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[Continued on next page]

(54) **Title**: TOLEROGENIC SYNTHETIC NANOCARRIERS FOR ANTIGEN-SPECIFIC DELETION OF T EFFECTOR CELLS

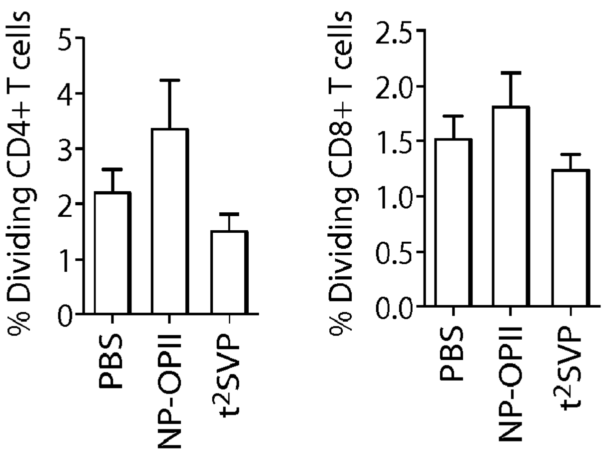

Fig. 5

(57) **Abstract**: Disclosed are synthetic nanocarrier methods, and related compositions, comprising administering immunosuppressants and MHC Class I-restricted and/or MHC Class II- restricted epitopes that can generate tolerogenic immune responses (e.g., antigen- specific T effector cell deletion).

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TOLEROGENIC SYNTHETIC NANOCARRIERS FOR ANTIGEN-SPECIFIC DELETION OF T EFFECTOR CELLS

RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 of United States provisional application 61/480,946, filed April 29, 2011, 61/513,514, filed July 29, 2011, 61/531,147, filed September 6, 2011, 61/531,153, filed September 6, 2011, 61/531,164, filed September 6, 2011, 61/531,168, filed September 6, 2011, 61/531,175, filed September 6, 2011, 61/531,180, filed September 6, 2011, 61/531,194, filed September 6, 2011, 61/531,204, filed September 6, 2011, 61/531,209, filed September 6, 2011, 61/531,215, filed September 6, 2011, the entire contents of each of which are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to methods of administering synthetic nanocarrier compositions with immunosuppressants and MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen that when presented with an MHC Class I molecule or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells, and related compositions. The methods, in some embodiments, allow for efficient uptake by APCs to shift the immune response in favor of deleting antigen-specific T effector cells.

BACKGROUND OF THE INVENTION

Conventional strategies for generating immunosuppression associated with an undesired immune response are based on broad-acting immunosuppressive drugs. Additionally, in order to maintain immunosuppression, immunosuppressant drug therapy is generally a life-long proposition. Unfortunately, the use of broad-acting immunosuppressants are associated with a risk of severe side effects, such as tumors, infections, nephrotoxicity and metabolic disorders. Accordingly, new immunosuppressant therapies would be beneficial.

SUMMARY OF THE INVENTION

In one aspect, a method comprising administering to a subject a composition according to a protocol that was previously shown to reduce the number or activity of antigen-specific T effector cells in one or more test subjects; wherein the composition comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted or MHC Class II-restricted epitopes of an antigen is provided. In another aspect, a method comprising reducing the number or activity of antigen-specific T effector cells in one or more test subjects by administering to the one or more test subjects a composition that comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen is provided. In another aspect, a method comprising administering to a subject a composition that comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen is provided.

Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In one embodiment, the first population and the second population are the same population. In another embodiment, the first population and the second population are different populations.

In another embodiment, the method further comprises providing or identifying the subject.

In another embodiment, the antigen is a therapeutic protein, an autoantigen or an allergen, or is associated with an inflammatory disease, an autoimmune disease, organ or tissue rejection or graft versus host disease.

In another embodiment, the method further comprises assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration of the composition.

In another embodiment, the subject has or is at risk of having an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft versus host disease. In another embodiment, the subject has undergone or will undergo transplantation. In another embodiment, the subject has or is at risk of having an undesired immune response against a therapeutic protein that is being administered or will be administered to the subject.

In another embodiment, the method further comprises administering a transplantable graft or therapeutic protein. In another embodiment, one or more maintenance doses of the composition comprising the first population and second population of synthetic nanocarriers is administered to the subject.

In another embodiment, the administering is by intravenous, intraperitoneal, transmucosal, oral, subcutaneous, pulmonary, intranasal, intradermal or intramuscular administration. In another embodiment, the administering is by inhalation or intravenous, subcutaneous or transmucosal administration. In another embodiment, the administering of the transplantable graft or therapeutic protein, when the therapeutic protein is provided as one or more cells, is by parenteral, intraarterial, intranasal or intravenous administration or by injection to lymph nodes or anterior chamber of the eye or by local administration to an organ or tissue of interest.

In another embodiment, the immunosuppressants comprise a statin, an mTOR inhibitor, a TGF-β signaling agent, a corticosteroid, an inhibitor of mitochondrial function, a P38 inhibitor, an NF-κβ inhibitor, an adenosine receptor agonist, a prostaglandin E2 agonist, a phosphodiesterasse 4 inhibitor, an HDAC inhibitor or a proteasome inhibitor. In another embodiment, the mTOR inhibitor is rapamycin or a rapamycin analog.

In another embodiment, the load of the immunosuppressants and/or epitopes, or proteins, polypeptides or peptides comprising the epitopes that are coupled to the synthetic nanocarriers, on average across the first and/or second population of synthetic nanocarriers is between 0.0001% and 50% (weight/weight). In another embodiment, the load of the immunosuppressants and/or epitopes, or proteins, polypeptides or peptides comprising the epitopes that are coupled to the synthetic nanocarriers, on average across the first and/or second population of synthetic nanocarriers is between 0.1% and 10% (weight/weight).

In another embodiment, the synthetic nanocarriers of the first population and/or second population comprise lipid nanoparticles, polymeric nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles or peptide or protein particles. In another embodiment, the synthetic nanocarriers of the first population and/or second population comprise lipid nanoparticles. In another embodiment, the synthetic nanocarriers of the first population and/or second population comprise liposomes. In another embodiment, the synthetic nanocarriers of the first population and/or second population comprise metallic nanoparticles. In another embodiment, the metallic nanoparticles comprise gold nanoparticles. In another embodiment, the synthetic nanocarriers of the first population and/or second population comprise polymeric nanoparticles. In another embodiment, the polymeric nanoparticle comprises polymer that is a non-methoxy-terminated, pluronic polymer. In another embodiment, the polymeric nanoparticles comprise a polyester, a polyester coupled to a polyether, polyamino acid, polycarbonate, polyacetal, polyketal, polysaccharide, polyethyloxazoline or polyethyleneimine. In another embodiment, the polyester comprises a poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid) or polycaprolactone. In another embodiment, the polymeric nanoparticles comprise a polyester and a polyester coupled to a polyether. In another embodiment, the polyether comprises polyethylene glycol or polypropylene glycol.

In another embodiment, the mean of a particle size distribution obtained using dynamic light scattering of the synthetic nanocarriers of the first and/or second population is a diameter greater than 100nm. In another embodiment, the diameter is greater than 150nm. In another embodiment, the diameter is greater than 200nm. In another embodiment, the diameter is greater than 250nm. In another embodiment, the diameter is greater than 300nm.

In another embodiment, the aspect ratio of the synthetic nanocarriers of the first population and/or second population is greater than 1:1, 1:1.2, 1:1.5, 1:2, 1:3, 1:5, 1:7 or 1:10.

In another aspect, a method comprising (i) producing a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) producing a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; and evaluating the effect of the first and second population of synthetic nanocarriers on antigen-specific T effector cell number or activity is provided. In one embodiment, this effect is evaluated in a subject after the first and second population of synthetic nanocarriers are administered to the subject. In another embodiment, the effect is evaluated using a sample obtained from the subject.

In another embodiment, the first population and second population are the same population. In another embodiment, the first population and second population are different populations.

In another embodiment, the method further comprises making a dosage form comprising the first population and second population of synthetic nanocarriers. In another embodiment, the method further comprises making a composition comprising the first population and second population of synthetic nanocarriers or the dosage form available to a subject for administration. In another embodiment, the method further comprises assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration of the composition or dosage form

Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In another embodiment, the first population and second population of synthetic nanocarriers that are produced are as defined in any of the methods and compositions provided herein.

In another aspect, a process for producing a composition or dosage form comprising the steps of (i) coupling a first population of synthetic nanocarriers to immunosuppressants, (ii) coupling a second population of synthetic nanocarriers to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen, and (iii) evaluating the effect of the first and second population of synthetic nanocarriers on antigen-specific T effector cell number or activity is provided. In one embodiment, the effect is evaluated in a subject after the first and second population of synthetic nanocarriers are administered to the subject. In another embodiment, the effect is evaluated using a sample obtained from the subject. In another aspect, the process comprises the steps as defined in any of the methods or processes provided herein.

In another aspect, a composition or dosage form obtainable by any of the methods or processes provided herein is provided.

In another aspect, a composition comprising a first population of synthetic nanocarriers coupled to immunosuppressants; a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; and a pharmaceutically acceptable excipient is provided. In one embodiment, the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject. Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In another aspect, a composition comprising a first population of synthetic nanocarriers coupled to immunosuppressants; a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; and a transplantable graft or therapeutic protein; and optionally a pharmaceutically acceptable excipient is provided. In one embodiment, the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject. Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In another aspect, a composition comprising a first population of synthetic nanocarriers coupled to immunosuppressants; and a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; for use in therapy or prophylaxis is provided. In one embodiment, the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject. Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In another aspect, a composition comprising a first population of synthetic nanocarriers coupled to immunosuppressants, and a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen, for use in a method of:

a. treatment, comprising the step of administering said composition to a subject and assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration;
b. treatment, comprising the step of administering said composition to a subject and assessing the deletion of antigen-specific T effector cells in the subject prior to and/or after the administration;
c. treatment, comprising the step of administering said composition to a subject according to a protocol that was previously shown to reduce the number or activity of antigen-specific T effector cells in one or more test subjects;
d. deleting antigen-specific T effector cells;
e. treatment or prophylaxis as defined in any of the methods provided herein;
f. treatment or prophylaxis of an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft versus host disease, for example by the reduction of the number or activity of antigen-specific T effector cells;
g. treatment of a subject who has undergone or will undergo transplantation;

h. treatment of a subject who has been or will be administered a therapeutic protein; or

i. treatment in conjunction with a transplantable graft or therapeutic protein

is provided. In one embodiment, the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject. Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In another aspect, a use of a composition comprising (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen, for the manufacture of a medicament for use in any of the methods provided herein is provided. In one embodiment, the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject. Preferably, the epitopes when presented with an MHC Class I or MHC Class II molecule, respectively, are cognate epitopes for antigen-specific T effector cells. In one embodiment, the T effector cells are CD4+ or CD8+ T cells.

In an embodiment of any of the compositions or uses provided herein, the composition is as defined in any of the methos provided and/or the composition is for use in a method of therapy or prophylaxis comprising administration by a intravenous, intraperitoneal, transmucosal, oral, subcutaneous, pulmonary, intranasal, intradermal or intramuscular administration, for example as defined in any of the methods provided.

In another aspect, a dosage form comprising any of the compositions provided herein is provided.

In an embodiment of any of the compositions and methods provided herein, the antigens comprise substantially no B cell epitopes.

In an embodiment of any of the compositions and methods provided herein, antigens that are proteins that comprise the aforementioned epitopes can be coupled to the synthetic nanocarriers. In another embodiment, polypeptides or peptides that comprise the aforementioned epitopes but additional amino acids that flank one or both ends of the epitope(s) can be coupled to the synthetic nanocarriers. In another embodiment, the epitopes themselves are coupled to the synthetic nanocarriers.

BRIEF DESCRIPTION OF FIGURES

Fig. 1 shows results from a flow cytometric analysis of Treg cells.

Fig. 2 shows an effect on the number of antigen-specific effector T cells and percentage of FoxP3+ cells with synthetic nanocarriers of the invention comprising immunosuppressant (rapamycin or simvastatin) (after a single injection).

Fig. 3 shows a decrease in the number of popliteal lymph node cells with synthetic nanocarriers of the invention comprising immunosuppressant (rapamycin or simvastatin) (after multiple injections).

Fig. 4 shows a reduction in the number of CD4+ T cells and CD8+ T cells with the administration of synthetic nanocarriers comprising immunosuppressant and OVA peptide.

Fig. 5 shows a reduction in the percentage of dividing CD4+ T cells and CD8+ T cells with the administration of synthetic nanocarriers comprising immunosuppressant and OVA peptide.

DETAILED DESCRIPTION OF THE INVENTION

Before describing the present invention in detail, it is to be understood that this invention is not limited to particularly exemplified materials or process parameters as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments of the invention only, and is not intended to be limiting of the use of alternative terminology to describe the present invention.

All publications, patents and patent applications cited herein, whether supra or infra, are hereby incorporated by reference in their entirety for all purposes.

As used in this specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the content clearly dictates otherwise. For example, reference to "a polymer" includes a mixture of two or more such molecules or a mixture of differing molecular weights of a single polymer species, reference to "a synthetic nanocarrier" includes a mixture of two or more such synthetic nanocarriers or a plurality of such synthetic nanocarriers, reference to “a DNA molecule” includes a mixture of two or more such DNA molecules or a plurality of such DNA molecules, reference to "an immunosuppressant" includes mixture of two or more such materials or a plurality of immunosuppressant molecules, and the like.

As used herein, the term “comprise” or variations thereof such as “comprises” or “comprising” are to be read to indicate the inclusion of any recited integer (e.g. a feature, element, characteristic, property, method/process step or limitation) or group of integers (e.g. features, element, characteristics, properties, method/process steps or limitations) but not the exclusion of any other integer or group of integers. Thus, as used herein, the term "comprising" is inclusive and does not exclude additional, unrecited integers or method/process steps.

In embodiments of any of the compositions and methods provided herein, "comprising" may be replaced with "consisting essentially of" or "consisting of". The phrase "consisting essentially of" is used herein to require the specified integer(s) or steps as well as those which do not materially affect the character or function of the claimed invention. As used herein, the term "consisting" is used to indicate the presence of the recited integer (e.g. a feature, element, characteristic, property, method/process step or limitation) or group of integers (e.g. features, element, characteristics, properties, method/process steps or limitations) alone.

A. INTRODUCTION

As previously mentioned, current conventional immunosuppressants are broad acting and generally result in an overall systemic downregulation of the immune system. The compositions and methods provided herein allow for more targeted immune effects by, for example, allowing for the targeted delivery to immune cells of interest. Thus, the compositions and methods can achieve immune suppression in a more directed manner. This can be helpful in reducing off-target effects and/or toxicity. It has been found that delivering immunosuppressants and MHC Class I-restricted and/or MHC Class II-restricted epitopes more directly to cells of interest, in particular APCs, can result in a reduction in the number and/or activity of T effector cells (e.g., CD4+, CD8+ T cells). The reduction in number and/or activity of T effector cells (i.e., effector T cells) can occur via T effector cell deletion, anergy, a reduction in or lack of T effector cell stimulation, a shift to a tolerogenic phenotype, etc. This reduction can be assessed in a number of ways including those provided herein or otherwise known to those of ordinary skill in the art. For example, the reduction of T effector cell number or activity can be measured by assessing the number of T effector cells, by assessing the proliferation of T effector cells, by assessing the cytokines produced by T effector cells, etc. Such assessment may be performed in vitro or in vivo. As an example, a subject may be administered a composition as provided herein and the assessment may be performed after the administration. This may be done on a sample obtained from the subject.

As has been shown in the Examples below compositions of the invention have been successfully used to reduce effector T cell number or activity in vivo. The Examples show a reduction in the number of CD4+ T cells and CD8+ T cells, as well as the percentage of such cells that are dividing, with the administration of synthetic nanocarriers comprising immunosuppressant and antigen, such as OVA peptide. Therefore, this invention is useful, for example, to promote tolerogenic immune responses through the reduction in T effector cell number and/or activity in subjects, such as those who have or are at risk of having an allergy, autoimmune disease, an inflammatory disease, organ or tissue rejection or graft versus host disease. This invention is also useful for promoting tolerogenic immune responses in subjects who have undergone or will undergo transplantation. This invention is also useful for promoting tolerogenic immune responses in subjects that have received, are receiving or will receive a therapeutic protein against which undesired immune responses are generated or are expected to be generated. The present invention, in some embodiments, prevents or suppresses undesired immune responses that may neutralize the beneficial effect of certain therapeutic treatments.

The inventors have unexpectedly and surprisingly discovered that the problems and limitations noted above can be overcome by practicing the invention disclosed herein. In particular, the inventors have unexpectedly discovered that it is possible to provide synthetic nanocarrier compositions, and related methods, that induce a tolerogenic immune response. In embodiments, the methods provided herein can be used to reduce the number or activity of T effector cells either in vitro (e.g., in a population of cells in culture, or in vivo (e.g., in a subject)). Without wishing to be bound by any particular theory, it is believed that tolerogenic compositions provided herein can effect a reduction in number or activity of T effector cells in vitro and/or in vivo by interacting with T effector cells or T effector cell precursors, e.g., naïve T cells, in the presence of the immunosuppressant.

The methods described herein include administering to a subject a composition that comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes. Preferably, the composition is in an amount effective to reduce T effector cell number or activity in the subject. In another aspect, a method comprising reducing T effector cell number or activity in a subject by administering a composition that comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC

Class I-restricted and/or MHC Class II-restricted epitopes is provided. In another aspect, a method comprising administering to a subject a composition according to a protocol that was previously shown to reduce T effector cell number or activity in one or more test subjects wherein the composition comprises (i) a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes is provided.

Transplantable grafts, therapeutic proteins, etc. may also be administered to the subjects as provided herein. Such compositions may be administered to a subject prior to, concomitantly with or after the administration of the first and second populations of synthetic nanocarriers. Such additional agents may or may not be coupled to the first or second population of synthetic nanocarriers or another population of synthetic nanocarriers. In embodiments, the compositions provided may also be administered as one or more maintenance doses to a subject. In such embodiments, the compositions provided are administered such that the number and/or activity of T effector cells is reduced for a certain length of time. Examples of such lengths of time are provided elsewhere herein.

In yet another aspect, the compositions comprising the first population and second population of synthetic nanocarriers are also provided. In another aspect, dosage forms of any of the compositions herein are provided. Such dosage forms may be administered to a subject, such as one in need of antigen-specific tolerogenic immune responses (e.g., a reduction in antigen-specific T effector cell number or activity).

In yet another aspect, a method of (i) producing a first population of synthetic nanocarriers coupled to immunosuppressants, and (ii) producing a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes is provided. In one embodiment, the method further comprises producing a dosage form comprising the first and second populations of synthetic nanocarriers. In another embodiment, the method further comprises ensuring the second population of synthetic nanocarriers comprises MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen. In one embodiment, such ensuring can be performed by coupling a full length protein to the synthetic nanocarriers. In another embodiment, such ensuring can be performed by coupling a polypeptide or peptide comprising the epitopes to the synthetic nanocarriers. Methods for testing synthetic nanocarriers to determine the immune responses that can be produced are provided elsewhere herein. Preferably, the compositions are effective in reducing the number or activity of T effector cells. Such methods, along with other methods known to those of ordinary skill in the art can be used to ensure the synthetic nanocarriers are coupled to the desired epitopes.

In still another embodiment, the method further comprises assessing the reduction in number and/or activity of T effector cells with a composition or dosage form comprising the first population and second population of synthetic nanocarriers. In yet another embodiment, the method further comprises making a composition comprising the first population and second population of synthetic nanocarriers or the dosage form available to a subject for administration.

In another aspect, the compositions or dosage forms produced by any of the methods provided herein are also provided.

The invention will now be described in more detail below.

B. DEFINITIONS

"Administering" or "administration" means providing a material to a subject in a manner that is pharmacologically useful.

“Allergens” are any substances that can cause an undesired (e.g., a Type 1 hypersensitive) immune response (i.e., allergic response or reaction) in a subject. Allergens include, but are not limited to, plant allergens (e.g., pollen, ragweed allergen), insect allergens, insect sting allergens (e.g., bee sting allergens), animal allergens (e.g., pet allergens, such as animal dander or cat Fel d 1 antigen), latex allergens, mold allergens, fungal allergens, cosmetic allergens, drug allergens, food allergens, dust, insect venom, viruses, bacteria, etc. Food allergens include, but are not limited to milk allergens, egg allergens, nut allergens (e.g., peanut or tree nut allergens, etc. (e.g., walnuts, cashews, etc.)), fish allergens, shellfish allergens, soy allergens, legume allergens, seed allergens and wheat allergens. Insect sting allergens include allergens that are or are associated with bee stings, wasp stings, hornet stings, yellow jacket stings, etc. Insect allergens also include house dust mite allergens (e.g., Der P1 antigen) and cockroach allergens. Drug allergens include allergens that are or are associated with antibiotics, NSAIDs, anaesthetics, etc. Pollen allergens include grass allergens, tree allergens, weed allergens, flower allergens, etc. Subjects that develop or are at risk of developing an undesired immune response to any of the allergens provided herein may be treated with any of the compositions and methods provided herein. Subjects that may be treated with any of the compositions and methods provided also include those who have or are at risk of having an allergy to any of the allergens provided.

An "allergy" also referred to herein as an "allergic condition," is any condition where there is an undesired (e.g., a Type 1 hypersensitive) immune response (i.e., allergic response or reaction) to a substance. Such substances are referred to herein as allergens. Allergies or allergic conditions include, but are not limited to, allergic asthma, hay fever, hives, eczema, plant allergies, bee sting allergies, pet allergies, latex allergies, mold allergies, cosmetic allergies, food allergies, allergic rhinitis or coryza, topic allergic reactions, anaphylaxis, atopic dermatitis, hypersensitivity reactions and other allergic conditions. The allergic reaction may be the result of an immune reaction to any allergen. In some embodiments, the allergy is a food allergy. Food allergies include, but are not limited to, milk allergies, egg allergies, nut allergies, fish allergies, shellfish allergies, soy allergies or wheat allergies.

"Amount effective" in the context of a composition or dosage form for administration to a subject refers to an amount of the composition or dosage form that produces one or more desired immune responses in the subject, for example, the generation of a tolerogenic immune response (e.g, a reduction in the proliferation, activation, induction, recruitment of CD8+ T cells). Therefore, in some embodiments, an amount effective is any amount of a composition provided herein that produces one or more of these desired immune responses. This amount can be for in vitro or in vivo purposes. For in vivo purposes, the amount can be one that a clinician would believe may have a clinical benefit for a subject in need of antigen-specific tolerization.

Amounts effective can involve only reducing the level of an undesired immune response, although in some embodiments, it involves preventing an undesired immune response altogether. Amounts effective can also involve delaying the occurrence of an undesired immune response. An amount that is effective can also be an amount of a composition provided herein that produces a desired therapeutic endpoint or a desired therapeutic result. Amounts effective, preferably, result in a tolerogenic immune response in a subject to an antigen. The achievement of any of the foregoing can be monitored by routine methods. Preferably, the amounts effective herein are those that result in a reduction in T effector cell number and/or activity such as through T effector cell deletion.

In some embodiments of any of the compositions and methods provided, the amount effective is one in which the desired immune response persists in the subject for at least 1 week, at least 2 weeks, at least 1 month, at least 2 months, at least 3 months, at least 4 months, at least 5 months, at least 6 months, at least 9 months, at least 1 year, at least 2 years, at least 5 years, or longer. In other embodiments of any of the compositions and methods provided, the amount effective is one which produces a measurable desired immune response, for example, a measurable decrease in an immune response (e.g., to a specific antigen), for at least 1 week, at least 2 weeks, at least 1 month, at least 2 months, at least 3 months, at least 4 months, at least 5 months, at least 6 months, at least 9 months, at least 1 year, at least 2 years, at least 5 years, or longer.

Amounts effective will depend, of course, on the particular subject being treated; the severity of a condition, disease or disorder; the individual patient parameters including age, physical condition, size and weight; the duration of the treatment; the nature of concurrent therapy (if any); the specific route of administration and like factors within the knowledge and expertise of the health practitioner. These factors are well known to those of ordinary skill in the art and can be addressed with no more than routine experimentation. It is generally preferred that a maximum dose be used, that is, the highest safe dose according to sound medical judgment. It will be understood by those of ordinary skill in the art, however, that a patient may insist upon a lower dose or tolerable dose for medical reasons, psychological reasons or for virtually any other reason.

In general, doses of the immunosuppressants and/or antigens in the compositions of the invention can range from about 10 μg/kg to about 100,000 μg/kg. In some embodiments, the doses can range from about 0.1 mg/kg to about 100 mg/kg. In still other embodiments, the doses can range from about 0.1 mg/kg to about 25 mg/kg, about 25 mg/kg to about 50 mg/kg, about 50 mg/kg to about 75 mg/kg or about 75 mg/kg to about 100 mg/kg. Alternatively, the dose can be administered based on the number of synthetic nanocarriers that provide the desired amount of immunosuppressants and/or antigens. For example, useful doses include greater than 10^6, 10^7, 10^8, 10^9 or 10^{10} synthetic nanocarriers per dose. Other examples of useful doses include from about $1x10^6$ to about $1x10^{10}$, about $1x10^7$ to about $1x10^9$ or about $1x10^8$ to about $1x10^9$ synthetic nanocarriers per dose.

"Antigen" means a B cell antigen or T cell antigen. "Type(s) of antigens" means molecules that share the same, or substantially the same, antigenic characteristics. In some embodiments, antigens may be proteins, polypeptides, peptides, lipoproteins, glycolipids, polynucleotides, polysaccharides or are contained or expressed in cells. In some embodiments, such as when the antigens are not well defined or characterized, the antigens may be contained within a cell or tissue preparation, cell debris, cell exosomes, conditioned media, etc. An antigen can be combined with the synthetic nanocarriers in the same form as what a subject is exposed to that causes an undesired immune response but may also be a fragment or derivative thereof. When a fragment or derivative, however, a desired immune response to the form encountered by such a subject is the preferable result with the compositions and methods provided.

"Antigen-specific" refers to any immune response that results from the presence of the antigen, or portion thereof, or that generates molecules that specifically recognize or bind the antigen. For example, where the immune response is antigen-specific antibody production, antibodies are produced that specifically bind the antigen. As another example, where the immune response is antigen-specific CD8+ T cell or CD4+ T cell proliferation and/or activity, the proliferation and/or activity can result from recognition of the antigen, or portion thereof, alone or in complex with MHC molecules.

"Antigens associated" with a disease, disorder or condition provided herein are antigens that can generate an undesired immune response against, as a result of, or in conjunction with the disease, disorder or condition; the cause of the disease, disorder or condition (or a symptom or effect thereof); and/or can generate an undesired immune response that is a symptom, result or effect of the disease, disorder or condition. Preferably, in some embodiments, the use of an antigen associated with a disease, disorder or condition, etc. in the compositions and methods provided herein will lead to a tolerogenic immune response against the antigen and/or the cells, by, on or in which the antigen is expressed. The antigens can be in the same form as expressed in a subject with the disease, disorder or condition but may also be a fragment or derivative thereof. When a fragment or derivative, however, a desired immune response to the form expressed in such a subject is the preferable result with the compositions and methods provided. The antigens associated with a disease, disorder or condition, in some embodiments, comprise MHC Class I-restricted epitopes and/or MHC Class II-restricted epitopes. In some embodiments, the antigens substantially do not comprise B cell epitopes, such as when the disease, disorder or condition is an autoimmune disease or an allergy and the inclusion of the B cell epitope would exacerbate an undesired immune response. In other embodiments, the antigens do comprise B cell epitopes.

In one embodiment, the antigen is an antigen associated with an inflammatory disease, autoimmune disease, organ or tissue rejection or graft versus host disease. Such antigens include autoantigens, such as myelin basic protein, collagen (e.g., collagen type 11), human cartilage gp 39, chromogranin A, gp130-RAPS, proteolipid protein, fibrillarin, nuclear proteins, nucleolar proteins (e.g., small nucleolar protein), thyroid stimulating factor receptor, histones, glycoprotein gp 70, ribosomal proteins, pyruvate dehydrogenase dehydrolipoamide acetyltransferase, hair follicle antigens, human tropomyosin isoform 5, mitochondrial proteins, pancreatic β-cell proteins, myelin oligodendrocyte glycoprotein, insulin, glutamic acid decarboxylase (GAD), gluten, and fragments or derivatives thereof. Other autoantigens are provided in Table 1 below.

Antigens also include those associated with organ or tissue rejection. Examples of such antigens include, but are not limited to, antigens from allogeneic cells, e.g., antigens from an allogeneic cell extract and antigens from other cells, such as endothelial cell antigens.

Antigens also include those associated with an allergy. Such antigens include the allergens described elsewhere herein.

Antigens also include those associated with a transplantable graft. Such antigens are associated with a transplantable graft, or an undesired immune response in a recipient of a transplantable graft that is generated as a result of the introduction of the transplantable graft in the recipient, that can be presented for recognition by cells of the immune system and that can generate an undesired immune response. Transplant antigens include those associated with organ or tissue rejection or graft versus host disease. Transplant antigens may be obtained or derived from cells of a biological material or from information related to a transplantable graft. Transplant antigens generally include proteins, polypeptides, peptides, lipoproteins, glycolipids, polynucleotides or are contained or expressed in cells. Information related to a transplantable graft is any information about a transplantable graft that can be used to obtain or derive transplant antigens. Such information includes information about antigens that would be expected to be present in or on cells of a transplantable graft such as, for example, sequence information, types or classes of antigens and/or their MHC I, MHC II or B cell presentation restrictions. Such information may also include information about the type of transplantable graft (e.g, autograft, allograft, xenograft), the molecular and cellular composition of the graft, the bodily location from which the graft is derived or to which the graft to be transplanted (e.g., whole or partial organ, skin, bone, nerves, tendon, neurons, blood vessels, fat, cornea, etc.).

Antigens also include antigens associated with a therapeutic protein that can be presented for recognition by cells of the immune system and that can generate an undesired immune response against the therapeutic protein. Therapeutic protein antigens generally include proteins, polypeptides, peptides, lipoproteins, or are contained or expressed in, by or on cells.

Antigens, can be antigens that are fully defined or characterized. However, in some embodiments, an antigen is not fully defined or characterized. Antigens, therefore, also include those that are contained within a cell or tissue preparation, cell debris, cell exosome or conditioned media and can be delivered in such form in some embodiments.

"Assessing an immune response" refers to any measurement or determination of the level, presence or absence, reduction, increase in, etc. of an immune response in vitro or in vivo. Such measurements or determinations may be performed on one or more samples obtained from a subject. Such assessing can be performed with any of the methods provided herein or otherwise known in the art.

An "at risk" subject is one in which a health practitioner believes has a chance of having a disease, disorder or condition as provided herein or is one a health practitioner believes has a chance of experiencing an undesired immune response as provided herein.

An "autoimmune disease" is any disease where the immune system mounts an undesired immune response against self (e.g., one or more autoantigens). In some embodiments, an autoimmune disease comprises an aberrant destruction of cells of the body as part of the self-targeted immune response. In some embodiments, the destruction of self manifests in the malfunction of an organ, for example, the colon or pancreas. Examples of autoimmune diseases are described elsewhere herein. Additional autoimmune diseases will be known to those of skill in the art and the invention is not limited in this respect.

"Average", as used herein, refers to the arithmetic mean unless otherwise noted.

"B cell antigen" means any antigen that triggers an immune response in a B cell (e.g., an antigen that is specifically recognized by a B cell or a receptor thereon). In some embodiments, an antigen that is a T cell antigen is also a B cell antigen. In other embodiments, the T cell antigen is not also a B cell antigen. B cell antigens include, but are not limited to proteins, peptides, small molecules, and carbohydrates. In some embodiments, the B cell antigen comprises a non-protein antigen (i.e., not a protein or peptide antigen). In some embodiments, the B cell antigen comprises a autoantigen. In other embodiments, the B cell antigen is obtained or derived from an allergen, autoantigen, therapeutic protein, or transplantable graft.

"Concomitantly" means administering two or more substances to a subject in a manner that is correlated in time, preferably sufficiently correlated in time so as to provide a modulation in an immune response. In embodiments, concomitant administration may occur through administration of two or more substances in the same dosage form. In other embodiments, concomitant administration may encompass administration of two or more substances in different dosage forms, but within a specified period of time, preferably within 1 month, more preferably within 1 week, still more preferably within 1 day, and even more preferably within 1 hour.

"Couple" or "Coupled" or "Couples" (and the like) means to chemically associate one entity (for example a moiety) with another. In some embodiments, the coupling is covalent, meaning that the coupling occurs in the context of the presence of a covalent bond between the two entities. In non-covalent embodiments, the non-covalent coupling is mediated by non-covalent interactions including but not limited to charge interactions, affinity interactions, metal coordination, physical adsorption, host-guest interactions, hydrophobic interactions, TT stacking interactions, hydrogen bonding interactions, van der Waals interactions, magnetic interactions, electrostatic interactions, dipole-dipole interactions, and/or combinations thereof. In embodiments, encapsulation is a form of coupling.

"Derived" means prepared from a material or information related to a material but is not "obtained" from the material. Such materials may be substantially modified or processed forms of materials taken directly from a biological material. Such materials also include materials produced from information related to a biological material.

"Dosage form" means a pharmacologically and/or immunologically active material in a medium, carrier, vehicle, or device suitable for administration to a subject.

"Encapsulate" means to enclose at least a portion of a substance within a synthetic nanocarrier. In some embodiments, a substance is enclosed completely within a synthetic nanocarrier. In other embodiments, most or all of a substance that is encapsulated is not exposed to the local environment external to the synthetic nanocarrier. In other embodiments, no more than 50%, 40%, 30%, 20%, 10% or 5% (weight/weight) is exposed to the local environment. Encapsulation is distinct from absorption, which places most or all of a substance on a surface of a synthetic nanocarrier, and leaves the substance exposed to the local environment external to the synthetic nanocarrier.

"Epitope", also known as an antigenic determinant, is the part of an antigen that is recognized by the immune system, specifically by, for example, antibodies, B cells, or T cells. As used herein, "MHC Class I-restricted epitopes" are epitopes that are presented to immune cells by MHC class I molecules found on nucleated cells. "MHC Class II-restricted epitopes" are epitopes that are presented to immune cells by MHC class II molecules found on antigen-presenting cells (APCs), for example, on professional antigen-presenting immune cells, such as on macrophages, B cells, and dendritic cells, or on non-hematopoietic cells, such as hepatocytes. “B cell epitopes” are molecular structures that are recognized by antibodies or B cells. In some embodiments, the epitope itself is an antigen. Preferably, to result in the desired tolerogenic immune responses provided herein, the MHC Class I-restricted and/or MHC Class II-restricted epitopes are those that when presented with an MHC Class I or MHC Class II molecule, respectively, bind to receptors on T cells and results in the deletion, inhibition of the activity of, etc. T effector cells. As T effector cells secrete cytokines and other molecules that can result in undesired immune responses, their reduction may then downregulate other undesired immune responses.

A number of epitopes are known to those of skill in the art, and exemplary epitopes suitable according to some aspects of this invention include, but are not limited to those listed in the Immune Epitope Database (www.immuneepitope.org, Vita R, Zarebski L, Greenbaum JA, Emami H, Hoof I, Salimi N, Damle R, Sette A, Peters B. The immune epitope database 2.0. Nucleic Acids Res. 2010 Jan;38(Database issue):D854-62; the entire contents of which as well as all database entries of IEDB version 2.4, August 2011, and particularly all epitopes disclosed therein, are incorporated herein by reference). Epitopes can also be identified with publicly available algorithms, for example, the algorithms described in Wang P, Sidney J, Kim Y, Sette A, Lund O, Nielsen M, Peters B. 2010. peptide binding predictions for HLA DR, DP and DQ molecules. BMC Bioinformatics 2010, 11:568; Wang P, Sidney J, Dow C, Mothé B, Sette A, Peters B. 2008. A systematic assessment of MHC class II peptide binding predictions and evaluation of a consensus approach. PLoS Comput Biol. 4(4):e1000048; Nielsen M, Lund O. 2009. NN-align. An artificial neural network-based alignment algorithm for MHC class II peptide binding prediction. BMC Bioinformatics. 10:296; Nielsen M, Lundegaard C, Lund O. 2007. Prediction of MHC class II binding affinity using SMM-align, a novel stabilization matrix alignment method. BMC Bioinformatics. 8:238; Bui HH, Sidney J, Peters B, Sathiamurthy M, Sinichi A, Purton KA, Mothé BR, Chisari FV, Watkins DI, Sette A. 2005. Immunogenetics. 57:304-314; Sturniolo T, Bono E, Ding J, Raddrizzani L, Tuereci O, Sahin U, Braxenthaler M, Gallazzi F, Protti MP, Sinigaglia F, Hammer J. 1999. Generation of tissue-specific and promiscuous HLA ligand databases using DNA microarrays and virtual HLA class II matrices. Nat Biotechnol. 17(6):555-561; Nielsen M, Lundegaard C, Worning P, Lauemoller SL, Lamberth K, Buus S, Brunak S, Lund O. 2003. Reliable prediction of T-cell epitopes using neural networks with novel sequence representations. Protein Sci 12:1007-1017; Bui HH, Sidney J, Peters B, Sathiamurthy M, Sinichi A, Purton

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Other examples of epitopes provided herein include any of the MHC Class I-restricted, MHC Class II-restricted and B cell epitopes as provided as SEQ ID NOs: 1-943. Without wishing to being bound by any particular theory, MHC Class I-restricted epitopes include those set forth in SEQ ID NOs: 1-186, MHC Class II-restricted epitopes include those set forth in SEQ ID NOs: 187-537, and B cell epitopes include those set forth in SEQ ID NOs: 538-943. These epitopes include MHC Class I-restricted autoantigens, MHC Class II-restricted epitopes of allergens and B cell epitopes of autoantigens and allergens.

"Generating" means causing an action, such as an immune response (e.g., a tolerogenic immune response) to occur, either directly oneself or indirectly, such as, but not limited to, an unrelated third party that takes an action through reliance on one's words or deeds.

"Identifying" is any action or set of actions that allows a clinician to recognize a subject as one who may benefit from the methods and compositions provided herein. Preferably, the identified subject is one who is in need of a tolerogenic immune response as provided herein. The action or set of actions may be either directly oneself or indirectly, such as, but not limited to, an unrelated third party that takes an action through reliance on one's words or deeds.

"Immunosuppressant" means a compound that causes an APC to have an immunosuppressive (e.g., tolerogenic effect). An immunosuppressive effect generally refers to the production or expression of cytokines or other factors by the APC that reduces, inhibits or prevents an undesired immune response or that promotes a desired immune response. When the APC results in an immunosuppressive effect on immune cells that recognize an antigen presented by the APC, the immunosuppressive effect is said to be specific to the presented antigen. Such effect is also referred to herein as a tolerogenic effect. Without being bound by any particular theory, it is thought that the immunosuppressive or tolerogenic effect is a result of the immunosuppressant being delivered to the APC, preferably in the presence of an antigen (e.g., an administered antigen or one that is already present in vivo). Accordingly, the immunosuppressant includes compounds that provide a tolerogenic immune response to an antigen that may or may not be provided in the same composition or a different composition. In one embodiment, the immunosuppressant is one that causes an APC to promote a regulatory phenotype in one or more immune effector cells. For example, the regulatory phenotype may be characterized by the inhibition of the production, induction, stimulation or recruitment of antigen-specific CD4+ T cells or CD8+ T cells, the production, induction, stimulation or recruitment of Treg cells (e.g., CD4+CD25highFoxP3+ Treg cells), etc. This may be the result of the conversion of CD4+ T cells or CD8+ T cells or B cells to a regulatory phenotype. This may also be the result of induction of FoxP3 in other immune cells, such as CD8+ T cells, macrophages and iNKT cells. In one embodiment, the immunosuppressant is one that affects the response of the APC after it processes an antigen. In another embodiment, the immunosuppressant is not one that interferes with the processing of the antigen. In a further embodiment, the immunosuppressant is not an apoptotic-signaling molecule. In another embodiment, the immunosuppressant is not a phospholipid.

Immunosuppressants include, but are not limited to, statins; mTOR inhibitors, such as rapamycin or a rapamycin analog; TGF-β signaling agents; TGF-β receptor agonists; histone deacetylase inhibitors, such as Trichostatin A; corticosteroids; inhibitors of mitochondrial function, such as rotenone; P38 inhibitors; NF-κβ inhibitors, such as 6Bio, Dexamethasone, TCPA-1, IKK VII; adenosine receptor agonists; prostaglandin E2 agonists (PGE2), such as Misoprostol; phosphodiesterase inhibitors, such as phosphodiesterase 4 inhibitor (PDE4), such as Rolipram; proteasome inhibitors; kinase inhibitors; G-protein coupled receptor agonists; G-protein coupled receptor antagonists; glucocorticoids; retinoids; cytokine inhibitors; cytokine receptor inhibitors; cytokine receptor activators; peroxisome proliferator-activated receptor antagonists; peroxisome proliferator-activated receptor agonists; histone deacetylase inhibitors; calcineurin inhibitors; phosphatase inhibitors; PI3KB inhibitors, such as TGX-221; autophagy inhibitors, such as 3-Methyladenine; aryl hydrocarbon receptor inhibitors; proteasome inhibitor I (PSI); and oxidized ATPs, such as P2X receptor blockers. Immunosuppressants also include IDO, vitamin D3, cyclosporins, such as cyclosporine A, aryl hydrocarbon receptor inhibitors, resveratrol, azathiopurine (Aza), 6-mercaptopurine (6-MP), 6-thioguanine (6-TG), FK506, sanglifehrin A, salmeterol, mycophenolate mofetil (MMF), aspirin and other COX inhibitors, niflumic acid, estriol and triptolide. In embodiments, the immunosuppressant may comprise any of the agents provided herein.

The immunosuppressant can be a compound that directly provides the immunosuppressive (e.g., tolerogenic) effect on APCs or it can be a compound that provides the immunosuppressive (e.g., tolerogenic) effect indirectly (i.e., after being processed in some way after administration). Immunosuppressants, therefore, include prodrug forms of any of the compounds provided herein.

Immunosuppressants also include nucleic acids that encode the peptides, polypeptides or proteins provided herein that result in an immunosuppressive (e.g., tolerogenic) immune response. In embodiments, therefore, the immunosuppressant is a nucleic acid that encodes a peptide, polypeptide or protein that results in an immunosuppressive (e.g., tolerogenic) immune response, and it is the nucleic acid that is coupled to the synthetic nanocarrier.

The nucleic acid may be DNA or RNA, such as mRNA. In embodiments, the inventive compositions comprise a complement, such as a full-length complement, or a degenerate (due to degeneracy of the genetic code) of any of the nucleic acids provided herein. In embodiments, the nucleic acid is an expression vector that can be transcribed when transfected into a cell line. In embodiments, the expression vector may comprise a plasmid, retrovirus, or an adenovirus amongst others. Nucleic acids can be isolated or synthesized using standard molecular biology approaches, for example by using a polymerase chain reaction to produce a nucleic acid fragment, which is then purified and cloned into an expression vector. Additional techniques useful in the practice of this invention may be found in Current Protocols in Molecular Biology 2007 by John Wiley and Sons, Inc.; Molecular Cloning: A Laboratory Manual (Third Edition) Joseph Sambrook, Peter MacCallum Cancer Institute, Melbourne, Australia; David Russell, University of Texas Southwestern Medical Center, Dallas, Cold Spring Harbor.

In embodiments, the immunosuppressants provided herein are coupled to synthetic nanocarriers. In preferable embodiments, the immunosuppressant is an element that is in addition to the material that makes up the structure of the synthetic nanocarrier. For example, in one embodiment, where the synthetic nanocarrier is made up of one or more polymers, the immunosuppressant is a compound that is in addition and coupled to the one or more polymers. As another example, in one embodiment, where the synthetic nanocarrier is made up of one or more lipids, the immunosuppressant is again in addition and coupled to the one or more lipids. In embodiments, such as where the material of the synthetic nanocarrier also results in an immunosuppressive (e.g., tolerogenic) effect, the immunosuppressant is an element present in addition to the material of the synthetic nanocarrier that results in an immunosuppressive (e.g., tolerogenic) effect.

Other exemplary immunosuppressants include, but are not limited, small molecule drugs, natural products, antibodies (e.g., antibodies against CD20, CD3, CD4), biologics-based drugs, carbohydrate-based drugs, nanoparticles, liposomes, RNAi, antisense nucleic acids, aptamers, methotrexate, NSAIDs; fingolimod; natalizumab; alemtuzumab; anti-CD3; tacrolimus (FK506), etc. Further immunosuppressants, are known to those of skill in the art, and the invention is not limited in this respect.

“Inflammatory disease” means any disease, disorder or condition in which undesired inflammation occurs.

“Load” of the immunosuppressant or antigen is the amount of the immunosuppressant or antigen coupled to a synthetic nanocarrier based on the total weight of materials in an entire synthetic nanocarrier (weight/weight). Generally, the load is calculated as an average across a population of synthetic nanocarriers. In one embodiment, the load of the immunosuppressant on average across the first population of synthetic nanocarriers is between 0.0001% and 50%. In another embodiment, the load of the antigen on average across the first and/or second population of synthetic nanocarriers is between 0.0001% and 50%. In yet another embodiment, the load of the immunosuppressant and/or antigen is between 0.01% and 20%. In a further embodiment, the load of the immunosuppressant and/or antigen is between 0.1% and 10%. In still a further embodiment, the load of the immunosuppressant and/or antigen is between 1% and 10%. In yet another embodiment, the load of the immunosuppressant and/or the antigen is at least 0.1%, at least 0.2%, at least 0.3%, at least 0.4%, at least 0.5%, at least 0.6%, at least 0.7%, at least 0.8%, at least 0.9%, at least 1%, at least 2%, at least 3%, at least 4%, at least 5%, at least 6%, at least 7%, at least 8%, at least 9%, at least 10%, at least 11%, at least 12%, at least 13%, at least 14%, at least 15%, at least 16%, at least 17%, at least 18%, at least 19% or at least 20% on average across a population of synthetic nanocarriers. In yet a further embodiment, the load of the immunosuppressant and/or the antigen is 0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.6%, 0.7%, 0.8%, 0.9%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 11%, 12%, 13%, 14%, 15%, 16%, 17%, 18%, 19% or 20% on average across a population of synthetic nanocarriers. In some embodiments of the above embodiments, the load of the immunosuppressant and/or the antigen is no more than 25% on average across a population of synthetic nanocarriers. In embodiments, the load is calculated as described in the Examples.

In embodiments of any of the compositions and methods provided herein, the load may be calculated as follows: Approximately 3 mg of synthetic nanocarriers are collected and centrifuged to separate supernatant from synthetic nanocarrier pellet. Acetonitrile is added to the pellet, and the sample is sonicated and centrifuged to remove any insoluble material. The supernatant and pellet are injected on RP-HPLC and absorbance is read at 278nm. The µg found in the pellet is used to calculate % entrapped (load), µg in supernatant and pellet are used to calculate total µg recovered.

“Maintenance dose” refers to a dose that is administered to a subject, after an initial dose has resulted in an immunosuppressive (e.g., tolerogenic) response in a subject, to sustain a desired immunosuppressive (e.g., tolerogenic) response. A maintenance dose, for example, can be one that maintains the tolerogenic effect achieved after the initial dose, prevents an undesired immune response in the subject, or prevents the subject becoming a subject at risk of experiencing an undesired immune response, including an undesired level of an immune response. In some embodiments, the maintenance dose is one that is sufficient to sustain an appropriate level of a desired immune response. In some embodiments, the maintenance dose is one that is sufficient to sustain an appropriate level of CD4+ T cell or CD8+ T cell number or activity or defend against a challenge with an agent that results in an undesired immune response.

"Maximum dimension of a synthetic nanocarrier" means the largest dimension of a nanocarrier measured along any axis of the synthetic nanocarrier. "Minimum dimension of a synthetic nanocarrier" means the smallest dimension of a synthetic nanocarrier measured along any axis of the synthetic nanocarrier. For example, for a spheroidal synthetic nanocarrier, the maximum and minimum dimension of a synthetic nanocarrier would be substantially identical, and would be the size of its diameter. Similarly, for a cuboidal synthetic nanocarrier, the minimum dimension of a synthetic nanocarrier would be the smallest of its height, width or length, while the maximum dimension of a synthetic nanocarrier would be the largest of its height, width or length. In an embodiment, a minimum dimension of at least 75%, preferably at least 80%, more preferably at least 90%, of the synthetic nanocarriers in a sample, based on the total number of synthetic nanocarriers in the sample, is equal to or greater than 100 nm. In an embodiment, a maximum dimension of at least 75%, preferably at least 80%, more preferably at least 90%, of the synthetic nanocarriers in a sample, based on the total number of synthetic nanocarriers in the sample, is equal to or less than 5 μm. Preferably, a minimum dimension of at least 75%, preferably at least 80%, more preferably at least 90%, of the synthetic nanocarriers in a sample, based on the total number of synthetic nanocarriers in the sample, is greater than 110 nm, more preferably greater than 120 nm, more preferably greater than 130 nm, and more preferably still greater than 150 nm. Aspects ratios of the maximum and minimum dimensions of inventive synthetic nanocarriers may vary depending on the embodiment. For instance, aspect ratios of the maximum to minimum dimensions of the synthetic nanocarriers may vary from 1:1 to 1,000,000:1, preferably from 1:1 to 100,000:1, more preferably from 1:1 to 10,000:1, more preferably from 1:1 to 1000:1, still more preferably from 1:1 to 100:1, and yet more preferably from 1:1 to 10:1. Preferably, a maximum dimension of at least 75%, preferably at least 80%, more preferably at least 90%, of the synthetic nanocarriers in a sample, based on the total number of synthetic nanocarriers in the sample is equal to or less than 3 μm, more preferably equal to or less than 2 μm, more preferably equal to or less than 1 μm, more preferably equal to or less than 800 nm, more preferably equal to or less than 600 nm, and more preferably still equal to or less than 500 nm. In preferred embodiments, a minimum dimension of at least 75%, preferably at least 80%, more preferably at least 90%, of the synthetic nanocarriers in a sample, based on the total number of synthetic nanocarriers in the sample, is equal to or greater than 100nm, more preferably equal to or greater than 120 nm, more preferably equal to or greater than 130 nm, more preferably equal to or greater than 140 nm, and more preferably still equal to or greater than 150 nm. Measurement of synthetic nanocarrier dimensions (e.g., diameter) is obtained by suspending the synthetic nanocarriers in a liquid (usually aqueous) media and using dynamic light scattering (DLS) (e.g. using a Brookhaven ZetaPALS instrument). For example, a suspension of synthetic nanocarriers can be diluted from an aqueous buffer into purified water to achieve a final synthetic nanocarrier suspension concentration of approximately 0.01 to 0.1 mg/mL. The diluted suspension may be prepared directly inside, or transferred to, a suitable cuvette for DLS analysis. The cuvette may then be placed in the DLS, allowed to equilibrate to the controlled temperature, and then scanned for sufficient time to acquire a stable and reproducible distribution based on appropriate inputs for viscosity of the medium and refractive indicies of the sample. The effective diameter, or mean of the distribution, is then reported. "Dimension" or "size" or "diameter" of synthetic nanocarriers means the mean of a particle size distribution obtained using dynamic light scattering.

"MHC" refers to major histocompatibility complex, a large genomic region or gene family found in most vertebrates that encodes MHC molecules that display fragments or epitopes of processed proteins on the cell surface. The presentation of MHC:peptide on cell surfaces allows for surveillance by immune cells, usually a T cell. There are two general classes of MHC molecules: Class I and Class II. Generally, Class I MHC molecules are found on nucleated cells and present peptides to cytotoxic T cells. Class II MHC molecules are found on certain immune cells, chiefly macrophages, B cells and dendritic cells, collectively known as professional APCs. The best-known genes in the MHC region are the subset that encodes antigen-presenting proteins on the cell surface. In humans, these genes are referred to as human leukocyte antigen (HLA) genes.

"Non-methoxy-terminated polymer" means a polymer that has at least one terminus that ends with a moiety other than methoxy. In some embodiments, the polymer has at least two termini that ends with a moiety other than methoxy. In other embodiments, the polymer has no termini that ends with methoxy. "Non-methoxy-terminated, pluronic polymer" means a polymer other than a linear pluronic polymer with methoxy at both termini. Polymeric nanoparticles as provided herein can comprise non-methoxy-terminated polymers or non-methoxy-terminated, pluronic polymers.

"Obtained" means taken directly from a material and used with substantially no modification and/or processing.

"Pharmaceutically acceptable excipient" means a pharmacologically inactive material used together with the recited synthetic nanocarriers to formulate the inventive compositions. Pharmaceutically acceptable excipients comprise a variety of materials known in the art, including but not limited to saccharides (such as glucose, lactose, and the like), preservatives such as antimicrobial agents, reconstitution aids, colorants, saline (such as phosphate buffered saline), and buffers.

"Protocol " refers to any dosing regimen of one or more substances to a subject. A dosing regimen may include the amount, frequency and/or mode of administration. In some embodiments, such a protocol may be used to administer one or more compositions of the invention to one or more test subjects. Immune responses in these test subject can then be assessed to determine whether or not the protocol was effective in reducing an undesired immune response or generating a desired immune response (e.g., the promotion of a tolerogenic effect). Any other therapeutic and/or prophylactic effect may also be assessed instead of or in addition to the aforementioned immune responses. Whether or not a protocol had a desired effect can be determined using any of the methods provided herein or otherwise known in the art. For example, a population of cells may be obtained from a subject to which a composition provided herein has been administered according to a specific protocol in order to determine whether or not specific immune cells, cytokines, antibodies, etc. were reduced, generated, activated, etc. Useful methods for detecting the presence and/or number of immune cells include, but are not limited to, flow cytometric methods (e.g., FACS) and immunohistochemistry methods. Antibodies and other binding agents for specific staining of immune cell markers, are commercially available. Such kits typically include staining reagents for multiple antigens that allow for FACS-based detection, separation and/or quantitation of a desired cell population from a heterogeneous population of cells.

"Providing a subject" is any action or set of actions that causes a clinician to come in contact with a subject and administer a composition provided herein thereto or to perform a method provided herein thereupon. Preferably, the subject is one who is in need of a tolerogenic immune response as provided herein. The action or set of actions may be either directly oneself or indirectly, such as, but not limited to, an unrelated third party that takes an action through reliance on one's words or deeds.

"Subject" means animals, including warm blooded mammals such as humans and primates; avians; domestic household or farm animals such as cats, dogs, sheep, goats, cattle, horses and pigs; laboratory animals such as mice, rats and guinea pigs; fish; reptiles; zoo and wild animals; and the like.

"Substantially no B cell epitopes" refers to the absence of B cell epitopes in an amount (by itself, within the context of the antigen, in conjunction with a carrier or in conjunction with an inventive composition) that stimulates substantial activation of a B cell response. In embodiments, a composition with substantially no B cell epitopes does not contain a measurable amount of B cell epitopes of an antigen. In other embodiments, such a composition may comprise a measurable amount of B cell epitopes of an antigen but said amount is not effective to generate a measurable B cell immune response (by itself, within the context of the antigen, in conjunction with a carrier or in conjunction with an inventive composition), such as antigen-specific antibody production or antigen-specific B cell proliferation and/or activity, or is not effective to generate a significant measurable B cell immune response (by itself, within the context of the antigen, in conjunction with a carrier or in conjunction with an inventive composition). In some embodiments, a significant measurable B cell immune response is one that produces or would be expected to produce an adverse clinical result in a subject. In other embodiments, a significant measurable B cell immune response is one that is greater than the level of the same type of immune response (e.g., antigen-specific antibody production or antigen-specific B cell proliferation and/or activity) produced by a control antigen (e.g., one known not to comprise B cell epitopes of the antigen or to stimulate B cell immune responses). In some embodiments, a significant measurable B cell immune response, such as a measurement of antibody titers (e.g., by ELISA) is 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold or more greater than the same type of response produced by a control (e.g., control antigen). In other embodiments, a composition with substantially no B cell epitopes is one that produces little to no antigen-specific antibody titers (by itself, within the context of the antigen, in conjunction with a carrier or in conjunction with an inventive composition). Such compositions include those that produce an antibody titer (as an EC50 value) of less than 500, 400, 300, 200, 100, 50, 40, 30, 20 or 10. In other embodiments, a significant measurable B cell immune response, is a measurement of the number or proliferation of B cells that is 10%, 25%, 50%, 100%, 2-fold, 3-fold, 4-fold, 5-fold, 6-fold, 7-fold, 8-fold, 9-fold, 10-fold, 15-fold, 20-fold or more greater that the same type of response produced by a control. Other methods for measuring B cell responses are known to those of ordinary skill in the art.

In embodiments, to ensure that a composition comprises substantially no B cell epitopes, antigens are selected such that they do not comprise B cell epitopes for coupling to the synthetic nanocarriers as provided herein. In other embodiments, to ensure that a composition comprises substantially no B cell epitopes of an antigen, the synthetic nanocarriers coupled to the antigen are produced and tested for B cell immune responses (e.g., antigen-specific antibody production, B cell proliferation and/or activity). Compositions that exhibit the desired properties may then be selected.

"Synthetic nanocarrier(s)" means a discrete object that is not found in nature, and that possesses at least one dimension that is less than or equal to 5 microns in size. Albumin nanoparticles are generally included as synthetic nanocarriers, however in certain embodiments the synthetic nanocarriers do not comprise albumin nanoparticles. In embodiments, inventive synthetic nanocarriers do not comprise chitosan. In other embodiments, inventive synthetic nanocarriers are not lipid-based nanoparticles. In further embodiments, inventive synthetic nanocarriers do not comprise a phospholipid.

A synthetic nanocarrier can be, but is not limited to, one or a plurality of lipid-based nanoparticles (also referred to herein as lipid nanoparticles, i.e., nanoparticles where the majority of the material that makes up their structure are lipids), polymeric nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles (i.e., particles that are primarily made up of viral structural proteins but that are not infectious or have low infectivity), peptide or protein-based particles (also referred to herein as protein particles, i.e., particles where the majority of the material that makes up their structure are peptides or proteins) (such as albumin nanoparticles) and/or nanoparticles that are developed using a combination of nanomaterials such as lipid-polymer nanoparticles. Synthetic nanocarriers may be a variety of different shapes, including but not limited to spheroidal, cuboidal, pyramidal, oblong, cylindrical, toroidal, and the like. Synthetic nanocarriers according to the invention comprise one or more surfaces. Exemplary synthetic nanocarriers that can be adapted for use in the practice of the present invention comprise: (1) the biodegradable nanoparticles disclosed in US Patent 5,543,158 to Gref et al., (2) the polymeric nanoparticles of Published US Patent Application 20060002852 to Saltzman et al., (3) the lithographically constructed nanoparticles of Published US Patent Application

20090028910 to DeSimone et al., (4) the disclosure of WO 2009/051837 to von Andrian et al., (5) the nanoparticles disclosed in Published US Patent Application 2008/0145441 to Penades et al., (6) the protein nanoparticles disclosed in Published US Patent Application 20090226525 to de los Rios et al., (7) the virus-like particles disclosed in published US Patent Application 20060222652 to Sebbel et al., (8) the nucleic acid coupled virus-like particles disclosed in published US Patent Application 20060251677 to Bachmann et al., (9) the virus-like particles disclosed in WO2010047839A1 or WO2009106999A2, (10) the nanoprecipitated nanoparticles disclosed in P. Paolicelli et al., "Surface-modified PLGA-based Nanoparticles that can Efficiently Associate and Deliver Virus-like Particles" Nanomedicine. 5(6):843-853 (2010), or (11) apoptotic cells, apoptotic bodies or the synthetic or semisynthetic mimics disclosed in U.S. Publication 2002/0086049. In embodiments, synthetic nanocarriers may possess an aspect ratio greater than 1:1, 1:1.2, 1:1.5, 1:2, 1:3, 1:5, 1:7, or greater than 1:10.

Synthetic nanocarriers according to the invention that have a minimum dimension of equal to or less than about 100 nm, preferably equal to or less than 100 nm, do not comprise a surface with hydroxyl groups that activate complement or alternatively comprise a surface that consists essentially of moieties that are not hydroxyl groups that activate complement. In a preferred embodiment, synthetic nanocarriers according to the invention that have a minimum dimension of equal to or less than about 100 nm, preferably equal to or less than 100 nm, do not comprise a surface that substantially activates complement or alternatively comprise a surface that consists essentially of moieties that do not substantially activate complement. In a more preferred embodiment, synthetic nanocarriers according to the invention that have a minimum dimension of equal to or less than about 100 nm, preferably equal to or less than 100 nm, do not comprise a surface that activates complement or alternatively comprise a surface that consists essentially of moieties that do not activate complement. In embodiments, synthetic nanocarriers exclude virus-like particles. In embodiments, synthetic nanocarriers may possess an aspect ratio greater than 1:1, 1:1.2, 1:1.5, 1:2, 1:3, 1:5, 1:7, or greater than 1:10.

"T cell antigen" means a CD4+ T-cell antigen or CD8+ cell antigen. "CD4+ T-cell antigen" means any antigen that is recognized by and triggers an immune response in a CD4+ T-cell e.g., an antigen that is specifically recognized by a T-cell receptor on a CD4+T cell via presentation of the antigen or portion thereof bound to a Class II major histocompatability complex molecule (MHC). "CD8+ T cell antigen" means any antigen that is recognized by and triggers an immune response in a CD8+ T-cell e.g., an antigen that is specifically recognized by a T-cell receptor on a CD8+T cell via presentation of the antigen or portion thereof bound to a Class I major histocompatability complex molecule (MHC). In some embodiments, an antigen that is a T cell antigen is also a B cell antigen. In other embodiments, the T cell antigen is not also a B cell antigen. T cell antigens generally are proteins or peptides.

"T effector cells" are art-recognized with the term referring to T cells carrying out a T cell function, and including T cells with cytotoxic activities, T helper cells, T cells which secrete cytokines and activate and/or direct other immune cells, etc. T effector cells include, for example, Th0, Th1, Th2, Th9, Th17, and effector memory T cells, which are all CD4+, as well as CD8+ cytotoxic T cells.

A "therapeutic protein" refers to any protein or protein-based therapy that may be administered to a subject and have a therapeutic effect. Such therapies include protein replacement and protein supplementation therapies. Such therapies also include the administration of exogenous or foreign protein, antibody therapies, and cell or cell-based therapies. Therapeutic proteins include enzymes, enzyme cofactors, hormones, blood clotting factors, cytokines, growth factors, monoclonal antibodies and polyclonal antibodies. Examples of other therapeutic proteins are provided elsewhere herein. Therapeutic proteins may be produced in, on or by cells and may be obtained from such cells or administered in the form of such cells. In embodiments, the therapeutic protein is produced in, on or by mammalian cells, insect cells, yeast cells, bacteria cells, plant cells, transgenic animal cells, transgenic plant cells, etc. The therapeutic protein may be recombinantly produced in such cells. The therapeutic protein may be produced in, on or by a virally transformed cell. The therapeutic protein may also be produced in, on or by autologous cells that have been transfected, transduced or otherwise manipulated to express it. Alternatively, the therapeutic protein may be administered as a nucleic acid or by introducing a nucleic acid into a virus, VLP, liposome, etc.. Alternatively, the therapeutic protein may be obtained from such forms and administered as the therapeutic protein itself. Subjects, therefore, include any subject that has received, is receiving or will receive any of the foregoing. Such subject includes subjects that have received, is receiving or will receive gene therapy, autologous cells that have been transfected, transduced or otherwise manipulated to express a therapeutic protein, polypeptide or peptide; or cells that express a therapeutic protein, polypeptide or peptide.

"Therapeutic protein antigen" means an antigen that is associated with a therapeutic protein that can be, or a portion of which can be, presented for recognition by cells of the immune system and can generate an undesired immune response (e.g., the production of therapeutic protein-specific antibodies) against the therapeutic protein. Therapeutic protein antigens generally include proteins, polypeptides, peptides, lipoproteins, or are contained or expressed in, on or by cells.

"Tolerogenic immune response" means any immune response that can lead to immune suppression specific to an antigen or a cell, tissue, organ, etc. that expresses such an antigen. Such immune responses include any reduction, delay or inhibition in an undesired immune response specific to the antigen or cell, tissue, organ, etc. that expresses such antigen. Such immune responses also include any stimulation, production, induction, promotion or recruitment in a desired immune response specific to the antigen or cell, tissue, organ, etc. that expresses such antigen. Tolerogenic immune responses, therefore, include the absence of or reduction in an undesired immune response to an antigen that can be mediated by antigen reactive cells as well as the presence or promotion of suppressive cells. Tolerogenic immune responses as provided herein include immunological tolerance. To "generate a tolerogenic immune response" refers to the generation of any of the foregoing immune responses specific to an antigen or cell, tissue, organ, etc. that expresses such antigen. The tolerogenic immune response can be the result of MHC Class I-restricted presentation and/or MHC Class II-restricted presentation and/or B cell presentation and/or presentation by CD1d, etc.

Tolerogenic immune responses include any reduction, delay or inhibition in CD4+ T cell, CD8+ T cell or B cell proliferation and/or activity. Tolerogenic immune responses also include a reduction in antigen-specific antibody production. Tolerogenic immune responses can also include any response that leads to the stimulation, induction, production or recruitment of regulatory cells, such as CD4+ Treg cells, CD8+ Treg cells, Breg cells, etc. In some embodiments, the tolerogenic immune response, is one that results in the conversion to a regulatory phenotype characterized by the production, induction, stimulation or recruitment of regulatory cells.

Tolerogenic immune responses also include any response that leads to the stimulation, production or recruitment of CD4+ Treg cells and/or CD8+ Treg cells. CD4+ Treg cells can express the transcription factor FoxP3 and inhibit inflammatory responses and auto-immune inflammatory diseases (Human regulatory T cells in autoimmune diseases. Cvetanovich GL, Hafler DA. Curr Opin Immunol. 2010 Dec;22(6):753-60. Regulatory T cells and autoimmunity. Vila J, Isaacs JD, Anderson AE.Curr Opin Hematol. 2009 Jul;16(4):274-9). Such cells also suppress T-cell help to B-cells and induce tolerance to both self and foreign antigens (Therapeutic approaches to allergy and autoimmunity based on FoxP3+ regulatory T-cell activation and expansion. Miyara M, Wing K, Sakaguchi S. J Allergy Clin Immunol. 2009 Apr;123(4):749-55). CD4+ Treg cells recognize antigen when presented by Class II proteins on APCs. CD8+ Treg cells, which recognize antigen presented by Class I (and Qa-1), can also suppress T-cell help to B-cells and result in activation of antigen-specific suppression inducing tolerance to both self and foreign antigens. Disruption of the interaction of Qa-1 with CD8+ Treg cells has been shown to dysregulate immune responses and results in the development of auto-antibody formation and an auto-immune lethal systemic-lupus-erythematosus (Kim et al., Nature. 2010 Sep 16, 467 (7313): 328-32). CD8+ Treg cells have also been shown to inhibit models of autoimmune inflammatory diseases including rheumatoid arthritis and colitis (CD4+CD25+ regulatory T cells in autoimmune arthritis. Oh S, Rankin AL, Caton AJ. Immunol Rev. 2010 Jan;233(1):97-111. Regulatory T cells in inflammatory bowel disease. Boden EK, Snapper SB. Curr Opin Gastroenterol. 2008 Nov;24(6):733-41). In some embodiments, the compositions provided can effectively result in both types of responses (CD4+ Treg and CD8+ Treg). In other embodiments, FoxP3 can be induced in other immune cells, such as macrophages, iNKT cells, etc., and the compositions provided herein can result in one or more of these responses as well.

Tolerogenic immune responses also include, but are not limited to, the induction of regulatory cytokines, such as Treg cytokines; induction of inhibitory cytokines; the inhibition of inflammatory cytokines (e.g., IL-4, IL-1b, IL-5, TNF-α, IL-6, GM-CSF, IFN-γ, IL-2, IL-9, IL-12, IL-17, IL-18, IL-21, IL-22, IL-23, M-CSF, C reactive protein, acute phase protein, chemokines (e.g., MCP-1, RANTES, MIP-1α, MIP-1β, MIG, ITAC or IP-10), the production of anti-inflammatory cytokines (e.g., IL-4, IL-13, IL-10, etc.), chemokines (e.g., CCL-2, CXCL8), proteases (e.g., MMP-3, MMP-9), leukotrienes (e.g., CysLT-1, CysLT-2), prostaglandins (e.g., PGE2) or histamines; the inhibition of polarization to a Th17, Th1 or Th2 immune response; the inhibition of effector cell-specific cytokines: Th17 (e.g., IL-17, IL-25), Th1 (IFN-γ), Th2 (e.g., IL-4, IL-13); the inhibition of Th1-, Th2- or TH17-specific transcription factors; the inhibition of proliferation of effector T cells; the induction of apoptosis of effector T cells; the induction of tolerogenic dendritic cell-specific genes, the induction of FoxP3 expression, the inhibition of IgE induction or IgE-mediated immune responses; the inhibition of antibody responses (e.g., antigen-specific antibody production); the inhibition of T helper cell response; the production of TGF-β and/or IL-10; the inhibition of effector function of autoantibodies (e.g., inhibition in the depletion of cells, cell or tissue damage or complement activation); etc.

Any of the foregoing may be measured *in vivo* in one or more animal models or may be measured *in vitro*. One of ordinary skill in the art is familiar with such *in vivo* or *in vitro* measurements. Undesired immune responses or tolerogenic immune responses can be monitored using, for example, methods of assessing immune cell number and/or function, tetramer analysis, ELISPOT, flow cytometry-based analysis of cytokine expression, cytokine secretion, cytokine expression profiling, gene expression profiling, protein expression profiling, analysis of cell surface markers, PCR-based detection of immune cell receptor gene usage (see T. Clay et al., "Assays for Monitoring Cellular Immune Response to Active Immunotherapy of Cancer" Clinical Cancer Research 7:1127-1135 (2001)), etc. Undesired immune responses or tolerogenic immune responses may also be monitored using, for example, methods of assessing protein levels in plasma or serum, immune cell proliferation and/or functional assays, etc. In some embodiments, tolerogenic immune responses can be monitored by assessing the induction of FoxP3. In addition, specific methods are described in more detail in the Examples.

Preferably, tolerogenic immune responses lead to the inhibition of the development, progression or pathology of the diseases, disorders or conditions described herein. Whether or not the inventive compositions can lead to the inhibition of the development, progression or pathology of the diseases, disorders or conditions described herein can be measured with animal models of such diseases, disorders or conditions. In some embodiments, the reduction of an undesired immune response or generation of a tolerogenic immune response may be assessed by determining clinical endpoints, clinical efficacy, clinical symptoms, disease biomarkers and/or clinical scores. Undesired immune responses or tolerogenic immune responses can also be assessed with diagnostic tests to assess the presence or absence of a disease, disorder or condition as provided herein. Undesired immune responses can further be assessed by methods of measuring therapeutic proteins levels and/or function in a subject. In embodiments, methods for monitoring or assessing undesired allergic responses include assessing an allergic response in a subject by skin reactivity and/or allergen-specific antibody production.

In some embodiments, monitoring or assessing the generation of an undesired immune response or a tolerogenic immune response in a subject can be prior to the administration of a composition of synthetic nanocarriers provided herein and/or prior to administration of a transplantable graft or therapeutic protein or exposure to an allergen. In other embodiments, assessing the generation of an undesired immune response or tolerogenic immune response can be after administration of a composition of synthetic nanocarriers provided herein and/or after administration of a transplantable graft or therapeutic protein or exposure to an allergen. In some embodiments, the assessment is done after administration of the composition of synthetic nanocarriers, but prior to administration of a transplantable graft or therapeutic protein or exposure to an allergen. In other embodiments, the assessment is done after administration of a transplantable graft or therapeutic protein or exposure to an allergen, but prior to administration of the composition. In still other embodiments, the assessment is performed prior to both the administration of the synthetic nanocarriers and administration of a transplantable graft or therapeutic protein or exposure to an allergen, while in yet other embodiments the assessment is performed after both the administration of synthetic nanocarriers and the administration of a transplantable graft or therapeutic protein or exposure to an allergen. In further embodiments, the assessment is performed both prior to and after the administration of the synthetic nanocarriers and/or administration of a transplantable graft or therapeutic protein or exposure to an allergen. In still other embodiments, the assessment is performed more than once on the subject to determine that a desirable immune state is maintained in the subject, such as a subject that has or is at risk of having an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft verus host disease. Other subjects include those that have undergone or will undergo transplantation as well as those that have received, are receiving or will receive a therapeutic protein against which they have experienced, are experiencing or are expected to experience an undesired immune response.

An antibody response can be assessed by determining one or more antibody titers. “Antibody titer” means a measurable level of antibody production. Methods for measuring antibody titers are known in the art and include Enzyme-linked Immunosorbent Assay (ELISA). In embodiments, the antibody response can be quantitated, for example, as the number of antibodies, concentration of antibodies or titer. The values can be absolute or they can be relative. Assays for quantifying an antibody response include antibody capture assays, enzyme-linked immunosorbent assays (ELISAs), inhibition liquid phase absorption assays

(ILPAAs), rocket immunoelectrophoresis (RIE) assays and line immunoelectrophoresis (LIE) assays. When an antibody response is compared to another antibody response the same type of quantitative value (e.g., titer) and method of measurement (e.g., ELISA) is preferably used to make the comparison.

An ELISA method for measuring an antibody titer, for example, a typical sandwich ELISA, may consist of the following steps (i) preparing an ELISA-plate coating material such that the antibody target of interest is coupled to a substrate polymer or other suitable material (ii) preparing the coating material in an aqueous solution (such as PBS) and delivering the coating material solution to the wells of a multiwell plate for overnight deposition of the coating onto the multiwell plate (iii) thoroughly washing the multiwell plate with wash buffer (such as 0.05% Tween-20 in PBS) to remove excess coating material (iv) blocking the plate for nonspecific binding by applying a diluent solution (such as 10% fetal bovine serum in PBS), (v) washing the blocking/diluent solution from the plate with wash buffer (vi) diluting the serum sample(s) containing antibodies and appropriate standards (positive controls) with diluent as required to obtain a concentration that suitably saturates the ELISA response (vii) serially diluting the plasma samples on the multiwell plate such to cover a range of concentrations suitable for generating an ELISA response curve (viii) incubating the plate to provide for antibody-target binding (ix) washing the plate with wash buffer to remove antibodies not bound to antigen (x) adding an appropriate concentration of a secondary detection antibody in same diluent such as a biotin-coupled detection antibody capable of binding the primary antibody (xi) incubating the plate with the applied detection antibody, followed by washing with wash buffer (xii) adding an enzyme such as streptavidin-HRP (horse radish peroxidase) that will bind to biotin found on biotinylated antibodies and incubating (xiii) washing the multiwell plate (xiv) adding substrate(s) (such as TMB solution) to the plate (xv) applying a stop solution (such as 2N sulfuric acid) when color development is complete (xvi) reading optical density of the plate wells at a specific wavelength for the substrate (450 nm with subtraction of readings at 570 nm) (xvi) applying a suitable multiparameter curve fit to the data and defining half-maximal effective concentration (EC50) as the concentration on the curve at which half the maximum OD value for the plate standards is achieved.

A “transplantable graft” refers to a biological material, such as cells, tissues and organs (in whole or in part) that can be administered to a subject. Transplantable grafts may be autografts, allografts, or xenografts of, for example, a biological material such as an organ, tissue, skin, bone, nerves, tendon, neurons, blood vessels, fat, cornea, pluripotent cells, differentiated cells (obtained or derived in vivo or in vitro), etc. In some embodiments, a transplantable graft is formed, for example, from cartilage, bone, extracellular matrix, or collagen matrices. Transplantable grafts may also be single cells, suspensions of cells and cells in tissues and organs that can be transplanted. Transplantable cells typically have a therapeutic function, for example, a function that is lacking or diminished in a recipient subject. Some non-limiting examples of transplantable cells are β-cells, hepatocytes, hematopoietic stem cells, neuronal stem cells, neurons, glial cells, or myelinating cells. Transplantable cells can be cells that are unmodified, for example, cells obtained from a donor subject and usable in transplantation without any genetic or epigenetic modifications. In other embodiments, transplantable cells can be modified cells, for example, cells obtained from a subject having a genetic defect, in which the genetic defect has been corrected, or cells that are derived from reprogrammed cells, for example, differentiated cells derived from cells obtained from a subject.

"Transplantation" refers to the process of transferring (moving) a transplantable graft into a recipient subject (e.g., from a donor subject, from an in vitro source (e.g.,differentiated autologous or heterologous native or induced pluripotent cells)) and/or from one bodily location to another bodily location in the same subject.

"Undesired immune response" refers to any undesired immune response that results from exposure to an antigen, promotes or exacerbates a disease, disorder or condition provided herein (or a symptom thereof), or is symptomatic of a disease, disorder or condition provided herein. Such immune responses generally have a negative impact on a subject's health or is symptomatic of a negative impact on a subject's health. Undesired immune responses include antigen-specific T effector cell (e.g., CD4+ T cell CD8+ T cell) proliferation and/or activity. Desired immune responses, therefore, include the deletion of T effector cells, the inhibition in the stimulation or activation of such cells, the inhibition of T effector cell proliferation, the inhibition of the production of cytokines by T effector cells, etc. When CD4+ T cell activity is inhibited, such inhibition can also result in a reduction in B cell immune responses. Methods for testing these immune responses are provided herein or are otherwise known to those of ordinary skill in the art.

C. INVENTIVE COMPOSITIONS

Provided herein are tolerogenic methods that include the administration of synthetic nanocarrier compositions comprising immunosuppressants and MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen and related compositions. Such methods and compositions are useful for reducing T effector cell number and/or function and promoting the generation of tolerogenic immune responses specific to the antigen that comprises the epitopes. The compositions may be administered to subjects in which a tolerogenic immune response is desired. Such subjects include those that have or are at risk of having an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft versus host disease. Such subjects also include those that have been, are being or will be administered a therapeutic protein against which the subject has experienced or is expected to experience an undesired immune response. Such subjects also include those that have undergone or will undergo transplantation.

Preferably, the compositions of the invention result in the deletion of T effector cells and/or a reduction in their activity. Surface marker expression profiles and cytokine secretion profiles of T effector cells are known in the art (e.g., as described in Rag, Immunology: a Textbook, Alpha Science Intl Ltd (August 15, 2005), ISBN-10: 1842652559, (e.g., Chapter 13) and can be used to assess the effects of the compositions provided. Exemplary populations of T effector cells include all those that contribute to, initiate, enhance or support an immune response such as by CD4+CD25- cells and CD8+CD45RA+ cells and also memory cells (e.g., CD4+CD25+FoxP3-). Additional surface markers that can be used to identify T effector cells are known to those of skill in the art, and such markers include, but are not limited to IL-12 receptor (α and β1 chains) and chemokine receptors CXCR3 and CCR5 (Th1 cells); IL-1 receptor, ST2L/T1 (an IL-1 RI-like molecule), chemokine receptors CXCR4, CCR3, CCR4, CCR7 and CCR8, and CD30 (Th2 cells). T effector cells further secrete cytokines, for example, IFN-gamma, IL-2, and/or TNF-beta (Th1 cells); IL-4, IL-5, IL-13 (Th2 cells), IL-9 (Th9), IL-17 (Th17), IL-22 (Th22) or other inflammatory cytokines. Cytokine secretion profiles of other T effector cells are known to those of skill in the art. Based on the knowledge of surface markers useful for the identification of various T effector cell populations, those of skill in the art are able to identify and enumerate T effector cells in a heterogeneous population of cells, for example, in a population of cells in culture or in a population of cells obtained from a subject. In other embodiments, the one of ordinary skill in the art may look for apoptosis, loss of specific T cells, such as CD4+ or CD8+ T cells or for CD69 activation to assess the function of the compositions provided herein.

A wide variety of synthetic nanocarriers can be used according to the invention. In some embodiments, synthetic nanocarriers are spheres or spheroids. In some embodiments, synthetic nanocarriers are flat or plate-shaped. In some embodiments, synthetic nanocarriers are cubes or cubic. In some embodiments, synthetic nanocarriers are ovals or ellipses. In some embodiments, synthetic nanocarriers are cylinders, cones, or pyramids.

In some embodiments, it is desirable to use a population of synthetic nanocarriers that is relatively uniform in terms of size, shape, and/or composition so that each synthetic nanocarrier has similar properties. For example, at least 80%, at least 90%, or at least 95% of the synthetic nanocarriers, based on the total number of synthetic nanocarriers, may have a minimum dimension or maximum dimension that falls within 5%, 10%, or 20% of the average diameter or average dimension of the synthetic nanocarriers. In some embodiments, a population of synthetic nanocarriers may be heterogeneous with respect to size, shape, and/or composition.

Synthetic nanocarriers can be solid or hollow and can comprise one or more layers. In some embodiments, each layer has a unique composition and unique properties relative to the other layer(s). To give but one example, synthetic nanocarriers may have a core/shell structure, wherein the core is one layer (e.g. a polymeric core) and the shell is a second layer (e.g. a lipid bilayer or monolayer). Synthetic nanocarriers may comprise a plurality of different layers.

In some embodiments, synthetic nanocarriers may optionally comprise one or more lipids. In some embodiments, a synthetic nanocarrier may comprise a liposome. In some embodiments, a synthetic nanocarrier may comprise a lipid bilayer. In some embodiments, a synthetic nanocarrier may comprise a lipid monolayer. In some embodiments, a synthetic nanocarrier may comprise a micelle. In some embodiments, a synthetic nanocarrier may comprise a core comprising a polymeric matrix surrounded by a lipid layer (e.g., lipid bilayer, lipid monolayer, etc.). In some embodiments, a synthetic nanocarrier may comprise a non-polymeric core (e.g., metal particle, quantum dot, ceramic particle, bone particle, viral particle, proteins, nucleic acids, carbohydrates, etc.) surrounded by a lipid layer (e.g., lipid bilayer, lipid monolayer, etc.).

In other embodiments, synthetic nanocarriers may comprise metal particles, quantum dots, ceramic particles, etc. In some embodiments, a non-polymeric synthetic nanocarrier is an aggregate of non-polymeric components, such as an aggregate of metal atoms (e.g., gold atoms).

In some embodiments, synthetic nanocarriers may optionally comprise one or more amphiphilic entities. In some embodiments, an amphiphilic entity can promote the production of synthetic nanocarriers with increased stability, improved uniformity, or increased viscosity. In some embodiments, amphiphilic entities can be associated with the interior surface of a lipid membrane (e.g., lipid bilayer, lipid monolayer, etc.). Many amphiphilic entities known in the art are suitable for use in making synthetic nanocarriers in accordance with the present invention. Such amphiphilic entities include, but are not limited to, phosphoglycerides; phosphatidylcholines; dipalmitoyl phosphatidylcholine (DPPC); dioleylphosphatidyl ethanolamine (DOPE); dioleyloxypropyltriethylammonium (DOTMA); dioleoylphosphatidylcholine; cholesterol; cholesterol ester; diacylglycerol; diacylglycerolsuccinate; diphosphatidyl glycerol (DPPG); hexanedecanol; fatty alcohols such as polyethylene glycol (PEG); polyoxyethylene-9-lauryl ether; a surface active fatty acid, such as palmitic acid or oleic acid; fatty acids; fatty acid monoglycerides; fatty acid diglycerides; fatty acid amides; sorbitan trioleate (Span®85) glycocholate; sorbitan monolaurate (Span®20); polysorbate 20 (Tween®20); polysorbate 60 (Tween®60); polysorbate 65 (Tween®65); polysorbate 80 (Tween®80); polysorbate 85 (Tween®85); polyoxyethylene monostearate; surfactin; a poloxomer; a sorbitan fatty acid ester such as sorbitan trioleate; lecithin; lysolecithin; phosphatidylserine; phosphatidylinositol;sphingomyelin; phosphatidylethanolamine (cephalin); cardiolipin; phosphatidic acid; cerebrosides; dicetylphosphate; dipalmitoylphosphatidylglycerol; stearylamine; dodecylamine; hexadecyl-amine; acetyl palmitate; glycerol ricinoleate; hexadecyl sterate; isopropyl myristate; tyloxapol; poly(ethylene glycol)5000-phosphatidylethanolamine; poly(ethylene glycol)400-monostearate; phospholipids; synthetic and/or natural detergents having high surfactant properties; deoxycholates; cyclodextrins; chaotropic salts; ion pairing agents; and combinations thereof. An amphiphilic entity component may be a mixture of different amphiphilic entities. Those skilled in the art will recognize that this is an exemplary, not comprehensive, list of substances with surfactant activity. Any amphiphilic entity may be used in the production of synthetic nanocarriers to be used in accordance with the present invention.

In some embodiments, synthetic nanocarriers may optionally comprise one or more carbohydrates. Carbohydrates may be natural or synthetic. A carbohydrate may be a derivatized natural carbohydrate. In certain embodiments, a carbohydrate comprises monosaccharide or disaccharide, including but not limited to glucose, fructose, galactose, ribose, lactose, sucrose, maltose, trehalose, cellbiose, mannose, xylose, arabinose, glucoronic acid, galactoronic acid, mannuronic acid, glucosamine, galatosamine, and neuramic acid. In certain embodiments, a carbohydrate is a polysaccharide, including but not limited to pullulan, cellulose, microcrystalline cellulose, hydroxypropyl methylcellulose (HPMC), hydroxycellulose (HC), methylcellulose (MC), dextran, cyclodextran, glycogen, hydroxyethylstarch, carageenan, glycon, amylose, chitosan, N,O-carboxylmethylchitosan, algin and alginic acid, starch, chitin, inulin, konjac, glucommannan, pustulan, heparin, hyaluronic acid, curdlan, and xanthan. In embodiments, the inventive synthetic nanocarriers do not comprise (or specifically exclude) carbohydrates, such as a polysaccharide. In certain embodiments, the carbohydrate may comprise a carbohydrate derivative such as a sugar alcohol, including but not limited to mannitol, sorbitol, xylitol, erythritol, maltitol, and lactitol.

In some embodiments, synthetic nanocarriers can comprise one or more polymers. In some embodiments, the synthetic nanocarriers comprise one or more polymers that is a nonmethoxy-terminated, pluronic polymer. In some embodiments, at least 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, or 99% (weight/weight) of the polymers that make up the synthetic nanocarriers are non-methoxy-terminated, pluronic polymers. In some embodiments, all of the polymers that make up the synthetic nanocarriers are non-methoxy-terminated, pluronic polymers. In some embodiments, the synthetic nanocarriers can comprise one or more polymers that is a non-methoxy-terminated polymer. In some embodiments, at least 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, or 99% (weight/weight) of the polymers that make up the synthetic nanocarriers are nonmethoxy-terminated polymers. In some embodiments, all of the polymers that make up the synthetic nanocarriers are non-methoxy-terminated polymers. In some embodiments, the synthetic nanocarriers comprise one or more polymers that does not comprise pluronic polymer. In some embodiments, at least 1%, 2%, 3%, 4%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 97%, or 99% (weight/weight) of the polymers that make up the synthetic nanocarriers do not comprise pluronic polymer. In some embodiments, all of the polymers that make up the synthetic nanocarriers do not comprise pluronic polymer. In some embodiments, such a polymer can be surrounded by a coating layer (e.g., liposome, lipid monolayer, micelle, etc.).

In some embodiments, various elements of the synthetic nanocarriers can be coupled with the polymer.

The immunosuppressants and/or antigens can be coupled to the synthetic nanocarriers by any of a number of methods. Generally, the coupling can be a result of bonding between the immunosuppressants and/or antigens and the synthetic nanocarrier. This bonding can result in the immunosuppressants and/or antigens being attached to the surface of the synthetic nanocarrier and/or contained within (encapsulated) the synthetic nanocarrier. In some embodiments, however, the immunosuppressants and/or antigens are encapsulated by the synthetic nanocarrier as a result of the structure of the synthetic nanocarrier rather than bonding to the synthetic nanocarrier. In preferable embodiments, the synthetic nanocarrier comprises a polymer as provided herein, and the immunosuppressants and/or antigens are coupled to the polymer.

When coupling occurs as a result of bonding between the immunosuppressants and/or antigens and synthetic nanocarriers, the coupling may occur via a coupling moiety. A coupling moiety can be any moiety through which an immunosuppressant and/or antigen is bonded to a synthetic nanocarrier. Such moieties include covalent bonds, such as an amide bond or ester bond, as well as separate molecules that bond (covalently or non-covalently) the immunosuppressant and/or antigen to the synthetic nanocarrier. Such molecules include linkers or polymers or a unit thereof. For example, the coupling moiety can comprise a charged polymer to which an immunosuppressant and/or antigen electrostatically binds. As another example, the coupling moiety can comprise a polymer or unit thereof to which it is covalently bonded.

In preferred embodiments, the synthetic nanocarriers comprise a polymer as provided herein. These synthetic nanocarriers can be completely polymeric or they can be a mix of polymers and other materials.

In some embodiments, the polymers of a synthetic nanocarrier associate to form a polymeric matrix. In some of these embodiments, a component, such as an immunosuppressant or antigen, can be covalently associated with one or more polymers of the polymeric matrix. In some embodiments, covalent association is mediated by a linker. In some embodiments, a component can be noncovalently associated with one or more polymers of a polymeric matrix. For example, in some embodiments a component can be encapsulated within, surrounded by, and/or dispersed throughout a polymeric matrix. Alternatively or additionally, a component can be associated with one or more polymers of a polymeric matrix by hydrophobic interactions, charge interactions, van der Waals forces, etc. A wide variety of polymers and methods for forming polymeric matrices therefrom are known conventionally.

Polymers may be natural or unnatural (synthetic) polymers. Polymers may be homopolymers or copolymers comprising two or more monomers. In terms of sequence, copolymers may be random, block, or comprise a combination of random and block sequences. Typically, polymers in accordance with the present invention are organic polymers.

In some embodiments, the polymer comprises a polyester, polycarbonate, polyamide, or polyether, or unit thereof. In other embodiments, the polymer comprises poly(ethylene glycol) (PEG), polypropylene glycol, poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid), or a polycaprolactone, or unit thereof. In some embodiments, it is preferred that the polymer is biodegradable. Therefore, in these embodiments, it is preferred that if the polymer comprises a polyether, such as poly(ethylene glycol) or polypropylene glycol or unit thereof, the polymer comprises a block-co-polymer of a polyether and a biodegradable polymer such that the polymer is biodegradable. In other embodiments, the polymer does not solely comprise a polyether or unit thereof, such as poly(ethylene glycol) or polypropylene glycol or unit thereof.

Other examples of polymers suitable for use in the present invention include, but are not limited to polyethylenes, polycarbonates (e.g. poly(1,3-dioxan-2one)), polyanhydrides (e.g. poly(sebacic anhydride)), polypropylfumerates, polyamides (e.g. polycaprolactam), polyacetals, polyethers, polyesters (e.g., polylactide, polyglycolide, polylactide-co-glycolide, polycaprolactone, polyhydroxyacid (e.g. poly(β-hydroxyalkanoate))), poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polyureas, polystyrenes, and polyamines, polylysine, polylysine-PEG copolymers, and poly(ethyleneimine), poly(ethylene imine)-PEG copolymers.

In some embodiments, polymers in accordance with the present invention include polymers which have been approved for use in humans by the U.S. Food and Drug Administration (FDA) under 21 C.F.R. § 177.2600, including but not limited to polyesters (e.g., polylactic acid, poly(lactic-co-glycolic acid), polycaprolactone, polyvalerolactone, poly(1,3-dioxan-2one)); polyanhydrides (e.g., poly(sebacic anhydride)); polyethers (e.g., polyethylene glycol); polyurethanes; polymethacrylates; polyacrylates; and polycyanoacrylates.

In some embodiments, polymers can be hydrophilic. For example, polymers may comprise anionic groups (e.g., phosphate group, sulphate group, carboxylate group); cationic groups (e.g., quaternary amine group); or polar groups (e.g., hydroxyl group, thiol group, amine group). In some embodiments, a synthetic nanocarrier comprising a hydrophilic polymeric matrix generates a hydrophilic environment within the synthetic nanocarrier. In some embodiments, polymers can be hydrophobic. In some embodiments, a synthetic nanocarrier comprising a hydrophobic polymeric matrix generates a hydrophobic environment within the synthetic nanocarrier. Selection of the hydrophilicity or hydrophobicity of the polymer may have an impact on the nature of materials that are incorporated (e.g. coupled) within the synthetic nanocarrier.

In some embodiments, polymers may be modified with one or more moieties and/or functional groups. A variety of moieties or functional groups can be used in accordance with the present invention. In some embodiments, polymers may be modified with polyethylene glycol (PEG), with a carbohydrate, and/or with acyclic polyacetals derived from polysaccharides (Papisov, 2001, ACS Symposium Series, 786:301). Certain embodiments may be made using the general teachings of US Patent No. 5543158 to Gref et al., or WO publication WO2009/051837 by Von Andrian et al.

In some embodiments, polymers may be modified with a lipid or fatty acid group. In some embodiments, a fatty acid group may be one or more of butyric, caproic, caprylic, capric, lauric, myristic, palmitic, stearic, arachidic, behenic, or lignoceric acid. In some embodiments, a fatty acid group may be one or more of palmitoleic, oleic, vaccenic, linoleic, alpha-linoleic, gamma-linoleic, arachidonic, gadoleic, arachidonic, eicosapentaenoic, docosahexaenoic, or erucic acid.

In some embodiments, polymers may be polyesters, including copolymers comprising lactic acid and glycolic acid units, such as poly(lactic acid-co-glycolic acid) and poly(lactide-co-glycolide), collectively referred to herein as “PLGA”; and homopolymers comprising glycolic acid units, referred to herein as “PGA,” and lactic acid units, such as poly-L-lactic acid, poly-D-lactic acid, poly-D,L-lactic acid, poly-L-lactide, poly-D-lactide, and poly-D,L-lactide, collectively referred to herein as “PLA.” In some embodiments, exemplary polyesters include, for example, polyhydroxyacids; PEG copolymers and copolymers of lactide and glycolide (e.g., PLA-PEG copolymers, PGA-PEG copolymers, PLGA-PEG copolymers, and derivatives thereof. In some embodiments, polyesters include, for example, poly(caprolactone), poly(caprolactone)-PEG copolymers, poly(L-lactide-co-L-lysine), poly(serine ester), poly(4-hydroxy-L-proline ester), poly[α-(4-aminobutyl)-L-glycolic acid], and derivatives thereof.

In some embodiments, a polymer may be PLGA. PLGA is a biocompatible and biodegradable co-polymer of lactic acid and glycolic acid, and various forms of PLGA are characterized by the ratio of lactic acid:glycolic acid. Lactic acid can be L-lactic acid, D-lactic acid, or D,L-lactic acid. The degradation rate of PLGA can be adjusted by altering the lactic acid:glycolic acid ratio. In some embodiments, PLGA to be used in accordance with the present invention is characterized by a lactic acid:glycolic acid ratio of approximately 85:15, approximately 75:25, approximately 60:40, approximately 50:50, approximately 40:60, approximately 25:75, or approximately 15:85.

In some embodiments, polymers may be one or more acrylic polymers. In certain embodiments, acrylic polymers include, for example, acrylic acid and methacrylic acid copolymers, methyl methacrylate copolymers, ethoxyethyl methacrylates, cyanoethyl methacrylate, aminoalkyl methacrylate copolymer, poly(acrylic acid), poly(methacrylic acid), methacrylic acid alkylamide copolymer, poly(methyl methacrylate), poly(methacrylic acid anhydride), methyl methacrylate, polymethacrylate, poly(methyl methacrylate) copolymer, polyacrylamide, aminoalkyl methacrylate copolymer, glycidyl methacrylate copolymers, polycyanoacrylates, and combinations comprising one or more of the foregoing polymers. The acrylic polymer may comprise fully-polymerized copolymers of acrylic and methacrylic acid esters with a low content of quaternary ammonium groups.

In some embodiments, polymers can be cationic polymers. In general, cationic polymers are able to condense and/or protect negatively charged strands of nucleic acids (e.g. DNA, or derivatives thereof). Amine-containing polymers such as poly(lysine) (Zauner et al., 1998, Adv. Drug Del. Rev., 30:97; and Kabanov et al., 1995, Bioconjugate Chem., 6:7), poly(ethylene imine) (PEI; Boussif et al., 1995, Proc. Natl. Acad. Sci., USA, 1995, 92:7297), and poly(amidoamine) dendrimers (Kukowska-Latallo et al., 1996, Proc. Natl. Acad. Sci., USA, 93:4897; Tang et al., 1996, Bioconjugate Chem., 7:703; and Haensler et al., 1993, Bioconjugate Chem., 4:372) are positively-charged at physiological pH, form ion pairs with nucleic acids, and mediate transfection in a variety of cell lines. In embodiments, the inventive synthetic nanocarriers may not comprise (or may exclude) cationic polymers.

In some embodiments, polymers can be degradable polyesters bearing cationic side chains (Putnam et al., 1999, Macromolecules, 32:3658; Barrera et al., 1993, J. Am. Chem. Soc., 115:11010; Kwon et al., 1989, Macromolecules, 22:3250; Lim et al., 1999, J. Am.

Chem. Soc., 121:5633; and Zhou et al., 1990, Macromolecules, 23:3399). Examples of these polyesters include poly(L-lactide-co-L-lysine) (Barrera et al., 1993, J. Am. Chem. Soc., 115:11010), poly(serine ester) (Zhou et al., 1990, Macromolecules, 23:3399), poly(4-hydroxy-L-proline ester) (Putnam et al., 1999, Macromolecules, 32:3658; and Lim et al., 1999, J. Am. Chem. Soc., 121:5633), and poly(4-hydroxy-L-proline ester) (Putnam et al., 1999, Macromolecules, 32:3658; and Lim et al., 1999, J. Am. Chem. Soc., 121:5633).

The properties of these and other polymers and methods for preparing them are well known in the art (see, for example, U.S. Patents 6,123,727; 5,804,178; 5,770,417; 5,736,372; 5,716,404; 6,095,148; 5,837,752; 5,902,599; 5,696,175; 5,514,378; 5,512,600; 5,399,665; 5,019,379; 5,010,167; 4,806,621; 4,638,045; and 4,946,929; Wang et al., 2001, J. Am. Chem. Soc., 123:9480; Lim et al., 2001, J. Am. Chem. Soc., 123:2460; Langer, 2000, Acc. Chem. Res., 33:94; Langer, 1999, J. Control. Release, 62:7; and Uhrich et al., 1999, Chem. Rev., 99:3181). More generally, a variety of methods for synthesizing certain suitable polymers are described in Concise Encyclopedia of Polymer Science and Polymeric Amines and Ammonium Salts, Ed. by Goethals, Pergamon Press, 1980; Principles of Polymerization by Odian, John Wiley & Sons, Fourth Edition, 2004; Contemporary Polymer Chemistry by Allcock et al., Prentice-Hall, 1981; Deming et al., 1997, Nature, 390:386; and in U.S. Patents 6,506,577, 6,632,922, 6,686,446, and 6,818,732.

In some embodiments, polymers can be linear or branched polymers. In some embodiments, polymers can be dendrimers. In some embodiments, polymers can be substantially cross-linked to one another. In some embodiments, polymers can be substantially free of cross-links. In some embodiments, polymers can be used in accordance with the present invention without undergoing a cross-linking step. It is further to be understood that inventive synthetic nanocarriers may comprise block copolymers, graft copolymers, blends, mixtures, and/or adducts of any of the foregoing and other polymers. Those skilled in the art will recognize that the polymers listed herein represent an exemplary, not comprehensive, list of polymers that can be of use in accordance with the present invention.

Compositions according to the invention comprise synthetic nanocarriers in combination with pharmaceutically acceptable excipients, such as preservatives, buffers, saline, or phosphate buffered saline. The compositions may be made using conventional pharmaceutical manufacturing and compounding techniques to arrive at useful dosage forms.

In an embodiment, inventive synthetic nanocarriers are suspended in sterile saline solution for injection together with a preservative.

In embodiments, when preparing synthetic nanocarriers as carriers, methods for coupling components to the synthetic nanocarriers may be useful. If the component is a small molecule it may be of advantage to attach the component to a polymer prior to the assembly of the synthetic nanocarriers. In embodiments, it may also be an advantage to prepare the synthetic nanocarriers with surface groups that are used to couple the component to the synthetic nanocarrier through the use of these surface groups rather than attaching the component to a polymer and then using this polymer conjugate in the construction of synthetic nanocarriers.

In certain embodiments, the coupling can be a covalent linker. In embodiments, peptides according to the invention can be covalently coupled to the external surface via a 1,2,3-triazole linker formed by the 1,3-dipolar cycloaddition reaction of azido groups on the surface of the nanocarrier with antigen or immunosuppressant containing an alkyne group or by the 1,3-dipolar cycloaddition reaction of alkynes on the surface of the nanocarrier with components containing an azido group. Such cycloaddition reactions are preferably performed in the presence of a Cu(I) catalyst along with a suitable Cu(I)-ligand and a reducing agent to reduce Cu(II) compound to catalytic active Cu(I) compound. This Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC) can also be referred as the click reaction.

Additionally, the covalent coupling may comprise a covalent linker that comprises an amide linker, a disulfide linker, a thioether linker, a hydrazone linker, a hydrazide linker, an imine or oxime linker, an urea or thiourea linker, an amidine linker, an amine linker, and a sulfonamide linker.

An amide linker is formed via an amide bond between an amine on one component with the carboxylic acid group of a second component such as the nanocarrier. The amide bond in the linker can be made using any of the conventional amide bond forming reactions with suitably protected amino acids or components and activated carboxylic acid such N-hydroxysuccinimide-activated ester.

A disulfide linker is made via the formation of a disulfide (S-S) bond between two sulfur atoms of the form, for instance, of R1-S-S-R2. A disulfide bond can be formed by thiol exchange of a component containing thiol/mercaptan group(-SH) with another activated thiol group on a polymer or nanocarrier or a nanocarrier containing thiol/mercaptan groups with a component containing activated thiol group.

A triazole linker, specifically a 1,2,3-triazole of the form  , wherein R1 and R2 may be any chemical entities, is made by the 1,3-dipolar cycloaddition reaction of an azide attached to a first component such as the nanocarrier with a terminal alkyne attached to a second component such as the immunosuppressant or antigen. The 1,3-dipolar cycloaddition reaction is performed with or without a catalyst, preferably with Cu(I)-catalyst, which links the two components through a 1,2,3-triazole function. This chemistry is described in detail by Sharpless et al., Angew. Chem. Int. Ed. 41(14), 2596, (2002) and Meldal, et al, Chem. Rev., 2008, 108(8), 2952-3015 and is often referred to as a "click" reaction or CuAAC.

In embodiments, a polymer containing an azide or alkyne group, terminal to the polymer chain is prepared. This polymer is then used to prepare a synthetic nanocarrier in such a manner that a plurality of the alkyne or azide groups are positioned on the surface of that nanocarrier. Alternatively, the synthetic nanocarrier can be prepared by another route, and subsequently functionalized with alkyne or azide groups. The component is prepared with the presence of either an alkyne (if the polymer contains an azide) or an azide (if the polymer contains an alkyne) group. The component is then allowed to react with the nanocarrier via the 1,3-dipolar cycloaddition reaction with or without a catalyst which covalently couples the component to the particle through the 1,4-disubstituted 1,2,3-triazole linker.

A thioether linker is made by the formation of a sulfur-carbon (thioether) bond in the form, for instance, of R1-S-R2. Thioether can be made by either alkylation of a thiol/mercaptan (-SH) group on one component such as the component with an alkylating group such as halide or epoxide on a second component such as the nanocarrier. Thioether linkers can also be formed by Michael addition of a thiol/mercaptan group on one component to an electron-deficient alkene group on a second component such as a polymer containing a maleimide group or vinyl sulfone group as the Michael acceptor. In another way, thioether linkers can be prepared by the radical thiol-ene reaction of a thiol/mercaptan group on one component with an alkene group on a second component such as a polymer or nanocarrier.

A hydrazone linker is made by the reaction of a hydrazide group on one component with an aldehyde/ketone group on the second component such as the nanocarrier.

A hydrazide linker is formed by the reaction of a hydrazine group on one component with a carboxylic acid group on the second component such as the nanocarrier. Such reaction is generally performed using chemistry similar to the formation of amide bond where the carboxylic acid is activated with an activating reagent.

An imine or oxime linker is formed by the reaction of an amine or N-alkoxyamine (or aminooxy) group on one component with an aldehyde or ketone group on the second component such as the nanocarrier.

An urea or thiourea linker is prepared by the reaction of an amine group on one component with an isocyanate or thioisocyanate group on the second component such as the nanocarrier.

An amidine linker is prepared by the reaction of an amine group on one component with an imidoester group on the second component such as the nanocarrier.

An amine linker is made by the alkylation reaction of an amine group on one component with an alkylating group such as halide, epoxide, or sulfonate ester group on the second component such as the nanocarrier. Alternatively, an amine linker can also be made by reductive amination of an amine group on one component with an aldehyde or ketone group on the second component such as the nanocarrier with a suitable reducing reagent such as sodium cyanoborohydride or sodium triacetoxyborohydride.

A sulfonamide linker is made by the reaction of an amine group on one component with a sulfonyl halide (such as sulfonyl chloride) group on the second component such as the nanocarrier.

A sulfone linker is made by Michael addition of a nucleophile to a vinyl sulfone. Either the vinyl sulfone or the nucleophile may be on the surface of the nanocarrier or attached to a component.

The component can also be conjugated to the nanocarrier via non-covalent conjugation methods. For examples, a negative charged antigen or immunosuppressant can be conjugated to a positive charged nanocarrier through electrostatic adsorption. A component containing a metal ligand can also be conjugated to a nanocarrier containing a metal complex via a metal-ligand complex.

In embodiments, the component can be attached to a polymer, for example polylactic acid-block-polyethylene glycol, prior to the assembly of the synthetic nanocarrier or the synthetic nanocarrier can be formed with reactive or activatible groups on its surface. In the latter case, the component may be prepared with a group which is compatible with the attachment chemistry that is presented by the synthetic nanocarriers' surface. In other embodiments, a peptide can be attached to VLPs or liposomes using a suitable linker. A linker is a compound or reagent that capable of coupling two molecules together. In an embodiment, the linker can be a homobifuntional or heterobifunctional reagent as described in Hermanson 2008. For example, an VLP or liposome synthetic nanocarrier containing a carboxylic group on the surface can be treated with a homobifunctional linker, adipic dihydrazide (ADH), in the presence of EDC to form the corresponding synthetic nanocarrier with the ADH linker. The resulting ADH linked synthetic nanocarrier is then conjugated with a peptide containing an acid group via the other end of the ADH linker on NC to produce the corresponding VLP or liposome peptide conjugate.

For detailed descriptions of available conjugation methods, see Hermanson G T "Bioconjugate Techniques", 2nd Edition Published by Academic Press, Inc., 2008. In addition to covalent attachment the component can be coupled by adsorption to a pre-formed synthetic nanocarrier or it can be coupled by encapsulation during the formation of the synthetic nanocarrier.

Any immunosuppressant as provided herein can be coupled to the synthetic nanocarrier. Immunosuppressants include, but are not limited to, statins; mTOR inhibitors, such as rapamycin or a rapamycin analog; TGF-β signaling agents; TGF-β receptor agonists; histone deacetylase (HDAC) inhibitors; corticosteroids; inhibitors of mitochondrial function, such as rotenone; P38 inhibitors; NF-κβ inhibitors; adenosine receptor agonists; prostaglandin E2 agonists; phosphodiesterase inhibitors, such as phosphodiesterase 4 inhibitor; proteasome inhibitors; kinase inhibitors; G-protein coupled receptor agonists; G-protein coupled receptor antagonists; glucocorticoids; retinoids; cytokine inhibitors; cytokine receptor inhibitors; cytokine receptor activators; peroxisome proliferator-activated receptor antagonists; peroxisome proliferator-activated receptor agonists; histone deacetylase inhibitors; calcineurin inhibitors; phosphatase inhibitors and oxidized ATPs. Immunosuppressants also include IDO, vitamin D3, cyclosporine A, aryl hydrocarbon receptor inhibitors, resveratrol, azathiopurine, 6-mercaptopurine, aspirin, niflumic acid, estriol, tripolide, interleukins (e.g., IL-1, IL-10), cyclosporine A, siRNAs targeting cytokines or cytokine receptors and the like.

Examples of statins include atorvastatin (LIPITOR®, TORVAST®), cerivastatin, fluvastatin (LESCOL®, LESCOL® XL), lovastatin (MEVACOR®, ALTOCOR®, ALTOPREV®), mevastatin (COMPACTIN®), pitavastatin (LIVALO®, PIAVA®), rosuvastatin (PRAVACHOL®, SELEKTINE®, LIPOSTAT®), rosuvastatin (CRESTOR®), and simvastatin (ZOCOR®, LIPEX®).

Examples of mTOR inhibitors include rapamycin and analogs thereof (e.g., CCL-779, RAD001, AP23573, C20-methallylrapamycin (C20-Marap), C16-(S)-butylsulfonamidorapamycin (C16-BSrap), C16-(S)-3-methylindolerapamycin (C16-iRap) (Bayle et al. Chemistry & Biology 2006, 13:99-107)), AZD8055, BEZ235 (NVP-BEZ235), chrysophanic acid (chrysophanol), deforolimus (MK-8669), everolimus (RAD0001), KU-0063794, PI-103, PP242, temsirolimus, and WYE-354 (available from Selleck, Houston, TX, USA).

Examples of TGF-β signaling agents include TGF-β ligands (e.g., activin A, GDF1, GDF11, bone morphogenic proteins, nodal, TGF-βs) and their receptors (e.g., ACVR1B, ACVR1C, ACVR2A, ACVR2B, BMPR2, BMPR1A, BMPR1B, TGFβRI, TGFβRII), R-SMADS/co-SMADS (e.g., SMAD1, SMAD2, SMAD3, SMAD4, SMAD5, SMAD8), and ligand inhibitors (e.g, follistatin, noggin, chordin, DAN, lefty, LTBP1, THBS1, Decorin).

Examples of inhibitors of mitochondrial function include atractyloside (dipotassium salt), bongkrekic acid (triammonium salt), carbonyl cyanide m-chlorophenylhydrazone, carboxyatractyloside (e.g., from *Atractylis gummifera*), CGP-37157, (-)-Deguelin (e.g., from *Mundulea sericea*), F16, hexokinase II VDAC binding domain peptide, oligomycin, rotenone, Ru360, SFK1, and valinomycin (e.g., from *Streptomyces fulvissimus*) (EMD4Biosciences, USA).

Examples of P38 inhibitors include SB-203580 (4-(4-Fluorophenyl)-2-(4-methylsulfinylphenyl)-5-(4-pyridyl)1H-imidazole), SB-239063 (trans-1-(4hydroxycyclohexyl)-4-(fluorophenyl)-5-(2-methoxy-pyrimidin-4-yl) imidazole), SB-220025 (5-(2amino-4-pyrimidinyl)-4-(4-fluorophenyl)-1-(4-piperidinyl)imidazole)), and ARRY-797.

Examples of NF (e.g., NK-κβ) inhibitors include IFRD1, 2-(1,8-naphthyridin-2-yl)-Phenol, 5-aminosalicylic acid, BAY 11-7082, BAY 11-7085, CAPE (Caffeic Acid Phenethylester), diethylmaleate, IKK-2 Inhibitor IV, IMD 0354, lactacystin, MG-132 [Z-Leu-Leu-Leu-CHO], NFκB Activation Inhibitor III, NF-κB Activation Inhibitor II, JSH-23, parthenolide, Phenylarsine Oxide (PAO), PPM-18, pyrrolidinedithiocarbamic acid ammonium salt, QNZ, RO 106-9920, rocaglamide, rocaglamide AL, rocaglamide C, rocaglamide I, rocaglamide J, rocaglaol, (R)-MG-132, sodium salicylate, triptolide (PG490), wedelolactone.

Examples of adenosine receptor agonists include CGS-21680 and ATL-146e.

Examples of prostaglandin E2 agonists include E-Prostanoid 2 and E-Prostanoid 4.

Examples of phosphodiesterase inhibitors (non-selective and selective inhibitors) include caffeine, aminophylline, IBMX (3-isobutyl-1-methylxanthine), paraxanthine, pentoxifylline, theobromine, theophylline, methylated xanthines, vinpocetine, EHNA (erythro-9-(2-hydroxy-3-nonyl)adenine), anagrelide, enoximone (PERFAN™), milrinone, levosimendon, mesembrine, ibudilast, piclamilast, luteolin, drotaverine, roflumilast (DAXAS™, DALIRESP™), sildenafil (REVATION®, VIAGRA®), tadalafil (ADCIRCA®, CIALIS®), vardenafil (LEVITRA®, STAXYN®), udenafil, avanafil, icariin, 4-methylpiperazine, and pyrazolo pyrimidin-7-1.

Examples of proteasome inhibitors include bortezomib, disulfiram, epigallocatechin-3-gallate, and salinosporamide A.

Examples of kinase inhibitors include bevacizumab, BIBW 2992, cetuximab (ERBITUX®), imatinib (GLEEVEC®), trastuzumab (HERCEPTIN®), gefitinib (IRESSA®), ranibizumab (LUCENTIS®), pegaptanib, sorafenib, dasatinib, sunitinib, erlotinib, nilotinib, lapatinib, panitumumab, vandetanib, E7080, pazopanib, mubritinib.

Examples of glucocorticoids include hydrocortisone (cortisol), cortisone acetate, prednisone, prednisolone, methylprednisolone, dexamethasone, betamethasone, triamcinolone, beclometasone, fludrocortisone acetate, deoxycorticosterone acetate (DOCA), and aldosterone.

Examples of retinoids include retinol, retinal, tretinoin (retinoic acid, RETIN-A®), isotretinoin (ACCUTANE®, AMNESTEEM®, CLARAVIS®, SOTRET®), alitretinoin (PANRETIN®), etretinate (TEGISON™) and its metabolite acitretin (SORIATANE®), tazarotene (TAZORAC®, AVAGE®, ZORAC®), bexarotene (TARGRETIN®), and adapalene (DIFFERIN®).

Examples of cytokine inhibitors include IL1ra, IL1 receptor antagonist, IGFBP, TNF-BF, uromodulin, Alpha-2-Macroglobulin, Cyclosporin A, Pentamidine, and Pentoxifylline (PENTOPAK®, PENTOXIL®, TRENTAL®).

Examples of peroxisome proliferator-activated receptor antagonists include GW9662, PPARγ antagonist III, G335, T0070907 (EMD4Biosciences, USA).

Examples of peroxisome proliferator-activated receptor agonists include pioglitazone, ciglitazone, clofibrate, GW1929, GW7647, L-165,041, LY 171883, PPARγ activator, Fmoc-Leu, troglitazone, and WY-14643 (EMD4Biosciences, USA).

Examples of histone deacetylase inhibitors include hydroxamic acids (or hydroxamates) such as trichostatin A, cyclic tetrapeptides (such as trapoxin B) and depsipeptides, benzamides, electrophilic ketones, aliphatic acid compounds such as phenylbutyrate and valproic acid, hydroxamic acids such as vorinostat (SAHA), belinostat (PXD101), LAQ824, and panobinostat (LBH589), benzamides such as entinostat (MS-275), CI994, and mocetinostat (MGCD0103), nicotinamide, derivatives of NAD, dihydrocoumarin, naphthopyranone, and 2-hydroxynaphaldehydes.

Examples of calcineurin inhibitors include cyclosporine, pimecrolimus, voclosporin, and tacrolimus.

Examples of phosphatase inhibitors include BN82002 hydrochloride, CP-91149, calyculin A, cantharidic acid, cantharidin, cypermethrin, ethyl-3,4-dephostatin, fostriecin sodium salt, MAZ51, methyl-3,4-dephostatin, NSC 95397, norcantharidin, okadaic acid ammonium salt from prorocentrum concavum, okadaic acid, okadaic acid potassium salt, okadaic acid sodium salt, phenylarsine oxide, various phosphatase inhibitor cocktails, protein phosphatase 1C, protein phosphatase 2A inhibitor protein, protein phosphatase 2A1, protein phosphatase 2A2, sodium orthovanadate.

In some embodiments, antigens as described herein are also coupled to synthetic nanocarriers. In some embodiments, the antigens are coupled to the same or different synthetic nanocarriers as to which the immunosuppressants are coupled. In other embodiments, the antigens are not coupled to any synthetic nanocarriers. Antigens include any of the antigens provided herein, or fragments or derivatives thereof, such antigens are associated with inflammatory, autoimmune diseases, allergy, organ or tissue rejection, graft versus host disease, transplant antigens and therapeutic protein antigens. The epitopes, or proteins, polypeptides or peptides that comprise the epitopes, can be obtained or derived from any of the antigens provided or otherwise known in the art.

Therapeutic proteins include, but are not limited to, infusible therapeutic proteins, enzymes, enzyme cofactors, hormones, blood clotting factors, cytokines and interferons, growth factors, monoclonal antibodies, and polyclonal antibodies (e.g., that are administered to a subject as a replacement therapy), and proteins associated with Pompe's disease (e.g., alglucosidase alfa, rhGAA (e.g., Myozyme and Lumizyme (Genzyme)). Therapeutic proteins also include proteins involved in the blood coagulation cascade. Therapeutic proteins include, but are not limited to, Factor VIII, Factor VII, Factor IX, Factor V, von Willebrand Factor, von Heldebrant Factor, tissue plasminogen activator, insulin, growth hormone, erythropoietin alfa, VEGF, thrombopoietin, lysozyme, antithrombin and the like. Therapeutic proteins also include adipokines, such as leptin and adiponectin. Other examples of therapeutic proteins are as described below and elsewhere herein. Also included are fragments or derivatives of any of the therapeutic proteins provided as the epitope, or protein, polypeptide or peptide that comprises the epitope.

Examples of therapeutic proteins used in enzyme replacement therapy of subjects having a lysosomal storage disorder include, but are not limited to, imiglucerase for the treatment of Gaucher's disease (e.g., CEREZYME™), a-galactosidase A (a-gal A) for the treatment of Fabry disease (e.g., agalsidase beta, FABRYZYME™), acid a-glucosidase (GAA) for the treatment of Pompe disease (e.g., alglucosidase alfa, LUMIZYME™, MYOZYME™), arylsulfatase B for the treatment of Mucopolysaccharidoses (e.g., laronidase, ALDURAZYME™, idursulfase, ELAPRASE™, arylsulfatase B, NAGLAZYME™).

Examples of enzymes include oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases.

Examples of hormones include Melatonin (N-acetyl-5-methoxytryptamine), Serotonin, Thyroxine (or tetraiodothyronine) (a thyroid hormone), Triiodothyronine (a thyroid hormone), Epinephrine (or adrenaline), Norepinephrine (or noradrenaline), Dopamine (or prolactin inhibiting hormone), Antimullerian hormone (or mullerian inhibiting factor or hormone), Adiponectin, Adrenocorticotropic hormone (or corticotropin), Angiotensinogen and angiotensin, Antidiuretic hormone (or vasopressin, arginine vasopressin), Atrial-natriuretic peptide (or atriopeptin), Calcitonin, Cholecystokinin, Corticotropin-releasing hormone, Erythropoietin, Follicle-stimulating hormone, Gastrin, Ghrelin, Glucagon, Glucagon-like peptide (GLP-1), GIP, Gonadotropin-releasing hormone, Growth hormone-releasing hormone, Human chorionic gonadotropin, Human placental lactogen, Growth hormone, Inhibin, Insulin, Insulin-like growth factor (or somatomedin), Leptin, Luteinizing hormone, Melanocyte stimulating hormone, Orexin, Oxytocin, Parathyroid hormone, Prolactin, Relaxin, Secretin, Somatostatin, Thrombopoietin, Thyroid-stimulating hormone (or thyrotropin), Thyrotropin-releasing hormone, Cortisol, Aldosterone, Testosterone, Dehydroepiandrosterone, Androstenedione, Dihydrotestosterone, Estradiol, Estrone, Estriol, Progesterone, Calcitriol (1,25-dihydroxyvitamin D3), Calcidiol (25-hydroxyvitamin D3), Prostaglandins, Leukotrienes, Prostacyclin, Thromboxane, Prolactin releasing hormone, Lipotropin, Brain natriuretic peptide, Neuropeptide Y, Histamine, Endothelin, Pancreatic polypeptide, Renin, and Enkephalin.

Examples of blood and blood coagulation factors include Factor I (fibrinogen), Factor II (prothrombin), tissue factor, Factor V (proaccelerin, labile factor), Factor VII (stable factor, proconvertin), Factor VIII (antihemophilic globulin), Factor IX (Christmas factor or plasma thromboplastin component), Factor X (Stuart-Prower factor), Factor Xa, Factor XI, Factor XII (Hageman factor), Factor XIII (fibrin-stabilizing factor), von Willebrand factor, prekallikrein (Fletcher factor), high-molecular weight kininogen (HMWK) (Fitzgerald factor), fibronectin, fibrin, thrombin, antithrombin III, heparin cofactor II, protein C, protein S, protein Z, protein Z-related protease inhibitot (ZPI), plasminogen, alpha 2-antiplasmin, tissue plasminogen activator (tPA), urokinase, plasminogen activator inhibitor-1 (PAI1), plasminogen activator inhibitor-2 (PAI2), cancer procoagulant, and epoetin alfa (Epogen, Procrit).

Examples of cytokines include lymphokines, interleukins, and chemokines, type 1 cytokines, such as IFN-γ, TGF-β, and type 2 cytokines, such as IL-4, IL-10, and IL-13.

Examples of growth factors include Adrenomedullin (AM), Angiopoietin (Ang), Autocrine motility factor, Bone morphogenetic proteins (BMPs), Brain-derived neurotrophic factor (BDNF), Epidermal growth factor (EGF), Erythropoietin (EPO), Fibroblast growth factor (FGF), Glial cell line-derived neurotrophic factor (GDNF), Granulocyte colony-stimulating factor (G-CSF), Granulocyte macrophage colony-stimulating factor (GM-CSF), Growth differentiation factor-9 (GDF9), Hepatocyte growth factor (HGF), Hepatoma-derived growth factor (HDGF), Insulin-like growth factor (IGF), Migration-stimulating factor, Myostatin (GDF-8), Nerve growth factor (NGF) and other neurotrophins, Platelet-derived growth factor (PDGF), Thrombopoietin (TPO), Transforming growth factor alpha(TGF-α), Transforming growth factor beta(TGF-β), Tumour_necrosis_factor-alpha(TNF-α), Vascular endothelial growth factor (VEGF), Wnt Signaling Pathway, placental growth factor (PlGF), [(Foetal Bovine Somatotrophin)] (FBS), IL-1, IL-2, IL-3, IL-4, IL-5, IL-6, and IL-7.

Examples of monoclonal antibodies include Abagovomab, Abciximab, Adalimumab, Adecatumumab, Afelimomab, Afutuzumab, Alacizumab pegol, ALD, Alemtuzumab, Altumomab pentetate, Anatumomab mafenatox, Anrukinzumab, Anti-thymocyte globin, Apolizumab, Arcitumomab, Aselizumab, Atlizumab (tocilizumab), Atorolimumab, Bapineuzumab, Basiliximab, Bavituximab, Bectumomab, Belimumab, Benralizumab, Bertilimumab, Besilesomab, Bevacizumab, Biciromab, Bivatuzumab mertansine, Blinatumomab, Brentuximab vedotin, Briakinumab, Canakinumab, Cantuzumab mertansine, Capromab pendetide, Catumaxomab, Cedelizumab, Certolizumab pegol, Cetuximab, Citatuzumab bogatox, Cixutumumab, Clenoliximab, Clivatuzumab tetraxetan, Conatumumab, Dacetuzumab, Daclizumab, Daratumumab, Denosumab, Detumomab, Dorlimomab aritox, Dorlixizumab, Ecromeximab, Eculizumab, Edobacomab, Edrecolomab, Efalizumab, Efungumab, Elotuzumab, Elsilimomab, Enlimomab pegol, Epitumomab cituxetan, Epratuzumab, Erlizumab, Ertumaxomab, Etaracizumab, Exbivirumab, Fanolesomab, Faralimomab, Farletuzumab, Felvizumab, Fezakinumab, Figitumumab, Fontolizumab , Foravirumab, Fresolimumab, Galiximab, Gantenerumab, Gavilimomab, Gemtuzumab ozogamicin, GC1008, Girentuximab, Glembatumumab vedotin, Golimumab, Gomiliximab, Ibalizumab, Ibritumomab tiuxetan, Igovomab, Imciromab, Infliximab, Intetumumab, Inolimomab, Inotuzumab ozogamicin, Ipilimumab, Iratumumab, Keliximab, Labetuzumab, Lebrikizumab, Lemalesomab, Lerdelimumab, Lexatumumab, Libivirumab, Lintuzumab, Lorvotuzumab mertansine, Lucatumumab, Lumiliximab, Mapatumumab, Maslimomab, Matuzumab, Mepolizumab, Metelimumab, Milatuzumab, Minretumomab, Mitumomab, Morolimumab, Motavizumab, Muromonab-CD3, Nacolomab tafenatox, Naptumomab estafenatox, Natalizumab, Nebacumab, Necitumumab, Nerelimomab, Nimotuzumab, Nofetumomab merpentan, Ocrelizumab, Odulimomab, Ofatumumab, Olaratumab, Omalizumab, Oportuzumab monatox, Oregovomab, Otelixizumab, Pagibaximab, Palivizumab, Panitumumab, Panobacumab, Pascolizumab, Pemtumomab, Pertuzumab, Pexelizumab, Pintumomab, Priliximab, Pritumumab, Rafivirumab, Ramucirumab, Ranibizumab, Raxibacumab, Regavirumab Reslizumab, Rilotumumab, Rituximab, Robatumumab, Rontalizumab, Rovelizumab, Ruplizumab, Satumomab pendetide, Sevirumab, Sibrotuzumab, Sifalimumab, Siltuximab, Siplizumab, Solanezumab, Sonepcizumab, Sontuzumab, Stamulumab, Sulesomab, Tacatuzumab tetraxetan, Tadocizumab, Talizumab, Tanezumab, Taplitumomab paptox, Tefibazumab, Telimomab aritox, Tenatumomab, Teneliximab, Teplizumab, Ticilimumab (tremelimumab), Tigatuzumab, Tocilizumab (atlizumab), Toralizumab, Tositumomab, Trastuzumab, Tremelimumab, Tucotuzumab celmoleukin, Tuvirumab, Urtoxazumab, Ustekinumab, Vapaliximab, Vedolizumab, Veltuzumab, Vepalimomab, Visilizumab, Volociximab, Votumumab, Zalutumumab, Zanolimumab, Ziralimumab, and Zolimomab aritox.

Examples of infusion therapy or injectable therapeutic proteins include, for example, Tocilizumab (Roche/Actemra®), alpha-1 antitrypsin (Kamada/AAT), Hematide® (Affymax and Takeda, synthetic peptide), albinterferon alfa-2b (Novartis/Zalbin™), Rhucin® (Pharming Group, C1 inhibitor replacement therapy), tesamorelin (Theratechnologies/Egrifta, synthetic growth hormone-releasing factor), ocrelizumab (Genentech, Roche and Biogen), belimumab (GlaxoSmithKline/Benlysta®), pegloticase (Savient Pharmaceuticals/Krystexxa™), taliglucerase alfa (Protalix/Uplyso), agalsidase alfa (Shire/Replagal®), velaglucerase alfa (Shire).

Additional therapeutic proteins useful in accordance to aspects of this invention will be apparent to those of skill in the art, and the invention is not limited in this respect.

In some embodiments, a component, such as an antigen or immunosuppressant, may be isolated. Isolated refers to the element being separated from its native environment and present in sufficient quantities to permit its identification or use. This means, for example, the element may be (i) selectively produced by expression cloning or (ii) purified as by chromatography or electrophoresis. Isolated elements may be, but need not be, substantially pure. Because an isolated element may be admixed with a pharmaceutically acceptable excipient in a pharmaceutical preparation, the element may comprise only a small percentage by weight of the preparation. The element is nonetheless isolated in that it has been separated from the substances with which it may be associated in living systems, i.e., isolated from other lipids or proteins. Any of the elements provided herein can be included in the compositions in isolated form.

D. METHODS OF MAKING AND USING THE INVENTIVE COMPOSITIONS AND RELATED METHODS

Synthetic nanocarriers may be prepared using a wide variety of methods known in the art. For example, synthetic nanocarriers can be formed by methods as nanoprecipitation, flow focusing using fluidic channels, spray drying, single and double emulsion solvent evaporation, solvent extraction, phase separation, milling, microemulsion procedures, microfabrication, nanofabrication, sacrificial layers, simple and complex coacervation, and other methods well known to those of ordinary skill in the art. Alternatively or additionally, aqueous and organic solvent syntheses for monodisperse semiconductor, conductive, magnetic, organic, and other nanomaterials have been described (Pellegrino et al., 2005, Small, 1:48; Murray et al., 2000, Ann. Rev. Mat. Sci., 30:545; and Trindade et al., 2001, Chem. Mat., 13:3843). Additional methods have been described in the literature (see, e.g., Doubrow, Ed., “Microcapsules and Nanoparticles in Medicine and Pharmacy,” CRC Press, Boca Raton, 1992; Mathiowitz et al., 1987, J. Control. Release, 5:13; Mathiowitz et al., 1987, Reactive Polymers, 6:275; and Mathiowitz et al., 1988, J. Appl. Polymer Sci., 35:755; US Patents 5578325 and 6007845; P. Paolicelli et al., “Surface-modified PLGA-based Nanoparticles that can Efficiently Associate and Deliver Virus-like Particles” Nanomedicine. 5(6):843-853 (2010)).

Various materials may be encapsulated into synthetic nanocarriers as desirable using a variety of methods including but not limited to C. Astete et al., “Synthesis and characterization of PLGA nanoparticles” J. Biomater. Sci. Polymer Edn, Vol. 17, No. 3, pp. 247–289 (2006); K. Avgoustakis “Pegylated Poly(Lactide) and Poly(Lactide-Co-Glycolide) Nanoparticles: Preparation, Properties and Possible Applications in Drug Delivery” Current Drug Delivery 1:321-333 (2004); C. Reis et al., “Nanoencapsulation I. Methods for preparation of drug-loaded polymeric nanoparticles” Nanomedicine 2:8– 21 (2006); P. Paolicelli et al., “Surface-modified PLGA-based Nanoparticles that can Efficiently Associate and Deliver Virus-like Particles” Nanomedicine. 5(6):843-853 (2010). Other methods suitable for encapsulating materials into synthetic nanocarriers may be used, including without limitation methods disclosed in United States Patent 6,632,671 to Unger October 14, 2003.

In certain embodiments, synthetic nanocarriers are prepared by a nanoprecipitation process or spray drying. Conditions used in preparing synthetic nanocarriers may be altered to yield particles of a desired size or property (e.g., hydrophobicity, hydrophilicity, external morphology, “stickiness,” shape, etc.). The method of preparing the synthetic nanocarriers and the conditions (e.g., solvent, temperature, concentration, air flow rate, etc.) used may depend on the materials to be coupled to the synthetic nanocarriers and/or the composition of the polymer matrix.

If particles prepared by any of the above methods have a size range outside of the desired range, particles can be sized, for example, using a sieve.

Elements (i.e., components) of the inventive synthetic nanocarriers (such as moieties of which an immunofeature surface is comprised, targeting moieties, polymeric matrices, epitopes, or proteins, polypeptides or peptides that comprise the epitopes, immunosuppressants and the like) may be coupled to the overall synthetic nanocarrier, e.g., by one or more covalent bonds, or may be coupled by means of one or more linkers.

Additional methods of functionalizing synthetic nanocarriers may be adapted from Published US Patent Application 2006/0002852 to Saltzman et al., Published US Patent Application 2009/0028910 to DeSimone et al., or Published International Patent Application WO/2008/127532 A1 to Murthy et al.

Alternatively or additionally, synthetic nanocarriers can be coupled to components directly or indirectly via non-covalent interactions. In non-covalent embodiments, the non-covalent coupling is mediated by non-covalent interactions including but not limited to charge interactions, affinity interactions, metal coordination, physical adsorption, host-guest interactions, hydrophobic interactions, TT stacking interactions, hydrogen bonding interactions, van der Waals interactions, magnetic interactions, electrostatic interactions, dipole-dipole interactions, and/or combinations thereof. Such couplings may be arranged to be on an external surface or an internal surface of an inventive synthetic nanocarrier. In embodiments, encapsulation and/or absorption is a form of coupling. In embodiments, the inventive synthetic nanocarriers can be combined with an antigen by admixing in the same vehicle or delivery system.

Populations of synthetic nanocarriers may be combined to form pharmaceutical dosage forms according to the present invention using traditional pharmaceutical mixing methods. These include liquid-liquid mixing in which two or more suspensions, each containing one or more subsets of nanocarriers, are directly combined or are brought together via one or more vessels containing diluent. As synthetic nanocarriers may also be produced or stored in a powder form, dry powder-powder mixing could be performed as could the re-suspension of two or more powders in a common media. Depending on the properties of the nanocarriers and their interaction potentials, there may be advantages conferred to one or another route of mixing.

Typical inventive compositions that comprise synthetic nanocarriers may comprise inorganic or organic buffers (e.g., sodium or potassium salts of phosphate, carbonate, acetate, or citrate) and pH adjustment agents (e.g., hydrochloric acid, sodium or potassium hydroxide, salts of citrate or acetate, amino acids and their salts) antioxidants (e.g., ascorbic acid, alpha-tocopherol), surfactants (e.g., polysorbate 20, polysorbate 80, polyoxyethylene9-10 nonyl phenol, sodium desoxycholate), solution and/or cryo/lyo stabilizers (e.g., sucrose, lactose, mannitol, trehalose), osmotic adjustment agents (e.g., salts or sugars), antibacterial agents (e.g., benzoic acid, phenol, gentamicin), antifoaming agents (e.g., polydimethylsilozone), preservatives (e.g., thimerosal, 2-phenoxyethanol, EDTA), polymeric stabilizers and viscosity-adjustment agents (e.g., polyvinylpyrrolidone, poloxamer 488, carboxymethylcellulose) and co-solvents (e.g., glycerol, polyethylene glycol, ethanol).

Compositions according to the invention comprise inventive synthetic nanocarriers in combination with pharmaceutically acceptable excipients. The compositions may be made using conventional pharmaceutical manufacturing and compounding techniques to arrive at useful dosage forms. Techniques suitable for use in practicing the present invention may be found in Handbook of Industrial Mixing: Science and Practice, Edited by Edward L. Paul, Victor A. Atiemo-Obeng, and Suzanne M. Kresta, 2004 John Wiley & Sons, Inc.; and Pharmaceutics: The Science of Dosage Form Design, 2nd Ed. Edited by M. E. Auten, 2001, Churchill Livingstone. In an embodiment, inventive synthetic nanocarriers are suspended in sterile saline solution for injection together with a preservative.

It is to be understood that the compositions of the invention can be made in any suitable manner, and the invention is in no way limited to compositions that can be produced using the methods described herein. Selection of an appropriate method may require attention to the properties of the particular moieties being associated.

In some embodiments, inventive synthetic nanocarriers are manufactured under sterile conditions or are terminally sterilized. This can ensure that resulting composition are sterile and non-infectious, thus improving safety when compared to non-sterile compositions. This provides a valuable safety measure, especially when subjects receiving synthetic nanocarriers have immune defects, are suffering from infection, and/or are susceptible to infection. In some embodiments, inventive synthetic nanocarriers may be lyophilized and stored in suspension or as lyophilized powder depending on the formulation strategy for extended periods without losing activity.

The compositions of the invention can be administered by a variety of routes, including but not limited to subcutaneous, intranasal, oral, intravenous, intraperitoneal, intramuscular, transmucosal, transmucosal, sublingual, rectal, ophthalmic, pulmonary, intradermal, transdermal, transcutaneous or intradermal or by a combination of these routes. Routes of administration also include administration by inhalation or pulmonary aerosol. Techniques for preparing aerosol delivery systems are well known to those of skill in the art (see, for example, Sciarra and Cutie, "Aerosols," in Remington's Pharmaceutical Sciences, 18th edition, 1990, pp. 1694-1712; incorporated by reference).

The transplantable grafts or therapeutic proteins provided as a cell-based therapy of the invention may be administered by parenteral, intraarterial, intranasal or intravenous administration or by injection to lymph nodes or anterior chamber of the eye or by local administration to an organ or tissue of interest. The administration may be by subcutaneous, intrathecal, intraventricular, intramuscular, intraperitoneal, intracoronary, intrapancreatic, intrahepatic or bronchial injection.

The compositions of the invention can be administered in effective amounts, such as the effective amounts described elsewhere herein. Doses of dosage forms contain varying amounts of populations of synthetic nanocarriers and/or varying amounts of antigens and/or immunosuppressants, according to the invention. The amount of synthetic nanocarriers and/or antigens and/or immunosuppressants present in the inventive dosage forms can be varied according to the nature of the antigens and/or immunosuppressants, the therapeutic benefit to be accomplished, and other such parameters. In embodiments, dose ranging studies can be conducted to establish optimal therapeutic amount of the population of synthetic nanocarriers and the amount of antigens and/or immunosuppressants to be present in the dosage form. In embodiments, the synthetic nanocarriers and/or the antigens and/or immunosuppressants are present in the dosage form in an amount effective to generate a tolerogenic immune response to the antigens upon administration to a subject. It may be possible to determine amounts of the antigens and/or immunosuppressants effective to generate a tolerogenic immune response using conventional dose ranging studies and techniques in subjects. Inventive dosage forms may be administered at a variety of frequencies. In a preferred embodiment, at least one administration of the dosage form is sufficient to generate a pharmacologically relevant response. In more preferred embodiments, at least two administrations, at least three administrations, or at least four administrations, of the dosage form are utilized to ensure a pharmacologically relevant response.

Prophylactic administration of the inventive compositions can be initiated prior to the onset of disease, disorder or condition or therapeutic administration can be initiated after a disorder, disorder or condition is established.

In some embodiments, administration of synthetic nanocarriers is undertaken e.g., prior to administration of a therapeutic protein or transplantable graft or exposure to an allergen. In exemplary embodiments, synthetic nanocarriers are administered at one or more times including, but not limited to, 30, 25, 20, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1, or 0 days prior to administration of a therapeutic protein or transplantable graft or exposure to an allergen. In addition or alternatively, synthetic nanocarriers can be administered to a subject following administration of a therapeutic protein or transplantable graft or exposure to an allergen. In exemplary embodiments, synthetic nanocarriers are administered at one or more times including, but not limited to, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, etc. days following administration of a therapeutic protein or transplantable graft or exposure to an allergen.

In some embodiments, a maintenance dose (e.g., of a synthetic nanocarrier composition provided herein) is administered to a subject after an initial administration has resulted in a tolerogenic response in the subject, for example to maintain the tolerogenic effect achieved after the initial dose, to prevent an undesired immune reaction in the subject, or to prevent the subject becoming a subject at risk of experiencing an undesired immune response or an undesired level of an immune response. In some embodiments, the maintenance dose is the same dose as the initial dose the subject received. In some embodiments, the maintenance dose is a lower dose than the initial dose. For example, in some embodiments, the maintenance dose is about 3/4, about 2/3, about 1/2, about 1/3, about 1/4, about 1/8, about 1/10, about 1/20, about 1/25, about 1/50, about 1/100, about 1/1,000, about 1/10,000, about 1/100,000, or about 1/1,000,000 (weight/weight) of the initial dose.

The compositions and methods described herein can be used to induce or enhance a tolerogenic immune response and/or to suppress, modulate, direct or redirect an undesired immune response for the purpose of immune suppression. The compositions and methods described herein can be used in the diagnosis, prophylaxis and/or treatment of diseases, disorders or conditions in which immune suppression (e.g., a tolerogenic immune response) would confer a treatment benefit. Such diseases, disorders or conditions include inflammatory diseases, autoimmune diseases, allergies, organ or tissue rejection and graft versus host disease. The compositions and methods described herein can also be used in subjects who have undergone or will undergo transplantation. The compositions and methods described herein can also be used in subjects who have received, are receiving or will receive a therapeutic protein against which they have generated or are expected to generate an undesired immune response.

Autoimmune diseases include, but are not limited to, rheumatoid arthritis, multiple sclerosis, immune-mediated or Type I diabetes mellitus, inflammatory bowel disease (e.g., Crohn's disease or ulcerative colitis), systemic lupus erythematosus, psoriasis, scleroderma, autoimmune thyroid disease, alopecia areata, Grave’s disease, Guillain-Barré syndrome, celiac disease, Sjögren's syndrome, rheumatic fever, gastritis, autoimmune atrophic gastritis, autoimmune hepatitis, insulitis, oophoritis, orchitis, uveitis, phacogenic uveitis, myasthenia gravis, primary myxoedema, pernicious anemia, autoimmune haemolytic anemia, Addison's disease, scleroderma, Goodpasture's syndrome, nephritis, for example, glomerulonephritis, psoriasis, pemphigus vulgaris, pemphigoid, sympathetic opthalmia, idiopathic thrombocylopenic purpura, idiopathic feucopenia, Wegener's granulomatosis and poly/dermatomyositis.

Some additional exemplary autoimmune diseases, associated autoantigens, and autoantibodies, which are contemplated for use in the invention, are described in Table 1 below:

Autoantibody Type	Autoantibody	Autoantigen	Autoimmune disease or disorder
Antinuclear antibodies	Anti-SSA/Ro autoantibodies	ribonucleoproteins	Systemic lupus erythematosus, neonatal heart block, primary Sjögren's syndrome
	Anti-La/SS-B autoantibodies	ribonucleoproteins	Primary Sjögren's syndrome
	Anti-centromere antibodies	centromere	CREST syndrome
	Anti-neuronal nuclear antibody-2	Ri[disambiguation needed]	Opsoclonus
	Anti-dsDNA	double-stranded DNA	SLE
	Anti-Jo1	histidine-tRNA ligase	Inflammatory myopathy
	Anti-Smith	snRNP core proteins	SLE
	Anti-topoisomerase antibodies	Type I topoisomerase	Systemic sclerosis (anti-Scl-70 antibodies)
	Anti-histone antibodies	histones	SLE and Drug-induced LE[2]
	Anti-p62 antibodies[3]	nucleoporin 62	Primary biliary cirrhosis[3][4][5]
	Anti-sp100 antibodies [4]	Sp100 nuclear antigen	
	Anti-glycoprotein-210 antibodies[5]	nucleoporin 210kDa	
Anti-transglutaminase antibodies	Anti-tTG		Coeliac disease
	Anti-eTG		Dermatitis herpetiformis

Anti-ganglioside antibodies		ganglioside GQ1B	Miller-Fisher Syndrome
		ganglioside GD3	Acute motor axonal neuropathy (AMAN)
		ganglioside GM1	Multifocal motor neuropathy with conduction block (MMN)
Anti-actin antibodies		actin	Coeliac disease anti-actin antibodies correlated with the level of intestinal damage [6][7]
Liver kidney microsomal type 1 antibody			Autoimmune hepatitis.[8]
Lupus anticoagulant	Anti-thrombin antibodies	thrombin	Systemic lupus erythematosus
Anti-neutrophil cytoplasmic antibody		phospholipid	Antiphospholipid syndrome
	c-ANCA	proteins in neutrophil cytoplasm	Wegener's granulomatosis
	p-ANCA	neutrophil perinuclear	Microscopic polyangiitis, Churg-Strauss syndrome, systemic vasculitides (non-specific)
Rheumatoid factor		IgG	Rheumatoid arthritis
Anti-smooth muscle antibody		smooth muscle	Chronic autoimmune hepatitis
Anti-mitochondrial antibody		mitochondria	Primary biliary cirrhosis[9]
Anti-SRP		signal recognition particle	Polymyositis[10]
		exosome complex	Scleromyositis
		nicotinic acetylcholine receptor	Myasthenia gravis
		muscle-specific kinase (MUSK)	Myasthenia gravis
Anti-VGCC		voltage-gated calcium channel (P/Q-type)	Lambert-Eaton myasthenic syndrome
		thyroid peroxidase (microsomal)	Hashimoto's thyroiditis
		TSH receptor	Graves' disease

		Hu	Paraneoplastic cerebellar syndrome
		Yo (cerebellar Purkinje Cells)	Paraneoplastic cerebellar syndrome
		amphiphysin	Stiff person syndrome, paraneoplastic cerebellar syndrome
Anti-VGKC		voltage-gated potassium channel (VGKC)	Limbic encephalitis, Isaac's Syndrome (autoimmune neuromyotonia)
		basal ganglia neurons	Sydenham's chorea, paediatric autoimmune neuropsychiatric disease associated with Streptococcus (PANDAS)
		N-methyl-D-aspartate receptor (NMDA)	Encephalitis
		glutamic acid decarboxylase (GAD)	Diabetes mellitus type 1, stiff person syndrome
		aquaporin-4	Neuromyelitis optica (Devic's syndrome)

Inflammatory diseases include, but are not limited to, Alzheimer's, Ankylosing spondylitis, arthritis, asthma, atherosclerosis, Behcet's disease, chronic inflammatory demyelinating polyradiculoneuropathy, Crohn's disease, colitis, cystic fibrosis, dermatitis, diverticulitis, hepatitis, irritable bowel syndrome (IBS), lupus erythematous, muscular dystrophy, nephritis, Parkinson's, shingles and ulcerative colitis. Inflammatory diseases also include, for example, cardiovascular disease, chronic obstructive pulmonary disease (COPD), bronchiectasis, chronic cholecystitis, tuberculosis, Hashimoto's thyroiditis, sepsis, sarcoidosis, silicosis and other pneumoconioses, and an implanted foreign body in a wound, but are not so limited. As used herein, the term “sepsis” refers to a well-recognized clinical syndrome associated with a host's systemic inflammatory response to microbial invasion. The term “sepsis” as used herein refers to a condition that is typically signaled by fever or hypothermia, tachycardia, and tachypnea, and in severe instances can progress to hypotension, organ dysfunction, and even death.

In some embodiments, the inflammatory disease is non-autoimmune inflammatory bowel disease, post-surgical adhesions, coronary artery disease, hepatic fibrosis, acute respiratory distress syndrome, acute inflammatory pancreatitis, endoscopic retrograde cholangiopancreatography-induced pancreatitis, burns, atherogenesis of coronary, cerebral and peripheral arteries, appendicitis, cholecystitis, diverticulitis, visceral fibrotic disorders, wound healing, skin scarring disorders (keloids, hidradenitis suppurativa), granulomatous disorders (sarcoidosis, primary biliary cirrhosis), asthma, pyoderma gandrenosum, Sweet's syndrome, Behcet's disease, primary sclerosing cholangitis or an abscess. In some preferred embodiment the inflammatory disease is inflammatory bowel disease (e.g., Crohn's disease or ulcerative colitis).

In other embodiments, the inflammatory disease is an autoimmune disease. The autoimmune disease in some embodiments is rheumatoid arthritis, rheumatic fever, ulcerative colitis, Crohn's disease, autoimmune inflammatory bowel disease, insulin-dependent diabetes mellitus, diabetes mellitus, juvenile diabetes, spontaneous autoimmune diabetes, gastritis, autoimmune atrophic gastritis, autoimmune hepatitis, thyroiditis, Hashimoto's thyroiditis, insulitis, oophoritis, orchitis, uveitis, phacogenic uveitis, multiple sclerosis, myasthenia gravis, primary myxoedema, thyrotoxicosis, pernicious anemia, autoimmune haemolytic anemia, Addison's disease, Anklosing spondylitis, sarcoidosis, scleroderma, Goodpasture's syndrome, Guillain-Barre syndrome, Graves' disease, glomerulonephritis, psoriasis, pemphigus vulgaris, pemphigoid, excema, bulous pemiphigous, sympathetic opthalmia, idiopathic thrombocylopenic purpura, idiopathic feucopenia, Sjogren's syndrome, systemic sclerosis, Wegener's granulomatosis, poly/dermatomyositis, primary biliary cirrhosis, primary sclerosing cholangitis, lupus or systemic lupus erythematosus.

Graft versus host disease (GVHD) is a complication that can occur after a pluripotent cell (e.g., stem cell) or bone marrow transplant in which the newly transplanted material results in an attack on the transplant recipient's body. In some instances, GVHD takes place after a blood transfusion. Graft-versus-host-disease can be divided into acute and chronic forms. The acute or fulminant form of the disease (aGVHD) is normally observed within the first 100 days post-transplant, and is a major challenge to transplants owing to associated morbidity and mortality. The chronic form of graft-versus-host-disease (cGVHD) normally occurs after 100 days. The appearance of moderate to severe cases of cGVHD adversely influences long-term survival.

EXAMPLES

Example 1: Immune Response of Synthetic Nanocarriers with Coupled Rapamycin with and without Ovalbumin Peptide (323-339)

Materials

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505; Part # 4065609). Rapamycin was purchased from TSZ CHEM (185 Wilson Street, Framingham, MA 01702; Product Catalogue # R1017). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature.

Solution 2: Rapamycin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving rapamycin in pure methylene chloride.

Solution 3: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

Method for Preparing Synthetic Nanocarrier Containing Rapamycin and Ovalbumin (323-339)

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.2 mL), and solution 3 (1.0 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 4 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the synthetic nanocarriers to form. A portion of the synthetic nanocarriers were washed by transferring the synthetic nanocarrier suspension to a centrifuge tube and centrifuging at 21,000×g and 4 °C for one hour, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final synthetic nanocarrier dispersion of about 10 mg/mL.

The amounts of peptide and rapamycin in the synthetic nanocarriers were determined by HPLC analysis. The total dry-synthetic nanocarrier mass per mL of suspension was determined by a gravimetric method.

Method for Synthetic Nanocarrier Containing Rapamycin

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining 0.13 M hydrochloric acid solution (0.2 mL), solution 2 (0.2 mL), and solution 3 (1.0 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 4 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the synthetic nanocarriers to form. A portion of the synthetic nanocarriers were washed by transferring the synthetic nanocarrier suspension to a centrifuge tube and centrifuging at 21,000×g and 4 °C for one hour, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final synthetic nanocarrier dispersion of about 10 mg/mL.

The amount of rapamycin in the synthetic nanocarrier was determined by HPLC analysis. The total dry-synthetic nanocarrier mass per mL of suspension was determined by a gravimetric method.

Method for Measuring Rapamycin Load

Approximately 3 mg of synthetic nanocarriers were collected and centrifuged to separate supernatant from synthetic nanocarrier pellet. Acetonitrile was added to the pellet, and the sample was sonicated and centrifuged to remove any insoluble material. The supernatant and pellet were injected on RP-HPLC and absorbance was read at 278nm. The μg found in the pellet were used to calculate % entrapped (load), μg in supernatant and pellet were used to calculate total μg recovered.

Method for Measuring Ovalbumin (323-339) Load

Approximately 3 mg of synthetic nanocarriers were collected and centrifuged to separate supernatant from synthetic nanocarrier pellet. Trifluoroethanol was added to the pellet and the sample was sonicated to dissolve the polymer, 0.2% trifluoroacetic acid was added and sample was sonicated and then centrifuged to remove any insoluble material. The supernatant and pellet were injected on RP-HPLC and absorbance was read at 215nm. The μg found in the pellet were used to calculate % entrapped (load), μg in supernatant and pellet were used to calculate total μg recovered.

Antigen-specific Tolerogenic Dendritic Cells (Tdc) Activity on Treg Cell Development

The assay included the use of OTII mice which have a transgenic T-cell receptor specific for an immune-dominant ovalbumin (323-339). In order to create antigen-specific tDCs, CD11c+ splenocytes were isolated, and the ovalbumin (323-339) peptide added in vitro at 1μg/ml or no antigen. Soluble or nanocarrier-encapsulated rapamycin was then added to the DCs for 2 hours which were then washed extensively to remove free rapamycin from the culture. Purified responder CD4+CD25- cells were isolated from OTII mice and added to tDC at a 10:1 T to DC ratio. The mixture of tDC and OTII T-cells were then cultured for 4-5 days, and the frequency of Treg cells (CD4+CD25highFoxP3+) were analyzed by flow cytometry as shown in **Fig. 1**. Regions were selected based on isotype controls.

Example 2: Mesoporous Silica Nanoparticles with Coupled Ibuprofen (Prophetic)

Mesoporous SiO2 nanoparticle cores are created through a sol-gel process. Hexadecyltrimethyl-ammonium bromide (CTAB) (0.5 g) is dissolved in deionized water (500 mL), and then 2 M aqueous NaOH solution (3.5 mL) is added to the CTAB solution. The solution is stirred for 30 min, and then Tetraethoxysilane (TEOS) (2.5 mL) is added to the solution. The resulting gel is stirred for 3 h at a temperature of 80 °C. The white precipitate which forms is captured by filtration, followed by washing with deionized water and drying at room temperature. The remaining surfactant is then extracted from the particles by suspension in an ethanolic solution of HCl overnight. The particles are washed with ethanol, centrifuged, and redispersed under ultrasonication. This wash procedure is repeated two additional times.

The SiO2 nanoparticles are then functionalized with amino groups using (3-aminopropyl)-triethoxysilane (APTMS). To do this, the particles are suspended in ethanol (30 mL), and APTMS (50 μL) is added to the suspension. The suspension is allowed to stand at room temperature for 2 h and then is boiled for 4 h, keeping the volume constant by periodically adding ethanol. Remaining reactants are removed by five cycles of washing by centrifugation and redispersing in pure ethanol.

In a separate reaction, 1-4 nm diameter gold seeds are created. All water used in this reaction is first deionized and then distilled from glass. Water (45.5 mL) is added to a 100 mL round-bottom flask. While stirring, 0.2 M aqueous NaOH (1.5 mL) is added, followed by a 1% aqueous solution of tetrakis(hydroxymethyl)phosphonium chloride (THPC) (1.0 mL). Two minutes after the addition of THPC solution, a 10 mg/mL aqueous solution of chloroauric acid (2 mL), which has been aged at least 15 min, is added. The gold seeds are purified through dialysis against water.

To form the core-shell nanocarriers, the amino-functionalized SiO2 nanoparticles formed above are first mixed with the gold seeds for 2 h at room temperature. The gold-decorated SiO2 particles are collected through centrifugation and mixed with an aqueous solution of chloroauric acid and potassium bicarbonate to form the gold shell. The particles are then washed by centrifugation and redispersed in water. Ibuprofen is loaded by suspending the particles in a solution of sodium ibuprofen (1 mg/L) for 72 h. Free ibuprofen is then washed from the particles by centrifugation and redispersing in water.

Example 3: Liposomes Containing Cyclosporine A (Prophetic)

The liposomes are formed using thin film hydration. 1,2-Dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) (32 μmol), cholesterol (32 μmol), and cyclosporin A (6.4 μmol) are dissolved in pure chloroform (3 mL). This lipid solution is added to a 50 mL round-bottom flask, and the solvent is evaporated on a rotary evaporator at a temperature of 60 °C. The flask is then flushed with nitrogen gas to remove remaining solvent. Phosphate buffered saline (2 mL) and five glass beads are added to the flask, and the lipid film is hydrated by shaking at 60 °C for 1 h to form a suspension. The suspension is transferred to a small pressure tube and sonicated at 60 °C for four cycles of 30s pulses with a 30 s delay between each pulse. The suspension is then left undisturbed at room temperature for 2 h to allow for complete hydration. The liposomes are washed by centrifugation followed by resuspension in fresh phosphate buffered saline.

Example 4: Polymeric Nanocarrier Containing Polymer-Rapamycin Conjugate (Prophetic)

Preparation of PLGA-rapamycin conjugate:

PLGA polymer with acid end group (7525 DLG1A, acid number 0.46 mmol/g, Lakeshore Biomaterials; 5 g, 2.3 mmol, 1.0 eq) is dissolved in 30 mL of dichloromethane (DCM). N,N-Dicyclohexylcarbodimide (1.2 eq, 2.8 mmol, 0.57 g) is added followed by rapamycin (1.0 eq, 2.3 mmol, 2.1 g) and 4-dimethylaminopyridine (DMAP) (2.0 eq, 4.6 mmol, 0.56 g). The mixture is stirred at rt for 2 days. The mixture is then filtered to remove insoluble dicyclohexylurea. The filtrate is concentrated to ca. 10 mL in volume and added to 100 mL of isopropyl alcohol (IPA) to precipitate out the PLGA-rapamycin conjugate. The IPA layer is removed and the polymer is then washed with 50 mL of IPA and 50 mL of methyl t-butyl ether (MTBE). The polymer is then dried under vacuum at 35 C for 2 days to give PLGA-rapamycin as a white solid (ca. 6.5 g).

Preparation of nanocarrier containing PLGA-rapamycin conjugate and ovalbumin peptide (323-339):

Nanocarrier containing PLGA-rapamycin is prepared according to the procedure described in Example 1 as follows:

Solutions for nanocarrier formation are prepared as follows:

Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution is prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature. Solution 2: PLGA-rapamycin @ 100 mg/mL in methylene chloride. The solution is prepared by dissolving PLGA-rapamycin in pure methylene chloride. Solution 3: PLA-PEG @ 100 mg/mL in methylene chloride. The solution is prepared by dissolving PLA-PEG in pure methylene chloride. Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

A primary water-in-oil emulsion is prepared first. W1/O1 is prepared by combining solution 1 (0.2 mL), solution 2 (0.75 mL), and solution 3 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) is then prepared by combining solution 4 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250. The W1/O1/W2 emulsion is added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers is washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 75,600×g and 4 °C for 35 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure is repeated, and the pellet is re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Example 5: Preparation of Gold Nanocarriers (AuNCs) Containing Rapamycin (Prophetic)

Preparation of HS-PEG-rapamycin:

A solution of PEG acid disulfide (1.0 eq), rapamycin (2.0-2.5 eq), DCC (2.5 eq) and DMAP (3.0 eq) in dry DMF is stirred at rt overnight. The insoluble dicyclohexylurea is removed by filtration and the filtrate is added to isopropyl alcohol (IPA) to precipitate out the PEG-disulfide-di-rapamycin ester and washed with IPA and dried. The polymer is then treated with tris(2-carboxyethyl)phosphine hydrochloride in DMF to reduce the PEG disulfide to thiol PEG rapamycin ester (HS-PEG-rapamycin). The resulting polymer is recovered by precipitation from IPA and dried as previously described and analyzed by H NMR and GPC.

Formation of Gold NCs (AuNCs):

An aq. solution of 500 mL of 1 mM HAuCl4 is heated to reflux for 10 min with vigorous stirring in a 1 L round-bottom flask equipped with a condenser. A solution of 50 mL of 40 mM of trisodium citrate is then rapidly added to the stirring solution. The resulting deep wine red solution is kept at reflux for 25-30 min and the heat is withdrawn and the solution is cooled to room temperature. The solution is then filtered through a 0.8 μm membrane filter to give the AuNCs solution. The AuNCs are characterized using visible spectroscopy and transmission electron microscopy. The AuNCs are ca. 20 nm diameter capped by citrate with peak absorption at 520 nm.

AuNCs conjugate with HS-PEG-rapamycin:

A solution of 150 μl of HS-PEG-rapamycin (10 μM in 10 mM pH 9.0 carbonate buffer) is added to 1 mL of 20 nm diameter citrate-capped gold nanocarriers (1.16 nM) to produce a molar ratio of thiol to gold of 2500:1. The mixture is stirred at room temperature under argon for 1 hour to allow complete exchange of thiol with citrate on the gold nanocarriers. The AuNCs with PEG-rapamycin on the surface is then purified by centrifuge at 12,000g for 30 minutes. The supernatant is decanted and the pellet containing AuNC-S-PEG-rapamycin is then pellet washed with 1x PBS buffer. The purified Gold-PEG-rapamycin nanocarriers are then resuspend in suitable buffer for further analysis and bioassays.

Example 6: Mesoporous Silica-gold Core-shell Nanocarriers Containing Ovalbumin (Prophetic)

Mesoporous SiO2 nanoparticle cores are created through a sol-gel process. Hexadecyltrimethyl-ammonium bromide (CTAB) (0.5 g) is dissolved in deionized water (500 mL), and then 2 M aqueous NaOH solution (3.5 mL) is added to the CTAB solution. The solution is stirred for 30 min, and then Tetraethoxysilane (TEOS) (2.5 mL) is added to the solution. The resulting gel is stirred for 3 h at a temperature of 80 °C. The white precipitate which forms is captured by filtration, followed by washing with deionized water and drying at room temperature. The remaining surfactant is then extracted from the particles by suspension in an ethanolic solution of HCl overnight. The particles are washed with ethanol, centrifuged, and redispersed under ultrasonication. This wash procedure is repeated two additional times.

The SiO2 nanoparticles are then functionalized with amino groups using (3-aminopropyl)-triethoxysilane (APTMS). To do this, the particles are suspended in ethanol (30 mL), and APTMS (50 μL) is added to the suspension. The suspension is allowed to stand at room temperature for 2 h and then is boiled for 4 h, keeping the volume constant by periodically adding ethanol. Remaining reactants are removed by five cycles of washing by centrifugation and redispersing in pure ethanol.

In a separate reaction, 1-4 nm diameter gold seeds are created. All water used in this reaction is first deionized and then distilled from glass. Water (45.5 mL) is added to a 100 mL round-bottom flask. While stirring, 0.2 M aqueous NaOH (1.5 mL) is added, followed by a 1% aqueous solution of tetrakis(hydroxymethyl)phosphonium chloride (THPC) (1.0 mL). Two minutes after the addition of THPC solution, a 10 mg/mL aqueous solution of chloroauric acid (2 mL), which has been aged at least 15 min, is added. The gold seeds are purified through dialysis against water.

To form the core-shell nanocarriers, the amino-functionalized SiO2 nanoparticles formed above are first mixed with the gold seeds for 2 h at room temperature. The gold-decorated SiO2 particles are collected through centrifugation and mixed with an aqueous solution of chloroauric acid and potassium bicarbonate to form the gold shell. The particles are then washed by centrifugation and redispersed in water. Thiolated Ovalbumin (made by treating Ovalbumin with 2-iminothiolane hydrochloride) is loaded by suspending the particles in a solution of thiolated Ovalbumin (1 mg/L) for 72 h. The particles is then pellet washed with 1x PBS (pH 7.4) to remove free protein. The resulting silica-gold core-shell nanocarriers containing Ovalbumin are then re-suspended in 1x PBS for further analysis and assays.

Example 7: Liposomes Containing Rapamycin and Ovalbumin (Prophetic)

The liposomes are formed by thin film hydration. 1,2-Dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) (32 μmol), cholesterol (32 μmol), and rapamycin (6.4 μmol) are dissolved in pure chloroform (3 mL). This lipid solution is added to a 10 mL glass tube and the solvent is removed under nitrogen gas stream and desiccated for 6 hr. under vacuum. Multilamellar vesicles are obtained by hydration of the film with 2.0 ml of 25 mM MOPS buffer pH 8.5, containing excess amount of Ovalbumin. The tube is vortexed until the lipid film is peeled of from the tube surface. To break the multilamellar vesicles into monolamellar, ten cycles of freezing (liquid nitrogen) and thawing (30°C water bath) are applied. The sample is then diluted to 1 ml in 25 mM MOPS buffer pH 8.5. Size of the resulting liposome is homogenized by extrusion by passing the sample 10 fold through a 200 nm pore polycarbonate filters. The resulting liposomes are then used for further analysis and bioassays.

Example 8: Polymeric Nanocarriers Composed of Modified Polyamino Acid with Surface Conjugated Ovalbumin (Prophetic)

Step-1. Preparation of Poly(γ-glutamic acid) (γ-PGA) modified with L-phenylalanine ethyl ester (L-PAE): 4.7 unit mmol of γ-PGA (Mn= 300 kD) is dissolved in 0.3 N–NaHCO3 aqueous solution (50 mL). L-PAE (4.7 mmol) and EDC.HCl (4.7 mmol) are added to the solution and stirred for 30 min at 4 C. The solution is then maintained at room temperature with stirring for 24 h. Low-molecular-weight chemicals are removed by dialysis using dialysis membrane with MWCO 50 kD. The resulting γ-PGA-graft-L-PAE is obtained by freeze-drying.

Step-2. Preparation of nanoparticles from γ-PGA-graft-L-PAE polymer: Nanoparticles composed of γ-PGA-graft-L-PAE are prepared by a precipitation and dialysis method. γ-PGA-graft-L-PAE (20 mg) was dissolved in 2 ml of DMSO followed by addition of 2 mL of water to form a translucent solution. The solution is then dialyzed against distilled water using cellulose membrane tubing (50,000 MWCO) to form the nanoparticles and to remove the organic solvents for 72 h at room temperature. The distilled water is exchanged at intervals of 12 h. The resulting nanoparticle solution (10 mg/mL in water) is then used for antigen conjugation.

Step-3. Ovalbumin conjugation to γ-PGA nanoparticles: Surface carboxylic acid groups of the γ-PGA nanoparticles (10 mg/ml) are first activated by EDC and NHS (10 mg/mL each in phosphate buffer, pH 5.8) for 2 h at ambient temperature. After pellet washing to remove excess EDC/NHS, the activated nanoparticles are mixed with 1 mL of Ovalbumin (10 mg/ml) in phosphate-buffered saline (PBS, pH 7.4) and the mixture is incubated at 4-8 C for 24 h. The resulting Ovalbumin conjugated γ-PGA nanoparticles are washed twice with PBS and resuspended at 5 mg/mL in PBS for further analysis and bioassays.

Example 9: Erythropoietin (EPO)-encapsulated γ-PGA Nanoparticles (Prophetic)

To prepare the EPO-encapsulated γ-PGA nanoparticles, 0.25–4 mg of EPO is dissolved in 1 mL of PBS (pH 7.4) and 1 mL of the γ-PGA–graft-L-PAE (10 mg/mL in DMSO) is added to the EPO solution. The resulting solution is centrifuged at 14,000 x g for 15 min and repeatedly rinsed with PBS. The resulting EPO-encapsulated γ-PGA nanoparticles are then resuspended in PBS (5 mg/mL) for further analysis and bioassay.

Example 10: Preparation of Gold Nanocarriers (AuNCs) Containing Ovalbumin (Prophetic)

Step-1. Formation of Gold NCs (AuNCs): An aq. solution of 500 mL of 1 mM HAuCl4 is heated to reflux for 10 min with vigorous stirring in a 1 L round-bottom flask equipped with a condenser. A solution of 50 mL of 40 mM of trisodium citrate is then rapidly added to the stirring solution. The resulting deep wine red solution is kept at reflux for 25-30 min and the heat is withdrawn and the solution is cooled to room temperature. The solution is then filtered through a 0.8 μm membrane filter to give the AuNCs solution. The

AuNCs are characterized using visible spectroscopy and transmission electron microscopy. The AuNCs are ca. 20 nm diameter capped by citrate with peak absorption at 520 nm.

Step-2. Conjugation of Ovalbumin to AuNCs: A solution of 150 µl of thiolated Ovalbumin (10 µM in 10 mM pH 9.0 carbonate buffer) is added to 1 mL of 20 nm diameter citrate-capped gold nanocarriers (1.16 nM) to produce a molar ratio of thiol to gold of 2500:1. The mixture is stirred at room temperature under argon for 1 hour to allow complete exchange of thiol with citrate on the gold nanocarriers. The AuNCs with Ovalbumin on the surface is then purified by centrifuge at 12,000g for 30 minutes. The supernatant is decanted and the pellet containing AuNC-Ovalbumin is then pellet washed with 1x PBS buffer. The purified Gold-Ovalbumin nanocarriers are then resuspend in suitable buffer for further analysis and bioassays.

<u>Example 11: Evaluating Tolerogenic Immune Response by T cell Phenotypic Analysis (Prophetic)</u>

A composition of the invention is dissolved in phosphate-buffered saline (PBS) and injected into female Lewis rats intramuscularly in 0.1-0.2 ml containing 500 µg of the composition. A control group of rats receives 0.1-0.2 ml of PBS. Nine to ten days after the injection, spleen and lymph nodes are harvested from the rats and single cell suspensions obtained by macerating tissues through a 40 µm nyclon cell strainer. Samples are stained in PBS (1% FCS) with the appropriate dilution of relevant monoclonal antibodies. Propidum iodide staining cells are excluded from analysis. Samples are acquired on an LSR2 flow cytometer (BD Biosciences, USA) and analyzed using FACS Diva software. The expression of markers CD4, CD8, etc. is analyzed on the cells. A reduction in the presence of CD4+ T cells and/or CD8+ T cells, for example, suggests an induction of a desired immune response.

<u>Example 12: Evaluating Tolerogenic Immune Response to an Autoantigen In Vivo (Prophetic)</u>

Balb/c mice are administered an autoantigen comprising a MHC Class I-restricted and/or MHC Class II-restricted epitopes, and the level of CD8+ T cell and/or CD4+ T cell proliferation, respectively, is assessed. Subsequently, a composition of the invention comprising the autoantigen or portion thereof comprising the epitopes and immunosuppressant is administered subcutaneously in a dose-dependent manner. The level of CD8+ T cell and/or CD4+ T cell proliferation, respectively, is again assessed with a reduction in proliferation indicating a tolerogenic immune response.

Example 13: In Vivo Reduction of an Undesired Immune Response Against Transplantable Bone Marrow Cells (Prophetic)

A population of at least 10^6 synthetic nanocarriers comprising immunosuppressant and antigens obtained or derived from bone marrow cells are administered subcutaneously to a subject four weeks prior to the subject receiving a bone marrow transplant. After the transplant is received by the subject, the generation of an undesired immune response in the subject is assessed once daily during the first week after receiving the transplant, and then weekly for the next three weeks, and then monthly for the next 11 months. As part of the assessment, CD8+ T cell and/or CD4+ T cell counts are taken and compared to CD8+ T cell and/or CD4+ T cell counts taken prior to administering the bone marrow transplant or the synthetic nanocarriers to the subject. During the first year, maintenance doses of the synthetic nanocarriers are administered bi-monthly to the subject. The subject is expected to exhibit no or only a minimal level of CD8+ T cells and/or CD4+ T cells specific to the bone marrow transplant.

Example 14: Evaluating In vitro Depletion of T Effector Cells (Prophetic)

A cell population comprising T effector cells or T effector cell precursors is contacted in vitro with a composition provided herein. After a time sufficient for the composition to interact with the T effector cells or T effector cell precursors in the cell population, a reduction in the number of T effector cells is expected. A time sufficient for the reduction in the number of T effector cells in the population is, in some embodiment, a period of about 1 day, about 2 days, about 3 days, about 4 days, about 5 days, about 6 days, about 1 week, about 2 weeks, about 3 weeks, or about 4 weeks. In some embodiments, the number of T effector cells is reduced after that time, for example, to less than about 50%, to less than about 60%, to less than about 70%, to less than about 80%, to less than about 90%, to less than about 95%, to less than about 98%, or to less than about 99% of the original total or relative number of T effector cells in the population. In some embodiments, T effector cells are entirely absent from the cell population after that time. In some embodiments, the total and/or relative number of T effector cells in the population is determined before the population of cells is contacted with a composition provided herein to establish a baseline number of T effector cells in the population. In some embodiments, the population of cells is contacted once with a composition provided herein. In some embodiments, the population of cells is contacted repeatedly with a composition provided herein.

The number and/or presence of T effector cells in the population of cells is also determined after the contacting. In some embodiments, the number and/or presence of T effector cells is monitored over a period of time, for example, by performing a plurality of subsequent T effector cell detection assays. In some embodiments, the number and/or presence of T effector cells in the population of cells is determined by taking a sample from the cell population that is representative of the cell population, staining cells contained in that sample with antibodies or staining agents that specifically detect T effector cell markers, and detecting cells that express T effector cell markers in the sample, for example, by FACS or by immunohistochemistry. In some embodiments, the T effector cells are quantified. In some embodiments, the quantity of T effector cells determined after the contacting is compared to the quantity of T effector cells before the contacting, for example, to the baseline number of T effector cells, wherein, if the number of T effector cells in the population of cells is lower after the contacting than the baseline number, then it is determined that a tolerogenic response to the composition has occurred.

Example 15: Evaluating In vivo Depletion of T Effector Cells (Prophetic)

A cell population comprising T effector cells or T effector cell precursors is contacted in vivo with a composition provided herein. In some embodiments, the composition or cell population is administered to a subject harboring the cell population comprising T effector cells or T effector cell precursors. After a time sufficient for the composition to interact with the T effector cells or T effector cell precursors in the subject, a reduction in the number of T effector cells is expected. A time sufficient for the reduction in the number of T effector cells in the population is, in some embodiment, a period of about 1 day, about 2 days, about 3 days, about 4 days, about 5 days, about 6 days, about 1 week, about 2 weeks, about 3 weeks, or about 4 weeks. In some embodiments, the period of time sufficient to effect a reduction in the number of T effector cells is longer than 4 weeks. In some embodiments, the number of T effector cells is reduced after that time, for example, to less than about 50%, to less than about 60%, to less than about 70%, to less than about 80%, to less than about 90%, to less than about 95%, to less than about 98%, or to less than about 99% of the original total or relative number of T effector cells in the subject. In some embodiments, T effector cells, or a specific population of T effector cells (e.g., T effector cells targeting a specfic antigen) are entirely absent from the subject after that time. In some embodiments, the total and/or relative number of T effector cells in the subject is determined before the subject is administered a composition provided herein to establish a baseline number of T effector cells in the subject. In some embodiments, a composition provided herein is administered to a subject once. In some embodiments, a composition provided herein is administered to a subject multiple times, for example, until a desired reduction of T effector cells is observed in the subject.

The number and/or presence of T effector cells in the subject is determined after the administration. In some embodiments, the number and/or presence of T effector cells is monitored over a period of time, for example, by performing a plurality of subsequent T effector cell detection assays. In some embodiments, the number and/or presence of T effector cells in the subject is determined by taking a sample from the subject, for example, a peripheral blood sample, or a lymph sample, that is representative of a T cell population in the subject, staining cells contained in that sample with antibodies or staining agents that specifically detect T effector cell markers, and detecting cells that express T effector cell markers in the sample, for example, by FACS or by immunohistochemistry. In some embodiments, the T effector cells are quantified. In some embodiments, the quantity of T effector cells determined after administration is compared to the quantity of T effector cells before administration, for example, to the baseline number of T effector cells, wherein, if the number of T effector cells in the subject is lower after the contacting than the baseline number, then it is determined that a tolerogenic response to the composition has occurred.

Example 16: Evaluating Tolerogenic Immune Responses with Synthetic Nanocarriers Comprising Immunosuppressant and APC Presentable Antigen *In Vivo*

Materials and Methods of Synthetic Nanocarrier Production

Nanocarrier 1

Rapamycin was purchased from TSZ CHEM (185 Wilson Street, Framingham, MA 01702; Product Catalogue # R1017). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows:

Solution 1: Rapamycin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving rapamycin in pure methylene chloride.

Solution 2: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 3: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride.

Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

An oil-in-water emulsion was used to prepare the nanocarriers. The O/W emulsion was prepared by combining solution 1 (0.2 mL), solution 2 (0.75 mL), solution 3 (0.25 mL), and solution 4 (3 mL) in a small pressure tube and sonicating at 30% amplitude for 60 seconds using a Branson Digital Sonifier 250. The O/W emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers was washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 21,000×g and 4 °C for 45 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amount of rapamycin in the nanocarrier was determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Rapamycin Content (% w/w)
Nanocarrier 1	215	9.5

Nanocarrier 2

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505; Part # 4065609). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows:

Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature.

Solution 2: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 3: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride.

Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.75 mL), and solution 3 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 4 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers were washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 75,600×g and 4 °C for 35 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amount of peptide in the nanocarrier was determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Peptide Content (% w/w)
Nanocarrier 2	234	2.1

Nanocarrier 3

Simvastatin was purchased from LKT Laboratories, Inc. (2233 University Avenue West, St. Paul, MN 55114; Product Catalogue # S3449). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows:

Solution 1: Simvastatin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving simvastatin in pure methylene chloride.

Solution 2: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 3: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride.

Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

An oil-in-water emulsion was used to prepare the nanocarriers. The O/W emulsion was prepared by combining solution 1 (0.15 mL), solution 2 (0.75 mL), solution 3 (0.25 mL), and solution 4 (3 mL) in a small pressure tube and sonicating at 30% amplitude for 60 seconds using a Branson Digital Sonifier 250. The O/W emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers was washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 75,600×g and 4 °C for 35 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amount of simvastatin in the nanocarrier was determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Simvastatin Content (% w/w)
Nanocarrier 3	196	8.0

Nanocarrier 4

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505; Part # 4065609). Rapamycin was purchased from TSZ CHEM (185 Wilson Street, Framingham, MA 01702; Product Catalogue # R1017). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows:

Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature.

Solution 2: Rapamycin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving rapamycin in pure methylene chloride.

Solution 3: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 4: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride.

Solution 5: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.2 mL), solution 3 (0.75 mL), and solution 4 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a

Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 5 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers were washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 21,000×g and 4 °C for 45 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amounts of peptide and rapamycin in the nanocarrier were determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Rapamycin Content (% w/w)	Peptide Content (% w/w)
4	227	9.0	2.5

Nanocarrier 5

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505; Part # 4065609). Simvastatin was purchased from LKT Laboratories, Inc. (2233 University Avenue West, St. Paul, MN 55114; Product Catalogue # S3449). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows:

Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature.

Solution 2: Simvastatin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving simvastatin in pure methylene chloride.

Solution 3: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride.

Solution 4: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride.

Solution 5: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.15 mL), solution 3 (0.75 mL), and solution 4 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 5 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers were washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 75,600×g and 4 °C for 35 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amounts of peptide and simvastatin in the nanocarrier were determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Simvastatin Content (% w/w)	Peptide Content (% w/w)
Nanocarrier 5	226	2.7	1.9

***In vivo* Administration 1**

Spleens from B6.Cg-Tg(TcraTcrb)425Cbn/J (OTII) and C57BL/6 (B6) mice were harvested, mechanically dissociated and filtered separately through a 70 µM sieve to yield a single-cell suspension. Purified $CD4^{+}CD25-$ cells were then extracted in a 2-step process.

Using a Miltenyi Biotec AutoMACS magnetic cell sorter spleen cells were first labeled with $CD4^+$ T-cell isolation kit II and the unlabeled fraction was depleted of $CD25^+$ cells with CD25 depletion kit. The purified B6 cells were stained with an intracellular dye, Carboxyfluorescein Succinimidyl Ester (CFSE), before being admixed at equal concentrations with the purified OTII cells. They were then injected intravenously (i.v.) into B6.SJL-*Ptprc*^{a}/BoyAi (CD45.1) recipient mice.

The next day the recipient CD45.1 mice were treated with targeted tolerogenic synthetic vaccine particles (t^2SVP). They were loaded with combinations of ovalbumin peptide (323-339) (OVA $^{323\text{-}339}$), Rapamycin (Rapa) and/or Simvastatin (Simva) and were administered subcutaneously (s.c.).

The injection constitutes a tolerogenic treatment and was followed by 4 more injections each spaced 2 weeks apart. After the treatment schedule was completed the recipient CD45.1 animals were killed and their spleens and popliteal lymph nodes were harvested, mechanically dissociated and filtered separately through a 70 μM sieve to yield a single-cell suspension. The spleen cells were depleted of red blood cells (RBCs) by incubation with RBC lysis buffer (Stem Cell Technologies) and cell counts were performed on both the spleens and lymph nodes.

Spleen or lymph node cells were cultured in CM (complete media) supplemented with 10U/ml IL-2, restimulated with OPII at 0.3×10^6cells/well in 96-well round bottom (RB) plates and incubated at 37 °C, 5% CO_2. Cells were split at Day 2 and harvested on Day 5. Supernatants were collected and frozen while cells were stained for phenotypic analysis by flow cytometry. The cells were analyzed on a Becton Dickinson FacsCanto flow cytometer.

***In vivo* Administration 2**

Spleens from B6.Cg-Tg(TcraTcrb)425Cbn/J (OTII) and C57BL/6 (B6) mice were harvested, mechanically dissociated and filtered separately through a 70 μM sieve to yield a single-cell suspension. Purified $CD4^+$CD25- cells were then extracted in a 2-step process using a Miltenyi Biotec AutoMACS magnetic cell sorter. Spleen cells were labeled using Miltenyi's $CD4^+$ T-cell isolation kit II. The unlabeled CD4+ T-cell fraction was then depleted of $CD25^+$ cells with CD25 depletion kit. The purified CD4 cells from B6 mice were then stained with an intracellular dye, Carboxyfluorescein Succinimidyl Ester (CFSE), before being admixed at equal concentrations with the purified OTII cells. They were then injected intravenously (i.v.) into B6.SJL-*Ptprc*^{a}/BoyAi (CD45.1) recipient mice.

The next day the recipient CD45.1 mice were treated with targeted tolerogenic synthetic vaccine particles. They comprised combinations of ovalbumin peptide (323-339) ($OVA^{323-339}$), Rapamycin (Rapa) and Simvastatin (Simva) and were administered subcutaneously (s.c.) or intravenously (i.v.).

After the treatment schedule was completed the recipient CD45.1 animals were killed and their spleens and popliteal lymph nodes were harvested, mechanically dissociated and filtered separately through a 70 μM sieve to yield a single-cell suspension. The spleen cells were depleted of red blood cells (RBCs) by incorporation with RBC lysis buffer (Stem Cell Technologies) and cell counts were performed on both the spleens and lymph nodes.

Spleen or lymph node cells were cultured in CM supplemented with 10U/ml IL-2, restimulated with 1 μM OPII at $0.3x10^6$cells/well in 96-well round bottom (RB) plates and incubated at 37°C, 5% CO_2. Cells were split at Day 2 and harvested on Day 5. Supernatants were collected and frozen while cells were stained for phenotypic analysis by flow cytometry. The cells were analyzed on a Becton Dickinson FacsCanto flow cytometer.

Results

The results are shown in **Figs. 2** and **3** (Immunomodulator 1: rapamycin; immunomodulator 2: simvastatin). The figures show in vivo effects and demonstrates a reduction in the number of effector immune cells with synthetic nanocarriers comprising antigen and immunosuppressants as compared to antigen alone or synthetic nanocarriers comprising antigen with and without an immunostimulatory molecule. **Fig. 3** also demonstrates an increase in the percentage that express FoxP3 with synthetic nanocarriers comprising antigen and immunosuppressant as compared to synthetic nanocarriers that comprise only antigen.

Example 17: Assessing the Effects of Nanocarriers with Antigens and Immunosuppressants

Nanocarriers

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505; Part # 4065609). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom

Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows: Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature. Solution 2: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride. Solution 3: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride. Solution 4: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer. A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.75 mL), and solution 3 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 4 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers were washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 75,600×g and 4 °C for 35 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amount of peptide in the nanocarrier was determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier	Effective Diameter (nm)	Peptide Content (% w/w)
1	234	2.1

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T and B cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa

Street, Torrance CA 90505; Part # 4065609). Rapamycin was purchased from TSZ CHEM (185 Wilson Street, Framingham, MA 01702; Product Catalogue # R1017). PLGA with a lactide:glycolide ratio of 3:1 and an inherent viscosity of 0.75 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211; Product Code 7525 DLG 7A). PLA-PEG block co-polymer with a PEG block of approximately 5,000 Da and PLA block of approximately 20,000 Da was synthesized. Polyvinyl alcohol (85-89% hydrolyzed) was purchased from EMD Chemicals (Product Number 1.41350.1001).

Solutions were prepared as follows: Solution 1: Ovalbumin peptide 323-339 @ 20 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13 M hydrochloric acid solution at room temperature. Solution 2: Rapamycin @ 50 mg/mL in methylene chloride. The solution was prepared by dissolving rapamycin in pure methylene chloride. Solution 3: PLGA @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLGA in pure methylene chloride. Solution 4: PLA-PEG @ 100 mg/mL in methylene chloride. The solution was prepared by dissolving PLA-PEG in pure methylene chloride. Solution 5: Polyvinyl alcohol @ 50 mg/mL in 100 mM pH 8 phosphate buffer.

A primary water-in-oil emulsion was prepared first. W1/O1 was prepared by combining solution 1 (0.2 mL), solution 2 (0.2 mL), solution 3 (0.75 mL), and solution 4 (0.25 mL) in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A secondary emulsion (W1/O1/W2) was then prepared by combining solution 5 (3.0 mL) with the primary W1/O1 emulsion, vortexing for 10 s, and sonicating at 30% amplitude for 60 seconds using the Branson Digital Sonifier 250.

The W1/O1/W2 emulsion was added to a beaker containing 70 mM pH 8 phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow the methylene chloride to evaporate and for the nanocarriers to form. A portion of the nanocarriers were washed by transferring the nanocarrier suspension to a centrifuge tube and centrifuging at 21,000×g and 4 °C for 45 min, removing the supernatant, and re-suspending the pellet in phosphate buffered saline. The washing procedure was repeated, and the pellet was re-suspended in phosphate buffered saline for a final nanocarrier dispersion of about 10 mg/mL.

Nanocarrier size was determined by dynamic light scattering. The amounts of peptide and rapamycin in the nanocarrier were determined by HPLC analysis. The total dry-nanocarrier mass per mL of suspension was determined by a gravimetric method.

Nanocarrier ID	Effective Diameter (nm)	Rapamycin Content (% w/w)	Peptide Content (% w/w)
2	227	9.0	2.5

Measurement of synthetic nanocarrier dimensions was obtained by dynamic light scattering (DLS). A suspension of the synthetic nanocarriers was diluted with purified water to achieve a final synthetic nanocarrier suspension concentration of approximately 0.01 to 0.1 mg/mL. The diluted suspension was prepared directly inside a suitable cuvette for DLS analysis. The cuvette was then placed in a Brookhaven Instruments Corp. ZetaPALS, allowed to equilibrate to 25 °C, and then scanned for sufficient time to acquire a stable and reproducible distribution based on appropriate inputs for viscosity of the medium and refractive indicies of the sample. The effective diameter, or mean of the distribution, was then reported.

Immunization

The nanocarriers were thawed and equilibrated. Initial dilutions constituted a 10x stock solution, and were further diluted to a concentration of 100μg/ml in $OVA_{323-339}$, or a 1x solution. This 1x solution was used for injections at 200μl per i.v. injection. Animals were immunized with OVA protein (OVA) and treated with $OVA_{323-339}$ peptide. Immunization routes were as follows: 10μg of OVA+ 4mg Alum i.p. in 400μl per each Balb/C immunologically naïve female mouse. Experimental groups consisted of 5 animals each. Spleen cells were restimulated with antigen using CFSE or CTO to determine the amount of Ag-specific proliferation.

Levels of Specific Types of Immune Cells

FCS files were analyzed using FlowJo software. 7AAD positive cells (a nuclear dye that label dead cells) positive cells were excluded and cell morphologies dependent on expression of CD4, CD8, Gr-1, F4/80, B220, TCRb and CD11b were quantified.
Gating strategy for T-cell subsets → 7AAD- F4/80- GR-1- TCRb+ CD4+/- CD8+/-

Determination of % Dividing CD4+ and CD8+ T Cells

The frequency of Ovalbumin reactive CD4+ T and CD8+ T cells was calculated by way of flow cytometry. Splenocytes from experimental animals were stained with CFSE, a thiol-reactive Fluorescent Probe suitable for long-term cell labeling, and cultured in complete media at 37C, 5% CO2 with Ovalbumin protein for 3 days. On day 3 the cells were washed, blocked with anti-CD16/32 antibody and then stained with conjugated antibodies specific to TCR CD4 and CD8a. Splenocytes that were TCR+CD4 or TCR+CD8a+ were assessed for proliferation by comparing the differential CFSE staining.

Results

Figs. 4 and **5** demonstrate the effectiveness of the nanocarriers in an animal model. Specifically, **Fig. 4** demonstrates a reduction in the number of CD4+ T cells and CD8+ T cells in lavage samples from animal subjects treated with synthetic nanocarriers comprising $OVA_{323-339}$ and immunosuppressant. **Fig. 5** shows a reduction in the percentage of dividing CD4+ T cells and CD8+ T cells with the administration of synthetic nanocarriers comprising immunosuppressant and OVA peptide.

Example 18: Assessing the Effects of Nanocarriers with Antigens and Immunosuppressants (Prophetic)

Nanocarriers

Nanocarriers are prepared similar to the above example (Example 17) using the MHC Class I-restricted peptide SINFEKL (SEQ ID NO: 944) in place of ovalbumin peptide.

Immunization

The nanocarriers are thawed and equilibrated. Initial dilutions constitute a 10x stock solution, and are further diluted to a concentration of 100μg/ml in peptide, or a 1x solution. This 1x solution is used for injections at 200μl per i.v. injection. Animals are immunized with protein comprising the peptide and treated with peptide. Immunization routes are as follows: 10μg of peptide+ 4mg Alum i.p. in 400μl per each Balb/C immunologically naïve female mouse. Experimental groups consist of 5 animals each. Spleen cells are restimulated with antigen using CFSE or CTO to determine the amount of Ag-specific proliferation.

Levels of Specific Types of Immune Cells

FCS files are analyzed using FlowJo software. 7AAD positive cells (a nuclear dye that label dead cells) positive cells are excluded and cell morphologies dependent on expression of CD4, CD8, Gr-1, F4/80, B220, TCRb and CD11b are quantified.
Gating strategy for T-cell subsets → 7AAD- F4/80- GR-1- TCRb+ CD4+/- CD8+/-

Determination of % Dividing CD4+ and CD8+ T Cells

The frequency of Ovalbumin reactive CD4+ T and CD8+ T cells is calculated by way of flow cytometry. Splenocytes from experimental animals are stained with CFSE, a thiol-reactive Fluorescent Probe suitable for long-term cell labeling, and cultured in complete media at 37C, 5% CO2 with Ovalbumin protein for 3 days. On day 3 the cells are washed, blocked with anti-CD16/32 antibody and then stained with conjugated antibodies specific to TCR CD4 and CD8a. Splenocytes that are TCR+CD4 or TCR+CD8a+ are assessed for proliferation by comparing the differential CFSE staining.

What is claimed is:

CLAIMS

1. A method comprising:
administering to a subject a composition according to a protocol that was previously shown to reduce the number or activity of antigen-specific T effector cells in one or more test subjects; wherein the composition comprises:
(i) a first population of synthetic nanocarriers coupled to immunosuppressants, and
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen.

2. A method comprising:
reducing the number or activity of antigen-specific T effector cells in one or more test subjects by administering to the one or more test subjects a composition that comprises:
(i) a first population of synthetic nanocarriers coupled to immunosuppressants, and
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen.

3. A method comprising:
administering to a subject a composition that comprises:
(i) a first population of synthetic nanocarriers coupled to immunosuppressants, and
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen;
wherein the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells.

4. The method of any of claims 1-3, wherein the first population and the second population are the same population.

5. The method of any of claims 1-4, wherein the method further comprises providing or identifying the subject.

6. The method of any of claims 1-5, wherein the antigen is a therapeutic protein, an autoantigen or an allergen, or is associated with an inflammatory disease, an autoimmune disease, organ or tissue rejection or graft versus host disease.

7. The method of any of claims 1-6, wherein the method further comprises assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration of the composition.

8. The method of any of claims 1-7, wherein the subject has or is at risk of having an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft versus host disease.

9. The method of any of claims 1-7, wherein the subject has undergone or will undergo transplantation.

10. The method of any of claims 1-7, wherein the subject has or is at risk of having an undesired immune response against a therapeutic protein that is being administered or will be administered to the subject.

11. The method of any of claims 1-10, wherein one or more maintenance doses of the composition comprising the first population and second population of synthetic nanocarriers is administered to the subject.

12. The method of any of claims 1-11, wherein the administering is by intravenous, intraperitoneal, transmucosal, oral, subcutaneous, pulmonary, intranasal, intradermal or intramuscular administration.

13. The method of any of claims 1-11, wherein the administering is by inhalation or intravenous, subcutaneous or transmucosal administration.

14. The method of any of claims 1-13, wherein the immunosuppressants comprise a statin, an mTOR inhibitor, a TGF-β signaling agent, a corticosteroid, an inhibitor of mitochondrial

function, a P38 inhibitor, an NF-κβ inhibitor, an adenosine receptor agonist, a prostaglandin E2 agonist, a phosphodiesterasse 4 inhibitor, an HDAC inhibitor or a proteasome inhibitor.

15. The method of claim 14, wherein the mTOR inhibitor is rapamycin.

16. The method of any of claims 1-15, wherein the load of the immunosuppressants and/or epitopes on average across the first and/or second population of synthetic nanocarriers is between 0.0001% and 50% (weight/weight).

17. The method of claim 16, wherein the load of the immunosuppressants and/or epitopes on average across the first and/or second population of synthetic nanocarriers is between 0.1% and 10% (weight/weight).

18. The method of any of claims 1-17, wherein the synthetic nanocarriers of the first population and/or second population comprise lipid nanoparticles, polymeric nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles or peptide or protein particles.

19. The method of claim 18, wherein the synthetic nanocarriers of the first population and/or second population comprise lipid nanoparticles.

20. The method of claim 19, wherein the synthetic nanocarriers of the first population and/or second population comprise liposomes.

21. The method of claim 18, wherein the synthetic nanocarriers of the first population and/or second population comprise metallic nanoparticles.

22. The method of claim 21, wherein the metallic nanoparticles comprise gold nanoparticles.

23. The method of claim 18, wherein the synthetic nanocarriers of the first population and/or second population comprise polymeric nanoparticles.

24. The method of claim 23, wherein the polymeric nanoparticle comprises polymer that is a non-methoxy-terminated, pluronic polymer.

25. The method of claim 23 or 24, wherein the polymeric nanoparticles comprise a polyester, a polyester coupled to a polyether, polyamino acid, polycarbonate, polyacetal, polyketal, polysaccharide, polyethyloxazoline or polyethyleneimine.

26. The method of claim 25, wherein the polyester comprises a poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid) or polycaprolactone.

27. The method of claim 25 or 26, wherein the polymeric nanoparticles comprise a polyester and a polyester coupled to a polyether.

28. The method of any of claims 25-27, wherein the polyether comprises polyethylene glycol or polypropylene glycol.

29. The method of any of claims 1-28, wherein the mean of a particle size distribution obtained using dynamic light scattering of the synthetic nanocarriers of the first and/or second population is a diameter greater than 100nm.

30. The method of claim 29, wherein the diameter is greater than 150nm.

31. The method of claim 30, wherein the diameter is greater than 200nm.

32. The method of claim 31, wherein the diameter is greater than 250nm.

33. The method of claim 32, wherein the diameter is greater than 300nm.

34. The method of any of claims 1-33, wherein the aspect ratio of the synthetic nanocarriers of the first population and/or second population is greater than 1:1, 1:1.2, 1:1.5, 1:2, 1:3, 1:5, 1:7 or 1:10.

36. The method of any of claims 1-34, wherein the T effector cells are CD4+ and/or CD8+ T cells.

37. A method comprising:
(i) producing a first population of synthetic nanocarriers coupled to immunosuppressants, and
(ii) producing a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; and
(iii) evaluating the effect of the first and second population of synthetic nanocarriers on antigen-specific T effector cell number or activity.

38. The method of claim 37, wherein the first population and second population are the same population.

39. The method of claim 37 or 38, wherein the method further comprises making a dosage form comprising the first population and second population of synthetic nanocarriers.

40. The method of any of claims 37-39, wherein the method further comprises making a composition comprising the first population and second population of synthetic nanocarriers or the dosage form available to a subject for administration.

41. The method of claim 40, wherein the method further comprises assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration of the composition or dosage form.

42. The method of any of claims 37-41, wherein the T effector cells and CD4+ T cells and/or CD8+ T cells.

43. The method of any of claims 37-42, wherein the first population and second population of synthetic nanocarriers that are produced are as defined in any of claims 1-36.

44. A process for producing a composition or dosage form comprising the steps of:
(i) coupling a first population of synthetic nanocarriers to immunosuppressants,

(ii) coupling a second population of synthetic nanocarriers to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen, and
(iii) evaluating the effect of the first and second population of synthetic nanocarriers on antigen-specific T effector cell number or activity.

45. The process of claim 44, which comprises the steps as defined in the method of any one of claims 37-43.

46. A composition or dosage form obtainable by the method or process of any one of claims 37-45 or as defined in any one of claims 1-36.

47. A composition comprising:

(i) a first population of synthetic nanocarriers coupled to immunosuppressants;
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen; and
(iii) a pharmaceutically acceptable excipient,

wherein the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject.

48. A composition comprising:

(i) a first population of synthetic nanocarriers coupled to immunosuppressants; and
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen;

wherein the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject for use in therapy or prophylaxis.

49. A composition comprising:

(i) a first population of synthetic nanocarriers coupled to immunosuppressants; and
(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen;

wherein the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject for use in a method of:

j. treatment, comprising the step of administering said composition to a subject and assessing the number or activity of antigen-specific T effector cells in the subject prior to and/or after the administration;
k. treatment, comprising the step of administering said composition to a subject according to a protocol that was previously shown to reduce the number or activity of antigen-specific T effector cells in one or more test subjects;
l. treatment or prophylaxis as defined in any one of claims 1-36;
m. treatment or prophylaxis of an inflammatory disease, an autoimmune disease, an allergy, organ or tissue rejection or graft versus host disease, for example by the reduction of the number or activity of antigen-specific T effector cells;
n. treatment of a subject who has undergone or will undergo transplantation;
o. treatment of a subject subject who has been or will be administered a therapeutic protein; or
p. treatment in conjunction with a transplantable graft or therapeutic protein.

50. Use of a composition comprising:

(i) a first population of synthetic nanocarriers coupled to immunosuppressants; and

(ii) a second population of synthetic nanocarriers coupled to MHC Class I-restricted and/or MHC Class II-restricted epitopes of an antigen;

wherein the composition is in an amount effective to reduce the number or activity of antigen-specific T effector cells in a subject for the manufacture of a medicament for use in a method as defined in claim 49.

51. The composition of claim 49 or use of claim 50, wherein:

(a) the composition is as defined in any one of claims 1-36; and/or

(b) the composition is for use in a method of therapy or prophylaxis comprising administration by a intravenous, intraperitoneal, transmucosal, oral, subcutaneous, pulmonary, intranasal, intradermal or intramuscular administration, for example as defined in claim 12 or 13.

52. A dosage form comprising the composition of any of claims 46-49 and 51.

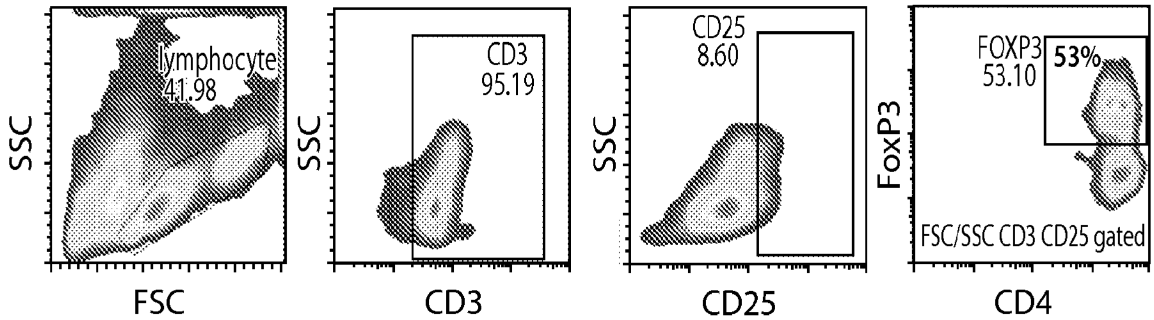


Fig. 1

In vivo effects of t2SVP after a single injection

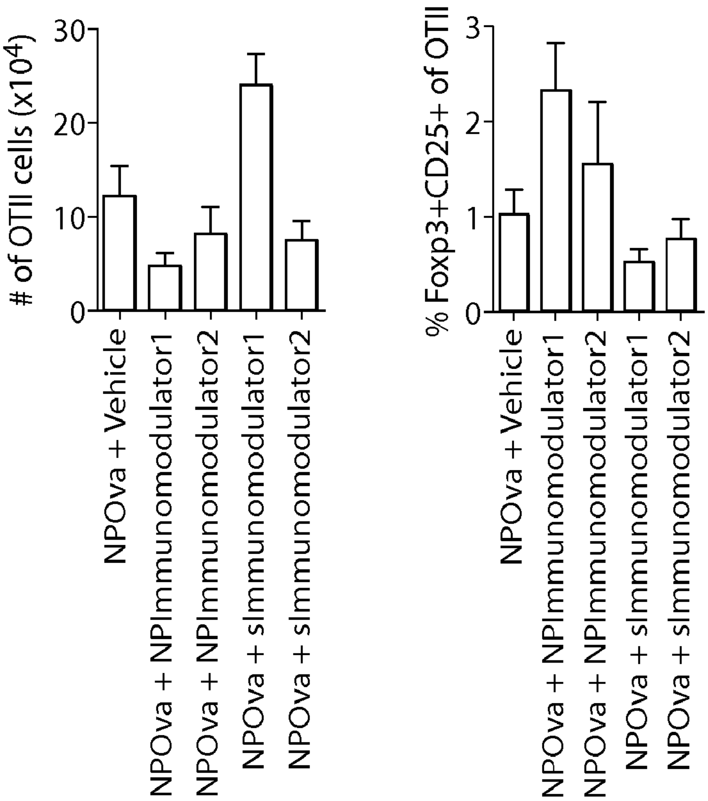


Fig. 2

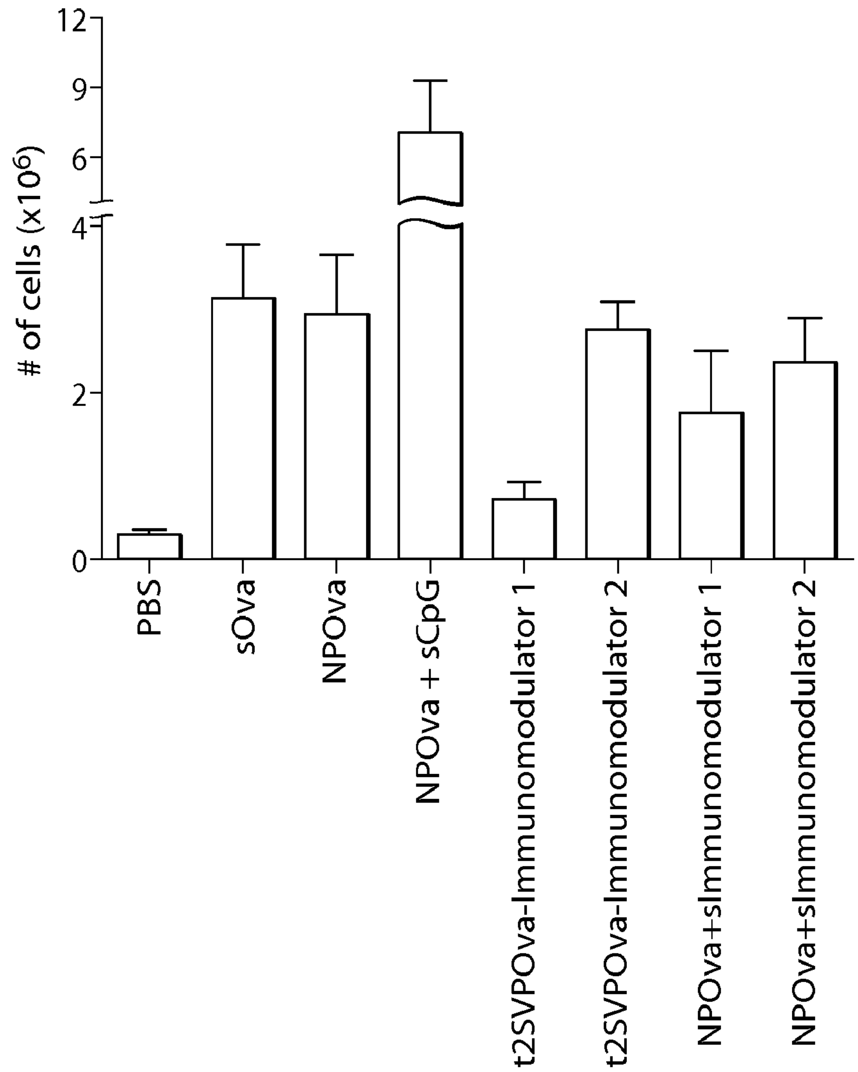
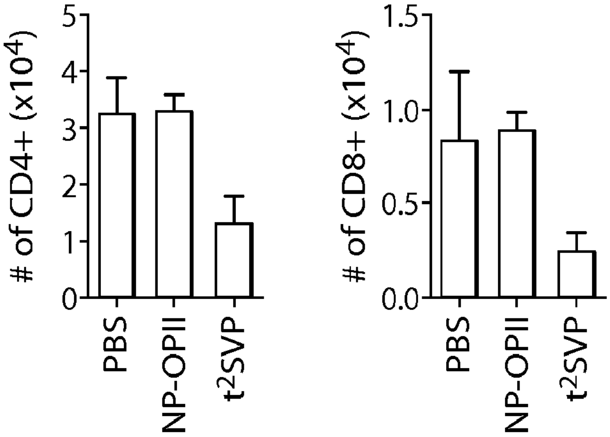
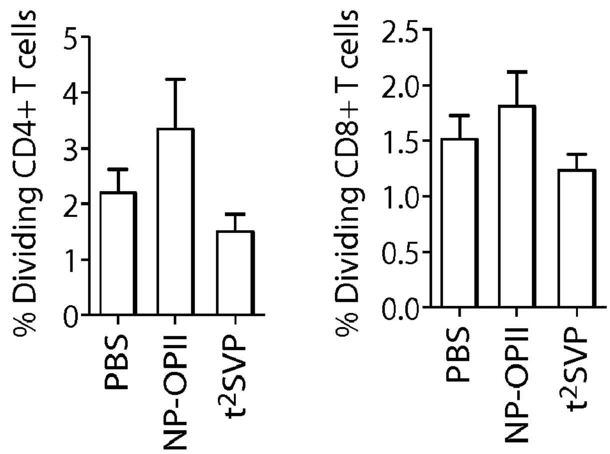

12
9
6
4
2
0
# of cells (x10^6)
PBS
sOva
NPOva
NPOva + sCpG
t2SVPOva-Immunomodulator 1
t2SVPOva-Immunomodulator 2
NPOva+sImmunomodulator 1
NPOva+sImmunomodulator 2

Fig. 3



# of CD4+ (x10^4)
5
4
3
2
1
0
PBS
NP-OPII
t2SVP
# of CD8+ (x10^4)
1.5
1.0
0.5
0.0
PBS
NP-OPII
t2SVP

Fig. 4



% Dividing CD4+ T cells
5
4
3
2
1
0
PBS
NP-OPII
t2SVP
% Dividing CD8+ T cells
2.5
2.0
1.5
1.0
0.5
0.0
PBS
NP-OPII
t2SVP

Fig. 5