integrase inhibitors.

15 Anti-fungal agents may be without limitation imidazoles and triazoles, polyene macrolide antibiotics, griseofulvin, amphotericin B, and flucytosine. Antiparasites include heavy metals, antimalarial quinolines, folate antagonists, nitroimidazoles, benzimidazoles, avermectins, praziquantel, ornithine decarboxylase inhibitors, phenols (*e.g.*, bithionol, niclosamide); synthetic alkaloid (*e.g.*, dehydroemetine); piperazines (*e.g.*, diethylcarbamazone); acetanilide (*e.g.*, diloxanide furonate); halogenated quinolines (*e.g.*, iodoquinol (diiodohydroxyquin)); nitrofurans (*e.g.*, nifurtimox); diamidines (*e.g.*, pentamidine); tetrahydropyrimidine (*e.g.*, pyrantel pamoate); or sulfated naphthylamine (*e.g.*, suramin).

25 Other anti-infective agents may be without limitation Difloxacin Hydrochloride; Lauryl Isoquinolinium Bromide; Moxalactam Disodium; Ornidazole; Pentisomicin; Sarafloxacin Hydrochloride; Protease inhibitors of HIV and other retroviruses; Integrase Inhibitors of HIV and other retroviruses; Cefaclor (Ceclor); Acyclovir (Zovirax); Norfloxacin (Noroxin); Cefoxitin (Mefoxin); Cefuroxime axetil (Ceftin); Ciprofloxacin (Cipro); Aminacrine Hydrochloride; Benzethonium Chloride : Bithionolate Sodium; Bromchlorenone; Carbamide Peroxide; 30 Cetalkonium Chloride; Cetylpyridinium Chloride : Chlorhexidine Hydrochloride; Clioquinol;

Domiphen Bromide; Fenticlor; Fludazonium Chloride; Fuchsin, Basic; Furazolidone; Gentian Violet; Halquinols; Hexachlorophene : Hydrogen Peroxide; Ichthammol; Imidecyl Iodine; Iodine; Isopropyl Alcohol; Mafenide Acetate; Meralein Sodium; Mercufenol Chloride; Mercury, Ammoniated; Methylbenzethonium Chloride; Nitrofurazone; Nitromersol; Octenidine
5 Hydrochloride; Oxychlorosene; Oxychlorosene Sodium; Parachlorophenol, Camphorated; Potassium Permanganate; Povidone-Iodine; Sepazonium Chloride; Silver Nitrate; Sulfadiazine, Silver; Symclosene; Thimerfonate Sodium; Thimerosal; or Troclosesene Potassium.

Subjects

10 The invention can be practiced in virtually any subject type. Human subjects are preferred subjects in some embodiments of the invention. Subjects also include animals such as household pets (*e.g.*, dogs, cats, rabbits, ferrets, etc.), livestock or farm animals (*e.g.*, cows, pigs, sheep, chickens and other poultry), horses such as thoroughbred horses, laboratory animals (*e.g.*, mice, rats, rabbits, etc.), and the like. Subjects also include fish and other aquatic species.

15 The subjects may have or may be at risk of developing a condition that can benefit from the methods of the invention. Such conditions include cancer (*e.g.*, solid tumor cancers), infections, autoimmune disorders, allergies or allergic conditions, asthma, transplant rejection, and the like.

The subject may be undergoing adoptive cell therapy. Such a subject may have already
20 received adoptive cell therapy, or may be receiving adoptive cell therapy, or will receive adoptive cell therapy in the near future. The adoptive cell therapy may take the form of tumor-reactive T cells.

Tests for diagnosing various of the conditions embraced by the invention are known in the art and will be familiar to the ordinary medical practitioner. These laboratory tests include
25 without limitation microscopic analyses, cultivation dependent tests (such as cultures), and nucleic acid detection tests. These include wet mounts, stain-enhanced microscopy, immune microscopy (*e.g.*, FISH), hybridization microscopy, particle agglutination, enzyme-linked immunosorbent assays, urine screening tests, DNA probe hybridization, serologic tests, etc. The medical practitioner will generally also take a full history and conduct a complete physical
30 examination in addition to running the laboratory tests listed above.

A subject having a cancer is a subject that has detectable cancer cells. A subject at risk of developing a cancer is a subject that has a higher than normal probability of developing cancer. These subjects include, for instance, subjects having a genetic abnormality that has been demonstrated to be associated with a higher likelihood of developing a cancer, subjects having a
5 familial disposition to cancer, subjects exposed to cancer causing agents (i.e., carcinogens) such as tobacco, asbestos, or other chemical toxins, and subjects previously treated for cancer and in apparent remission.

Subjects having an infection are those that exhibit symptoms thereof including without limitation fever, chills, myalgia, photophobia, pharyngitis, acute lymphadenopathy,
10 splenomegaly, gastrointestinal upset, leukocytosis or leukopenia, and/or those in whom infectious pathogens or byproducts thereof can be detected.

A subject at risk of developing an infection is one that is at risk of exposure to an infectious pathogen. Such subjects include those that live in an area where such pathogens are known to exist and where such infections are common. These subjects also include those that
15 engage in high risk activities such as sharing of needles, engaging in unprotected sexual activity, routine contact with infected samples of subjects (*e.g.*, medical practitioners), people who have undergone surgery, including but not limited to abdominal surgery, etc.

The subject may have or may be at risk of developing an infection such as a bacterial infection, a viral infection, a fungal infection, a parasitic infection or a mycobacterial infection.
20 In these embodiments, the particles may comprise an anti-microbial agent such as an anti-bacterial agent, an anti-viral agent, an anti-fungal agent, an anti-parasitic agent, or an anti-mycobacterial agent.

Cancer

25 The invention contemplates administration of the particles of the invention to subjects having or at risk of developing a cancer including for example a solid tumor cancer. The cancer may be carcinoma, sarcoma or melanoma. Carcinomas include without limitation to basal cell carcinoma, biliary tract cancer, bladder cancer, breast cancer, cervical cancer, choriocarcinoma, CNS cancer, colon and rectum cancer, kidney or renal cell cancer, larynx cancer, liver cancer,
30 small cell lung cancer, non-small cell lung cancer (NSCLC, including adenocarcinoma, giant (or

oat) cell carcinoma, and squamous cell carcinoma), oral cavity cancer, ovarian cancer, pancreatic cancer, prostate cancer, skin cancer (including basal cell cancer and squamous cell cancer), stomach cancer, testicular cancer, thyroid cancer, uterine cancer, rectal cancer, cancer of the respiratory system, and cancer of the urinary system.

5 Sarcomas are rare mesenchymal neoplasms that arise in bone (osteosarcomas) and soft tissues (fibrosarcomas). Sarcomas include without limitation liposarcomas (including myxoid liposarcomas and pleiomorphic liposarcomas), leiomyosarcomas, rhabdomyosarcomas, malignant peripheral nerve sheath tumors (also called malignant schwannomas, neurofibrosarcomas, or neurogenic sarcomas), Ewing's tumors (including Ewing's sarcoma of
10 bone, extraskeletal (i.e., not bone) Ewing's sarcoma, and primitive neuroectodermal tumor), synovial sarcoma, angiosarcomas, hemangiosarcomas, lymphangiosarcomas, Kaposi's sarcoma, hemangioendothelioma, desmoid tumor (also called aggressive fibromatosis), dermatofibrosarcoma protuberans (DFSP), malignant fibrous histiocytoma (MFH), hemangiopericytoma, malignant mesenchymoma, alveolar soft-part sarcoma, epithelioid
15 sarcoma, clear cell sarcoma, desmoplastic small cell tumor, gastrointestinal stromal tumor (GIST) (also known as GI stromal sarcoma), and chondrosarcoma.

Melanomas are tumors arising from the melanocytic system of the skin and other organs. Examples of melanoma include without limitation lentigo maligna melanoma, superficial spreading melanoma, nodular melanoma, and acral lentiginous melanoma.

20 The cancer may be a solid tumor lymphoma. Examples include Hodgkin's lymphoma, Non-Hodgkin's lymphoma, and B cell lymphoma.

The cancer may be without limitation bone cancer, brain cancer, breast cancer, colorectal cancer, connective tissue cancer, cancer of the digestive system, endometrial cancer, esophageal cancer, eye cancer, cancer of the head and neck, gastric cancer, intra-epithelial neoplasm,
25 melanoma neuroblastoma, Non-Hodgkin's lymphoma, non-small cell lung cancer, prostate cancer, retinoblastoma, or rhabdomyosarcoma.

Infection

The invention contemplates administration of the particles to subjects having or at risk of developing an infection such as a bacterial infection, a viral infection, a fungal infection, a parasitic infection or a mycobacterial infection.

5 The bacterial infection may be without limitation an E. coli infection, a Staphylococcal infection, a Streptococcal infection, a Pseudomonas infection, Clostridium difficile infection, Legionella infection, Pneumococcus infection, Haemophilus infection, Klebsiella infection, Enterobacter infection, Citrobacter infection, Neisseria infection, Shigella infection, Salmonella infection, Listeria infection, Pasteurella infection, Streptobacillus infection, Spirillum infection, 10 Treponema infection, Actinomyces infection, Borrelia infection, Corynebacterium infection, Nocardia infection, Gardnerella infection, Campylobacter infection, Spirochaeta infection, Proteus infection, Bacteriodes infection, H. pylori infection, or anthrax infection.

The mycobacterial infection may be without limitation tuberculosis or leprosy respectively caused by the M. tuberculosis and M. leprae species.

15 The viral infection may be without limitation a Herpes simplex virus 1 infection, a Herpes simplex virus 2 infection, cytomegalovirus infection, hepatitis A virus infection, hepatitis B virus infection, hepatitis C virus infection, human papilloma virus infection, Epstein Barr virus infection, rotavirus infection, adenovirus infection, influenza A virus infection, H1N1 (swine flu) infection, respiratory syncytial virus infection, varicella-zoster virus infections, small pox 20 infection, monkey pox infection, SARS infection or avian flu infection.

The fungal infection may be without limitation candidiasis, ringworm, histoplasmosis, blastomycosis, paracoccidioidomycosis, cryptococcosis, aspergillosis, chromomycosis, mycetoma infections, pseudallescheriasis, or tinea versicolor infection.

25 The parasite infection may be without limitation amebiasis, Trypanosoma cruzi infection, Fascioliasis, Leishmaniasis, Plasmodium infections, Onchocerciasis, Paragonimiasis, Trypanosoma brucei infection, Pneumocystis infection, Trichomonas vaginalis infection, Taenia infection, Hymenolepsis infection, Echinococcus infections, Schistosomiasis, neurocysticercosis, Necator americanus infection, or Trichuris trichuria infection.

Effective Amounts, Regimens, Formulations

The particles provided herein may be administered in effective amounts. An effective amount is a dosage sufficient to provide a medically desirable result. The effective amount will vary with the particular condition being treated, the age and physical condition of the subject
5 being treated, the severity of the condition, the duration of the treatment, the nature of the concurrent or combination therapy (if any), the specific route of administration and like factors within the knowledge and expertise of the health practitioner. It is preferred, generally, that a maximum dose be used (i.e., the highest safe dose according to sound medical judgment).

The invention provides compositions, including pharmaceutical compositions,
10 comprising the particles of the invention. Pharmaceutical compositions are compositions that may comprise the particles of the invention, preferably in a pharmaceutically-acceptable carrier. The term “pharmaceutically-acceptable carrier” means one or more compatible solid or liquid filler, diluents or encapsulating substances which are suitable for administration to a human or other subject contemplated by the invention. The term “carrier” denotes an organic or inorganic
15 ingredient, natural or synthetic, with which the particles are suspended to facilitate administration. Components of the pharmaceutical compositions are commingled in a manner that precludes interaction that would substantially impair their desired pharmaceutical efficiency.

The compositions of the invention may be formulated for parenteral administration by injection, *e.g.*, by bolus injection or continuous infusion. Formulations for injection may be
20 presented in unit dosage form, *e.g.*, in ampoules or in multi-dose containers. Pharmaceutical parenteral formulations include aqueous solutions of components. Aqueous injection suspensions may contain substances which increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. Alternatively, suspensions may be prepared as oil-based suspensions. Suitable lipophilic solvents or vehicles include fatty oils such
25 as sesame oil, or synthetic fatty acid esters, such as ethyl oleate or triglycerides.

The compositions of the invention may be administered parenterally including intravenously or subcutaneously, although other routes of administration are also contemplated.

Repeated administration

In some embodiments, particles of the invention may be administered before and/or at the same time as and/or after the administration of adoptive cell therapy. In some instances, the particles of the invention may be administered substantially simultaneously with adoptive cell
5 therapy as well as after adoptive cell therapy. Such a subject may be receiving the particles of the invention substantially simultaneously and within days or weeks of receiving adoptive cell therapy. As used herein, substantially simultaneously means within 6 hours, including within 4 hours, within 2 hours, or within 1 hour. The adoptive cell therapy may take the form of tumor-reactive T cells. In some embodiments, the first administration occurs substantially
10 simultaneously with the administration of adoptive cell therapy. In some embodiments, the first administration occurs after the administration of adoptive cell therapy. The second and subsequent administrations may occur after the administration of adoptive cell therapy.

Repeated administration means that the particles of the invention are administered to the subject at least twice. In some embodiments, targeting particles are administered at least 3 times,
15 at least 4 times, at least 5 times, at least 6 times, at least 7 times, at least 8 times, or more. Repeated administration may occur over the course of a week, 2 weeks, 3 weeks, 4 weeks or longer. Repeated administrations may be regularly or randomly spaced in time. They may be days apart, or weeks apart, or months apart. For example, particles of the invention may be administered every day, every 2 days, every 3 days, every 4 days, every 5 days, every 6 days,
20 every week, every 2 weeks, every 3 weeks, every 4 weeks, *etc.*

In some embodiments, the first administration of particles occurs substantially simultaneously with the administration of adoptive cell therapy, and the second administration of particles occurs 3 days later.

It is to be understood that because the particles of the invention can be used with other
25 immunotherapies, it is intended that any embodiments recited herein in the context of adoptive cell therapy are illustrative of such other therapies, and that such other therapies may be used in place of adoptive cell therapies.

EXAMPLES

Example 1

In adoptive cell therapy (ACT), autologous tumor-specific T-cells isolated from cancer patients are activated and expanded *ex vivo*, then infused back into the individual to eliminate metastatic tumors. A major limitation of this promising approach is the rapid loss of ACT T-cell effector function *in vivo* due to the highly immunosuppressive environment in tumors. Protection of T-cells from immunosuppressive signals can be achieved by systemic administration of supporting adjuvant drugs such as interleukins, chemotherapy, and other immunomodulators, but these adjuvant treatments are often accompanied by serious toxicities and may still fail to optimally stimulate lymphocytes in all tumor and lymphoid compartments. Here we propose a novel strategy to repeatedly stimulate or track ACT T-cells, using cytokines or ACT-cell-specific antibodies as ligands to target PEGylated liposomes to transferred T-cells *in vivo*. Using F(ab')₂ fragments against a unique cell surface antigen on ACT cells (Thy1.1) or an engineered interleukin-2 (IL-2) molecule on an Fc framework as targeting ligands, we demonstrate that >95% of ACT cells can be conjugated with liposomes following a single injection *in vivo*. Further, we show that IL-2-conjugated liposomes both target ACT cells and are capable of inducing repeated waves of ACT T-cell proliferation in tumor-bearing mice. These results demonstrate the feasibility of repeated functional targeting of T-cells *in vivo*, which will enable delivery of imaging contrast agents, immunomodulators, or chemotherapy agents in adoptive cell therapy regimens or boosting of endogenous T-cell responses against pathogens or tumors.

Materials

All lipids and polycarbonate membranes (0.2 μ m) for size extrusion were from Avanti Polar Lipids (Alabaster, AL) and used as received. DiD, ACK lysis buffer, Calcium Phosphate Transfection Kit, HEK293 Free Style Cells, Max Efficiency® DH5 α TM Competent cells and Phoenix eco viral packaging cells were obtained from Invitrogen Life Technologies (Grand Island, NY). Anti-thy1.1 (clone 19E12) and mouse IgG2a isotype control antibodies were purchased from BioXCell (West Lebanon, NH). Dithiothreitol (DTT), Fluorescein isothiocyanate (FITC) isomer I, Concanavalin A Type VI (ConA), and Triton X-100 were from Sigma-Aldrich (St. Louis, MO) and used as received. Recombinant IL-2 and IL-7 were purchased from

PeproTech (Rocky Hill, NJ). Anti-mouse CD16/32, anti-CD25, anti-CD25-Alexa 488, anti-CD8-PE, anti-Thy1.1, anti-Thy1.1-PerCP-Cy5.5 and anti-Thy1.1-FITC were from eBioscience (San Diego, CA). Anti-mouse α 13 T-cell Receptor-FITC was purchased from Becton Dickinson (Franklin Lakes, NJ). Protein A agarose column and Amicon Ultra-15 30kDa MWCO Centrifugal Filter Units were from Millipore (Billerica, MA). Polyethylenimine (PEI) was from Polysciences (Warrington, PA). F(ab')₂ Preparation Kits, BCA Protein Assay Kits, and Zeba desalting columns were from Pierce Thermo Scientific (Rockford, IL). IL-2 ELISA Kits were obtained from R&D Systems (Minneapolis, MN). Ficoll-Paque Plus was from GE Health Care (Waukesha, WI). EasySep™ Mouse CD8+ T Cell Enrichment Kit was from Stemcell (Vancouver, BC, Canada). Collagenase II and Hank's Balanced Salt Solution were purchased from (Gibco-Invitrogen, Carlsbad, CA). EndoFree Plasmid Maxi Kit was from Qiagen (Valencia, CA). Retronectin Recombinant Human Fibronectin Fragment was from Clontech (Mountain View, CA). D-Luciferin was from Caliper Life Sciences (Hopkinton, MA). B16F10 melanoma cells were from American Type Culture Collection (Manassas, VA).

Methods

Preparation of IL-2-Fc and anti-Thy1.1 F(ab')₂: IL-2-Fc is a bivalent fusion protein of the C-terminus of murine wild type IL-2 linked to a mouse IgG2a backbone [23]. A D265A mutation was introduced in the IgG2a Fc region to minimize interaction of IL-2-Fc with Fc receptors [24]. IL-2-Fc gene was transformed into DH5 α cells via heat shock and extracted after clone expansion using an EndoFree Plasmid Maxi Kit following the manufacturer's instructions. HEK293 Freestyle cells were transfected with IL-2-Fc gene/Polyethylenimine (PEI) complexes and grown in roller bottles at 37 °C for a week before harvest. Cells were spun down and secreted IL-2-Fc in the supernatant was purified by gravity flow/elution through Protein A agarose columns and concentrated by using centrifugal filter units (Amicon Ultra-15 30kDa MWCO).

Monoclonal antibodies (Abs) against Thy1.1 were digested with pepsin to generate the F(ab')₂ using a F(ab')₂ Preparation Kit following the manufacturer's instructions. IL-2-Fc and anti-Thy1.1 F(ab')₂ concentrations were determined by the BCA Protein Assay Kit. IL-2-Fc bioactivity concentration relative to wild type murine IL-2 was quantified by an IL-2 ELISA Kit.

Synthesis of IL-2-Fc-Liposome and anti-Thy1.1-Liposome: Vacuum dried lipid films composed of 1,2-distearoyl-sn-glycero-3-phosphoethanolamine-N-[maleimide(polyethylene glycol)-2000 (maleimide-PEG2000-DSPE)/ cholesterol /hydrogenated Soy L- α -phosphatidylcholine (HSPC) in a molar ratio of 2.5/27.5/69 together with 1% of a fluorescent lipophilic tracer dye 1,1'-Dioctadecyl-3,3,3',3'-Tetramethylindodicarbocyanine, 4-Chlorobenzenesulfonate Salt (DiD) were rehydrated in 250 μ l of 50 mM HEPES/150 mM NaCl-buffer (pH6.5). Lipids were vortexed every 10 min for 1 hr at 62°C to form vesicles and size extruded through a polycarbonate membrane (0.2 μ m). After washing in excess phosphate buffered saline (PBS) pH7.4 and spinning down by ultracentrifugation at 110,000xg for 4 hr, liposomes were re-suspended in 100 μ l PBS per 1.4 mg of lipids.

IL-2-Fc and anti-Thy1.1 F(ab')₂ were coupled to liposomes as previously described [23]. Briefly, Ab or cytokine (4-8 mg/ml) were treated with 1.8 mM DTT in the presence of 10 mM EDTA at 25°C for 20 min to expose hinge region free thiols. DTT was subsequently removed by using Zeba desalting columns before mixing with maleimide-bearing liposomes (1 mg protein/1 mg lipid) in PBS pH 7.4. After incubation for 18 hr at 25°C on a rotator, excess protein was removed by ultracentrifugation in excess PBS (if aggregation occurs, liposomes were size extruded through a 0.2 μ m polycarbonate membrane at 37°C before ultracentrifugation). Liposome sizes were characterized before/after coupling by dynamic light scattering (90Plus Particle Size Analyzer, Brookhaven, Holtsville, NY).

Quantification of targeting ligands coupled to liposomes: Anti-Thy1.1-FITC was concentrated to 4-8 mg/ml using Ultra-15 Centrifugal Filters before coupling to liposomes as previously described. After liposomes were solubilized in 2% Triton X-100 at 37°C for 5 min with gentle vortexing, FITC fluorescence was measured at ex/em wavelengths of 490/520nm using a fluorescence plate reader (Tecan Systems, San Jose, CA) and converted to protein concentrations using standard curves prepared from serial dilutions of neat anti-Thy1.1-FITC stock solutions. IL-2-Fc-Lips were solubilized in the same manner and the amount of IL-2 coupled was determined using an IL-2 ELISA Kit (R&D Systems, Minneapolis, MN) following the manufacturer's instructions.

Activation of pmel-1 Thy1.1+CD8+ T-cells: Animals were cared for in the USDA-inspected MIT Animal Facility under federal, state, local and NIH guidelines for animal care. Spleens from pmel-1 Thy1.1+ mice were ground through a 70 µm cell strainer and red blood cells were removed by incubating with ACK lysis buffer (2 ml per spleen) for 5 min at 25°C.

5 After 1 wash in PBS, the remaining cells were cultured at 37°C in RPMI 1640 medium containing 10% fetal calf serum (FCS). ConA at a final concentration of 2 µg/ml and IL-7 at 1 ng/ml were added to activate and expand splenocytes. After two days, dead cells were removed by Ficoll-Paque Plus gradient separation and CD8+ T-cells were isolated via magnetic negative selection using an EasySep™ Mouse CD8+ T Cell Enrichment Kit. Purified CD8+ T-cells were
10 re-suspended at 1.5×10^6 per ml RPMI containing 10 ng/ml recombinant murine IL-2. After 24 hr, cells were washed 3 times in PBS and re-suspended in 100×10^6 per ml for adoptive transfer.

For bioluminescence imaging experiments, Click Beetle Red luciferase (CBR-luc) [16] was introduced into pmel-1 T-cells (post ficoll purification and magnetic selection) by retroviral transduction. Phoenix eco viral packaging cells were seeded at 4×10^6 cells per 10 cm tissue
15 culture dish in 10ml DMEM medium containing 10% FCS. After incubation overnight at 37°C, phoenix cells were exchanged with 10ml fresh DMEM with 10% FCS, transfected with CBR-luc plasmid and phoenix eco plasmid using a Calcium Phosphate Transfection Kit and cultured at 32°C for 24 hr. DMEM was then replaced with 6 ml RPMI containing 10% FCS and transfected phoenix eco cells were incubated for another 24 hr. Supernatant containing the retrovirus-
20 packaged CBR-luc gene was collected and replaced with fresh RPMI for another 24 hr incubation. Supernatant was collected again and combined with that collected 24 hr earlier, and sterile filtered (0.45 µm). Six-well non-tissue culture plates (BD Falcon) were coated with 1 ml RetroNectin (15 µg/ml) 18 hr at 4°C, then excess RetroNectin was aspirated. Pmel-1 T-cells post ficoll purification and magnetic selection were suspended in filtered viral sups (RPMI collected
25 previously) with 10 ng/ml IL-2 at 1.8×10^6 /ml, 3 ml was added to each RetroNectin-coated well, and spinoculation was conducted by centrifuging at 2000x g for 1 hr at 25°C. Transduced T-cells were then incubated at 37°C. Six hours later, 1 ml of fresh RPMI was added with 10 ng/ml IL-2. Transduced, activated pmel-1 T-cells were used 1 day later for adoptive transfer studies.

In vitro liposome binding to T-cells: DiD-labeled protein-conjugated liposomes (0.7 mg lipids in 100 μ l) were incubated with 15×10^6 activated pmel-1 Thy1.1+ T-cells in 1ml complete RPMI supplemented with 10% FCS for 30 min at 37°C with gentle agitation every 10 min. In competitive conjugation assays, 100-fold molar excess soluble IL-2-Fc or anti-Thy1.1 free antibody (compare to the amount coupled to liposomes) was added 30 min before targeting liposomes to saturate IL-2 or Thy1.1 receptors on the cells, respectively. For IL-2-Fc-Liposome (IL-2-Fc-Lip) competition assays, 2.5×10^6 activated pmel-1 CD8+ T-cells were mixed with 2.5×10^6 naïve C57Bl/6 splenocytes in 100 μ l complete RPMI with 10% FCS. The cell mixture was incubated with or without 0.24 mg/ml soluble IL-2-Fc, followed by incubation with 0.07 mg/ml IL-2-Fc-Lip for 30 minutes at 37°C with total volume topped up to 300 μ l. For competition assays with anti-Thy1.1.-Liposome (anti-Thy1.1-Lip), 0.15 mg/ml liposomes (Lip) were incubated with a mixture of 2.5×10^6 activated pmel-1 T-cells and 2.5×10^6 naïve C57Bl/6 splenocytes (with or without pre-blocking by 1.34 mg/ml anti-Thy1.1). Cells without any liposomes added served as a control for cellular autofluorescence and cells conjugated with 0.15 mg/ml IgG2a-Liposomes (IgG2a-Lip) were used to test non-specific binding of non-targeting liposomes. For all *in vitro* conjugation experiments, cells were stained with anti-CD8 and anti-Thy1.1 after two washes in ice cold PBS to remove unbound liposomes, and analyzed by flow cytometry on a BD FACS Canto except competition assays which were done on a BD LSR II.

Titration of liposome concentration for in vitro conjugation: Varying amounts of DiD-labeled anti-Thy1.1-Lip were added to 5×10^6 activated pmel-1 Thy1.1+ T-cells in 100 μ l complete RPMI with 10% FCS. The total volume for all groups was topped up with RPMI with 10% FCS to 300 μ l and incubated at 37°C for 30 min. After two washes in ice cold PBS to remove unbound liposomes, cells were resuspended in FACS buffer, surface stained with fluorescently labeled anti-CD8 and anti-Thy1.1, and analyzed by flow cytometry on a BD LSR II.

Internalization of liposomes: Anti-Thy1.1-Liposomes were labeled with 1% (mol) carboxyfluorescein- 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine lipid (CF-DOPE) instead of DiD during the synthesis stage and incubated with 6×10^6 activated pmel-1 Thy1.1+ T-cells per

0.7 mg of lipids for 60 min at 4°C with gentle agitation every 15 min. After two washes in ice cold PBS pH7.4 to remove unbound liposomes, T-cells were resuspended in RPMI and aliquotted into four equal portions for 0, 2, 4 and 6 hr time points, respectively. After each incubation interval at 37°C, T-cells were washed 2x in ice cold PBS and re-suspended in flow
5 cytometry buffer (2% FCS in PBS). Cells were placed on ice to minimize further internalization and analyzed by flow cytometry on a BD LSR II. Cells were also imaged directly without fixation on a Zeiss LSM 510 laser scanning confocal microscope.

Adoptive transfer and in vivo liposome targeting: Albino C57BL/6 female mice 6-8 weeks of age were from the Jackson Laboratory (Bar Harbor, ME). One day before adoptive
10 transfer, mice were sublethally lymphodepleted with 5Gy total body irradiation. 15×10^6 activated pmel-1 CD8+ T-cells in 150 μ l PBS were injected intravenously (i.v.) into each recipient animal. DiD-labeled immunoliposomes (1.4 mg lipids) were re-suspended in 100 μ l PBS and injected i.v. immediately or three days after adoptive transfer. Twenty-four hr after administration of liposomes, mice were euthanized and blood, lymph node, and spleen cells were analyzed by flow
15 cytometry on a BD FACS Canto to assess liposome binding to T-cells.

Adoptive transfer of CBR-Luc T-cells and bioluminescence imaging: B16F10 melanoma cells were suspended at 1×10^6 cells per 200 μ l in Hank's Balanced Salt Solution and injected i.v. to induce lung metastases in albino C57Bl/6 mice (Day -8). Animals were then sublethally lymphodepleted by total body irradiation (5 Gy) 7 days post tumor inoculation (Day -
20 1). Pmel-1 CD8+ T-cells transduced with CBR-Luc (12×10^6) were resuspended in 150 μ l PBS and administered i.v. one day after lymphodepletion (Day 0). IL-2-Fc-Lip (1 mg of liposomes) or PBS were injected i.v. immediately after ACT and on day 6. D-Luciferin, a substrate for CBR-luc, was suspended in PBS (15 mg/ml) and 150 mg luciferin/kg body weight was injected Intraperitoneally (i.p.) in anesthetized animals 10 min before bioluminescence imaging
25 acquisitions (5 min, 3 min, 2min and 1min) on a Xenogen IVIS Spectrum Imaging System (Caliper Life Sciences). Images were collected every two days starting from day 0 (2hrs after ACT) to day 14. Living Image software version 3.0 (Caliper Life Sciences) was used to acquire and quantitate the bioluminescence imaging data sets. To compare the stimulatory effects of

soluble IL-2 and IL-2-Fc-Lip, a similar experiment was repeated with 1st/2nd dose as 0.5 mg/1 mg IL-2-Fc-Lip or 10 µg/20 µg soluble recombinant wild type mouse IL-2 (PeproTech, Rocky Hill, NJ), equivalent to the amount of IL-2 coupled on IL-2-Fc-Lip). On day 12 mice were sacrificed and T-cells from inguinal lymph nodes were collected and surface stained for CD8 and vβ13 before analyzing by flow cytometry on a BD FACS Canto to assess the percentage of tumor-specific T-cells in each group.

Sample preparation for flow cytometry: Inguinal lymph nodes and spleens were ground through a 70 µm cell strainer and washed once with ice cold PBS. Splenocytes were then lysed with ACK lysis buffer (2 ml per spleen) for 5 min at 25°C to remove red blood cells before washing in ice cold PBS. Blood samples were lysed with 2X 1ml ACK lysis buffer for 5 min at 25°C and then washed 1x with ice cold PBS. All cells were washed in FACS buffer (PBS with 2% Fetal Calf Serum) once before surface-staining with Ab. After staining, cells were washed 2x in FACS buffer and analyzed on a BD FACS Canto Flow Cytometer. All data was processed using FlowJo software.

Statistical analysis: Statistical analysis was done using GraphPad Prism software and two-tailed unpaired t-tests were conducted between groups of experimental data. Graphs show the mean ± SEM of sample groups.

Results and Discussion

Synthesis and Characterization of IL-2-Fc-Lip and anti-Thy1.1-Lip: To generate cytokine- or antibody (Ab)-conjugated liposomes (IL-2-Fc-Lip or anti-Thy1.1-Lip) for T-cell targeting, PEGylated liposomes incorporating maleimide-headgroup PEG-lipids (Mal-PEG-DSPE) were prepared from high-T_m lipids and sized by membrane filtration to a mean diameter of 173±13 nm (FIG. 1A, B). Murine IL-2 fused to the C-terminus of mouse IgG2a Fc or anti-Thy1.1 F(ab')₂ were coupled to the maleimide termini of PEG chains to serve as targeting ligands of the immunoliposomes. To minimize interaction of liposomes with phagocyte Fc receptors, a D265A mutation was introduced in the Fc portion of IL-2-Fc [24] and F(ab')₂ fragments of anti-Thy1.1 monoclonal antibodies were generated by pepsin digestion. Prior to F(ab')₂/cytokine coupling, IL-2-Fc and anti-Thy1.1 F(ab')₂ were mildly reduced by DTT to

expose hinge region free thiols for reaction with the liposome maleimide functional head groups. We tested liposomes containing two different mole fractions of maleimide-PEG lipid (1 or 2.5 mol% of total lipids), and found greater targeting ligand conjugation with higher fractions of maleimide-lipid, as expected (FIG. 1C). Negligible IL-2 or F(ab')₂ binding to liposomes was observed in the absence of the maleimide reactive groups. Liposomes with 2.5 mol% mal-PEG-DSPE gave 23 ± 2 μ g of IL-2 (cytokine equivalent, or 1.4 nmol IL-2) or 76 ± 7 μ g of anti-Thy1.1 (0.5 nmol F(ab')₂) per mg lipid after overnight coupling at 25°C. As shown in FIG. 1B, targeting ligand conjugation caused a slight increase in the mean size of the vesicles from 173 ± 13 nm to 186 ± 16 nm.

IL-2-Fc-Lip and anti-Thy1.1-Lip binding to T-cells in vitro: To generate a target population of T-cells to be used in adoptive transfer studies, CD8⁺ T-cells from pmel-1 Thy1.1+ mice (which express a transgenic T-cell receptor specific for the gp100 antigen of melanoma [25]) were isolated by magnetic negative selection from activated splenocytes, and expanded by culturing with IL-2 for 1 day to obtain an elevated expression of CD25 (the α -chain of the trimeric IL-2 receptor) compared to naive pmel-1 or naive polyclonal C57Bl/6 CD8⁺ T-cells (FIG. 2A and data not shown). Fluorescently labeled PEGylated vesicles showed very low background binding to activated pmel-1 T-cells following a 30 min incubation at 37° *in vitro*, but IL-2-Fc-Lip or anti-Thy1.1-Lip containing 1% or 2.5% maleimide functional groups efficiently bound to activated pmel-1 T-cells (FIG. 2B). The Mean Fluorescence Intensities (MFI) of cells after conjugation with different types of liposomes was quantified; the high expression levels of Thy1.1 on pmel-1 T-cells led to much greater per-cell binding of anti-Thy1.1-Lip vs. IL-2-Fc-Lip (FIG. 2C). For both targeting ligands, liposomes containing 2.5 mol% mal-PEG-DSPE (and therefore with higher ligand densities) achieved much greater binding to T-cells than vesicles with 1 mol% of the maleimide lipid, with MFIs of bound liposomes increased by 6-fold and 4-fold for anti-Thy1.1-Lip and IL-2-Fc-Lip, respectively (FIG. 2B, C).

To evaluate the specificity of anti-Thy1.1-Lip and IL-2-Fc-Lip binding, we assessed T-cell labeling in the presence of competing free IL-2-Fc or anti-Thy1.1 Abs added to a 1:1 mixture of naïve C57Bl/6 lymphocytes and pmel-1 T-cells 30 min before the targeted vesicles. IL-2-Fc-Lip bound to activated pmel-1 T-cells, but not naïve C57Bl/6 CD8⁺ T cells that lack IL-

2 receptors (FIG. 2D middle left). Pre-blocking pmel-1 T-cells with soluble IL-2-Fc blocked 90% of binding to pmel-1 T-cells (FIG. 2D middle right, 2E). Similarly, anti-Thy1.1-Lip selectively targeted pmel-1 CD8+ T cells but not naive C57Bl/6 (Thy1.2+) CD8+ T cells (FIG. 2D bottom left). Pre-incubation of pmel-1 T-cells with anti-Thy1.1 lowered anti-Thy1.1-Lip binding by 99% (FIG. 2D bottom right, 2E). Autofluorescence and non-specific binding of non-targeted control IgG2a-Lip were negligible (FIG. 2D top left and right, 2E). As expected from the pM affinity of IL-2 for its receptor [26, 27] and the typical nM affinity of commercial antibodies, liposomes at concentration of 0.4 mg/ml (equivalent to 2 nM of liposomes) labeled 100% of activated pmel-1 T-cells *in vitro*, and liposome binding reached a plateau at concentrations higher than 0.4 mg/ml (equivalent to 2 nM liposomes) (FIG. 2F). Thus, both IL-2- and anti-Thy1.1-targeted stealth liposomes achieve specific and avid binding to primed pmel-1 CD8+ T-cells. Even when the concentration was titrated down to 0.1 mg/ml, nearly 100% of cells were still labeled with liposomes, albeit with fewer liposomes bound per cell.

Internalization of Anti-Thy1.1-conjugated liposomes: We previously reported that IL-2-Fc-conjugated liposomes are rapidly internalized by activated T-cells *in vitro* [28]. To determine whether anti-Thy1.1-Lip would also trigger liposome endocytosis, we added anti-Thy1.1-Lip incorporating a carboxyfluorescein (CF)-headgroup lipid to pmel-1 T-cells at 4°C to allow binding without internalization, then warmed the cells to 37°C and assessed cell-associated fluorescence over time. Fluorescein has highly pH-sensitive fluorescence that is strongly quenched at acidic pHs [29]. The high avidity of liposome binding to cells led to no measurable release of free liposomes into the supernatant over 6 hr at 37°C (not shown); we thus attributed loss of the CF tracer signal to endocytic uptake by labeled cells. Over a time course of 6 hr, the MFI of liposome-labeled T-cells steadily dropped, corresponding to roughly 90% internalization over this time course (Fig 3A). Confocal imaging also showed that anti-Thy1.1-Lip fluorescence initially localized to the plasma membrane of labeled cells was largely lost by 6 hr (FIG. 3B).

In vivo targeting of IL-2-Fc-Lip and anti-Thy1.1-Lip in healthy animals: Next, we tested the capacity of anti-Thy1.1-Lip and IL-2-Fc-Lip to target pmel-1 T-cells *in vivo* in healthy mice. PEGylated liposomes conjugated with isotype control murine IgG2a were prepared to

serve as a control non-T-cell-targeting liposome. To model clinical adoptive T-cell therapy, recipient Thy1.2+ C57Bl/6 mice were lymphodepleted by sublethal irradiation, followed by i.v. injection of 15×10^6 activated pmel-1 Thy1.1+CD8+ T-cells one day later. Lymphodepletion removes cytokine sinks and regulatory T-cells to allow more efficient expansion and effector function of transferred T-cells [30, 31]. To assess T-cell targeting, IgG2a-Lip, IL-2-Fc-Lip, or anti-Thy1.1-Lip fluorescently labeled with the non-pH-sensitive tracer DiD were injected i.v. either immediately after adoptive transfer or 3 days after T-cell injection. Twenty-four hours after liposome injection, cells from the blood, lymph nodes (LNs), and spleens were analyzed by flow cytometry to assess binding of fluorescent liposomes (FIG. 4A). Thy1.1 expression allowed liposome binding to transferred pmel-1 T-cells to be distinguished from endogenous T-cells (FIG. 4B). Sample flow cytometry histograms are shown in FIG. 4C, illustrating conjugation efficiencies of IgG2a-Lip, IL-2-Fc-Lip, and anti-Thy1.1-Lip obtained when liposomes were injected immediately after ACT T-cells. The percentage endogenous or ACT CD8+ T-cells labeled by each type of liposome in the blood (FIG. 4D), lymph nodes (FIG. 4E) and spleens (FIG. 4F) were assessed; this analysis revealed that IgG2a-Lip exhibited low binding to both T-cell populations. In contrast, anti-Thy1.1-Lip labeled nearly 100% of the transferred T-cells in the blood and spleen whether injected on day 0 or day 3. The slightly greater background binding of isotype control IgG2a-Lip to ACT vs. endogenous T-cells in spleens was found to be an artifact of the liposome dose; injection of lower liposome doses of 0.18 mg (approximately ~0.1 mg/mL liposomes in the blood) led to a similar efficiency of specific T-cell binding but eliminated the low differential background binding to ACT vs. endogenous T-cells (data not shown). A lower fraction of T-cells in lymph nodes were labeled by anti-Thy1.1-Lip following a day 3 injection, which may reflect a combination of poor entry of targeted liposomes into LN and/or incomplete recirculation of T-cells from LN back into the blood in the 24 hr time window between liposome injection and our analysis. Anti-Thy1.1-Lip also showed low levels of background binding to endogenous (Thy1.1-) T-cells. IL-2-Fc-Lip labeled the majority of pmel-1 T-cells in the LNs, spleen and blood when injected just after T-cells, and also showed relatively low binding to endogenous T-cells. However, injection of IL-2Fc-Lip on day 3 led to relatively poor T-cell labeling in the blood and LNs, while still labeling a majority of ACT T-cells in the spleen. Poor labeling by IL-2-Fc-Lip on day 3 reflected rapid downregulation of the IL-2R *in*

vivo following T-cell transfer in the absence of antigen (data not shown). Thus, both IL-2-Fc and anti-Thy1.1 F(ab')₂ can be effective for specifically targeting adoptively transferred T-cells *in vivo*.

IL-2-Fc-Lip permit repeated boosting of ACT T-cells in a murine lung metastasis

5 **model:** To test the potential functional impact of stimulatory T-cell targeted liposomes, we assessed the response of pmel-1 melanoma-specific T-cells *in vivo* during ACT treatment of B16F10 tumors in a metastatic lung tumor model. B16F10 melanoma cells were injected via the tail vein to allow lung metastases to establish for 10 days, then animals were lymphodepleted and received adoptive transfer of luciferase-expressing pmel-1 melanoma-specific CD8⁺ T-cells
10 (FIG. 5A). In one group of animals, T-cell expansion was followed over time by bioluminescence imaging without further treatment, while in other two groups of mice, the adoptively-transferred cells were boosted on days 0 and 6 by injection of IL-2-Fc-Lip. Adoptively transferred cells without further adjuvant support showed a low level persistence in the tumor-bearing recipients that gradually declined over 14 days, as expected in the absence of
15 additional stimulation or protection from tumor immunosuppression [25] (Fig 5B, C). In contrast, following injection of the first dose of IL-2-Fc-Lip, pmel-1 T-cells expanded 3-fold more than the control T-cell therapy group. These boosted T-cells began to contract again between day 4 and day 6, but following a second dose of IL-2-Fc-Lip, re-expanded to an even greater level, reaching a peak by day 10 with 6-fold greater T-cell numbers relative to the T-cell-
20 only treatment group (Fig 5B, C). To assess the relative potency of stimulation achieved by IL-2-Fc-Lip compared to traditional systemic IL-2 therapy, we repeated this ACT experiment and compared the expansion of T-cells following injection of IL-2-Fc-Lip or soluble IL-2 (at an equivalent total amount of cytokine to that bound to the liposomes) on day 0 and day 6. Flow cytometry analysis of T-cells pooled from the inguinal lymph nodes 12 days after adoptive
25 transfer confirmed that the frequency of tumor-specific CD8⁺ T-cells (pmel-1 T-cells express the V β 13 TCR β chain) was nearly 3 times greater in animals that received IL-2-Fc-Lip injections compared to T-cells alone (Figs. 5D-E). Further, soluble IL-2 at these doses showed no enhancement in T-cell expansion. The difference between the potency of IL-2-Fc-Lip and soluble IL-2 may reflect the very short half-life of IL-2 *in vivo* [32], which the PEGylated

liposomes may partly overcome. Notably, this enhanced potency was not accompanied by overt toxicity as assessed by changes in animal weights during the therapy (data not shown). Thus, IL-2-targeted liposomes allow multiple boosts of ACT T-cells *in vivo*, leading to repeated waves of T-cells expansion in tumor-bearing animals, which exceed the response elicited by systemic free IL-2.

Here we synthesized and characterized antibody- and cytokine-decorated immunoliposomes targeting unique cell surface antigens or activation markers on T-cells, respectively. Targeting liposomes bound to ACT T-cells specifically *in vitro*, and further, anti-Thy1.1-Lip also labeled nearly 100% of transferred T-cells in systemic compartments and most of transferred T-cells in LN *in vivo* following a single injection of targeted vesicles. Despite its lower targeting specificity compared to anti-Thy1.1-Lip, IL-2-Fc-Lip was able to repeatedly boost transferred T-cells *in vivo* in tumor-bearing animals and provide direct stimulation to ACT T-cells. These results demonstrate the concept of repeated targeting of ACT T-cells for adjuvant stimulation *in vivo*. Also envisioned is functional targeting of supporting adjuvant drugs or imaging contrast agents to T-cells, in order to enhance the efficacy of ACT and/or permit longitudinal tracking of ACT T-cells *in vivo*.

Example 2

This Example provides data obtained from systemic delivery of anti-CD137-conjugated liposomes and IL-2-Fc-conjugated liposomes.

Antibody-conjugated liposomes were spherical and formed by single lipid bilayer, with the particle sizes of 30~50 nm (FIG. 6B), and their zeta potentials were around -30 mV.

In B16-OVA subcutaneous tumor model, 5×10^5 B16-OVA cells were inoculated to the flank of the mice. When the tumors reached $\sim 100 \text{ mm}^3$, mice were given intravenous (i.v.) injections of soluble CD137/IL-2-Fc or Lipo-CD137/Lipo-IL-2-Fc on day 0, 2 and 4 with a 100 $\mu\text{g}/\text{dose}$ of αCD137 and a 20 $\mu\text{g}/\text{dose}$ of IL-2-Fc. Isotype control IgG conjugated liposome (Lipo-IgG) was used as the control liposome. Both soluble CD137/IL-2-Fc and Lipo-CD137/Lipo-IL-2-Fc significantly suppressed the tumor growth (FIG. 7A). The mice in the soluble CD137/IL-2-Fc group started to lose body weight right after the treatment, and half of

them died on day 11. By contrast, all the mice in Lipo-CD137/Lipo-IL-2-Fc remained in good physical condition during the treatment, and they all survived after two weeks with little rebound in tumor burden (FIGs. 7B and 7C).

On day 6 post injection, CD8⁺ T cells were analyzed from lymphocytes in the peripheral blood. Soluble CD137/IL-2-Fc treatment induced 10 folds CD8⁺ T cell enrichment in PBMC comparing to the untreated group, while Lipo-CD137/ Lipo-IL-2-Fc triggered 5 folds CD8⁺ T cell enrichment. Lipo-IgG had no effect on CD8⁺ T cell number in PBMC (FIG. 8).

On day 6 post injection, lymphocytes from PBMC were pulsed with 10 μ M OVA protein for 8 hours, followed by addition of brefeldin A for 5 hours. Then, the intracellular staining of IFN γ and TNF α was analyzed by flow cytometry. Soluble CD137/IL-2-Fc dramatically triggered IFN γ and TNF α production, an about 30-fold increase relative to untreated group, in terms of total number of IFN γ ⁺/TNF α ⁺ CD8⁺ cells. Lipo-CD137/ Lipo-IL-2-Fc also induced an about 10-fold increase in IFN γ and TNF α production in CD8⁺ T cells relative to the untreated group. Lipo-IgG had little effect on the intracellular cytokine production (FIGs. 9A-9B).

In a B16F10 subcutaneous tumor model, 5×10^5 B16F10 cells were inoculated to the flank of the mice. When the tumors reached $\sim 60 \text{ mm}^3$, mice were given i.v. injections of soluble CD137/IL-2-Fc or Lipo-CD137/Lipo-IL-2-Fc on day 0, 3 and 6 with a 100 μ g/dose of α CD137 and a 60 μ g/dose of IL-2-Fc. Isotype control IgG conjugated liposome (Lipo-IgG) was used as the control liposome. Lipo-CD137/Lipo-IL-2-Fc significantly retarded the tumor growth comparing to untreated and Lipo-IgG groups. Soluble CD137/IL-2-Fc controlled the tumor growth in the early stage, but after the second i.v. injection, all the mice in soluble CD137/IL-2-Fc group died (FIG. 10C) due to the severe *in vivo* toxicity which coincided with their dramatic body weight loss right after the treatment (FIG. 10B). Unexpectedly, all the mice in Lipo-CD137/Lipo-IL-2-Fc remained good physical condition during the treatment, and all the mice survived during the therapeutic study (FIGs. 10B-10C).

Two days after a single i.v. injection in B16F10 tumor bearing mice, blood serums were collected, and serum cytokine levels were measured by LUMINEX[®] cytokine bead assay. Soluble CD137/IL-2-Fc triggered a dramatic increase in inflammatory cytokine levels, including IFN γ , IL6, MCP-1 and TNF α , which led to lethal *in vivo* toxicities observed in the therapeutic studies. Lipo-CD137/Lipo-IL-2-Fc had little effect on the elevation of inflammatory cytokine

levels, indicating systemic delivery of Lipo-CD137/Lipo-IL-2-Fc prevented lethal systemic inflammatory toxicity (FIG. 11).

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5

EQUIVALENTS

While several inventive embodiments have been described and illustrated herein, those of ordinary skill in the art will readily envision a variety of other means and/or structures for performing the function and/or obtaining the results and/or one or more of the advantages described herein, and each of such variations and/or modifications is deemed to be within the scope of the inventive embodiments described herein. More generally, those skilled in the art will readily appreciate that all parameters, dimensions, materials, and configurations described herein are meant to be exemplary and that the actual parameters, dimensions, materials, and/or configurations will depend upon the specific application or applications for which the inventive teachings is/are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific inventive embodiments described herein. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, inventive embodiments may be practiced otherwise than as specifically described and claimed. Inventive embodiments of the present disclosure are directed to each individual feature, system, article, material, kit, and/or method described herein. In addition, any combination of two or more such features, systems, articles, materials, kits, and/or methods, if such features, systems, articles, materials, kits, and/or methods are not mutually inconsistent, is included within the inventive scope of the present disclosure.

25 All definitions, as defined and used herein, should be understood to control over dictionary definitions, definitions in documents incorporated by reference, and/or ordinary meanings of the defined terms.

All references, patents and patent applications disclosed herein are incorporated by reference with respect to the subject matter for which each is cited, which in some cases may encompass the entirety of the document.

30

The indefinite articles “a” and “an,” as used herein in the specification and in the claims, unless clearly indicated to the contrary, should be understood to mean “at least one.”

The phrase “and/or,” as used herein in the specification and in the claims, should be understood to mean “either or both” of the elements so conjoined, i.e., elements that are
5 conjunctively present in some cases and disjunctively present in other cases. Multiple elements listed with “and/or” should be construed in the same fashion, i.e., “one or more” of the elements so conjoined. Other elements may optionally be present other than the elements specifically identified by the “and/or” clause, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, a reference to “A and/or B”, when used in
10 conjunction with open-ended language such as “comprising” can refer, in one embodiment, to A only (optionally including elements other than B); in another embodiment, to B only (optionally including elements other than A); in yet another embodiment, to both A and B (optionally including other elements); etc.

As used herein in the specification and in the claims, “or” should be understood to have
15 the same meaning as “and/or” as defined above. For example, when separating items in a list, “or” or “and/or” shall be interpreted as being inclusive, i.e., the inclusion of at least one, but also including more than one, of a number or list of elements, and, optionally, additional unlisted items. Only terms clearly indicated to the contrary, such as “only one of” or “exactly one of,” or, when used in the claims, “consisting of,” will refer to the inclusion of exactly one element of a
20 number or list of elements. In general, the term “or” as used herein shall only be interpreted as indicating exclusive alternatives (i.e. “one or the other but not both”) when preceded by terms of exclusivity, such as “either,” “one of,” “only one of,” or “exactly one of.” “Consisting essentially of,” when used in the claims, shall have its ordinary meaning as used in the field of patent law.

25 As used herein in the specification and in the claims, the phrase “at least one,” in reference to a list of one or more elements, should be understood to mean at least one element selected from any one or more of the elements in the list of elements, but not necessarily including at least one of each and every element specifically listed within the list of elements and not excluding any combinations of elements in the list of elements. This definition also allows
30 that elements may optionally be present other than the elements specifically identified within the

list of elements to which the phrase “at least one” refers, whether related or unrelated to those elements specifically identified. Thus, as a non-limiting example, “at least one of A and B” (or, equivalently, “at least one of A or B,” or, equivalently “at least one of A and/or B”) can refer, in one embodiment, to at least one, optionally including more than one, A, with no B present (and
5 optionally including elements other than B); in another embodiment, to at least one, optionally including more than one, B, with no A present (and optionally including elements other than A); in yet another embodiment, to at least one, optionally including more than one, A, and at least one, optionally including more than one, B (and optionally including other elements); etc.

It should also be understood that, unless clearly indicated to the contrary, in any methods
10 claimed herein that include more than one step or act, the order of the steps or acts of the method is not necessarily limited to the order in which the steps or acts of the method are recited.

In the claims, as well as in the specification above, all transitional phrases such as “comprising,” “including,” “carrying,” “having,” “containing,” “involving,” “holding,” “composed of,” and the like are to be understood to be open-ended, i.e., to mean including but
15 not limited to. Only the transitional phrases “consisting of” and “consisting essentially of” shall be closed or semi-closed transitional phrases, respectively, as set forth in the United States Patent Office Manual of Patent Examining Procedures, Section 2111.03.

What is claimed is:

CLAIMS

1. A method comprising
repeated systemic administration of a population of lymphocyte-targeting particles to a
5 subject, wherein the lymphocyte-targeting particles comprise on their surface at least one
lymphocyte-targeting molecule that binds to a lymphocyte cell surface marker.
2. The method of claim 1, wherein the at least one lymphocyte-targeting molecule
stimulates lymphocytes.
- 10 3. The method of claim 1 or 2, wherein the at least one lymphocyte-targeting molecule is a
lymphocyte-specific ligand.
4. The method of claim 1 or 2, wherein the at least one lymphocyte-targeting molecule is an
15 antibody or an antibody fragment.
5. The method of any one of claims 1-4, wherein the lymphocyte-targeting particles further
comprise an active agent.
- 20 6. The method of claim 5, wherein the active agent is encapsulated in the lymphocyte-
targeting particles.
7. The method of claim 5, wherein the active agent is bound to a surface of the lymphocyte-
targeting particles.
- 25 8. The method of any one of claims 1-7, wherein the population comprises (a) lymphocyte-
targeting particles comprising a first lymphocyte-targeting molecule and (b) lymphocyte-
targeting particles comprising a second lymphocyte-targeting molecule, wherein the second
lymphocyte-targeting molecule is different from the first lymphocyte-targeting molecule.

9. The method of any one of claims 1-7, wherein individual lymphocyte-targeting particles of the population comprise at least two lymphocyte-targeting molecules that are different from each other.

5

10. The method of any one of claims 1-9, wherein the lymphocyte-targeting particles target endogenous T cells.

11. The method of claim 10, wherein the lymphocyte-targeting particles comprise an active agent that stimulates activity and/or proliferation of endogenous T cells.

10

12. The method of any one of claims 1-11, wherein the lymphocyte-targeting particles target adoptively-transferred T-cells or T cells engineered to express a T cell receptor.

13. The method of any one of claims 2-12, wherein the lymphocyte cell surface marker is ART2, CD1a, CD1d, CD2, CD3, CD4, CD5, CD7, CD8, CD11b, CD25, CD28, CD38, CD45RO, CD72, CD134, CD137, CD150, CD154, CRTAM, FOXP3, FT2, GPCA, HLA-DR, HML-1, HT23A, LEU-22, LFA-1, LY-2, LY-M22, MICG, MRC-OX-8, MRC-OX-22, OX-40, PD-1, RT-6, TCR, THY-1 (CD90), TIM-3, CTLA-4 or TSA-2, or any combination thereof

20

14. The method of any one of claims 3-13, wherein the lymphocyte-specific ligand is a cytokine, interleukin, chemokine or growth factor.

15. The method of claim 14, wherein the lymphocyte-specific ligand is a cytokine.

25

16. The method of claim 15, wherein the cytokine is IL-2, IL-7, IL-15, CXCL10, CXCL5, MIP-1a, MIP-1b, or an Fc-fusion protein of any one of the foregoing cytokines.

17. The method of any one of claims 4-16, wherein the antibody is anti-Thy1, anti-CD137, anti-CTLA-4, anti-PD-1, or an antibody fragment of any one of the foregoing antibodies.

30

18. The method of any one of claims 5-17, wherein the active agent is a chemical entity, a protein, a polypeptide, a peptide, a nucleic acid, a virus-like particle, a steroid, a proteoglycan, a lipid or a carbohydrate.

5

19. The method of any one of claims 5-18, wherein the active agent is a therapeutic agent.

20. The method of any one of claims 5-19, wherein the active agent is an agent that inhibits immunosuppression.

10

21. The method of claim 20, wherein the active agent that inhibits immunosuppression is a Shp1/2 protein tyrosine phosphatase (PTPase) inhibitor.

22. The method of any one of claims 1-21, wherein the lymphocyte-targeting particles are lymphocyte-targeting liposomes.

15

23. The method of claim 22, wherein the lymphocyte-targeting liposomes are PEGylated lymphocyte-targeting liposomes.

24. The method of claim 22, wherein the lymphocyte-targeting particles are polymer-based lymphocyte-targeting particles.

20

25. The method of any one of claims 1-24, wherein repeated administration comprises daily, weekly or biweekly administration.

25

26. The method of any one of claims 1-25, wherein the subject has cancer.

27. The method of any one of claims 1-26, wherein the subject has an infection.

28. The method of any one of claims 1-27, wherein the lymphocyte-targeting particles are administered parenterally to the subject.

29. The method of any one of claims 1-28, wherein the subject is undergoing or has
5 undergone adoptive cell therapy.

30. The method of any one of claims 5-29, wherein the targeting molecule and/or active agent is administered at a dose that is greater than the maximum tolerated dose of a soluble form of the active agent.

31. A method comprising
repeated systemic administration of lymphocyte-targeting particles to a subject
undergoing adoptive cell therapy,
wherein the lymphocyte-targeting particles comprise
15 (a) on their surface, at least one of
(i) a lymphocyte specific ligand and
(ii) an antibody or antibody fragment that binds to a lymphocyte cell surface
marker, and
(b) internally, an active agent.

32. A method comprising
repeated systemic administration of particles to a subject undergoing adoptive cell
therapy,
wherein the particles comprise IL-2 on their surface.

33. The method of claim 32, wherein the particles internally comprise an active agent.

34. The method of claim 31 or 33, wherein the active agent is an agent that inhibits immunosuppression.

35. The method of claim 34, wherein the agent that inhibits immunosuppression is a Shp1/2 protein tyrosine phosphatase (PTPase) inhibitor.

36. The method of claim 31, wherein the lymphocyte specific ligand is a cytokine.

37. The method of claim 36, wherein the lymphocyte specific ligand is IL-2.

38. The method of claim 31, wherein the lymphocyte cell surface marker is Thy1.

39. The method of claim 31, wherein the lymphocyte cell surface marker is CD137.

40. The method of any one of claims 31-39, wherein repeated administration comprises daily, weekly or biweekly administration.

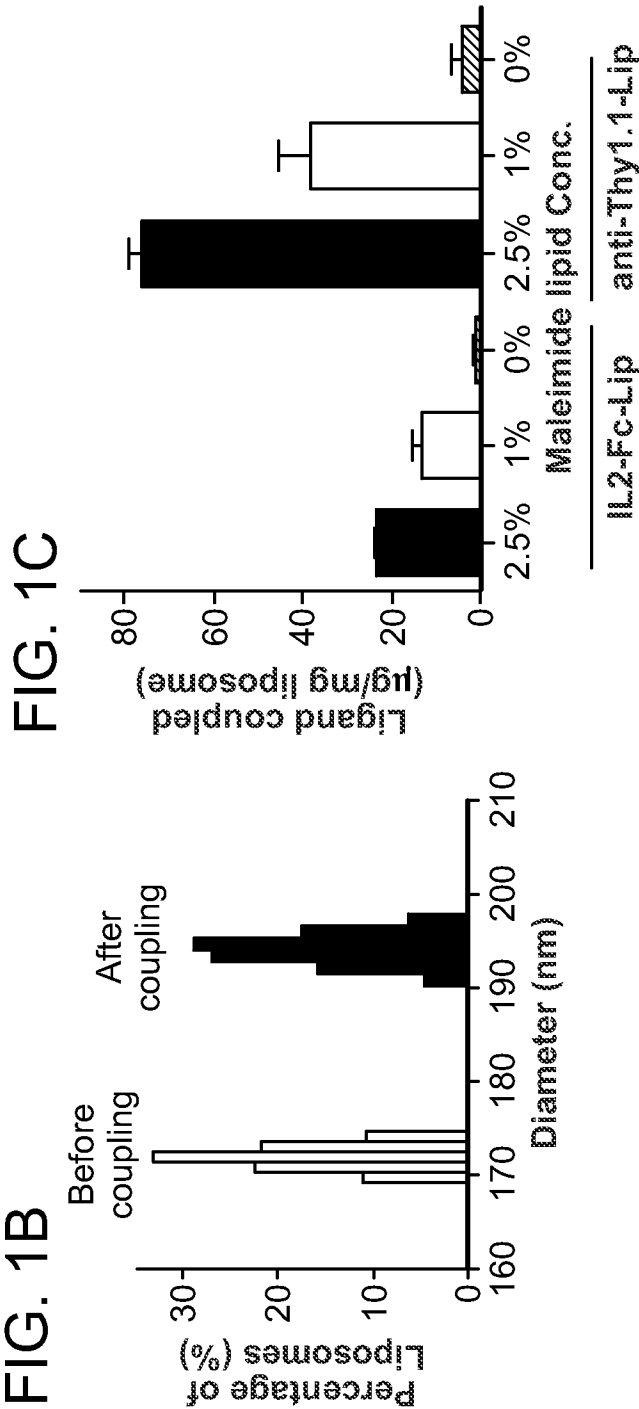
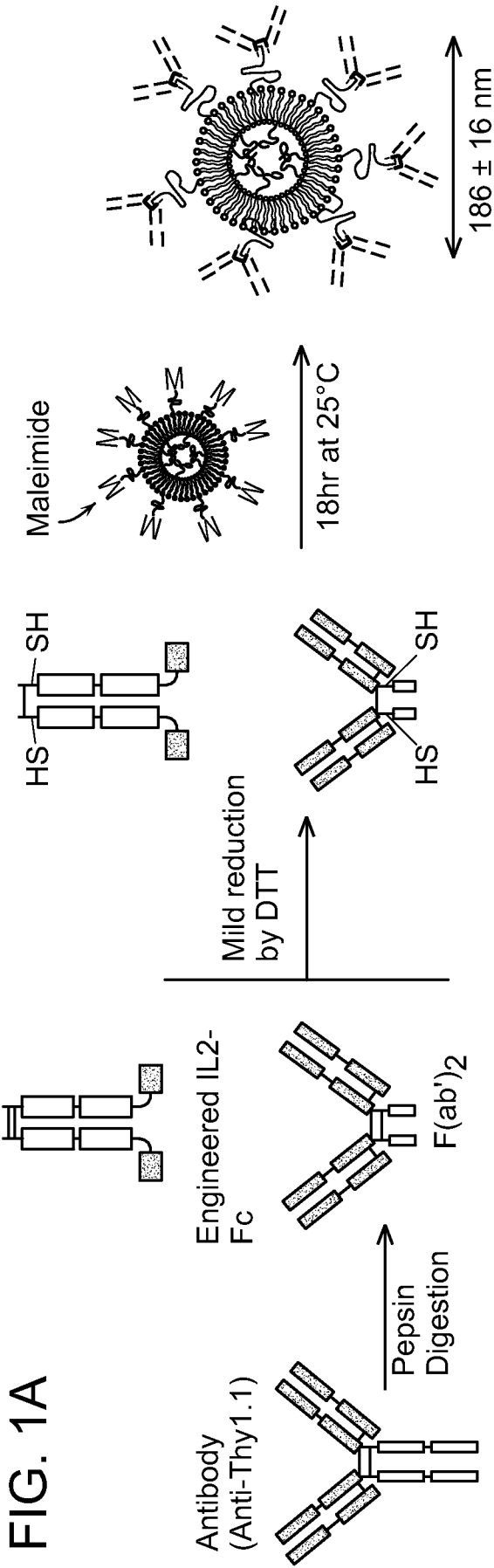
41. The method of any one of claims 31-40, wherein repeated administration comprises administration substantially simultaneously with the administration of tumor-reactive T cells, and at least one administration after administration of tumor-reactive T cells.

42. The method of any one of claims 31-41, wherein the adoptive cell therapy comprises administration of CD8+ T cells.

43. A method comprising
repeated administration of lymphocyte-targeting particles to a subject,
wherein the lymphocyte-targeting particles comprise
(a) on their surface, at least one of
(i) a lymphocyte-specific ligand and
(ii) an antibody or antibody fragment that binds to a lymphocyte cell
surface marker, and
(b) internally, an active agent.

44. A method comprising
repeated administration of particles to a subject,
wherein the particles comprise IL-2 or an IL-2-Fc fusion protein on their surface.
- 5 45. The method of claim 44, wherein the particles internally comprise an active agent.
46. The method of claim 43 or 45, wherein the active agent is an agent that inhibits
immunosuppression.
- 10 47. The method of claim 46, wherein the agent that inhibits immunosuppression is a Shp1/2
protein tyrosine phosphatase (PTPase) inhibitor.
48. The method of claim 43, wherein the lymphocyte specific ligand is a cytokine.
- 15 49. The method of claim 43, wherein the lymphocyte specific ligand is IL-2.
50. The method of claim 43, wherein the lymphocyte cell surface marker is Thy1.
51. The method of claim 43, wherein the lymphocyte cell surface marker is CD137, CTLA-4
20 or PD-1.
52. The method of any one of claims 43-51, wherein repeated administration comprises daily,
weekly or biweekly administration.
- 25 53. The method of any one of claims 43-52, wherein the particles target endogenous T cells.
54. The method of any one of claims 43-53, wherein the particles comprise an agent that
stimulates activity and/or proliferation of endogenous T cells.
- 30 55. The method of any one of claims 43-53, wherein the subject has an infection.

56. The method of any one of claims 43-53, wherein the subject has a cancer.
57. The method of any one of claims 31-56, wherein the particles are liposomes.
- 5 58. The method of claim 57, wherein the liposomes are PEGylated liposomes.
59. The method of any one of claims 31-56, wherein the particles are polymer-based particles.
- 10 60. The method of any one of claims 31-56, wherein the particles are administered parenterally.



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FIG. 2A

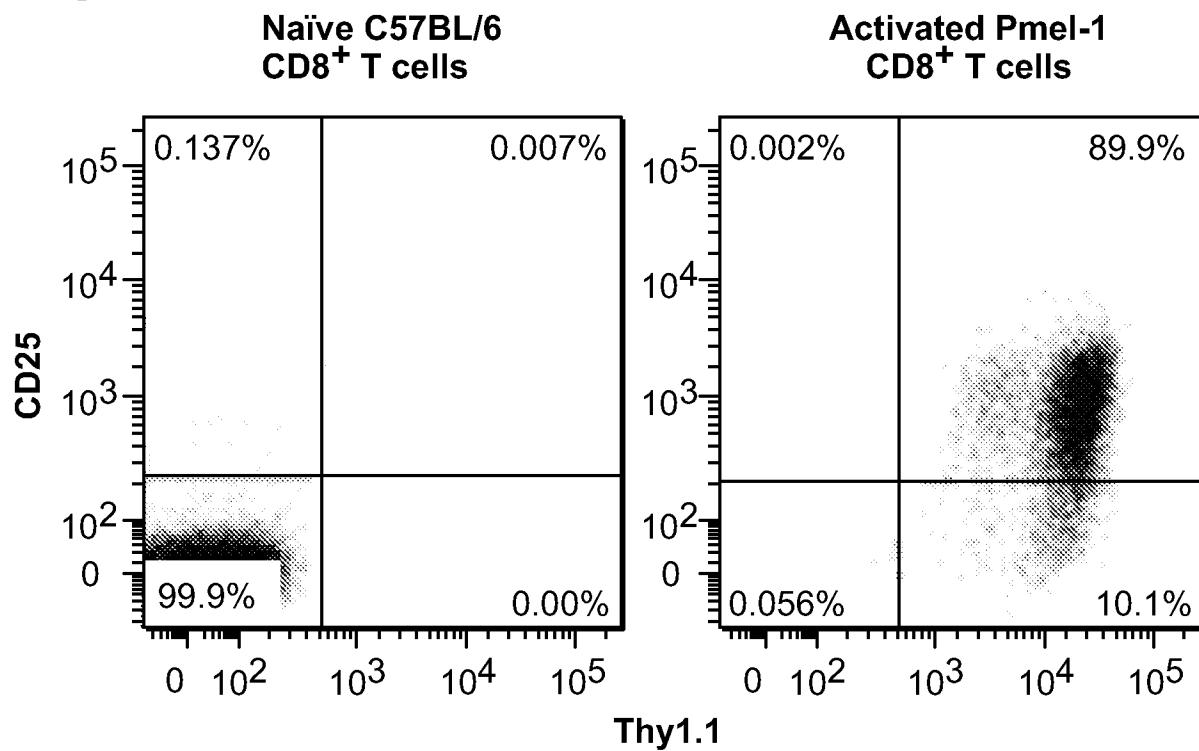
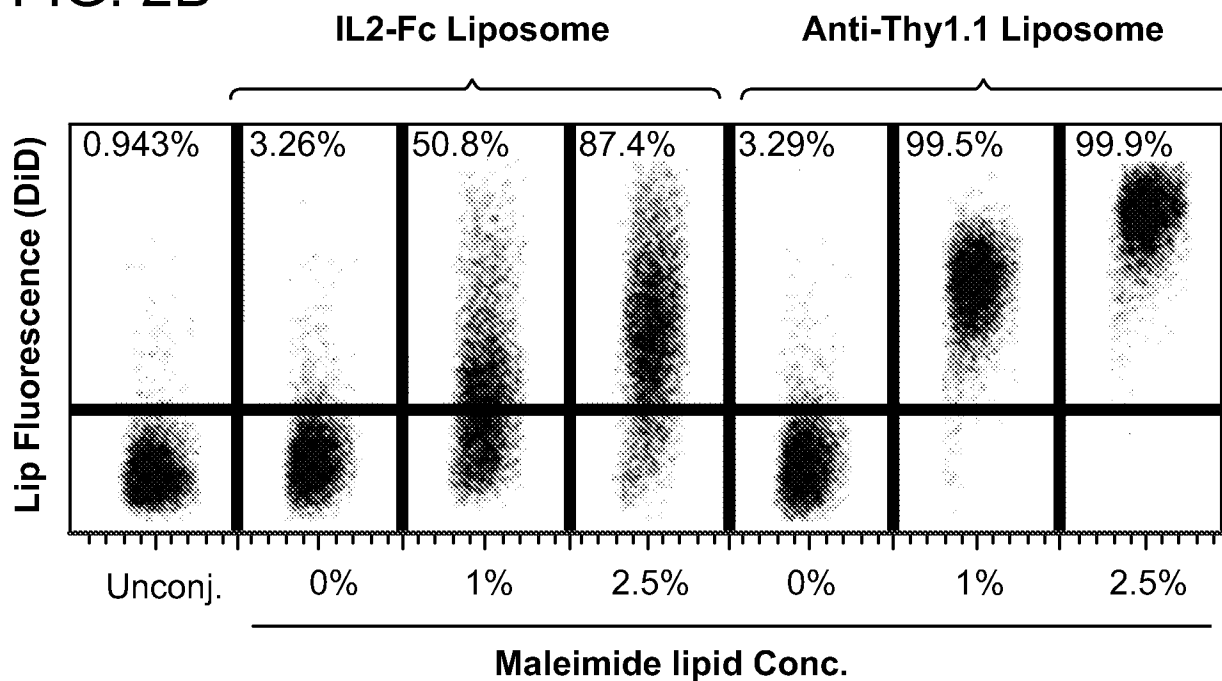
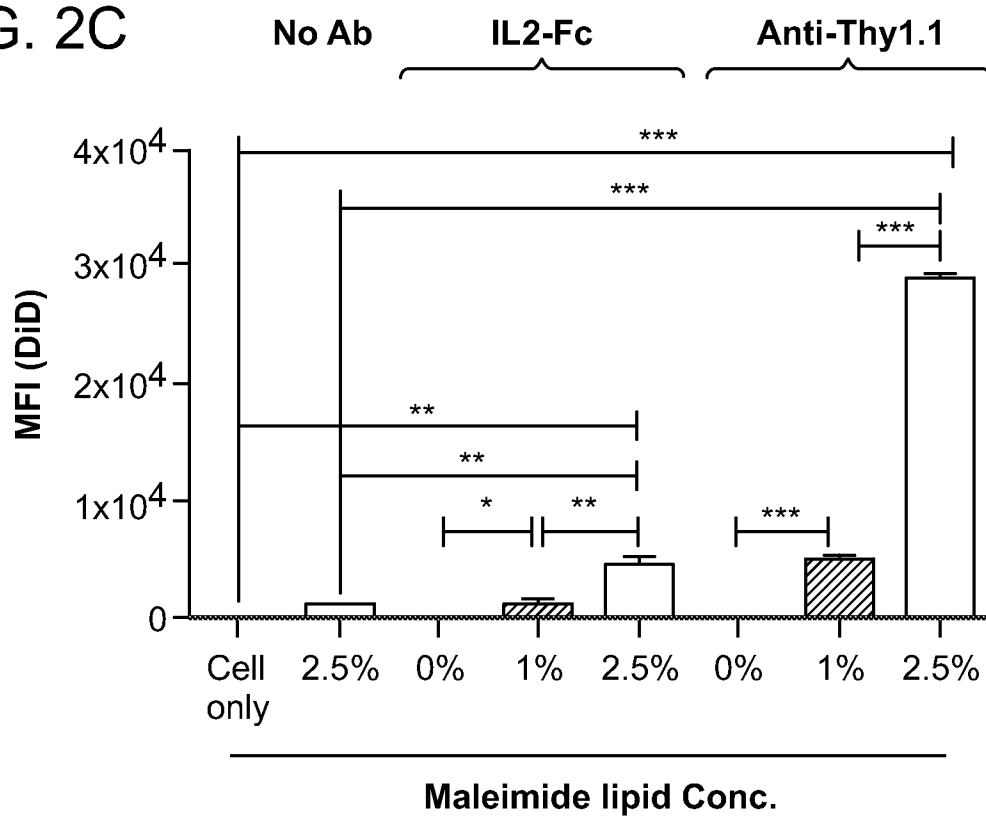


FIG. 2B



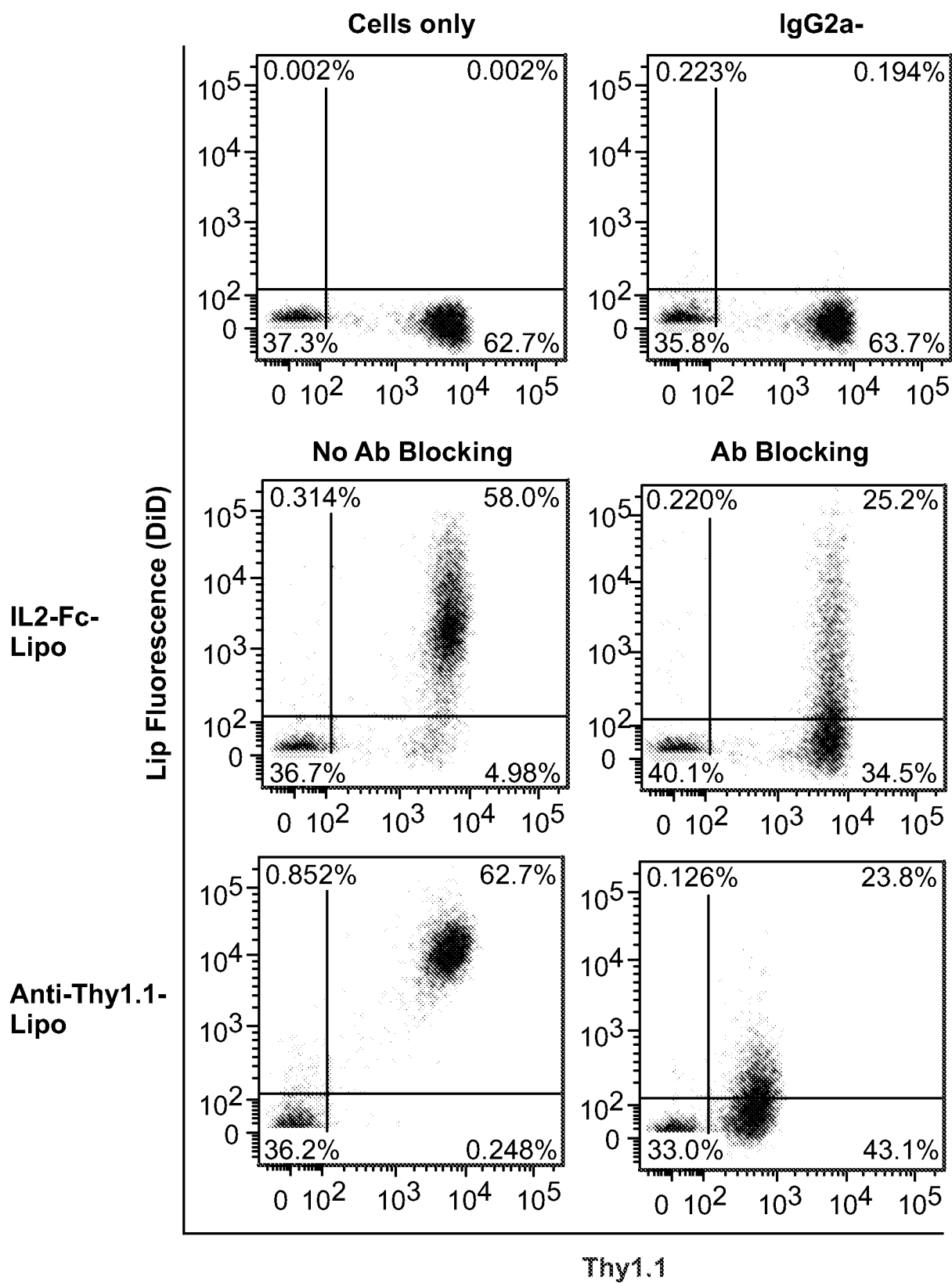
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FIG. 2C



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FIG. 2D



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FIG. 2E

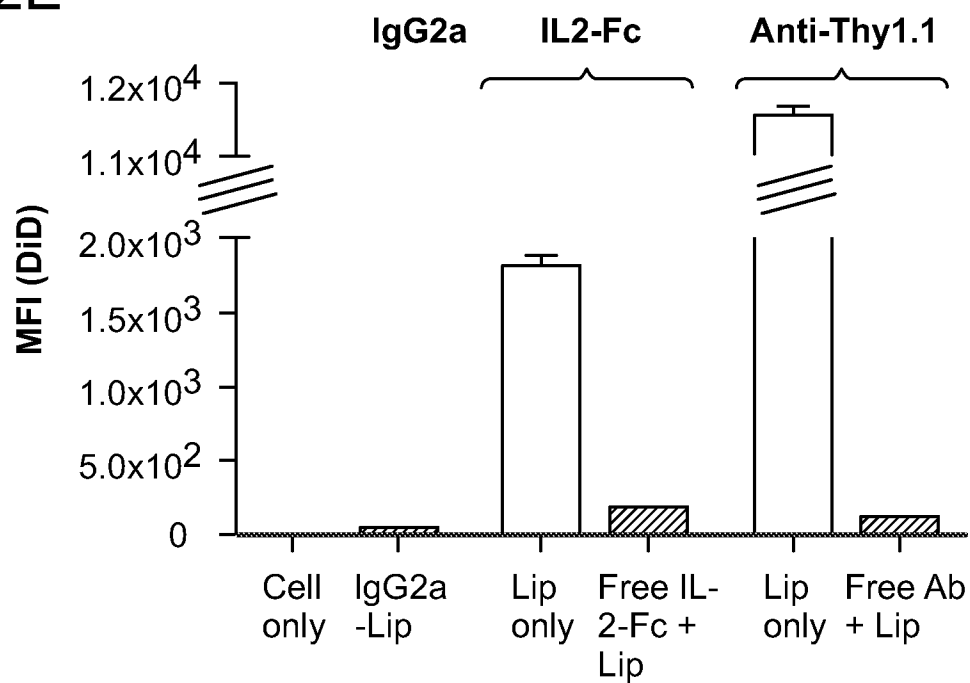


FIG. 2F

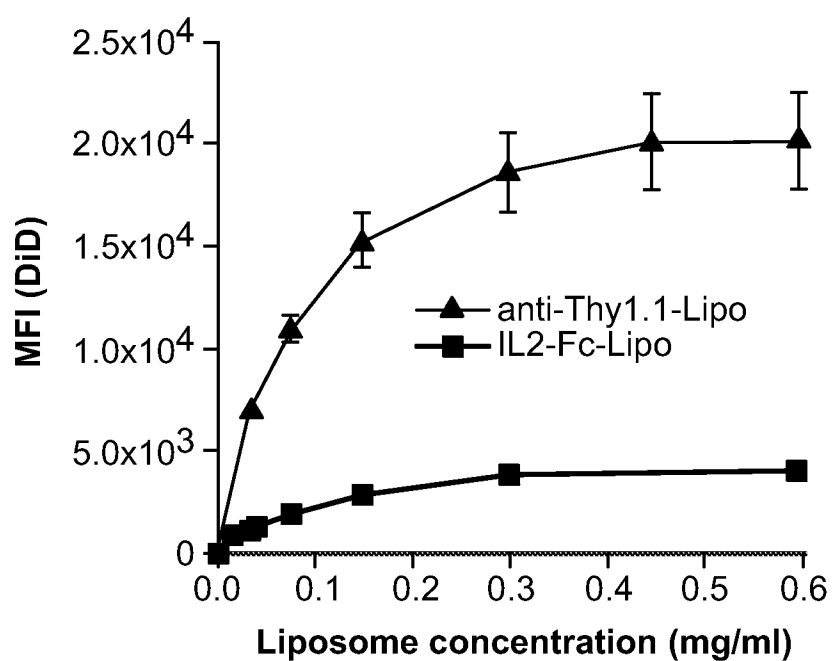


FIG. 3A

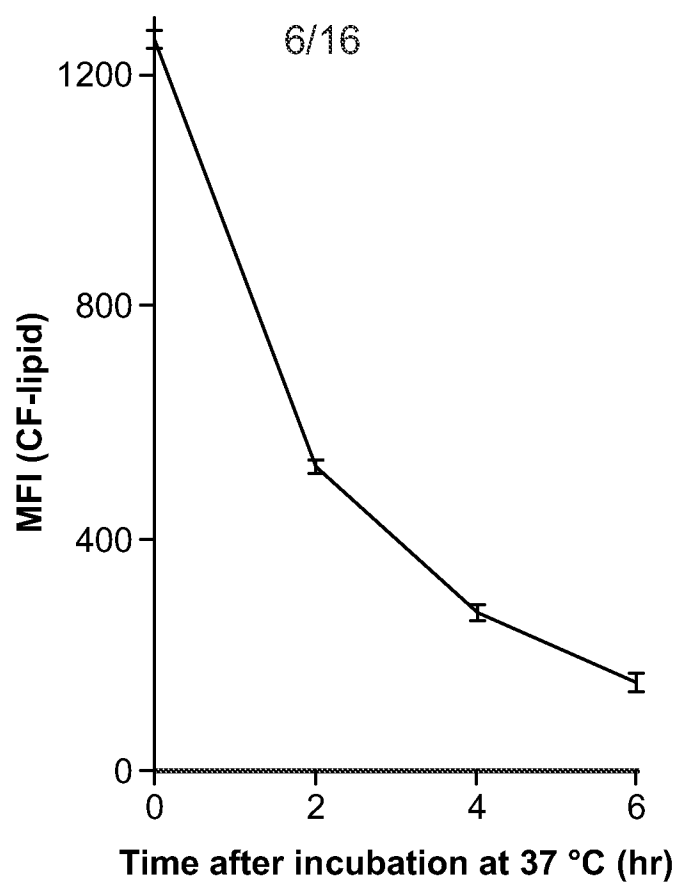
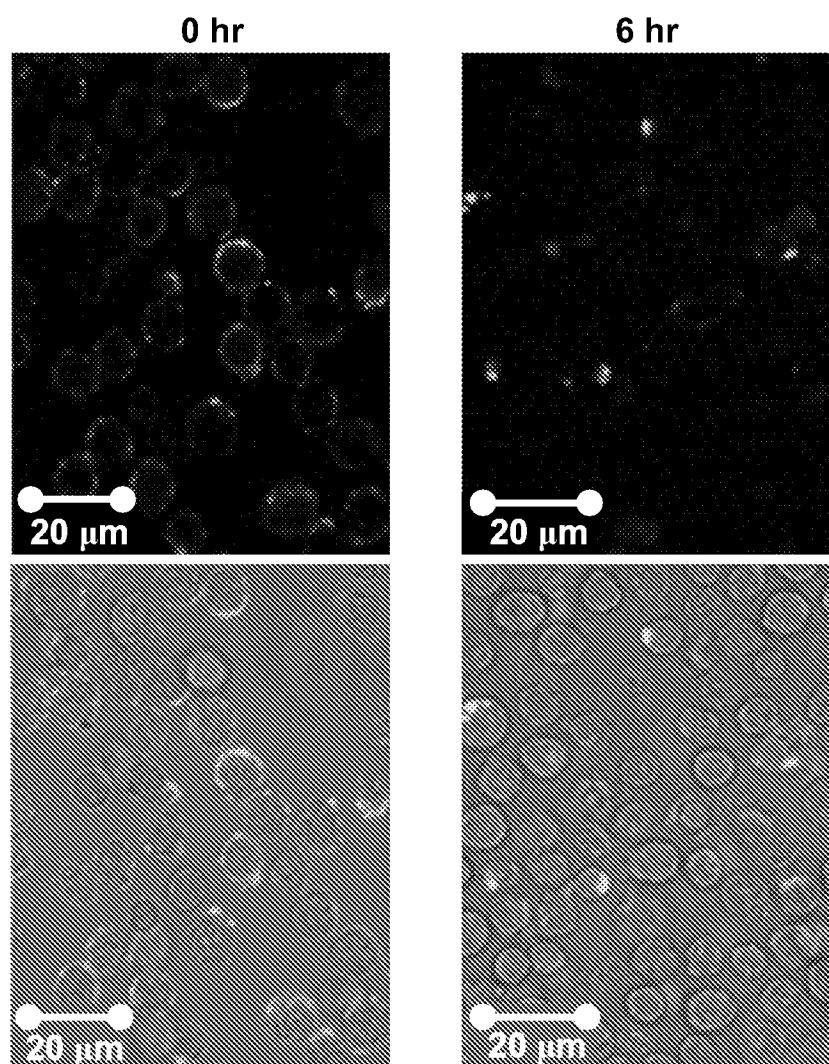


FIG. 3B



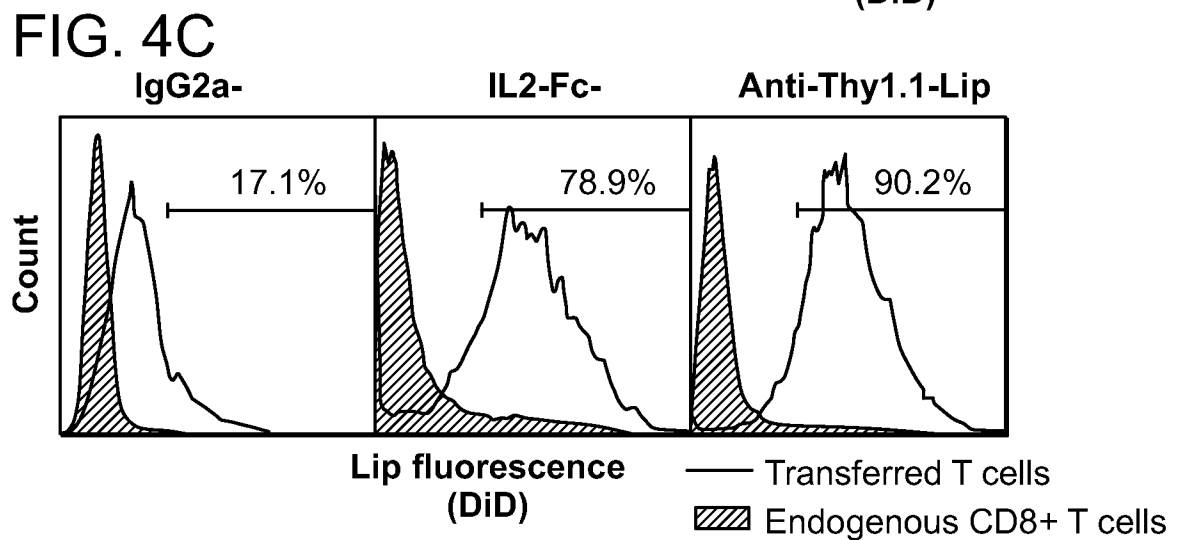
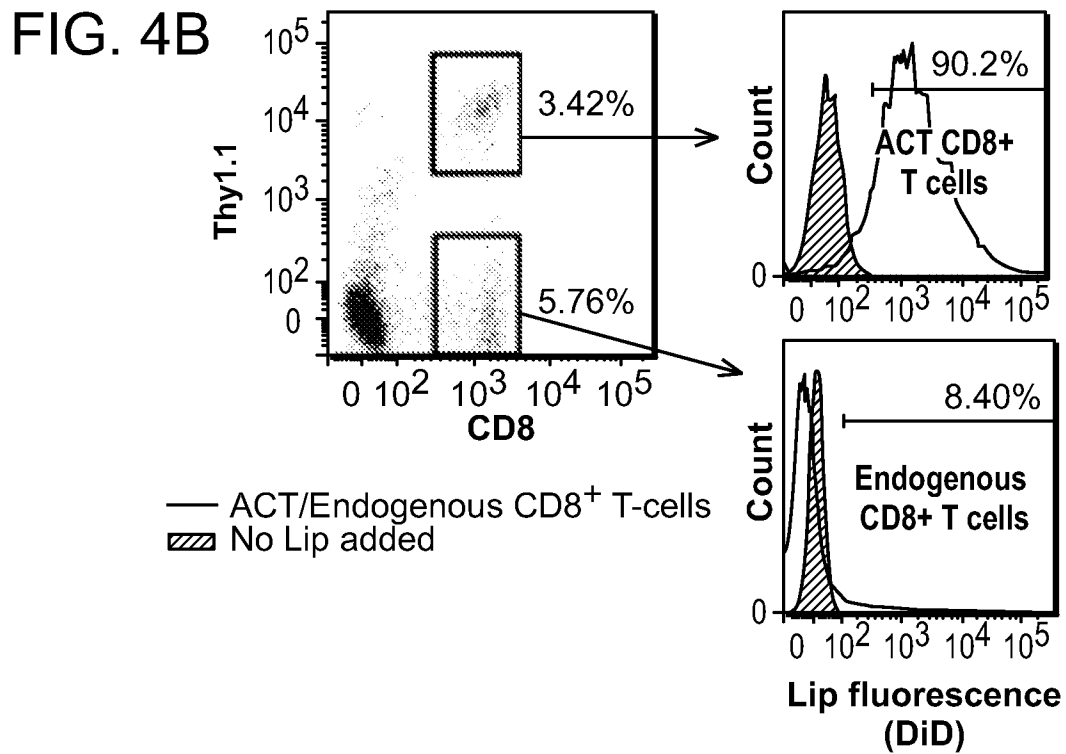
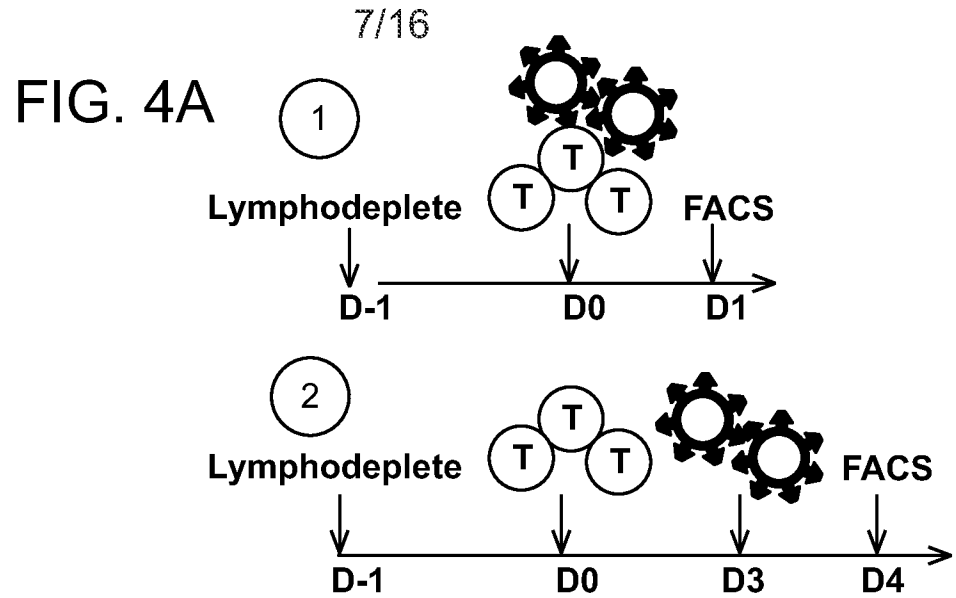


FIG. 4D

Blood

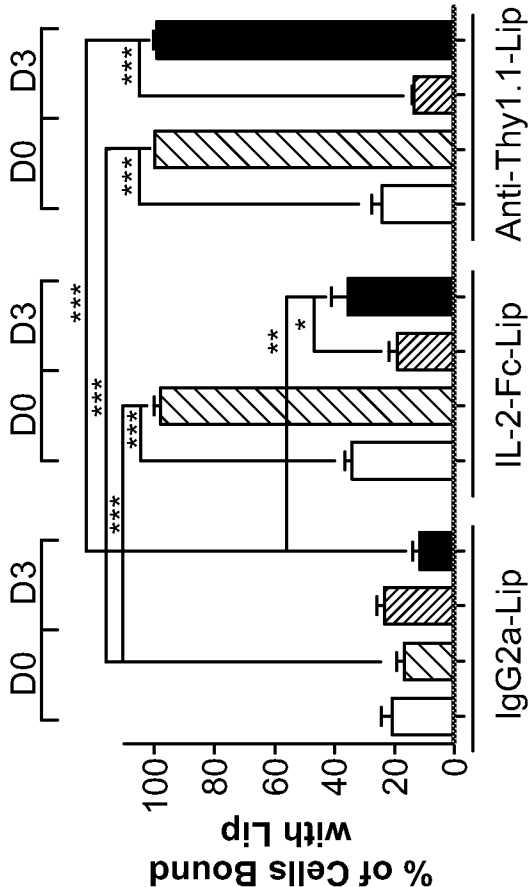
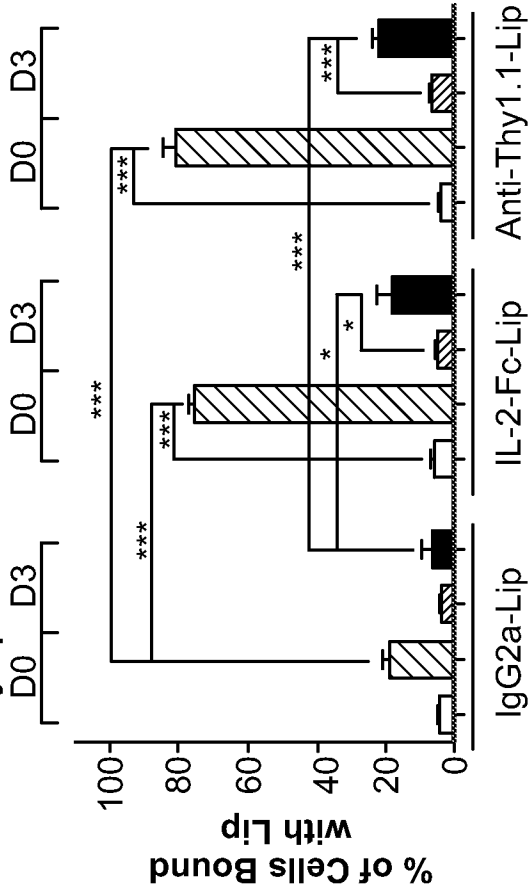


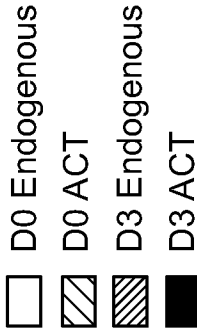
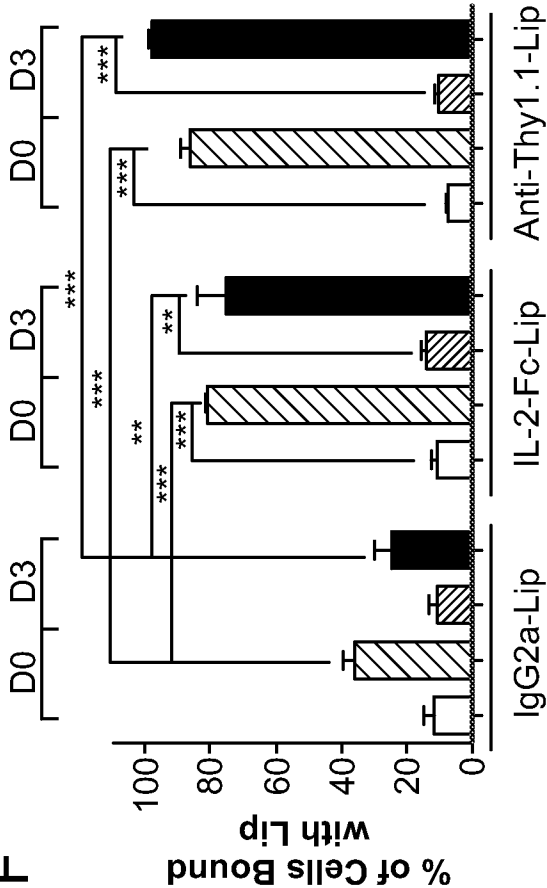
FIG. 4E

Lymph Nodes



Spleen

FIG. 4F



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FIG. 5A

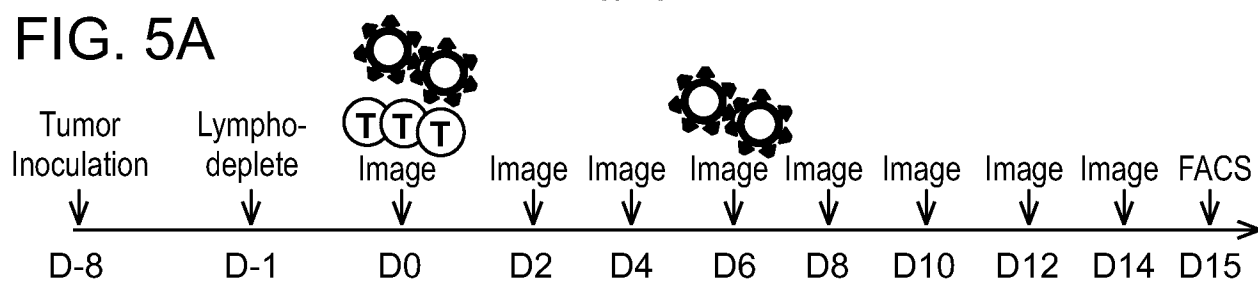
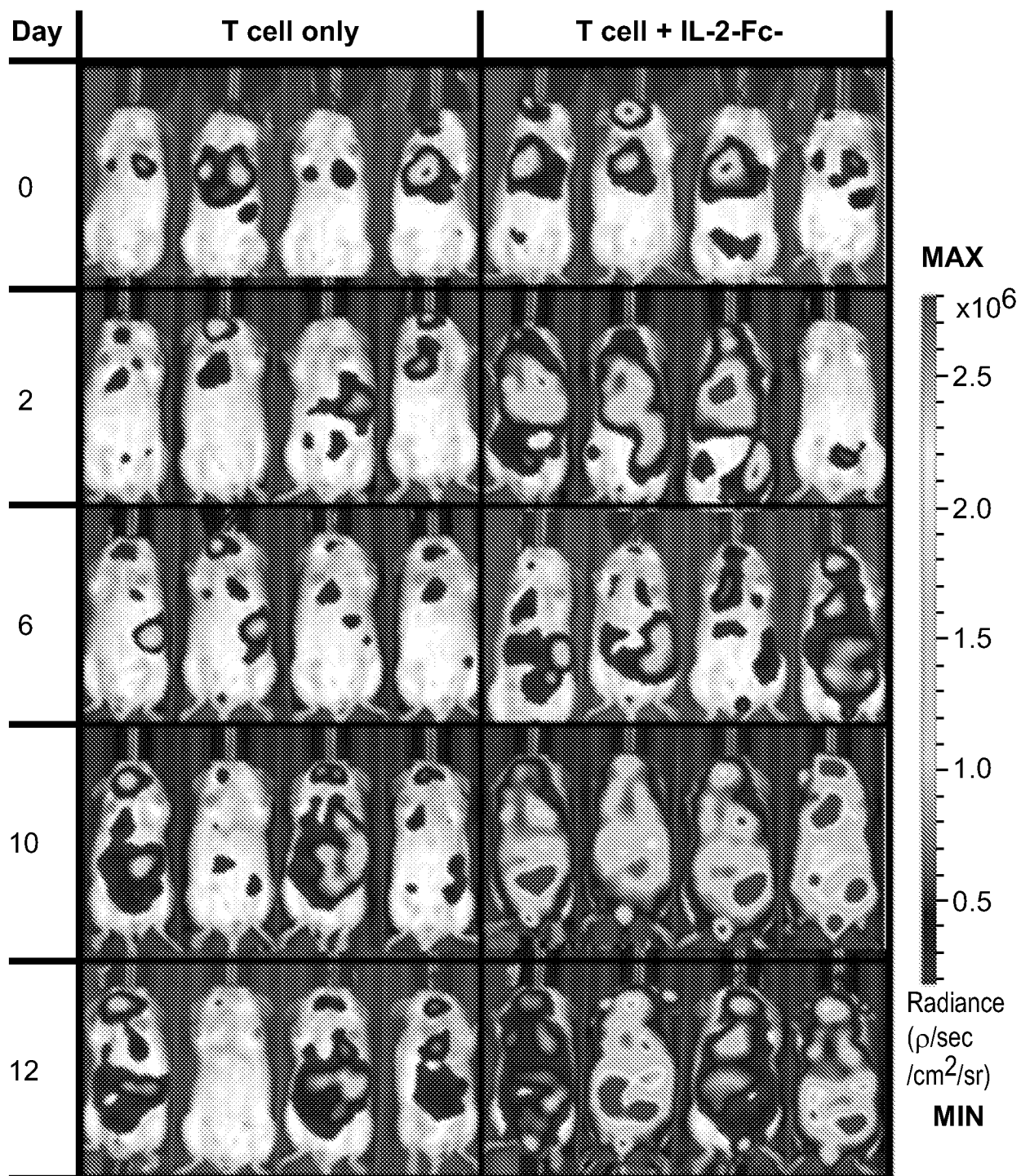
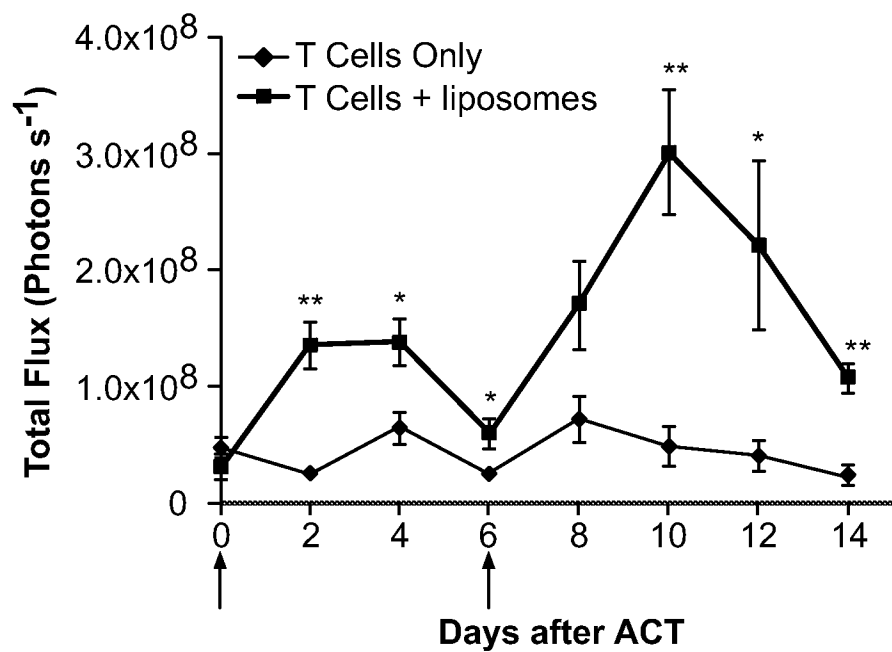


FIG. 5B



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FIG. 5C



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FIG. 5D

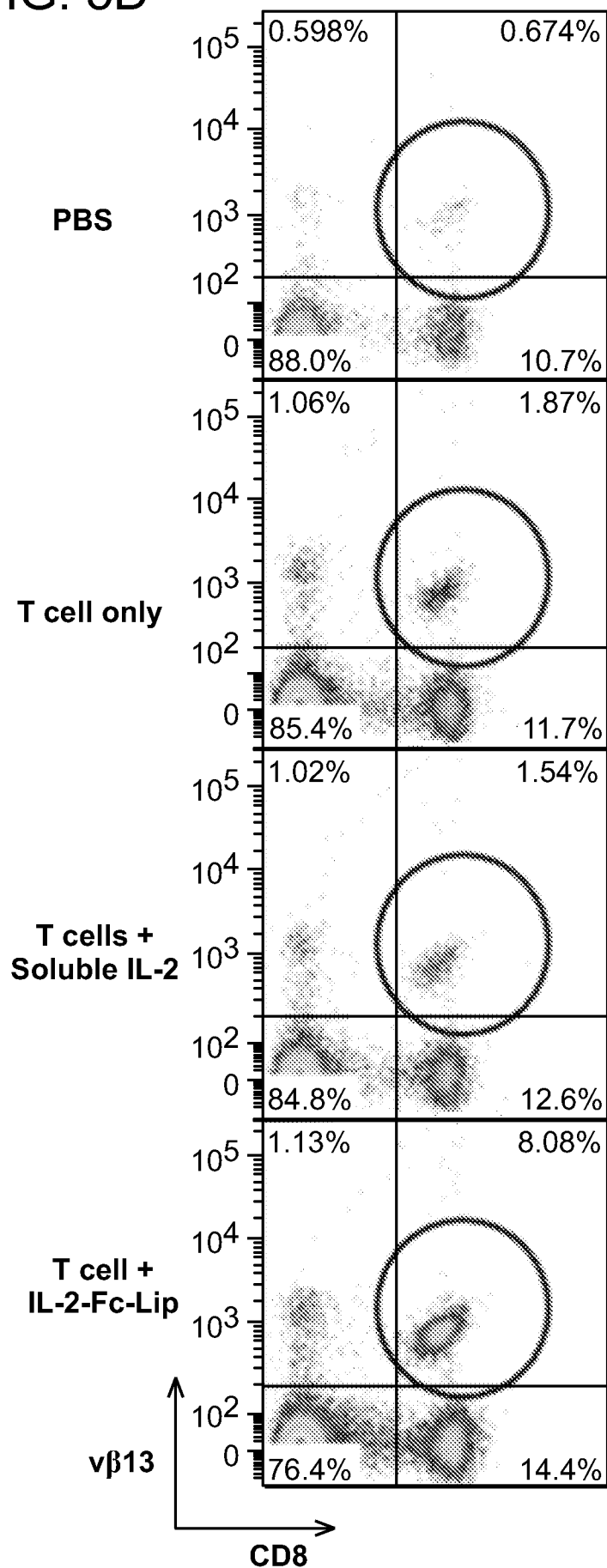


FIG. 5E

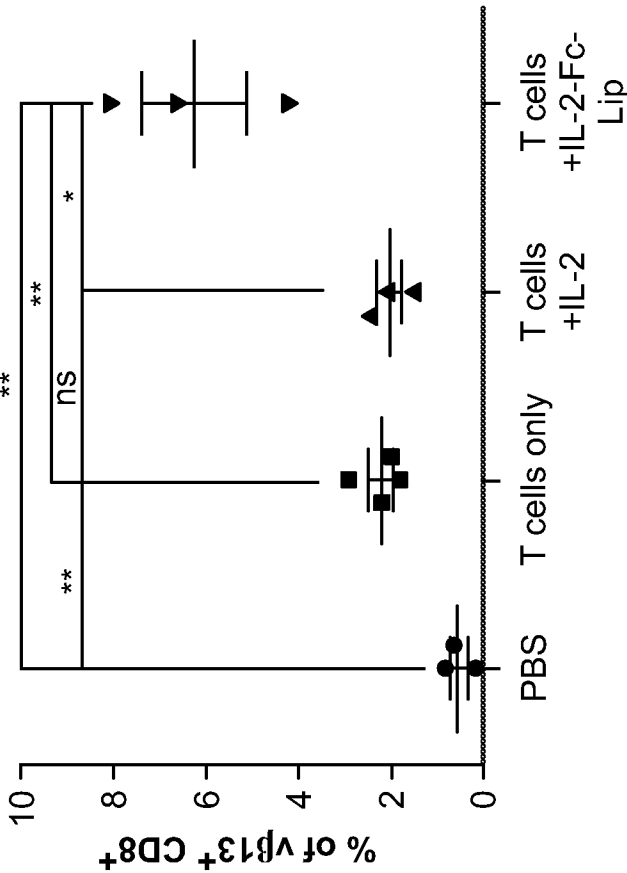


FIG. 6B

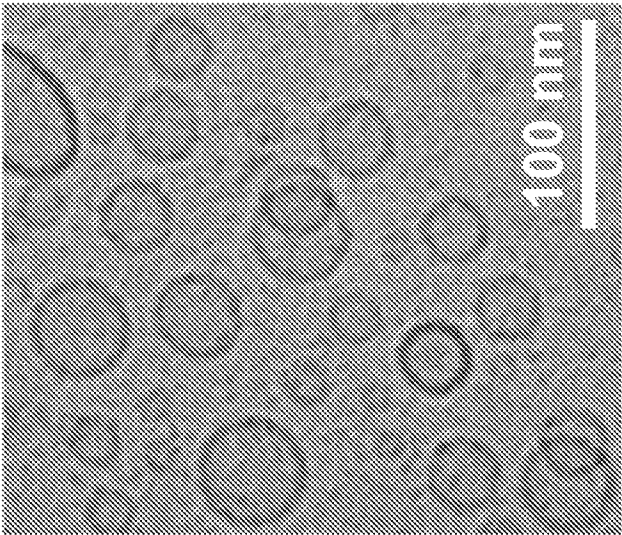
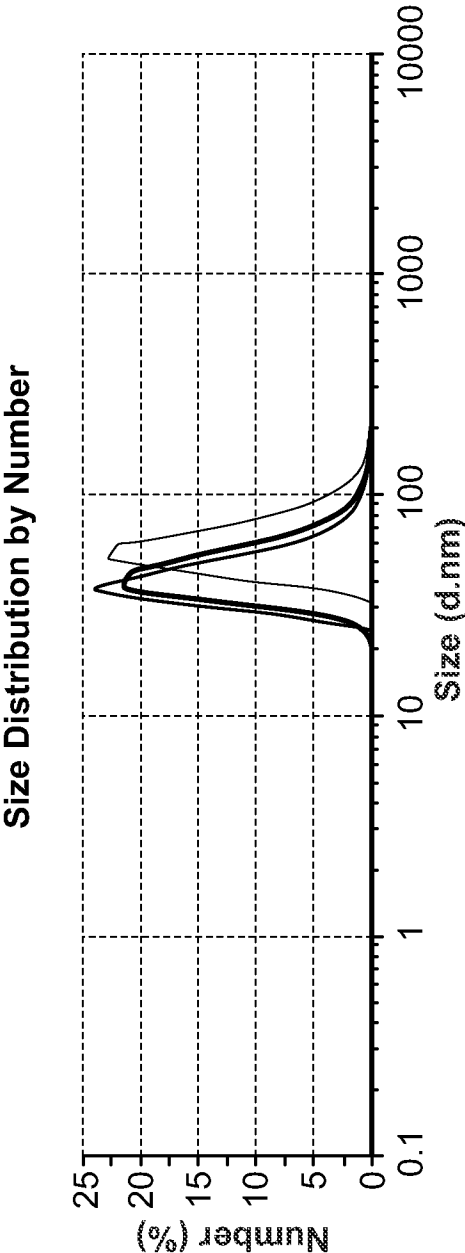


FIG. 6A



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FIG. 7A

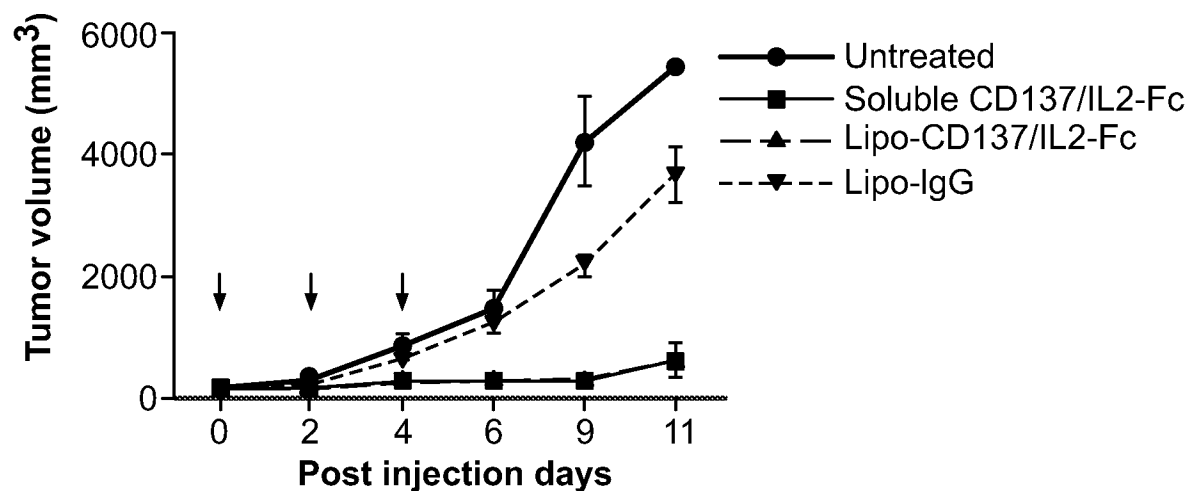


FIG. 7B

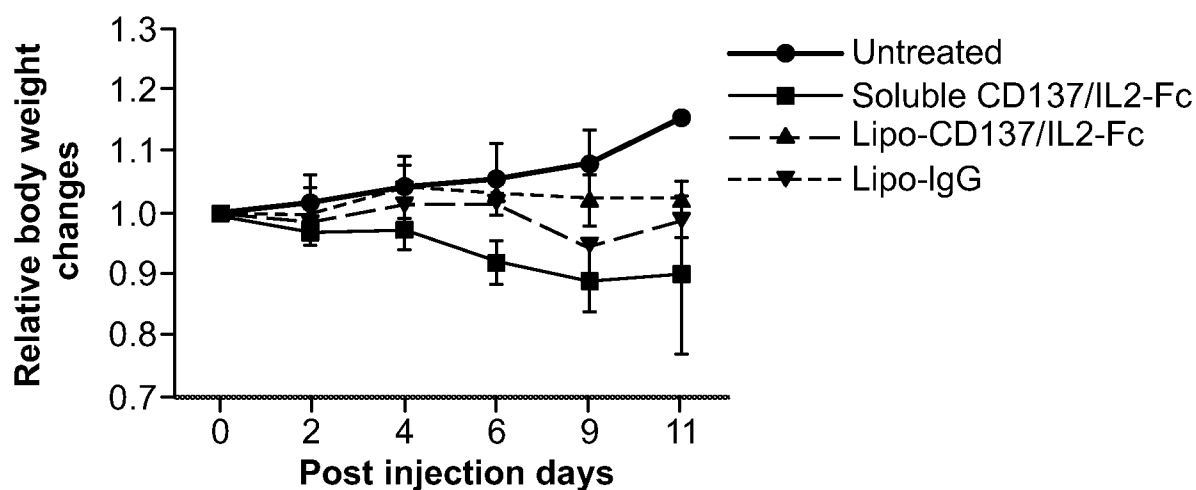


FIG. 7C

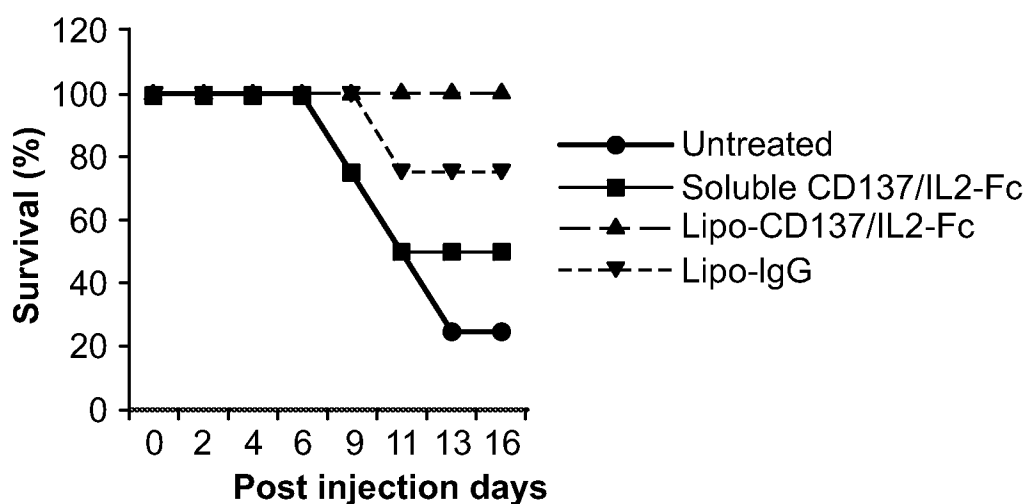


FIG. 8

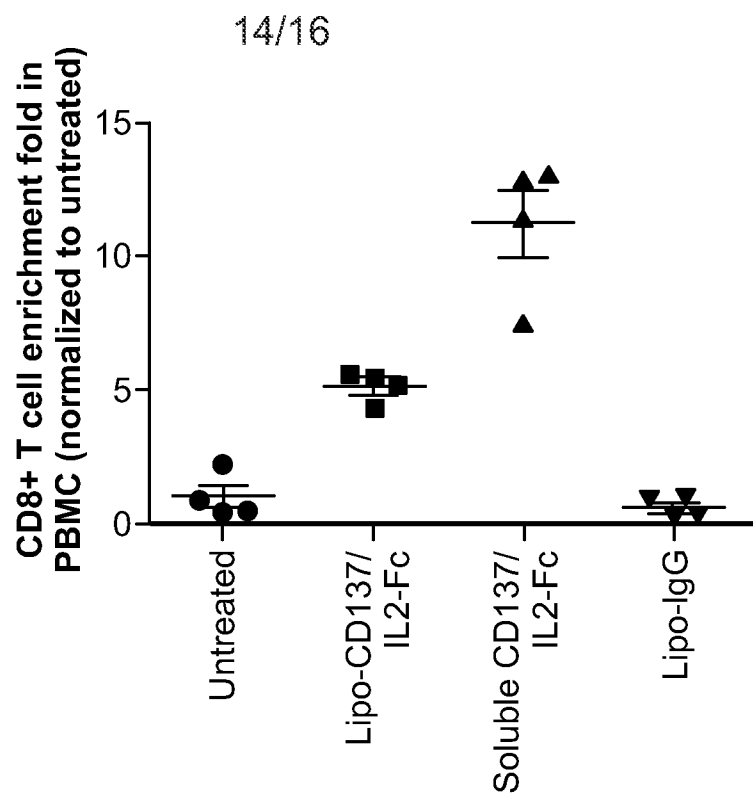


FIG. 9A

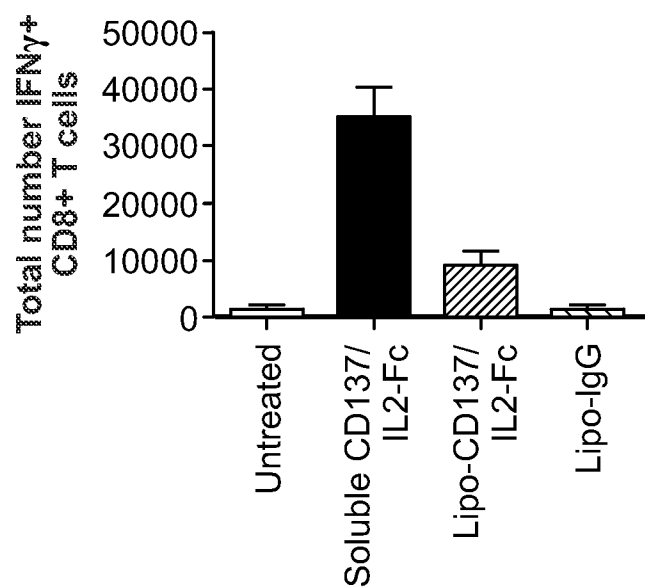
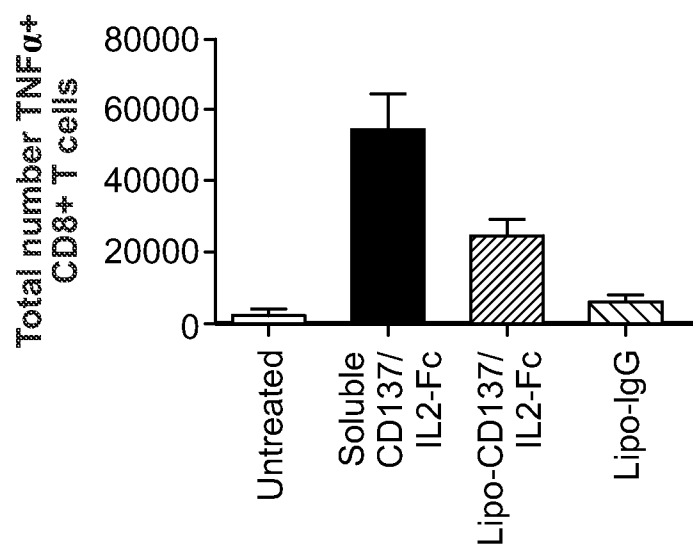


FIG. 9B



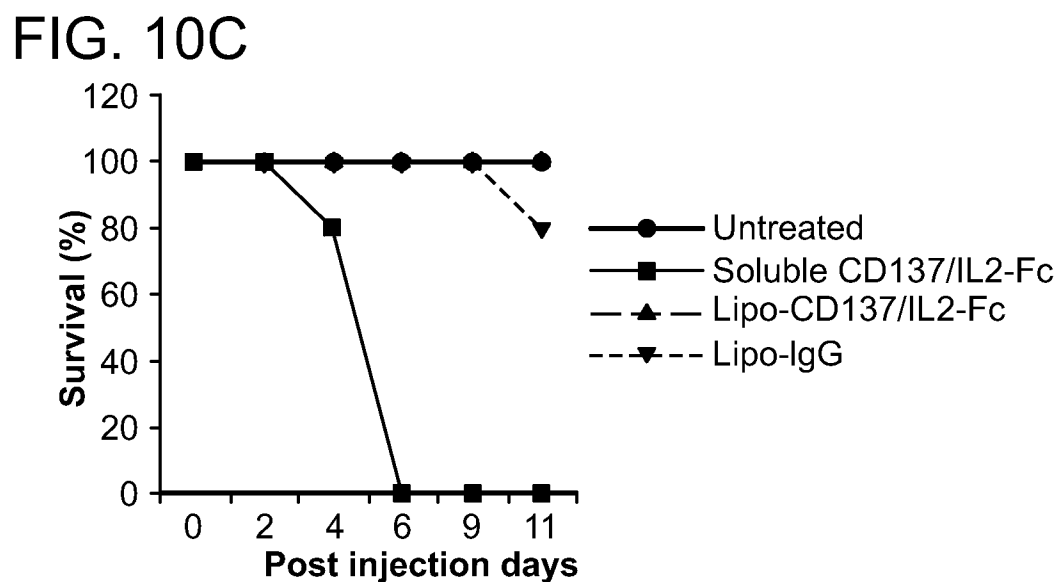
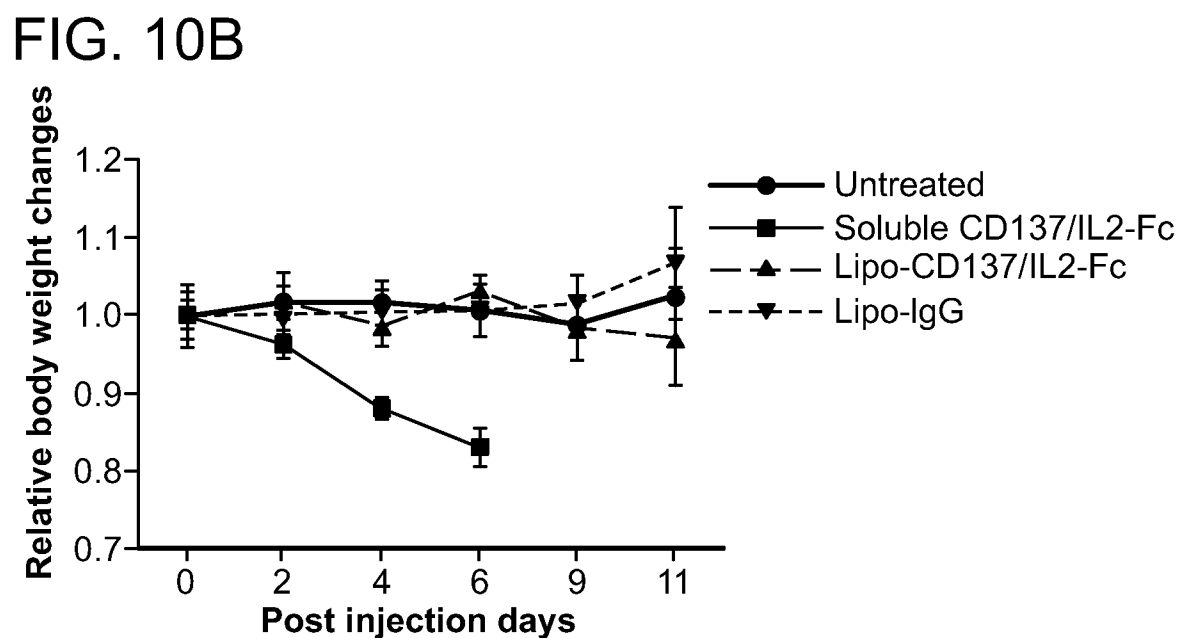
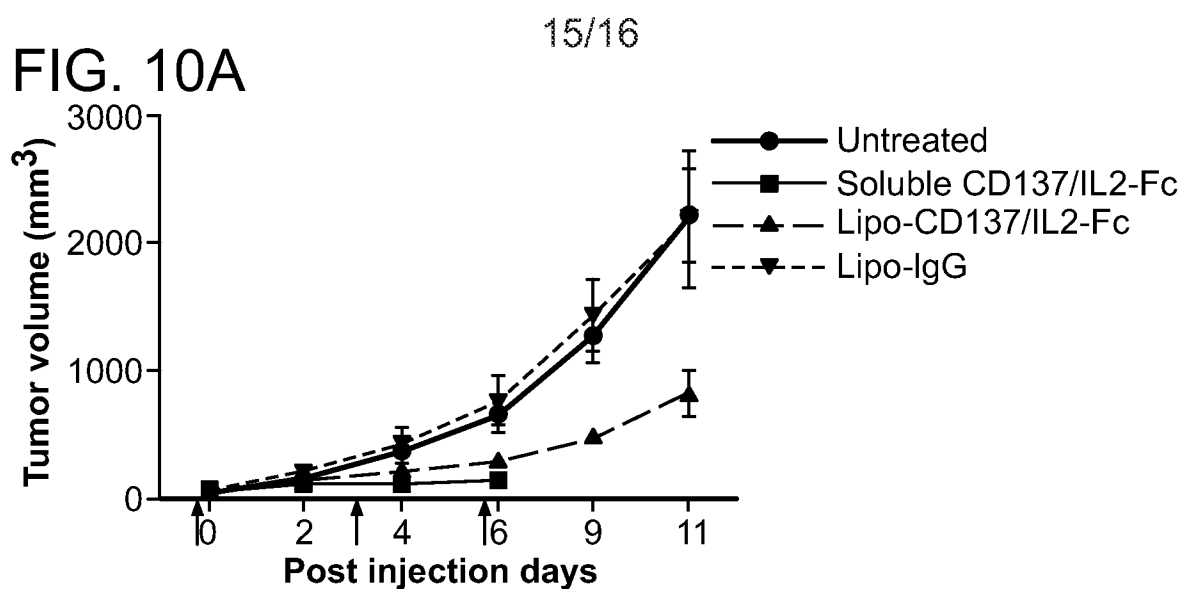
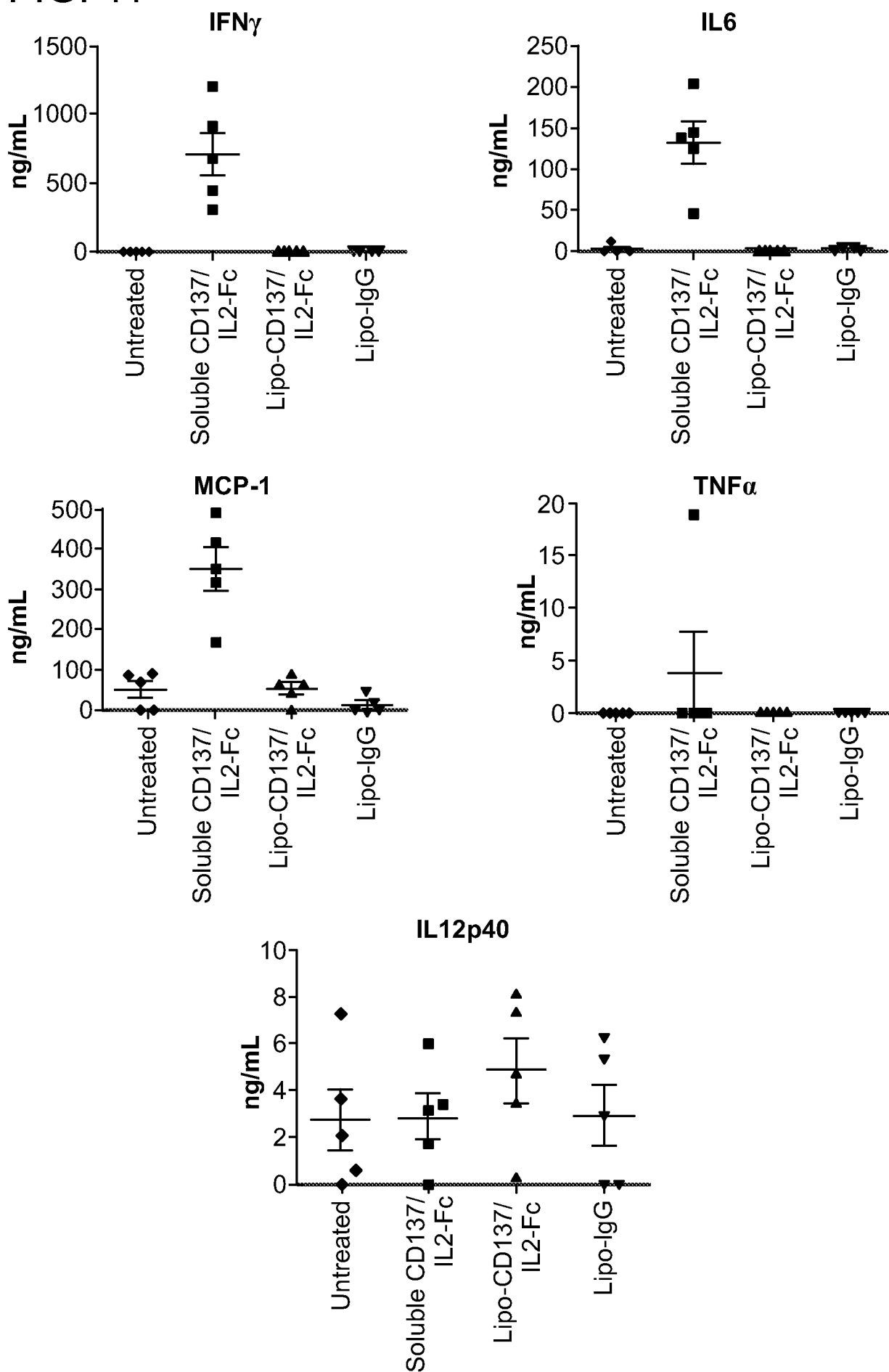


FIG. 11

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INTERNATIONAL SEARCH REPORT

014/042004 03.11.2014
International application No.

PCT/US14/42004

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A61K 38/20, 39/385, 39/39, 39/395, 39/44 (2014.01)

CPC - A61K 38/20, 38/2013, 39/0005, 39/385, 39/39, 39/395, 39/39541, 39/44

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): A61K 38/00, 38/19, 38/20, 39/00, 39/385, 39/39, 39/395, 39/44 (2014.01)

CPC: A61K 38/00, 38/005, 38/19, 38/20, 38/2013, 39/00, 39/0005, 39/385; USPC: 424/178.1, 184.1, 193.1, 194.1

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

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

MicroPatent (US-G, US-A, EP-A, EP-B, WO, JP-bib, DE-C,B, DE-A, DE-T, DE-U, GB-A, FR-A); Espacenet; Google; Google Scholar; PubMed; stimulate, enhance, lymphocyte, 'NK cells,' 'B cell,' 'T cell,' target, ligand, antibody, 'IL-2,' 'Thy1,' 'CD137,' '(Shp1 OR Shp2) near5 inhibitor,' 'repeated* near2 (systemic ADJ administration),' suppress

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ZHENG, Y et al. In Vivo Targeting Of Adoptively Transferred T-Cells With Antibody- And Cytokine-Conjugated Liposomes. J. Control Release. Epub, 11 June 2013. Vol. 172, No. 2:	1-4, 32, 44
Y	pages 426-435; abstract; page 427, column 1, paragraph 3; page 427, column 2, paragraphs 5 and 6; figures 1A, 4, 5.	31, 33-39, 43, 45-51
Y	IRVINE, DJ et al. Combining Cell Therapy With Nanotechnology For Enhanced Cancer Immunotherapy. 16th International Symposium on Recent Advances in Drug Delivery Systems. Salt Lake City, UT; 3-6 February 2013; abstract; pages 9-10; page 9, paragraph 5; page 9, paragraph 7; page 9, paragraph 9 to page 10, paragraph 1; page 10, paragraph 3.	31, 33-39, 43, 45-51
Y	KWONG, B et al. Localized Immunotherapy Via Liposome-Anchored Anti-CD137 + IL-2 Prevents Lethal Toxicity And Elicits Local And Systemic Antitumor Immunity. Cancer Res. 01 March 2013. Vol. 73, No. 5: pages 1547-1558; abstract; page 1547, column 1, paragraph 2; page 1548, column 1, paragraph 2; figure 1A; page 1554, column 2, paragraph 4.	39, 51

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30 September 2014 (30.09.2014)

Date of mailing of the international search report

03 NOV 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Shane Thomas

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 5-30, 40-42, 52-60
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.