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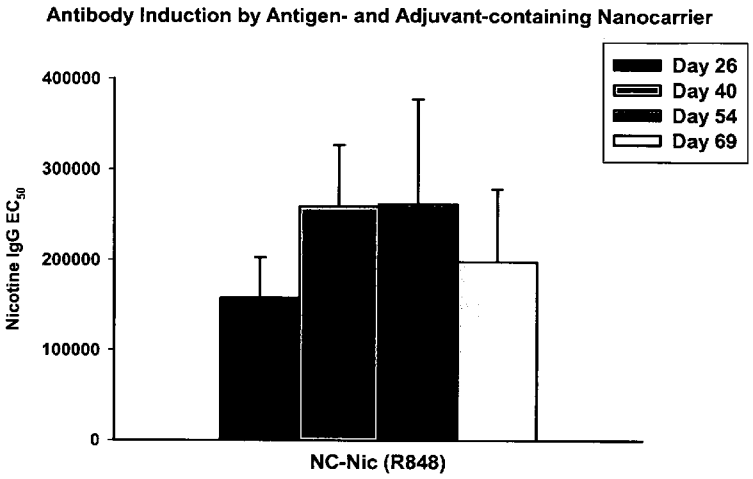

FIG. 1

(57) Abstract: This invention relates to compositions, and related methods, of synthetic nanocarriers that comprise immunomodulatory agents and antigens that are differentially released from the synthetic nanocarriers.

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NANOCARRIERS POSSESSING COMPONENTS WITH DIFFERENT RATES OF RELEASE

RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 of United States provisional applications 61/217129, 61/217117, 61/217124, and 61/217116, each filed May 27, 2009, the contents of each of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

This invention relates to compositions, and related methods, of synthetic nanocarriers that comprise immunomodulatory agents and antigens that are differentially released from the synthetic nanocarriers.

BACKGROUND

Common vaccination strategies include the administration of antigens with adjuvants. However, information regarding the biological interplay between these two agents and how the control of their delivery can provide for optimal in vivo effects is lacking. There is a need for new methods for delivering antigens with adjuvants that allow for optimal in vivo effects as well as related compositions.

SUMMARY OF THE INVENTION

Aspects of the invention relate to compositions comprising synthetic nanocarriers that comprise an immunomodulatory agent coupled to the synthetic nanocarrier, and an antigen coupled to the synthetic nanocarrier, wherein the immunomodulatory agent and antigen dissociates from the synthetic nanocarrier according to the following relationship: IA(rel) % / A(rel) % ≥ 1.2, wherein IA(rel) % is defined as a weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours divided by the sum of the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours plus a weight of immunomodulatory agent retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers, and wherein A(rel) % is defined as a weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5

for 24 hours divided by the sum of the weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours plus a weight of antigen retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers.

In some embodiments, the immunomodulatory agent is coupled to the synthetic nanocarrier via an immunomodulatory agent coupling moiety. In certain embodiments, the immunomodulatory agent is covalently coupled to the synthetic nanocarrier. In some embodiments, the immunomodulatory agent is encapsulated within the synthetic nanocarrier. In certain embodiments, the antigen is coupled to the synthetic nanocarrier via an antigen coupling moiety. In some embodiments, the antigen is covalently coupled to the synthetic nanocarrier. In certain embodiments, the antigen is encapsulated within the synthetic nanocarrier.

In some embodiments, the antigen is a B cell antigen. In certain embodiments, the B cell antigen is an antigen derived from an infectious agent. In some embodiments, the B cell antigen is a poorly immunogenic antigen. In certain embodiments, the B cell antigen is an abused substance or a portion thereof or an addictive substance or a portion thereof. In some embodiments, the B cell antigen is a toxin or hazardous environmental agent. In certain embodiments, the B cell antigen is an allergen, a degenerative disease antigen, a cancer antigen, an atopic disease antigen, or a metabolic disease antigen.

In some embodiments, the antigen is a T cell antigen. In certain embodiments, the T cell antigen is a MHC class I antigen. In some embodiments, the immunomodulatory agent is an adjuvant. In some embodiments, the adjuvant comprises a Toll-like receptor (TLR) agonist such as a TLR 3 agonist, TLR 7 agonist, TLR 8 agonist, TLR 7/8 agonist, or a TLR 9 agonist. In some embodiments, the TLR agonist is an imidazoquinoline. In certain embodiments, the imidazoquinoline is resiquimod or imiquimod. In some embodiments, the TLR agonist is an immunostimulatory nucleic acid such as an immunostimulatory DNA or immunostimulatory RNA. In certain embodiments, the immunostimulatory nucleic acid is a CpG-containing immunostimulatory nucleic acid.

In some embodiments, the adjuvant comprises a universal T-cell antigen. In certain embodiments, the synthetic nanocarriers comprise one or more biodegradable polymers. In some embodiments, the immunomodulatory agent is coupled to the one or more biodegradable polymers via the immunomodulatory agent coupling moiety. In certain embodiments, the immunomodulatory agent is covalently coupled to the one or more

biodegradable polymers. In some embodiments, the immunomodulatory agent coupling moiety comprises an amide bond. In certain embodiments, the immunomodulatory agent coupling moiety comprises an ester bond. In some embodiments, the immunomodulatory agent comprises an electrostatic bond.

In some embodiments, the biodegradable polymers comprise poly(lactide), poly(glycolide), or poly(lactide-co-glycolide). In certain embodiments, the biodegradable polymers have a weight average molecular weight ranging from 800 Daltons to 10,000 Daltons, as determined using gel permeation chromatography. In some embodiments, the synthetic nanocarriers further comprise an antigen presenting cell (APC) targeting feature.

In some embodiments, the synthetic nanocarriers comprise lipid-based nanoparticles, polymeric nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles, peptide or protein-based particles, nanoparticles that comprise a combination of nanomaterials, spheroidal nanoparticles, cubic nanoparticles, pyramidal nanoparticles, oblong nanoparticles, cylindrical nanoparticles or toroidal nanoparticles. In certain embodiments, compositions associated with the invention further comprise a pharmaceutically acceptable excipient.

Further aspects of the invention relate to compositions comprising vaccines comprising any of the compositions associated with the invention.

Further aspects of the invention relate to methods comprising administering any of the compositions associated with the invention to a subject. In some embodiments, the composition is in an amount effective to induce or enhance an immune response. In some embodiments, the subject has cancer, an infectious disease, a non-autoimmune metabolic disease, a degenerative disease, or an addiction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows that nicotine-specific antibodies were induced by synthetic nanocarriers that carried nicotine antigen and adjuvant and from which the adjuvant, but not the antigen, was detectably released at 24 hours.

DETAILED DESCRIPTION

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, reference to "a solvent" includes a mixture of two or more such solvents, reference to "an adhesive" includes mixtures of two or more such materials, and the like.

INTRODUCTION

This invention is useful in that it provides a way to deliver antigens with immunomodulatory agents to more optimally induce immune responses to the antigen. The compositions and methods provided allow for the release of the immunomodulatory agent prior to or concomitantly with the antigen. Such release can provide for strong and long-term immune responses and is, therefore, of particular interest in the use of vaccines for prophylactic and treatment purposes. Antigens can be coupled to the synthetic nanocarriers such that they are present on the surface of the synthetic nanocarriers, encapsulated within the nanocarriers or both, in some embodiments. In embodiments, the immunomodulatory agent augments an immune response to the antigen.

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 compositions, and related methods, comprising: synthetic nanocarriers that comprise (a) an immunomodulatory agent coupled to the synthetic nanocarrier; and (b) an antigen coupled to the synthetic nanocarrier; wherein the immunomodulatory agent and antigen dissociates from the synthetic nanocarrier according to the following relationship:

$$IA(rel)\ \% / A(rel)\ \% \geq 1.2$$

wherein IA(rel) % is defined as a weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours divided by the sum of the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours plus a weight of immunomodulatory agent retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours,

expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers; wherein A(rel) % is defined as a weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours divided by the sum of the weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours plus a weight of antigen retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers; and wherein t is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 18, 24, 30, 36, 42 or 48 hours. In preferred embodiments, t is 12, 24, or 48 hours.

In embodiments, the immunomodulatory agent and antigen dissociates from the synthetic nanocarrier according to following relationship: IA(rel) % / A(rel) % ≥ 1.3, IA(rel) % / A(rel) % ≥ 1.4, IA(rel) % / A(rel) % ≥ 1.5, IA(rel) % / A(rel) % ≥ 1.6, IA(rel) % / A(rel) % ≥ 1.7, IA(rel) % / A(rel) % ≥ 1.8, IA(rel) % / A(rel) % ≥ 1.9, IA(rel) % / A(rel) % ≥ 2, IA(rel) % / A(rel) % ≥ 2.5, IA(rel) % / A(rel) % ≥ 3, IA(rel) % / A(rel) % ≥ 3.5, IA(rel) % / A(rel) % ≥ 4, IA(rel) % / A(rel) % ≥ 4.5, IA(rel) % / A(rel) % ≥ 5, IA(rel) % / A(rel) % ≥ 6, IA(rel) % / A(rel) % ≥ 7, IA(rel) % / A(rel) % ≥ 8, IA(rel) % / A(rel) % ≥ 9, IA(rel) % / A(rel) % ≥ 10, IA(rel) % / A(rel) % ≥ 15, IA(rel) % / A(rel) % ≥ 20, IA(rel) % / A(rel) % ≥ 25, IA(rel) % / A(rel) % ≥ 30, IA(rel) % / A(rel) % ≥ 40, IA(rel) % / A(rel) % ≥ 50, IA(rel) % / A(rel) % ≥ 75, or IA(rel) % / A(rel) % ≥ 100, wherein IA(rel) %, A(rel) %, and t are as defined above.

In some embodiments, compositions, and related methods, comprising: synthetic nanocarriers that comprise (a) an immunomodulatory agent coupled to the synthetic nanocarrier; and (b) an antigen coupled to the synthetic nanocarrier; wherein at least 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 12%, 15%, 17%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 60%, 70%, 80% or 90% of the immunomodulatory agent is released, while the antigen is not detectably released. In these embodiments the percent released is 100 x (the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours divided by the sum of the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours plus a weight of immunomodulatory agent retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours, taken as an average across a sample of the

synthetic nanocarriers). In these embodiments, t is as defined above. In preferred embodiments, t is 12, 24, or 48 hours.

In particular, the inventors have noted that immune cell lysosomes change their character if they contain particulate matter that is not "digested" within a 24 to 48 hour period after having been endocytosed by the cell. Typically, most endocytosed biological materials are digested into smaller molecules (such as amino acids, small peptides, or nucleic acids) that are made available for cellular metabolism or extracellular disposal. However, lysosomes that cannot break down particles that they contain within the 24 to 48 period are modified by the cell. Signaling receptors and other systems are lost, and the lysosome is converted into a "dead end" vesicle, which is eventually processed for removal from the cell. Therefore, there is a window of time following endocytosis of a particle by a cell of the immune system. If a synthetic nanocarrier does not release its payload of immunomodulatory agent within this window of 24 to 48 hours, preferably 12 hours, then the signaling receptors that it is intended to target may be removed from the vesicle. This in turn makes any subsequent release of the immunomodulatory agent within that vesicle largely irrelevant in affecting immunogenic responses.

The inventors have also noted that the presence and engagement of signaling receptors, such as Toll-like receptors, during antigen uptake can control the kinetics and outcome of immune cell activation and/or maturation (e.g., phagosome maturation). The presence and engagement of signaling receptors not only leads to faster immune cell maturation but also confers a superior ability of immune cells to contribute peptides for recognition by major histocompatibility complex (MHC) molecules (Blander, Ann Rheum Dis 2008: 67(Suppl III):iii44-iii49).

It is desirable for receptor signaling in immune cells to occur prior to or concomitantly with antigen uptake. The compositions and methods provided herein provide for such receptor signaling by the delivery of the immunomodulatory agent and antigen as part of a synthetic nanocarrier that allows for the release of the immunomodulatory agent prior to or concomitantly with the antigen. Release of the immunomodulatory agent or antigen occurs, in embodiments, when the coupling of the immunomodulatory agent or antigen to the synthetic nanocarrier is significantly reduced or eliminated. Such coupling can be reduced or eliminated by the reduction or elimination of bonding between the immunomodulatory agent or antigen and a coupling moiety (an immunomodulatory agent or antigen coupling moiety, respectively). Such coupling can also be reduced or eliminated by the degradation of the synthetic nanocarrier such that the immunomodulatory agent or antigen

is released from being "housed" within the synthetic nanocarrier. In such an embodiment, the immunomodulatory agent or antigen is not coupled to the synthetic nanocarrier as a result of bonding prior to said degradation. In addition, such coupling can be reduced or eliminated by the degradation of the synthetic nanocarrier such that the immunomodulatory agent or antigen is still coupled to a portion of the synthetic nanocarrier (e.g., via an immunomodulatory or antigen coupling moiety, respectively) but that said portion is sufficiently degraded to be able to induce an immune response. In embodiments, the immune response is similar to or the same as the immune response that would be elicited in the same environment with the immunomodulatory agent or antigen when not coupled to the portion of the synthetic nanocarrier.

Preferably, the release of the immunomodulatory agent or antigen occurs in the lysosome or endosome. Therefore, the release of the immunomodulatory agent or antigen preferably occurs at a pH of 4.5. The efficiency of immunomodulatory agent release within a window of time can be approximated by comparing the in vitro release rate of antigen from a synthetic nanocarrier to the in vitro release rate of immunomodulatory agent under an environmental pH of approximately 4.5. The release of antigen from the synthetic nanocarrier serves as an indicator of how quickly the synthetic nanocarrier is being digested by a lysosome of an immune system cell. In fact, it has been found that an antigen can be coupled to a synthetic nanocarrier in such a way that release is not detected in vitro at a pH of 4.5 but instead at very basic conditions. In such instances, this demonstrates that the bonding of the antigen to the synthetic nanocarrier is very stable under physiological conditions (e.g., at a pH of 7.4 or 4.5) and that, generally, release of the antigen will occur as the synthetic nanocarrier is digested in vivo. It follows that such a synthetic nanocarrier would allow for the quicker release of an immunomodulatory agent.

If immunomodulatory agent is released from a synthetic nanocarrier more quickly than antigen under the simulated low pH conditions of the lysosome and during a relevant window of time, that is an indication that the active lysosome -- and consequently the immune system cell -- may be affected by the immunomodulatory agent. If the reverse is true, then that is an indication that some or all of the immunomodulatory agent payload may not have an optimal effect on the cell. Accordingly, synthetic nanocarriers according to the invention may provide greater immune response(s) and, as a result, enhanced therapeutic benefit to subjects.

DEFINITIONS

"Abused substance" is any substance taken by a subject (e.g., a human) for purposes other than those for which it is indicated or in a manner or in quantities other than directed by a physician. In some embodiments, the abused substance is a drug, such as an illegal drug. In certain embodiments, the abused substance is an over-the-counter drug. In some embodiments, the abused substance is a prescription drug. The abused substance, in some embodiments, is an addictive substance. In some embodiments, the abused substance has mood-altering effects, and, therefore, includes inhalants and solvents. In other embodiments, the abused substance is one that has no mood-altering effects or intoxication properties, and, therefore, includes anabolic steroids. Abused substances include, but are not limited to, cannabinoids (e.g., hashish, marijuana), depressants (e.g., barbituates, benodiazepines, flunitrazepam (Rohypnol), GHB, methaqualone (quaaludes)), dissociative anesthetics (e.g., ketamine, PCP), hallucinogens (e.g, LSD, mescaline, psilocybin), opioids and morphine derivatives (e.g., codeine, fentanyl, heroin, morphine, opium), stimulants (amphetamine, cocaine, Ecstacy (MDMA), methamphetamine, methylphenidate (Ritalin), nicotine), anabolic steriods, and inhalants. In some embodiments, the abused substance for inclusion in a nanocarrier is the complete molecule or a portion thereof.

"Addictive substance" is a substance that causes obsession, compulsion, or physical dependence or psychological dependence. In some embodiments, the addictive substance is an illegal drug. In other embodiment, the addictive substance is an over-the-counter drug. In still other embodiments, the addictive substance is a prescription drug. Addictive substances include, but are not limited to, cocaine, heroin, marijuana, methamphetamines, and nicotine. In some embodiments, the addictive substance for inclusion in a nanocarrier is the complete molecule or a portion thereof.

"Adjuvant" means an agent that does not constitute a specific antigen, but boosts the strength and longevity of immune response to an antigen. Such adjuvants may include, but are not limited to stimulators of pattern recognition receptors, such as Toll-like receptors, RIG-1 and NOD-like receptors (NLR), mineral salts, such as alum, alum combined with monphosphoryl lipid (MPL) A of Enterobacteria, such as Escherihia coli, Salmonella minnesota, Salmonella typhimurium, or Shigella flexneri or specifically with MPL® (AS04), MPL A of above-mentioned bacteria separately, saponins, such as QS-21,Quil-A, ISCOMs, ISCOMATRIX™, emulsions such as MF59™, Montanide® ISA 51 and ISA 720, AS02 (QS21+squalene+ MPL®) , liposomes and liposomal formulations such as AS01, synthesized or specifically prepared microparticles and microcarriers such as bacteria-derived outer membrane vesicles (OMV) of N. gonorrheae, Chlamydia trachomatis and others, or chitosan

particles, depot-forming agents, such as Pluronic® block co-polymers, specifically modified or prepared peptides, such as muramyl dipeptide, aminoalkyl glucosaminide 4-phosphates, such as RC529, or proteins, such as bacterial toxoids or toxin fragments. In embodiments, adjuvants comprise agonists for pattern recognition receptors (PRR), including, but not limited to Toll-Like Receptors (TLRs), specifically TLRs 2, 3, 4, 5, 7, 8, 9 and/or combinations thereof. In other embodiments, adjuvants comprise agonists for Toll-Like Receptors 3, agonists for Toll-Like Receptors 7 and 8, or agonists for Toll-Like Receptor 9; preferably the recited adjuvants comprise imidazoquinolines; such as resiquimod (also known as R848); adenine derivatives, such as those disclosed in US patent 6,329,381 (Sumitomo Pharmaceutical Company); immunostimulatory DNA; or immunostimulatory RNA. In specific embodiments, synthetic nanocarriers incorporate as adjuvants compounds that are agonists for toll-like receptors (TLRs) 7 & 8 ("TLR 7/8 agonists"). Of utility are the TLR 7/8 agonist compounds disclosed in US Patent 6,696,076 to Tomai et al., including but not limited to imidazoquinoline amines, imidazopyridine amines, 6,7-fused cycloalkylimidazopyridine amines, and 1,2-bridged imidazoquinoline amines. Preferred adjuvants comprise imiquimod and resiquimod. In specific embodiments, an adjuvant may be an agonist for the DC surface molecule CD40. In certain embodiments, a synthetic nanocarrier incorporates an adjuvant that promotes DC maturation (needed for effective priming of naive T cells) and the production of cytokines, such as type I interferons, which in turn stimulate antibody and cytotoxic immune responses against desired antigen. In embodiments, adjuvants also may comprise immunostimulatory RNA molecules, such as but not limited to dsRNA or poly I:C (a TLR3 stimulant), and/or those disclosed in F. Heil et al., "Species-Specific Recognition of Single-Stranded RNA via Toll-like Receptor 7 and 8" Science 303(5663), 1526-1529 (2004); J. Vollmer et al., "Immune modulation by chemically modified ribonucleosides and oligoribonucleotides" WO 2008033432 A2; A. Forsbach et al., "Immunostimulatory oligoribonucleotides containing specific sequence motif(s) and targeting the Toll-like receptor 8 pathway" WO 2007062107 A2; E. Uhlmann et al., "Modified oligoribonucleotide analogs with enhanced immunostimulatory activity" U.S. Pat. Appl. Publ. US 2006241076; G. Lipford et al., "Immunostimulatory viral RNA oligonucleotides and use for treating cancer and infections" WO 2005097993 A2; G. Lipford et al., "Immunostimulatory G,U-containing oligoribonucleotides, compositions, and screening methods" WO 2003086280 A2. In some embodiments, an adjuvant may be a TLR-4 agonist, such as bacterial lipopolysacccharide (LPS), VSV-G, and/or HMGB-1. In some embodiments, adjuvants may comprise TLR-5 agonists, such as flagellin, or portions or

derivatives thereof, including but not limited to those disclosed in US Patents 6,130,082, 6,585,980, and 7,192,725. In specific embodiments, synthetic nanocarriers incorporate a ligand for Toll-like receptor (TLR)-9, such as immunostimulatory DNA molecules comprising CpGs, which induce type I interferon secretion, and stimulate T and B cell activation leading to increased antibody production and cytotoxic T cell responses (Krieg et al., CpG motifs in bacterial DNA trigger direct B cell activation. Nature. 1995. 374:546-549; Chu et al. CpG oligodeoxynucleotides act as adjuvants that switch on T helper 1 (Th1) immunity. J. Exp. Med. 1997. 186:1623-1631; Lipford et al. CpG-containing synthetic oligonucleotides promote B and cytotoxic T cell responses to protein antigen: a new class of vaccine adjuvants. Eur. J. Immunol. 1997. 27:2340-2344; Roman et al. Immunostimulatory DNA sequences function as T helper-1-promoting adjuvants. Nat. Med. 1997. 3:849-854; Davis et al. CpG DNA is a potent enhancer of specific immunity in mice immunized with recombinant hepatitis B surface antigen. J. Immunol. 1998. 160:870-876; Lipford et al., Bacterial DNA as immune cell activator. Trends Microbiol. 1998. 6:496-500. In some embodiments, adjuvants may be proinflammatory stimuli released from necrotic cells (e.g., urate crystals). In some embodiments, adjuvants may be activated components of the complement cascade (e.g., CD21, CD35, etc.). In some embodiments, adjuvants may be activated components of immune complexes. The adjuvants also include complement receptor agonists, such as a molecule that binds to CD21 or CD35. In some embodiments, the complement receptor agonist induces endogenous complement opsonization of the synthetic nanocarrier. In some embodiments, adjuvants are cytokines, which are small proteins or biological factors (in the range of 5 kD – 20 kD) that are released by cells and have specific effects on cell-cell interaction, communication and behavior of other cells. In some embodiments, the cytokine receptor agonist is a small molecule, antibody, fusion protein, or aptamer.

"Administering" or "administration" means providing a drug to a patient in a manner that is pharmacologically useful.

"Allergen" refers to any agent that can cause an allergic response in a subject. Allergens include, but are not limited to, common dust, pollen, plants, animal dander, drugs (e.g., penicillin), food allergens, insect venom, fungal spores, viruses, and bacteria.

"Antigen coupling moiety" means any moiety through which an 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 antigen to the synthetic nanocarrier. Such molecules include linkers or polymers or a unit thereof.

For example, the antigen coupling moiety can comprise a charged polymer to which an antigen electrostatically binds. As another example, the antigen coupling moiety can comprise a polymer or unit thereof to which the antigen covalently bonds. In some embodiments, the moiety comprises a polyester. In other embodiments, the moiety comprises poly(ethylene glycol) (PEG), poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid), or a polycaprolactone. The moiety may also comprise a unit of any of the foregoing polymers, such as a lactide or glycolide.

"APC targeting feature" means one or more portions of which the inventive synthetic nanocarriers are comprised that target the synthetic nanocarriers to professional antigen presenting cells ("APCs"), such as but not limited to dendritic cells, SCS macrophages, follicular dendritic cells, and B cells. In embodiments, APC targeting features may comprise immunofeature surface(s) and/or targeting moieties that bind known targets on APCs. In embodiments, APC targeting features may comprise one or more B cell antigens present on a surface of synthetic nanocarriers. In embodiments, APC targeting features may also comprise one or more dimensions of the synthetic nanoparticles that is selected to promote uptake by APCs.

In embodiments, targeting moieties for known targets on macrophages ("Mphs") comprise any targeting moiety that specifically binds to any entity (e.g., protein, lipid, carbohydrate, small molecule, etc.) that is prominently expressed and/or present on macrophages (i.e., subcapsular sinus-Mph markers). Exemplary SCS-Mph markers include, but are not limited to, CD4 (L3T4, W3/25, T4); CD9 (p24, DRAP-1, MRP-1); CD11a (LFA-1α, α L Integrin chain); CD11b (αM Integrin chain, CR3, Mo1, C3niR, Mac-1); CD11c (αX Integrin, p150, 95, AXb2); CDw12 (p90-120); CD13 (APN, gp150, EC 3.4.11.2); CD14 (LPS-R); CD15 (X-Hapten, Lewis, X, SSEA-1, 3-FAL); CD15s (Sialyl Lewis X); CD15u (3' sulpho Lewis X); CD15su (6 sulpho-sialyl Lewis X); CD16a (FCRIIIA); CD16b (FcgRIIIb); CDw17 (Lactosylceramide, LacCer); CD18 (Integrin β2, CD11a,b,c β-subunit); CD26 (DPP IV ectoeneyme, ADA binding protein); CD29 (Platelet GPIIa, β-1 integrin, GP); CD31 (PECAM-1, Endocam); CD32 (FCγRII); CD33 (gp67); CD35 (CR1, C3b/C4b receptor); CD36 (GpIIIb, GPIV, PASIV); CD37 (gp52-40); CD38 (ADP-ribosyl cyclase, T10); CD39 (ATPdehydrogenase, NTPdehydrogenase-1); CD40 (Bp50); CD43 (Sialophorin, Leukosialin); CD44 (EMCRII, H-CAM, Pgp-1); CD45 (LCA, T200, B220, Ly5); CD45RA; CD45RB; CD45RC; CD45RO (UCHL-1); CD46 (MCP); CD47 (gp42, IAP, OA3, Neurophillin); CD47R (MEM-133); CD48 (Blast-1, Hulym3, BCM-1, OX-45); CD49a (VLA-1α, α1 Integrin); CD49b (VLA-2α, gpla, α2 Integrin); CD49c (VLA-3α, α3 Integrin);

CD49e (VLA-5α, α5 Integrin); CD49f (VLA-6α, α6 Integrin, gplc); CD50 (ICAM-3); CD51 (Integrin α, VNR-α, Vitronectin-Rα); CD52 (CAMPATH-1, HE5); CD53 (OX-44); CD54 (ICAM-1); CD55 (DAF); CD58 (LFA-3); CD59 (1F5Ag, H19, Protectin, MACIF, MIRL, P-18); CD60a (GD3); CD60b (9-O-acetyl GD3); CD61 (GP IIIa, β3 Integrin); CD62L (L-selectin, LAM-1, LECAM-1, MEL-14, Leu8, TQ1); CD63 (LIMP, MLA1, gp55, NGA, LAMP-3, ME491); CD64 (FcγRI); CD65 (Ceramide, VIM-2); CD65s (Sialylated-CD65, VIM2); CD72 (Ly-19.2, Ly-32.2, Lyb-2); CD74 (Ii, invariant chain); CD75 (sialo-masked Lactosamine); CD75S (α2,6 sialylated Lactosamine); CD80 (B7, B7-1, BB1); CD81 (TAPA-1); CD82 (4F9, C33, IA4, KAI1, R2); CD84 (p75, GR6); CD85a (ILT5, LIR2, HL9); CD85d (ILT4, LIR2, MIR10); CD85j (ILT2, LIR1, MIR7); CD85k (ILT3, LIR5, HM18); CD86 (B7-2/B70); CD87 (uPAR); CD88 (C5aR); CD89 (IgA Fc receptor, FcαR); CD91 (α2M-R, LRP); CDw92 (p70); CDw93 (GR11); CD95 (APO-1, FAS, TNFRSF6); CD97 (BL-KDD/F12); CD98 (4F2, FRP-1, RL-388); CD99 (MIC2, E2); CD99R (CD99 Mab restricted); CD100 (SEMA4D); CD101 (IGSF2, P126, V7); CD102 (ICAM-2); CD111 (PVRL1, HveC, PRR1, Nectin 1, HIgR); CD112 (HveB, PRR2, PVRL2, Nectin2); CD114 (CSF3R, G-CSRF, HG-CSFR); CD115 (c-fms, CSF-1R, M-CSFR); CD116 (GMCSFRα); CDw119 (IFNγR, IFNγRA); CD120a (TNFRI, p55); CD120b (TNFRII, p75, TNFR p80); CD121b (Type 2 IL-1R); CD122 (IL2Rβ); CD123 (IL-3Rα); CD124 (IL-4Rα); CD127 (p90, IL-7R, IL-7Rα); CD128a (IL-8Ra, CXCR1, (Tentatively renamed as CD181)); CD128b (IL-8Rb, CSCR2, (Tentatively renamed as CD182)); CD130 (gp130); CD131 (Common β subunit); CD132 (Common γ chain, IL-2Rγ); CDw136 (MSP-R, RON, p158-ron); CDw137 (4-1BB, ILA); CD139; CD141 (Thrombomodulin, Fetomodulin); CD147 (Basigin, EMMPRIN, M6, OX47); CD148 (HPTP-η, p260, DEP-1); CD155 (PVR); CD156a (CD156, ADAM8, MS2); CD156b (TACE, ADAM17, cSVP); CDw156C (ADAM10); CD157 (Mo5, BST-1); CD162 (PSGL-1); CD164 (MGC-24, MUC-24); CD165 (AD2, gp37); CD168 (RHAMM, IHABP, HMMR); CD169 (Sialoadhesin, Siglec-1); CD170 (Siglec 5); CD171 (L1CAM, NILE); CD172 (SIRP-1α, MyD-1); CD172b (SIRPβ); CD180 (RP105, Bgp95, Ly64); CD181 (CXCR1, (Formerly known as CD128a)); CD182 (CXCR2, (Formerly known as CD128b)); CD184 (CXCR4, NPY3R); CD191 (CCR1); CD192 (CCR2); CD195 (CCR5); CDw197 (CCR7 (was CDw197)); CDw198 (CCR8); CD204 (MSR); CD205 (DEC-25); CD206 (MMR); CD207 (Langerin); CDw210 (CK); CD213a (CK); CDw217 (CK); CD220 (Insulin R); CD221 (IGF1 R); CD222 (M6P-R, IGFII-R); CD224 (GGT); CD226 (DNAM-1, PTA1); CD230 (Prion Protein (PrP)); CD232 (VESP-R); CD244 (2B4, P38, NAIL); CD245 (p220/240); CD256 (APRIL, TALL2, TNF (ligand) superfamily, member 13); CD257 (BLYS, TALL1, TNF

(ligand) superfamily, member 13b); CD261 (TRAIL-R1, TNF-R superfamily, member 10a); CD262 (TRAIL-R2, TNF-R superfamily, member 10b); CD263 (TRAIL-R3, TNBF-R superfamily, member 10c); CD264 (TRAIL-R4, TNF-R superfamily, member 10d); CD265 (TRANCE-R, TNF-R superfamily, member 11a); CD277 (BT3.1, B7 family: Butyrophilin 3); CD280 (TEM22, ENDO180); CD281 (TLR1, TOLL-like receptor 1); CD282 (TLR2, TOLL-like receptor 2); CD284 (TLR4, TOLL-like receptor 4); CD295 (LEPR); CD298 (ATP1B3, Na K ATPase, β3 subunit); CD300a (CMRF-35H); CD300c (CMRF-35A); CD300e (CMRF-35L1); CD302 (DCL1); CD305 (LAIR1); CD312 (EMR2); CD315 (CD9P1); CD317 (BST2); CD321 (JAM1); CD322 (JAM2); CDw328 (Siglec7); CDw329 (Siglec9); CD68 (gp 110, Macrosialin); and/or mannose receptor; wherein the names listed in parentheses represent alternative names.

In embodiments, targeting moieties for known targets on dendritic cells ("DCs") comprise any targeting moiety that specifically binds to any entity (e.g., protein, lipid, carbohydrate, small molecule, etc.) that is prominently expressed and/or present on DCs (i.e., a DC marker). Exemplary DC markers include, but are not limited to, CD1a (R4, T6, HTA-1); CD1b (R1); CD1c (M241, R7); CD1d (R3); CD1e (R2); CD11b (αM Integrin chain, CR3, Mo1, C3niR, Mac-1); CD11c (αX Integrin, p150, 95, AXb2); CDw117 (Lactosylceramide, LacCer); CD19 (B4); CD33 (gp67); CD 35 (CR1, C3b/C4b receptor); CD 36 (GpIIIb, GPIV, PASIV); CD39 (ATPdehydrogenase, NTPdehydrogenase-1); CD40 (Bp50); CD45 (LCA, T200, B220, Ly5); CD45RA; CD45RB; CD45RC; CD45RO (UCHL-1); CD49d (VLA-4α, α4 Integrin); CD49e (VLA-5α, α5 Integrin); CD58 (LFA-3); CD64 (FcγRI); CD72 (Ly-19.2, Ly-32.2, Lyb-2); CD73 (Ecto-5'nucloticlase); CD74 (Ii, invariant chain); CD80 (B7, B7-1, BB1); CD81 (TAPA-1); CD83 (HB15); CD85a (ILT5, LIR3, HL9); CD85d (ILT4, LIR2, MIR10); CD85j (ILT2, LIR1, MIR7); CD85k (ILT3, LIR5, HM18); CD86 (B7-2/B70); CD88 (C5aB); CD97 (BL-KDD/F12); CD101 (IGSF2, P126, V7); CD116 (GM-CSFRα); CD120a (TMFRI, p55); CD120b (TNFRII, p75, TNFR p80); CD123 (IL-3Rα); CD139; CD148 (HPTP-η, DEP-1); CD150 (SLAM, IPO-3); CD156b (TACE, ADAM17, cSVP); CD157 (Mo5, BST-1); CD167a (DDR1, trkE, cak); CD168 (RHAMM, IHABP, HMMR); CD169 (Sialoadhesin, Siglec-1); CD170 (Siglec-5); CD171 (L1CAM, NILE); CD172 (SIRP-1α, MyD-1); CD172b (SIRPβ); CD180 (RP105, Bgp95, Ly64); CD184 (CXCR4, NPY3R); CD193 (CCR3); CD196 (CCR6); CD197 (CCR7 (ws CDw197)); CDw197 (CCR7, EBI1, BLR2); CD200 (OX2); CD205 (DEC-205); CD206 (MMR); CD207 (Langerin); CD208 (DC-LAMP); CD209 (DCSIGN); CDw218a (IL18Rα); CDw218b (IL8Rβ); CD227 (MUC1, PUM, PEM, EMA); CD230 (Prion Protein (PrP)); CD252 (OX40L, TNF (ligand)

superfamily, member 4); CD258 (LIGHT, TNF (ligand) superfamily, member 14); CD265 (TRANCE-R, TNF-R superfamily, member 11a); CD271 (NGFR, p75, TNFR superfamily, member 16); CD273 (B7DC, PDL2); CD274 (B7H1, PDL1); CD275 (B7H2, ICOSL); CD276 (B7H3); CD277 (BT3.1, B7 family: Butyrophilin 3); CD283 (TLR3, TOLL-like receptor 3); CD289 (TLR9, TOLL-like receptor 9); CD295 (LEPR); CD298 (ATP1B3, Na K ATPase β3 submit); CD300a (CMRF-35H); CD300c (CMRF-35A); CD301 (MGL1, CLECSF14); CD302 (DCL1); CD303 (BDCA2); CD304 (BDCA4); CD312 (EMR2); CD317 (BST2); CD319 (CRACC, SLAMF7); CD320 (8D6); and CD68 (gp110, Macrosialin); class II MHC; BDCA-1; Siglec-H; wherein the names listed in parentheses represent alternative names.

In embodiments, targeting can be accomplished by any targeting moiety that specifically binds to any entity (e.g., protein, lipid, carbohydrate, small molecule, etc.) that is prominently expressed and/or present on B cells (i.e., B cell marker). Exemplary B cell markers include, but are not limited to, CD1c (M241, R7); CD1d (R3); CD2 (E-rosette R, T11, LFA-2); CD5 (T1, Tp67, Leu-1, Ly-1); CD6 (T12); CD9 (p24, DRAP-1, MRP-1); CD11a (LFA-1α, αL Integrin chain); CD11b (αM Integrin chain, CR3, Mo1, C3niR, Mac-1); CD11c (αX Integrin, P150, 95, AXb2); CDw17 (Lactosylceramide, LacCer); CD18 (Integrin β2, CD11a, b, c β-subunit); CD19 (B4); CD20 (B1, Bp35); CD21 (CR2, EBV-R, C3dR); CD22 (BL-CAM, Lyb8, Siglec-2); CD23 (FceRII, B6, BLAST-2, Leu-20); CD24 (BBA-1, HSA); CD25 (Tac antigen, IL-2Rα, p55); CD26 (DPP IV ectoeneyme, ADA binding protein); CD27 (T14, S152); CD29 (Platelet GPIIa, β-1 integrin, GP); CD31 (PECAM-1, Endocam); CD32 (FCγRII); CD35 (CR1, C3b/C4b receptor); CD37 (gp52-40); CD38 (ADPribosyl cyclase, T10); CD39 (ATPdehydrogenase, NTPdehydrogenase-1); CD40 (Bp50); CD44 (ECMRII, H-CAM, Pgp-1); CD45 (LCA, T200, B220, Ly5); CD45RA; CD45RB; CD45RC; CD45RO (UCHL-1); CD46 (MCP); CD47 (gp42, IAP, OA3, Neurophilin); CD47R (MEM-133); CD48 (Blast-1, Hulym3, BCM-1, OX-45); CD49b (VLA-2α, gpla, α2 Integrin); CD49c (VLA-3α, α3 Integrin); CD49d (VLA-4α, α4 Integrin); CD50 (ICAM-3); CD52 (CAMPATH-1, HES); CD53 (OX-44); CD54 (ICAM-1); CD55 (DAF); CD58 (LFA-3); CD60a (GD3); CD62L (L-selectin, LAM-1, LECAM-1, MEL-14, Leu8, TQ1); CD72 (Ly-19.2, Ly-32.2, Lyb-2); CD73 (Ecto-5'-nuciotidase); CD74 (Ii, invariant chain); CD75 (sialo-masked Lactosamine); CD75S (α2, 6 sialytated Lactosamine); CD77 (Pk antigen, BLA, CTH/Gb3); CD79a (Igα, MB1); CD79b (Igβ, B29); CD80; CD81 (TAPA-1); CD82 (4F9, C33, IA4, KAI1, R2); CD83 (HB15); CD84 (P75, GR6); CD85j (ILT2, LIR1, MIR7); CDw92 (p70); CD95 (APO-1, FAS, TNFRSF6); CD98 (4F2, FRP-1, RL-388); CD99

(MIC2, E2); CD100 (SEMA4D); CD102 (ICAM-2); CD108 (SEMA7A, JMH blood group antigen); CDw119 (IFNγR, IFNγRa); CD120a (TNFRI, p55); CD120b (TNFRII, p75, TNFR p80); CD121b (Type 2 IL-1R); CD122 (IL2Rβ); CD124 (IL-4Rα); CD130 (gp130); CD132 (Common γ chain, IL-2Rγ); CDw137 (4-1BB, ILA); CD139; CD147 (Basigin, EMMPRIN, M6, OX47); CD150 (SLAM, IPO-3); CD162 (PSGL-1); CD164 (MGC-24, MUC-24); CD166 (ALCAM, KG-CAM, SC-1, BEN, DM-GRASP); CD167a (DDR1, trkE, cak); CD171 (L1CMA, NILE); CD175s (Sialyl-Tn (S-Tn)); CD180 (RP105, Bgp95, Ly64); CD184 (CXCR4, NPY3R); CD185 (CXCR5); CD192 (CCR2); CD196 (CCR6); CD197 (CCR7 (was CDw197)); CDw197 (CCR7, EBI1, BLR2); CD200 (OX2); CD205 (DEC-205); CDw210 (CK); CD213a (CK); CDw217 (CK); CDw218a (IL18Rα); CDw218b (IL18Rβ); CD220 (Insulin R); CD221 (IGF1 R); CD222 (M6P-R, IGFII-R); CD224 (GGT); CD225 (Leu13); CD226 (DNAM-1, PTA1); CD227 (MUC1, PUM, PEM, EMA); CD229 (Ly9); CD230 (Prion Protein (Prp)); CD232 (VESP-R); CD245 (p220/240); CD247 (CD3 Zeta Chain); CD261 (TRAIL-R1, TNF-R superfamily, member 10a); CD262 (TRAIL-R2, TNF-R superfamily, member 10b); CD263 (TRAIL-R3, TNF-R superfamily, member 10c); CD264 (TRAIL-R4, TNF-R superfamily, member 10d); CD265 (TRANCE-R, TNF-R superfamily, member 11a); CD267 (TACI, TNF-R superfamily, member 13B); CD268 (BAFFR, TNF-R superfamily, member 13C); CD269 (BCMA, TNF-R superfamily, member 16); CD275 (B7H2, ICOSL); CD277 (BT3.1.B7 family: Butyrophilin 3); CD295 (LEPR); CD298 (ATP1B3 Na K ATPase β3 subunit); CD300a (CMRF-35H); CD300c (CMRF-35A); CD305 (LAIR1); CD307 (IRTA2); CD315 (CD9P1); CD316 (EW12); CD317 (BST2); CD319 (CRACC, SLAMF7); CD321 (JAM1); CD322 (JAM2); CDw327 (Siglec6, CD33L); CD68 (gp 100, Macrosialin); CXCR5; VLA-4; class II MHC; surface IgM; surface IgD; APRL; and/or BAFF-R; wherein the names listed in parentheses represent alternative names. Examples of markers include those provided elsewhere herein.

In some embodiments, B cell targeting can be accomplished by any targeting moiety that specifically binds to any entity (e.g., protein, lipid, carbohydrate, small molecule, etc.) that is prominently expressed and/or present on B cells upon activation (i.e., activated B cell marker). Exemplary activated B cell markers include, but are not limited to, CD1a (R4, T6, HTA-1); CD1b (R1); CD15s (Sialyl Lewis X); CD15u (3' sulpho Lewis X); CD15su (6 sulpho-sialyl Lewis X); CD30 (Ber-H2, Ki-1); CD69 (AIM, EA 1, MLR3, gp34/28, VEA); CD70 (Ki-24, CD27 ligand); CD80 (B7, B7-1, BB1); CD86 (B7-2/B70); CD97 (BLKDD/F12); CD125 (IL-5Rα); CD126 (IL-6Rα); CD138 (Syndecan-1, Heparan sulfate proteoglycan); CD152 (CTLA-4); CD252 (OX40L, TNF(ligand) superfamily, member 4);

CD253 (TRAIL, TNF(ligand) superfamily, member 10); CD279 (PD1); CD289 (TLR9, TOLL-like receptor 9); and CD312 (EMR2); wherein the names listed in parentheses represent alternative names. Examples of markers include those provided elsewhere herein.

"A(rel) %" is defined as a weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours divided by the sum of the weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours plus a weight of antigen retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers. t is defined herein as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 18, 24, 30, 36, 42 or 48 hours. In preferred embodiments, t is 12, 24, or 48 hours.

"B cell antigen" means any antigen that naturally is or could be engineered to be recognized by a B cell, and triggers (naturally or being engineered as known in the art) an immune response in a B cell (e.g., an antigen that is specifically recognized by a B cell receptor on a B cell). 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 is a non-protein antigen (i.e., not a protein or peptide antigen). In some embodiments, the B cell antigen is a carbohydrate associated with an infectious agent. In some embodiments, the B cell antigen is a glycoprotein or glycopeptide associated with an infectious agent. The infectious agent can be a bacterium, virus, fungus, protozoan, parasite or prion. In some embodiments, the B cell antigen is a poorly immunogenic antigen. In some embodiments, the B cell antigen is an abused substance or a portion thereof. In some embodiments, the B cell antigen is an addictive substance or a portion thereof. Addictive substances include, but are not limited to, nicotine, a narcotic, a cough suppressant, a tranquilizer, and a sedative. In some embodiments, the B cell antigen is a toxin, such as a toxin from a chemical weapon or natural sources, or a pollutant. The B cell antigen may also be a hazardous environmental agent. In other embodiments, the B cell antigen is an alloantigen, an allergen, a contact sensitizer, a degenerative disease antigen, a hapten, an infectious disease antigen, a cancer antigen, an atopic disease antigen, an addictive substance, a xenoantigen, or a metabolic disease enzyme or enzymatic product thereof.

"Biodegradable polymer" means a polymer that degrades over time when introduced into the body of a subject. Biodegradable polymers, include but are not limited to, polyesters, polycarbonates, polyketals, or polyamides. Such polymers may comprise poly(lactic acid),

poly(glycolic acid), poly(lactic-co-glycolic acid), or polycaprolactone. In some embodiments, the biodegradable polymer comprises a block-co-polymer of a polyether, such as poly(ethylene glycol), and a polyester, polycarbonate, or polyamide or other biodegradable polymer. In embodiments, the biodegradable polymer comprises a block-co-polymer of poly(ethylene glycol) and poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid), or polycaprolactone. In some embodiments, however, the biodegradable polymer does not comprise a polyether, such as poly(ethylene glycol), or consists solely of the polyether. Generally, for use as part of a synthetic nanocarrier the biodegradable polymer is insoluble in water at pH = 7.4 and at 25°C. The biodegradable polymer, in embodiments, have a weight average molecular weight ranging from about 800 to about 50,000 Daltons, as determined using gel permeation chromatography. In some embodiments, the weight average molecular weight is from about 800 Daltons to about 10,000 Daltons, preferably from 800 Daltons to 10,000 Daltons, as determined using gel permeation chromatography. In other embodiments, the weight average molecular weight is from 1000 Daltons to 10,000 Daltons, as determined by gel permeation chromatography. In an embodiment, the biodegradable polymer does not comprise polyketal or unit thereof.

"Couple" or "Coupled" or "Couples" (and the like) means attached to or contained within the synthetic nanocarrier. In some embodiments, the coupling is covalent. In some embodiments, the covalent coupling is mediated by one or more linkers. In some embodiments, the coupling is non-covalent. In some embodiments, the non-covalent coupling is mediated by charge interactions, affinity interactions, metal coordination, physical adsorption, hostguest 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, the coupling may arise in the context of encapsulation within the synthetic nanocarriers, using conventional techniques. Any of the aforementioned couplings may be arranged to be on a surface or within an inventive synthetic nanocarrier.

"Derived" means adapted or modified from the original source. For example, as a non-limiting example, a peptide antigen derived from an infectious strain may have several non-natural amino acid residues substituted for the natural amino acid residues found in the original antigen found in the infectious strain. The adaptations or modifications may be for a variety of reasons, including but not limited to increased specificity, easier antigen processing, or improved safety.

"Dosage form" means a drug in a medium, carrier, vehicle, or device suitable for administration to a subject.

"Effective amount" of an inventive composition is that amount effective for a certain purpose. For example, when the effective amount is for a therapeutic purpose the amount is effective for treating, alleviating, ameliorating, relieving, delaying onset of, inhibiting progression of, reducing severity of, and/or reducing incidence of one or more symptoms or features of a disease, disorder, and/or condition provided herein.

"Encapsulate" means to enclose within a synthetic nanocarrier, preferably enclose completely within a synthetic nanocarrier. Most or all of a substance that is encapsulated is not exposed to the local environment external to the synthetic nanocarrier. Encapsulation is distinct from absorbtion, 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.

"Exhibits a pH sensitive dissociation" means that a coupling between two entities, such as the immunomodulatory agent or antigen and the synthetic nanocarrier or immunomodulatory agent or antigen coupling moiety, respectively, is significantly reduced or eliminated by a change in environmental pH. In embodiments, relevant pH sensitive dissociations may satisfy any of the relationships provided herein. In general, the coupling between the immunomodulatory agent and synthetic nanocarrier is more significantly reduced or eliminated at a pH of 4.5 than the coupling between the antigen and synthetic nanocarrier. The relationships that define the dissociation of immunodulatory agent and antigen is provide elsewhere herein.

"IA(rel) %" is defined as a weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours divided by the sum of the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours plus a weight of immunomodulatory agent retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for t hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers. t is defined herein as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 18, 24, 30, 36, 42 or 48 hours. In preferred embodiments, t is 12, 24, or 48 hours.

"Immunomodulatory agent" means an agent that modulates an immune response. "Modulate", as used herein, refers to inducing, enhancing, stimulating, or directing an immune response. Such agents include adjuvants that stimulate (or boost) an immune

response to an antigen but is not an antigen or derived from an antigen. In some embodiments, the immunomodulatory agent is on the surface of the synthetic nanocarrier and/or is incorporated within the synthetic nanocarrier. In embodiments, the immunomodulatory agent is coupled to the synthetic nanocarrier via a polymer or unit thereof.

In some embodiments, all of the immunomodulatory agents of a synthetic nanocarrier are identical to one another. In some embodiments, a synthetic nanocarrier comprises a number of different types of immunomodulatory agents. In some embodiments, a synthetic nanocarrier comprises multiple individual immunomodulatory agents, all of which are identical to one another. In some embodiments, a synthetic nanocarrier comprises exactly one type of immunomodulatory agent. In some embodiments, a synthetic nanocarrier comprises exactly two distinct types of immunomodulatory agents. In some embodiments, a synthetic nanocarrier comprises greater than two distinct types of immunomodulatory agents.

"Immunomodulatory agent coupling moiety" is any moiety through which an immunomodulatory agent 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 immunomodulatory agent to the synthetic nanocarrier. Such molecules include linkers or polymers or a unit thereof. For example, the immunomodulatory agent coupling moiety can comprise a charged polymer to which an immunomodulatory agent (e.g., an immunostimulatory nucleic acid) electrostatically bonds. As another example, the immunomodulatory agent coupling moiety can comprise a polymer or unit thereof to which the immunomodulatory agent covalently bonds. In some embodiments, the moiety comprises a polyester. In other embodiments, the moiety comprises poly(ethylene glycol), poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid), or a polycaprolactone. The moiety may also comprise a unit of any of the foregoing polymers, such as a lactide or glycolide.

"Infectious agent" refers to any agent that is derived from a bacterium, fungus, virus, protozoan, or parasite. In some embodiments, the virus is a pox virus, smallpox virus, ebola virus, marburg virus, dengue fever virus, influenza virus, parainfluenza virus, respiratory syncytial virus, rubeola virus, human immunodeficiency virus, human papillomavirus, varicella-zoster virus, herpes simplex virus, cytomegalovirus, Epstein-Barr virus, JC virus, rhabdovirus, rotavirus, rhinovirus, adenovirus, papillomavirus, parvovirus, picornavirus, poliovirus, virus that causes mumps, virus that causes rabies, reovirus, rubella virus, togavirus, orthomyxovirus, retrovirus, hepadnavirus, coxsackievirus, equine encephalitis

virus, Japanese encephalitis virus, yellow fever virus, Rift Valley fever virus, hepatitis A virus, hepatitis B virus, hepatitis C virus, hepatitis D virus, or hepatitis E virus.

"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 spheriodal 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 cubic 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 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 equal to or greater than 110 nm, more preferably equal to or greater than 120 nm, more preferably equal to or greater than 130 nm, and more preferably still equal to or greater than 150 nm. 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 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 greater than 100nm, more preferably equal to or greater than 120, 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 sizes is obtained by suspending the synthetic nanocarriers in a liquid (usually aqueous) media and using dynamic light scattering (e.g. using a Brookhaven ZetaPALS instrument).

"Obtained" means taken without adaptation or modification from the original source. For example, in embodiments, antigens obtained from a source may comprise the original amino acid residue sequence found in that source. In other embodiments, for example, antigens obtained from a source may comprise the original molecular structure found in that source.

"Pharmaceutically acceptable excipient" means a pharmacologically inactive substance added to an inventive composition to further facilitate administration of the composition. Examples, without limitation, of pharmaceutically acceptable excipients include calcium carbonate, calcium phosphate, various diluents, various sugars and types of starch, cellulose derivatives, gelatin, vegetable oils and polyethylene glycols.

"Poorly immunogenic antigen" refers to an antigen that does not trigger any or a sufficient level of a desired immune response. "Sufficient", as used herein, refers to the ability to elicit a detectable or protective immune response when administered in a composition that does not employ a nanocarrier described herein, e.g., as free antigen mixed with adjuvant in the absence of a nanocarrier. In some embodiments, the desired immune response is to treat or prevent a disease or condition. In certain embodiments, the desired immune response is to alleviate one or more symptoms of a disease or condition. Poorly immunogenic antigens include, but are not limited to, small molecules, and carbohydrates.

"Release Rate" means the rate that a coupled immunomodulatory agent or antigen flows from the particle into a surrounding media in an in vitro release test. First, the synthetic nanocarrier is prepared for the release testing by placing it into the appropriate in vitro release media. This is generally done by exchanging the buffer after centrifugation to pellet the synthetic nanocarrier and reconstitution of the synthetic nanocarriers under a mild condition. The assay is started by placing the sample at 37°C in an appropriate temperature-controlled apparatus. A sample is removed at various time points. In general, the bonding of an antigen to the synthetic nanocarrier via the antigen coupling moiety is more stable at a physiological pH (e.g., pH 4.5) than the bonding of an immunomodulatory agent to the synthetic nanocarrier via the immunomodulatory agent coupling moiety. In embodiments, the bonding of the antigen to the synthetic nanocarrier is less pH sensitive than the bonding of the immunomodulatory agent to the synthetic nanocarrier. In embodiments, the stability of the bonding of an antigen to a synthetic nanocarrier is determined by measuring the amount of the antigen released from the synthetic nanocarrier. In embodiments, the amount of antigen released from the synthetic nanocarrier is not significantly different at a pH of 4.5 than at a pH of 7.4. In embodiments, the amount of antigen released from the synthetic

nanocarrier at a pH of 4.5 is less than the amount of immunomodulatory agent released from the synthetic nanocarrier. In embodiments, the amount of antigen released is not detectable at a pH of 7.4 or 4.5.

The synthetic nanocarriers are separated from the release media by centrifugation to pellet the synthetic nanocarriers. The release media is assayed for the immunomodulatory agent or antigen that has dispersed from the synthetic nanocarriers. The immunomodulatory agent or antigen is measured using HPLC to determine the content and quality of the immunomodulatory agent or antigen. The pellet containing the remaining entrapped immunomodulatory agent or antigen is dissolved in solvents or hydrolyzed by base to free the entrapped immunomodulatory agent or antigen from the synthetic nanocarriers. The pellet-containing immunomodulatory agent or antigen is then also measured by HPLC to determine the content and quality of the immunomodulatory agent or antigen that has not been released at a given time point.

The mass balance is closed between immunomodulatory agent or antigen that has been released into the release media and what remains in the synthetic nanocarriers. Data are presented as the fraction released or as the net release presented as micrograms released over time.

"Small molecule" is understood in the art to be an organic molecule that is less than about 2000 g/mol in size. In some embodiments, the small molecule is less than about 1500 g/mol or less than about 1000 g/mol. In some embodiments, the small molecule is less than about 800 g/mol or less than about 500 g/mol. In some embodiments, small molecules are non-polymeric and/or non-oligomeric. In some embodiments, small molecules are not proteins, peptides, or amino acids. In some embodiments, small molecules are not nucleic acids or nucleotides. In some embodiments, small molecules are not saccharides or polysaccharides.

"Subject" means an animal, including 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; and the like.

"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 expressly included as synthetic nanocarriers.

Synthetic nanocarriers include polymeric nanoparticles. In some embodiments, synthetic nanocarriers can comprise one or more polymeric matrices. The synthetic nanocarriers, however, can also include other nanomaterials and may be, for example, lipid-

polymer nanoparticles. In some embodiments, a polymeric matrix can be surrounded by a coating layer (e.g., liposome, lipid monolayer, micelle, etc.). In some embodiments, the synthetic nanocarrier is not 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, the various elements of the synthetic nanocarriers can be coupled with the polymeric matrix.

The synthetic nanocarriers may 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 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.).

The synthetic nanocarriers may comprise lipid-based nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles, peptide or protein-based particles (such as albumin nanoparticles). Synthetic nanocarriers may be a variety of different shapes, including but not limited to spheroidal, cubic, 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 U.S. Patent 5,543,158 to Gref et al., (2) the polymeric nanoparticles of Published U.S. Patent Application 20060002852 to Saltzman et al., (3) the lithographically constructed nanoparticles of Published U.S. Patent Application 20090028910 to DeSimone et al., (4) the disclosure of WO 2009/051837 to von Andrian et al., or (5) the nanoparticles disclosed in Published U.S. Patent Application 2008/0145441 to Penades et al.

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 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.

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.

It is often 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 may have a minimum dimension or maximum dimension that falls within 5%, 10%, or 20% of the average diameter or average dimension. 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.

"T cell antigen" means any antigen that is recognized by and triggers an immune response in a T cell (e.g., an antigen that is specifically recognized by a T cell receptor on a T cell or an NKT cell via presentation of the antigen or portion thereof bound to a Class I or Class II major histocompatability complex molecule (MHC), or bound to a CD1 complex). 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 cell antigens may be an antigen that stimulates a CD8+ T cell response, a CD4+ T cell response, or both. The T cell antigens, therefore, in some embodiments can effectively stimulate both types of responses.

In some embodiments the T cell antigen is a T-helper antigen, which is a T cell antigen that can generate an augmented response to an unrelated B cell antigen through stimulation of T cell help. In embodiments, a T-helper antigen may comprise one or more peptides derived from tetanus toxoid, Epstein-Barr virus, influenza virus, respiratory syncytial virus, measles virus, mumps virus, rubella virus, cytomegalovirus, adenovirus, diphtheria toxoid, or a PADRE peptide. In other embodiments, a T-helper antigen may comprise one or more lipids, or glycolipids, including but not limited to: α-galactosylceramide (α-GalCer), α-linked glycosphingolipids (from *Sphingomonas* spp.), galactosyl diacylglycerols (from *Borrelia burgdorferi*), lypophosphoglycan (from *Leishmania donovani*), and phosphatidylinositol tetramannoside (PIM4) (from *Mycobacterium leprae*). For additional lipids and/or glycolipids useful as T-helper antigens, see V. Cerundolo et al., "Harnessing invariant NKT cells in vaccination strategies." Nature Rev Immun, 9:28-38 (2009). In embodiments, CD4+ T-cell antigens may be derivatives of a CD4+ T-cell antigen that is obtained from a source, such as a natural source. In such embodiments, CD4+ T-cell antigen sequences, such as those peptides that bind to MHC II, may have at least 70%, 80%, 90%, or 95% identity to the antigen obtained from the source. In embodiments, the T cell antigen, preferably a T-helper antigen, may be coupled to, or uncoupled from, a synthetic nanocarrier.

"Unit thereof" refers to a monomeric unit of a polymer, the polymer generally being made up of a series of linked monomers.

"Vaccine" means a composition of matter that improves the immune response to a particular pathogen or disease. A vaccine typically contains factors that stimulate a subject's immune system to recognize a specific antigen as foreign and eliminate it from the subject's body. A vaccine also establishes an immunologic 'memory' so the antigen will be quickly recognized and responded to if a person is re-challenged. Vaccines can be prophylactic (for example to prevent future infection by any pathogen), or therapeutic (for example a vaccine against a tumor specific antigen for the treatment of cancer). Vaccines according to the invention may comprise one or more of the synthetic nanocarriers or compositions provided herein.

METHODS OF MAKING THE INVENTIVE COMPOUNDS, CONJUGATES, OR SYNTHETIC NANOCARRIERS

The immunomodulatory agent and antigen can be coupled to the synthetic nanocarrier in any manner such that the dissociation of the immunomodulatory agent and antigen from the synthetic nanocarrier satisfies a dissociation relationship provided herein. Methods for determining whether or not a dissociation relationship is satisfied is provided elsewhere above and in the **EXAMPLES**.

In some embodiments, the immunomodulatory agent and/or antigen can be coupled (e.g., covalently) to the synthetic nanocarrier via an immunomodulatory agent coupling moiety or antigen coupling moiety, respectively. In some embodiments, the synthetic nanocarrier is comprised of polymers, such as biodegradable polymers (e.g., low molecular weight biodegradable polymers), and the immunomodulatory agent and/or antigen is coupled via an immunomodulatory agent coupling moiety or antigen coupling moiety, respectively, to the polymer. Methods for coupling immunomodulatory agents and antigens to polymers to form inventive synthetic nanocarriers are provided below as well as elsewhere herein including in the **EXAMPLES**.

Antigen coupling moieties can be synthesized using techniques to reduce their tendency for pH sensitive dissociation. Such techniques may include removing, or reducing the number of, chemical bonds present in the antigen coupling moieties that are sensitive to cleavage due to environmental pH effects. Less sensitive bonds may be substituted instead. Other techniques may involve use of sterically hindering chemical bonds that are sensitive to acidic or basic degradation.

Methods of synthesizing acid/base stable antigen coupling moieties include click chemistry to form triazole via 1,3 dipolar cyclization of an alkyne with an azide, Diels-Alder cycloaddition to form six-membered heterocycles, Michael addition or epoxide opening by thiol group to form Sulfur-carbon bond, nitrogen-carbon bond by epoxide opening with amine or reductive amination of amine with aldehyde or ketone, formations of ureas and carbamates by the reaction of amine with isocyanate or cyanate, sulfur-sulfur bond by oxidation, or epoxide opening with amine. In embodiments, the reactive group such as thiol, amine, alkyne or azide or double bond can be part of the antigen. In embodiments, such a reactive group could be part of, for example, one of the amino acid such as cysteine (thiol) or lysine (amino group) or added to the antigen via peptide or similar chemistry.

Additionally, the antigen may be contained within the synthetic nanocarrier such that it is exposed to the environment after the immunomodulatory agent is so exposed. For

example, the synthetic nanocarrier can be composed of two or more layers, and the antigen can be coupled to an inner layer, while the immunomodulatory agent may be coupled to an outer layer. As another example, an immunomodulatory agent can be coupled to the surface of the synthetic nanocarrier, while the antigen is encapsulated within the synthetic nanocarrier.

In contrast, immunomodulatory agent coupling moieties can be synthesized using techniques to increase their tendency for pH sensitive dissociation. Such techniques may include including, or increasing the number of, chemical bonds present in the antigen coupling moieties that are sensitive to cleavage due to environmental pH effects. Such bonds are described in more detail below.

The following methods or any step of the methods provided are exemplary and may be carried out under any suitable conditions. In some cases, the reaction or any step of the methods provided may be carried out in the presence of a solvent or a mixture of solvents. Non-limiting examples of solvents that may be suitable for use in the invention include, but are not limited to, *p*-cresol, toluene, xylene, mesitylene, diethyl ether, glycol, petroleum ether, hexane, cyclohexane, pentane, dichloromethane (or methylene chloride), chloroform, dioxane, tetrahydrofuran (THF), dimethyl sulfoxide (DMSO), dimethylformamide (DMF), ethyl acetate (EtOAc), triethylamine, acetonitrile, methyl-*t*-butyl ether (MTBE), *N*-methylpyrrolidone (NMP), dimethylacetamide (DMAC), isopropanol (IPA), mixtures thereof, or the like. In some cases, the solvent is selected from the group consisting of ethyl acetate, methylene chloride, THF, DMF, NMP, DMAC, DMSO, and toluene, or a mixture thereof.

A reaction or any step of the methods provided may be carried out at any suitable temperature. In some cases, a reaction or any step of the methods provided is carried out at about room temperature (e.g., about 25 °C, about 20 °C, between about 20 °C and about 25 °C, or the like). In some cases, however, the reaction or any step of the methods provided may be carried out at a temperature below or above room temperature, for example, at about -20 °C, at about -10 °C, at about 0 °C, at about 10 °C, at about 30 °C, about 40 °C, about 50 °C, about 60 °C, about 70 °C, about 80 °C, about 90 °C, about 100 °C , about 120 °C, about 140 °C, about 150 °C or greater. In particular embodiments, the reaction or any step of the methods provided is conducted at temperatures between 0 °C and 120 °C. In some embodiments, the reaction or any step of the methods provided may be carried out at more than one temperature (e.g., reactants added at a first temperature and the reaction mixture

agitated at a second wherein the transition from a first temperature to a second temperature may be gradual or rapid).

The reaction or any step of the methods provided may be allowed to proceed for any suitable period of time. In some cases, the reaction or any step of the methods provided is allowed to proceed for about 10 minutes, about 20 minutes, about 30 minutes, about 40 minutes, about 50 minutes, about 1 hour, about 2 hours, about 4 hours, about 8 hours, about 12 hours, about 16 hours, about 24 hours, about 2 days, about 3 days, about 4 days, or more. In some cases, aliquots of the reaction mixture may be removed and analyzed at an intermediate time to determine the progress of the reaction or any step of the methods provided. In some embodiments, a reaction or any step of the methods provided may be carried out under an inert atmosphere in anhydrous conditions (e.g., under an atmosphere of nitrogen or argon, anhydrous solvents, etc.)

The reaction products and/or intermediates may be isolated (e.g., via distillation, column chromatography, extraction, precipitation, etc.) and/or analyzed (e.g., gas liquid chromatography, high performance liquid chromatography, nuclear magnetic resonance spectroscopy, etc.) using commonly known techniques. In some cases, a synthetic nanocarrier may be analyzed to determine the loading of immunomodulatory agent or antigen, for example, using reverse phase HPLC.

The polymers may have any suitable molecular weight. For example, the polymers may have a low or high molecular weight. Non-limiting molecular weight values include 100 Da, 200 Da, 300 Da, 500 Da, 750 Da, 1000 Da, 2000 Da, 3000 Da, 4000 Da, 5000 Da, 6000 Da, 7000 Da, 8000 Da, 9000 Da, 10,000 Da, or greater. In some embodiments, the polymers have a weight average molecular weight of about 800 Da to about 10,000 Da. In other embodiments, any of the polymers provided herein has a weight average molecular weight of about 800 Da to 10,000 Da (e.g., 2,000 Da). The molecular weight of a polymer may be determined using gel permeation chromatography.

In some embodiments, the polymer is insoluble in water at pH = 7.4 and at 25°C, is biodegradable, or both. In other embodiments, the polymer is insoluble in water at pH = 7.4 and at 25°C but soluble at pH = 4.5 and at 25°C. In still other embodiments, the polymer is insoluble in water at pH = 7.4 and at 25°C but soluble at pH = 4.5 and at 25°C and biodegradable.

In some embodiments, the polymer comprises a polyester, polycarbonate, polyamide, or polyether. In other embodiments, the polymer comprises poly(ethylene glycol) (PEG), poly(lactic acid), poly(glycolic acid), poly(lactic-co-glycolic acid), or a polycaprolactone. In

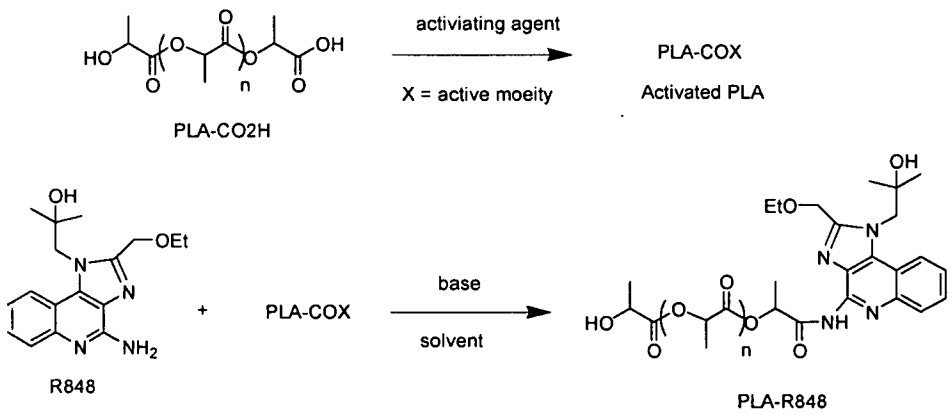
some embodiments, it is preferred that the polymer is biodegradable. Therefore, in these embodiments, it is preferred that if the polymer comprises a polyether, such as poly(ethylene glycol) or unit thereof, the polymer comprises a block-co-polymer of a polyether and a biodegradable polymer such that the polymer is biodegradable. In other embodiments, the polymer does not solely comprise a polyether, such as poly(ethylene glycol). The coupling moieties as provided herein, therefore, can comprise one of the aforementioned polymers or a unit thereof (e.g., a lactide or glycolide).

Provided below are exemplary reactions that are not intended to be limiting. The immunomodulatory agent to an immunomodulatory agent coupling moiety according to one these exemplary reactions.

Method 1

A polymer (e.g., PLA, PLGA) or unit thereof with at least one acid end groups is converted to a reactive acylating agent such as an acyl halide, acylimidazole, active ester, etc. using an activating reagent commonly used in amide synthesis.

In this two-step method, the resulting activated polymer or unit thereof (e.g., PLA, PLGA) is isolated and then reacted with an immunomodulatory agent (e.g., R848) in the presence of a base to give the desired conjugate (e.g., PLA-R848), for example, as shown in the following scheme:



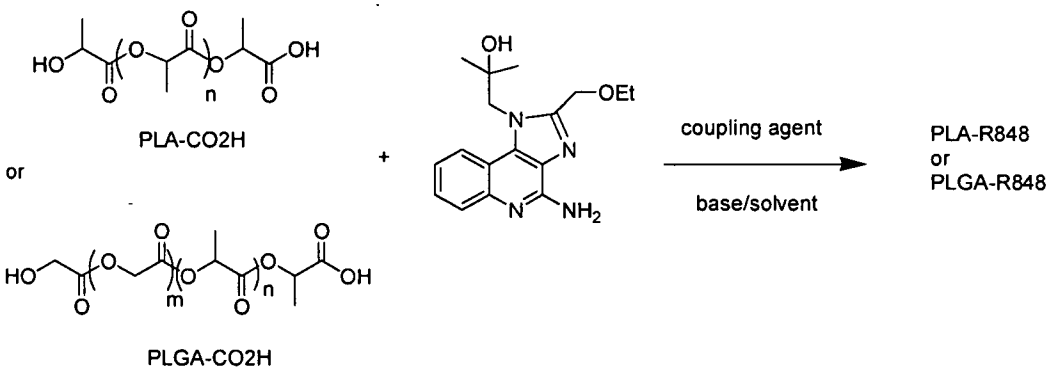
Activating reagents that can be used to convert polymers or units thereof, such as PLA or PLGA, to an activated acylating form include, but are not limited to cyanuric fluoride, N,N-tetramethylfluoroformamidinium hexafluorophosphate (TFFH); Acylimidazoles, such as carbonyl diimidazole (CDI), N,N'-carbonylbis(3-methylimidazolium) triflate (CBMIT); and Active esters, such as N-hydroxylsuccinimide (NHS or HOSu) in the presence of a carbodiimide such as N,N'-dicyclohexylcarbodiimide (DCC), N-ethyl-N'-(3-(dimethylamino)propyl)carbodiimide hydrochloride (EDC) or N, N'-

diisopropylcarbodiimide (DIC); N,N'-disuccinimidyl carbonate (DSC); pentaflurophenol in the presence of DCC or EDC or DIC; pentafluorophenyl trifluoroacetate.

The activated polymer or unit thereof may be isolated (e.g., via precipitation, extraction, etc.) and/or stored under suitable conditions (e.g., at low temperature, under argon) following activation, or may be used immediately. The activated polymer or unit thereof may be reacted with an immunomodulatory agent under any suitable conditions. In some cases, the reaction is carried out in the presence of a base and/or catalyst. Non-limiting examples of bases/catalysts include diisopropylethylamine (DIPEA) and 4-dimethylaminopyridine (DMAP).

Method 2

A polymer or unit thereof (e.g., PLA, PLGA having any suitable molecular weight) with an acid end group reacts with an immunomodulatory agent (e.g., R848) in the presence of an activating or coupling reagent, which converts the polymer or unit thereof (e.g., PLA, PLGA) to a reactive acylating agent in situ, to give the desired conjugate (e.g., PLA-R848, PLGA-R848).

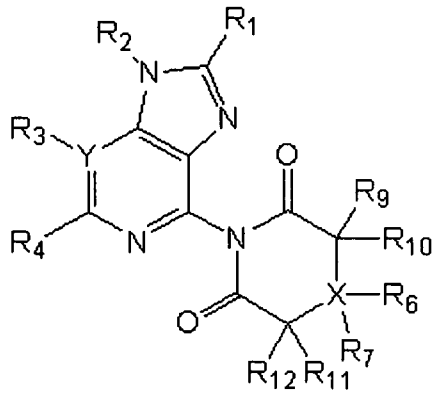


Coupling or activating agents include but are not limited to: activating agents used in the presence of an carbodiimide such as EDC or DCC or DIC, such as 1-Hydroxybenzotriazole (HOBt), 1-Hydroxy-7-azabenzotriazole (HOAt), 3,4-Dihydro-3-hydroxy-4-oxo-1,2,3-benzotriazine (HO-Dhbt), N-Hydroxysuccinimide (NHS or HOSu), Pentafluorophenol (PFP); Activating agents without carbodiimide: Phosphonium salts, such as O-Benzotriazol-1-yloxytris(dimethylamino) phosphonium hexafluorophosphate (BOP), O-Benzotriazol-1-yloxytris(pyrrolidino)phosphonium hexafluorophosphate (PyBOP), 7-Azabenzotriazol-1-yloxytris(pyrrolidino)phosphonium hexafluorophosphate (PyAOP); uronium salts such as O-Benzotriazol-1-yloxytris-1,1,3,3-tetramethyluronium tetrafluoroborate (TBTU) and hexafluorophosphate (HBTU), O-(7-Azabenzotriazol-1-yl)-1,1,3,3-tetramethyluronium hexafluorophosphate (HATU), O-(1,2-dihydro-2-oxo-1-pyridyl)-

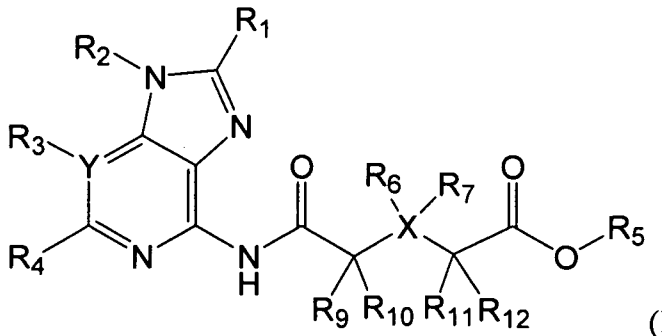
1,1,3,3-tetramethyl-uronium tetrafluoroborate (TPTU); Halouronium and halophosphonium salts such as bis(tetramethylene)fluoroformamidinium hexafluorophosphate (BTFFH), bromotris(dimethylamino) phosphonium hexafluoro-phosphate (BroP), bromotripyrrolidino phosphonium hexafluorophosphate (PyBroP) and chlorotripyrrolidino phosphonium hexafluorophosphate (PyClop); Benzotriazine derivatives such as O-(3,4-Dihydro-4-oxo-1,2,3-benzotriazine-3-yl)-N,N,N',N'-tetramethyluronium tetrafluoroborate (TDBTU) and 3-(diethyloxyphosphoryloxy)-1,2,3-benzotriazin-4(3H)-one (DEPBT). Non-limiting examples of suitable solvents include DMF, DCM, toluene, ethyl acetate, etc., as described herein.

Method 3

Immunomodulatory agents, such as R848, can also be coupled to polymers or units thereof that are terminated in a hydroxyl group. Such polymers or units thereof include polyethylene glycol, polylactide, polylactide-co-glycolide, polycaprolactone, and other like polyesters, or units thereof. In general, the reaction proceeds as follows where an imide of the general structure (IV) will react with the terminal hydroxyl of the aforementioned polymers or units thereof using a catalyst used in lactone ring opening polymerizations. The resulting reaction product (II) links the amide of the agent to the polymer or unit thereof via an ester bond. The compounds of formula (IV) and (II) are as follows:



(IV)

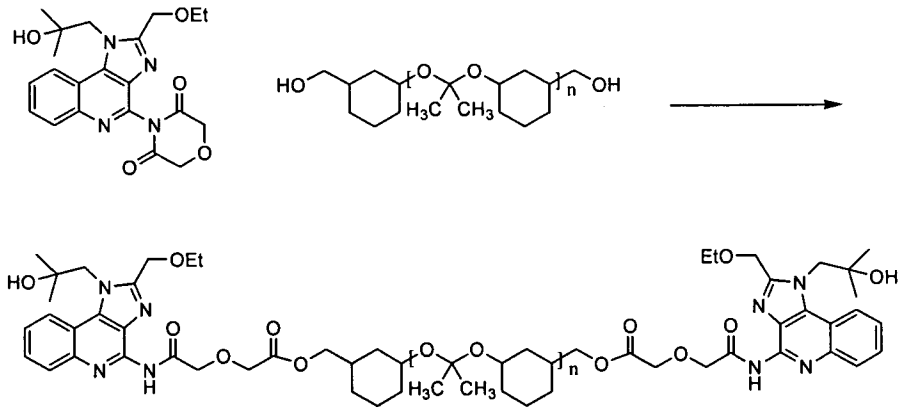


(II)

wherein R_1 = H, OH, SH, NH_2, or substituted or unsubstituted alkyl, alkoxy, alkylthio, or alkylamino; R_2 = H, alkyl, or substituted alkyl; Y = N or C; R_3 is absent if Y = N; or is H, alkyl, substituted alkyl, or combined with R_4 to form a carbocycle or heterocycle with the carbon atoms of the pyridine ring to which they are connected if Y = C; R_4 is H, or substituted or unsubstituted alkyl, alkoxy, alkylthio, or alkylamino when not combined with R_3 to form a carbocycle or heterocycle with the carbon atoms of the pyridine ring to which they are connected; or is combined with R_3 to form a carbocycle or heterocycle with the carbon atoms of the pyridine ring to which they are connected; R_5 is a polymer or unit thereof; X is C, N, O, or S; R_6 and R_7 are each independently H or substituted; and R_9, R_{10}, R_{11}, and R_{12} are each independently H, a halogen, OH, thio, NH_2, or substituted or unsubstituted alkyl, aryl, heterocyclic, alkoxy, aryloxy, alkylthio, arylthio, alkylamino, or arylamino.

Catalysts include, but are not limited to, phosphazine bases, 1,8-diazabicycloundec-7-ene (DBU), 1,4,7-triazabicyclodecene (TBD), and N-methyl-1,4,7-triazabicyclodecene (MTDB). Other catalysts are known in the art and provided, for example, in Kamber et al., Organocatalytic Ring-Opening Polymerization, *Chem. Rev.* 2007, 107, 58-13-5840. Non-limiting examples of suitable solvents include methylene chloride, chloroform, and THF.

A specific example of a reaction completed by such a method is shown here:



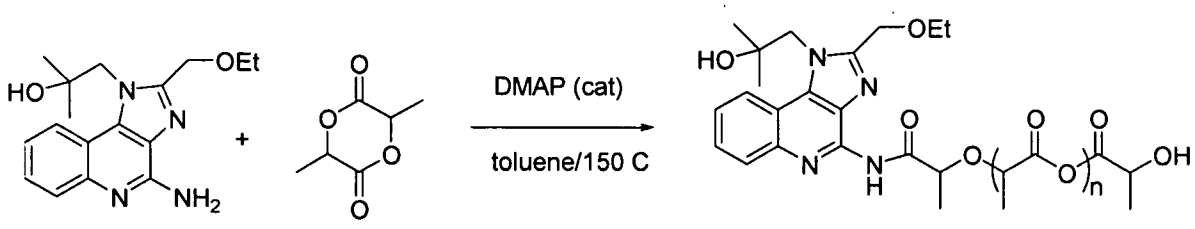
wherein R_5-OH contains two hydroxyl groups (e.g., a diol, HO-R_5-OH), each of which are functionalized by reaction with an imide associated with R848. In some cases, HO-R_5-OH is a poly-diol such as poly(hexamethyl carbonate) diol or polycaprolactone diol.

In embodiments where a poly-diol is employed, one of the diol groups may be protected with a protecting group (e.g., *t*-butyloxycarbonyl), thus the poly-diol would be a compound of formula HO-R_5-OP, wherein P is a protecting group. Following reaction with an immunomodulatory agent to form a immunomodulatory agent-R_5-OP conjugate, the

protecting group may be removed and the second diol group may be reacted with any suitable reagent (e.g., PLGA, PLA).

Method 4

A conjugate (e.g., R848-PLA) can be formed via a one-pot ring-opening polymerization of an immunomodulatory agent (e.g., R848) with a polymer or unit thereof (e.g., D/L-lactide) in the presence of a catalyst, for example, as shown in the following scheme:

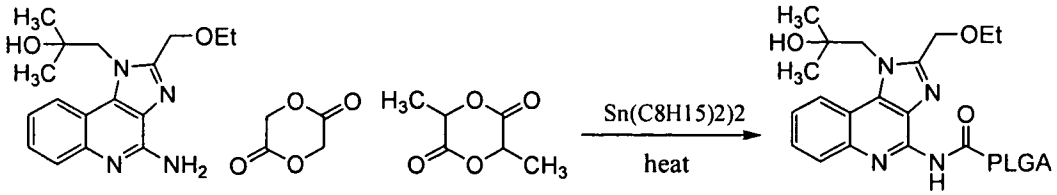


R848 dl-lactide R848-PLA (R848 loading 3 mg/g)

In a one-step procedure, the immunomodulatory agent and the polymer or unit thereof may be combined into a single reaction mixture comprising a catalyst. The reaction may proceed at a suitable temperature (e.g., at about 150 °C) and the resulting conjugate may be isolated using commonly known techniques. Non-limiting examples of suitable catalysts include DMAP and tin ethylhexanoate.

Method 5

A conjugate can be formed two-step ring opening polymerization of an immunomodulatory agent (e.g., R848) with one or more polymers or units thereof (e.g., D/L-lactide and glycolide) in the presence of a catalyst, for example, as shown in the following scheme:



The polymers or units thereof may be first combined, and in some cases, heated (e.g., to 135 °C) to form a solution. The immunomodulatory agent may be added to a solution comprising the polymers or units thereof, followed by addition of a catalyst (e.g., tin ethylhexanoate). The resulting conjugate may be isolated using commonly known techniques. Non-limiting examples of suitable catalysts include DMAP and tin ethylhexanoate.

The immunomodulatory agents (or antigens) can also be encapsulated within the nanocarriers. The nanocarriers, therefore, can be of any material that is pH sensitive provided that the resulting inventive synthetic nanocarriers satisfy the dissociation relationships provided herein. Such synthetic nanocarriers are well known in the art and include polyketal nanocarriers, pH sensitive liposomes, acid-swelling, cross-linked nanoparticles, such as those of Griset et al., J. Am. Chem. Soc. 2009, 131, 2469-2471, which in their initial state are hydrophobic, but upon cellular internalization transform to a hydrophilic structure (a hydrogel particle), and polymeric nanoparticles, such as those of Griset, Dissertation entitled: Delivery of Paclitaxel via pH-Responsive Polymeric Nanoparticles for Prevention of Lung Cancer and Mesothelioma Recurrence, Ohio State University, 2003. The pH sensitive synthetic nanocarriers also include those that comprise polymers that dissolve at a pH below 6 or polymers that swell at an acidic pH. In some embodiments, the synthetic nanocarriers are of a non-polyketal material. In other embodiment, the synthetic nanocarriers are not micelles.

In some embodiments, the immunomodulatory agent, antigen, and/or targeting moiety are covalently associated with a polymeric matrix. In some embodiments, covalent association is mediated by a linker. In some embodiments, the immunomodulatory agent, antigen, and/or targeting moiety are noncovalently associated with a polymeric matrix. For example, in some embodiments, the immunomodulatory agent, antigen, and/or targeting moiety can be encapsulated within, surrounded by, and/or dispersed throughout a polymeric matrix. Alternatively or additionally, the immunomodulatory agent, antigen, and/or targeting moiety can be associated with a polymeric matrix by hydrophobic interactions, charge interactions, van der Waals forces, etc. In some embodiments, synthetic nanocarriers comprise one or more polymeric matrices. In some embodiments, such a polymeric matrix can be surrounded by a coating layer (e.g., liposome, lipid monolayer, micelle, etc.). In some embodiments, the various elements of the synthetic nanocarriers can be coupled with the polymeric matrix.

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.).

A wide variety of polymers and methods for forming polymeric matrices therefrom are known conventially. In general, a polymeric matrix comprises one or more polymers. 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.

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)), polyhydroxyacids (e.g., poly(β-hydroxyalkanoate)), polypropylfumerates, polycaprolactones, polyamides (e.g., polycaprolactam), polyacetals, polyethers, polyesters (e.g., polylactide, polyglycolide), poly(orthoesters), polycyanoacrylates, polyvinyl alcohols, polyurethanes, polyphosphazenes, polyacrylates, polymethacrylates, polyureas, polystyrenes, polyamines, and polysaccharides (e.g., chitosan).

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 PEG, with a carbohydrate, and/or with acyclic polyacetals derived from polysaccharides (Papisov, 2001, ACS Symposium Series, 786:301).

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, polyanhydrides, poly(ortho ester), poly(ortho ester)-PEG copolymers, poly(caprolactone), poly(caprolactone)-PEG copolymers, polylysine, polylysine-PEG copolymers, poly(ethyleneimine), poly(ethylene imine)-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, RNA, 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 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-Llysine) (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 compounds and 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.

In some embodiments, synthetic nanocarriers may comprise metal particles, quantum dots, ceramic particles, etc.

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, starch, hydroxyethylstarch, carageenan, glycon, amylose, chitosan, N,O-carboxylmethylchitosan, algin and alginic acid, starch, chitin, heparin, konjac, glucommannan, pustulan, heparin, hyaluronic acid, curdlan, and xanthan. In certain embodiments, the carbohydrate is a sugar alcohol, including but not limited to mannitol, sorbitol, xylitol, erythritol, maltitol, and lactitol.

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, and also US Patents 5578325 and 6007845).

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.

Coupling can be achieved in a variety of different ways, and can be covalent or non-covalent. Such couplings may be arranged to be on a surface or within an inventive synthetic nanocarrier. Elements of the inventive synthetic nanocarriers (such as moieties of which an immunofeature surface is comprised, targeting moieties, polymeric matrices, and the like) may be directly coupled with one another, 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.

Any suitable linker can be used in accordance with the present invention. Linkers may be used to form amide linkages, ester linkages, disulfide linkages, etc. Linkers may contain carbon atoms or heteroatoms (e.g., nitrogen, oxygen, sulfur, etc.). In some embodiments, a linker is an aliphatic or heteroaliphatic linker. In some embodiments, the linker is a polyalkyl linker. In certain embodiments, the linker is a polyether linker. In certain embodiments, the linker is a polyethylene linker. In certain specific embodiments, the linker is a polyethylene glycol (PEG) linker.

In some embodiments, the linker is a cleavable linker. To give but a few examples, cleavable linkers include protease cleavable peptide linkers, nuclease sensitive nucleic acid

linkers, lipase sensitive lipid linkers, glycosidase sensitive carbohydrate linkers, pH sensitive linkers, hypoxia sensitive linkers, photo-cleavable linkers, heat-labile linkers, enzyme cleavable linkers (e.g., esterase cleavable linker), ultrasound-sensitive linkers, x-ray cleavable linkers, etc. In some embodiments, the linker is not a cleavable linker.

A variety of methods can be used to couple a linker or other element of a synthetic nanocarrier with the synthetic nanocarrier. General strategies include passive adsorption (e.g., via electrostatic interactions), multivalent chelation, high affinity non-covalent binding between members of a specific binding pair, covalent bond formation, etc. (Gao et al., 2005, Curr. Op. Biotechnol., 16:63). In some embodiments, click chemistry can be used to associate a material with a synthetic nanocarrier.

Non-covalent specific binding interactions can be employed. For example, either a particle or a biomolecule can be functionalized with biotin with the other being functionalized with streptavidin. These two moieties specifically bind to each other noncovalently and with a high affinity, thereby associating the particle and the biomolecule. Other specific binding pairs could be similarly used. Alternately, histidine-tagged biomolecules can be associated with particles conjugated to nickel-nitrolotriaceteic acid (Ni-NTA).

For additional general information on coupling, see the journal Bioconjugate Chemistry, published by the American Chemical Society, Columbus OH, PO Box 3337, Columbus, OH, 43210; "Cross-Linking," Pierce Chemical Technical Library, available at the Pierce web site and originally published in the 1994-95 Pierce Catalog, and references cited therein; Wong SS, Chemistry of Protein Conjugation and Cross-linking, CRC Press Publishers, Boca Raton, 1991; and Hermanson, G. T., Bioconjugate Techniques, Academic Press, Inc., San Diego, 1996.

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.

PHARMACEUTICAL COMPOSITIONS AND METHODS OF USE

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

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 inventive compositions may be administered by a variety of routes of administration, including but not limited to subcutaneous, intramuscular, intradermal, oral, parenteral, intranasal, transmucosal, rectal; ophthalmic, transdermal, transcutaneous or by a combination of these routes.

The compositions and methods described herein can be used to induce, enhance, stimulate, modulate, or direct an immune response. The compositions and methods described herein can be used in the diagnosis, prophylaxis and/or treatment of conditions such as cancers, infectious diseases, metabolic diseases, degenerative diseases, inflammatory diseases, immunological diseases, or other disorders and/or conditions. The compositions and methods described herein can also be used for the prophylaxis or treatment of an addiction, such as an addiction to nicotine or a narcotic. The compositions and methods described herein can also be used for the prophylaxis and/or treatment of a condition resulting from the exposure to a toxin, hazardous substance, environmental toxin, or other harmful agent.

EXAMPLES

Example 1: Preparation of Activated Polymer

PLA (dl-polylactide) (Resomer R202H from Boehringer-Ingelheim, KOH equivalent acid number of 0.21 mmol/g, intrinsic viscosity (iv): 0.21 dl/g) (10 g, 2.1 mmol, 1.0 eq) was dissolved in dichloromethane (DCM) (35 mL). EDC (2.0 g, 10.5 mmol, 5 eq) and NHS (1.2 g, 10.5 mmol, 5 eq) were added. The solids were dissolved with the aid of sonication. The resulting solution was stirred at room temperature for 6 days. The solution was concentrated to remove most of DCM and the residue was added to a solution of 250 mL of diethyl ether

and 5 mL of MeOH to precipitate out the activated PLA-NHS ester. The solvents were removed and the polymer was washed twice with ether (2x200 mL) and dried under vacuum to give PLA-NHS activated ester as a white foamy solid (~ 8 g recovered, H NMR was used to confirm the presence of NHS ester). The PLA-NHS ester was stored under argon in a below -10 C freezer before use.

Alternatively, the reaction can be performed in DMF, THF, dioxane, or CHCl3 instead of DCM. DCC can be used instead of EDC (resulting DCC-urea is filtered off before precipitation of the PLA-NHS ester from ether). The amount of EDC or DCC and NHS can be in the range of 2-10 eq of the PLA.

In the same manner, PLA with iv of 0.33 dl/g and acid number of 0.11 mmol/g or PLGA (Resomer RG653H, 65% lactide-35% glycolide, iv: 0.39 dl/g and acid number 0.08 mmol/g) or PLGA (Resomer RG752H, 75% lactide-25% glycolide, iv: 0.19 dl/g and acid number of 0.22 mmol/g) is converted to the corresponding PLA-NHS or PLGA-NHS activated ester and stored under argon in a below -10 C freezer before use.

Example 2: Preparation of Activated Polymer

PLA (R202H, acid number of 0.21 mmol/g) (2.0 g, 0.42 mmol, 1.0 eq) was dissolved in 10 mL of dry acetonitrile. N,N'-disuccinimidyl carbonate (DSC) (215 mg, 1.26 mmol, 3.0 eq) and catalytic amount of 4-(N,N-dimethylamino)pyridine (DMAP) were added. The resulting mixture was stirred under argon for 1 day. The resulting solution was concentrated to almost dryness. The residue was then added to 40 mL of ether to precipitate out the polymer which was washed twice with ether (2x30 mL) and dried under vacuum to give PLA-NHS activated ester (1H NMR showed the amount of NHS ester at about 80%).

Example 3: Preparation of Activated Polymer

PLA (R202H) (5.0 g, 1.05 mmol) was dissolved in 25 mL of anhydrous DCM and 2.5 mL of anhydrous DMF. DCC (650 mg, 3.15 mmol, 5.0 eq) and pentafluorophenol (PFP) (580 mg, 3.15 mmol, 5.0 eq) were added. The resulting solution was stirred at room temperature for 6 days and then concentrated to remove DCM. The resulting residue was added to 250 mL of ether to precipitate out the activated PLA polymer which was washed with ether (2x100mL) and dried under vacuum to give PLA-PFP activated ester as a white foamy solid (4.0 g).

Example 4: Conjugation of Immunomodulatory Agent

PLA-NHS (1.0 g), R848 (132 mg, 0.42 mmol) and diisopropylethylamine (DIPEA) (0.073 mL, 0.42 mmol) were dissolved in 2 mL of dry DMF under argon. The resulting solution was heated at 50-60 C for 2 days. The solution was cooled to rt and added to 40 mL of de-ionized (DI) water to precipitate out the polymer product. The polymer was then washed with DI water (40 mL) and ether (2x40 mL) and dried at 30 C under vacuum to give R848-PLA conjugate as a white foamy solid (0.8 g, H NMR showed the conjugation of R848 to PLA via the amide bond). The degree of conjugation (loading) of R848 on the polymer was confirmed by HPLC analysis as follows: a weighed amount of polymer was dissolved in THF/MeOH and treated with 15% NaOH. The resulting hydrolyzed polymer products were analyzed for the amount of R848 by HPLC in comparison with a standard curve.

Example 5: Conjugation of Immunomodulatory Agent

PLA-NHS (1.0 g, 0.21 mmol, 1.0 eq), R848 (132 mg, 0.42 mmol, 2.0 eq), DIPEA (0.15 mL, 0.84 mmol, 4.0 eq) and DMAP (25 mg, 0.21 mmol, 1.0 eq) were dissolved in 2 mL of dry DMF under argon. The resulting solution was heated at 50-60 C for 2 days. The solution was cooled to rt and added to 40 mL of de-ionized (DI) water to precipitate out the polymer product. The polymer was then washed with DI water (40 mL) and ether (2x40 mL) and dried at 30 C under vacuum to give PLA-R848 conjugate as a white foamy solid (0.7 g, 20 mg of the polymer was hydrolyzed in solution of 0.2 mL of THF, 0.1 mL of MeOH and 0.1 mL of 15% NaOH. The amount of R848 on the polymer was determined to be about 35 mg/g by reverse phase HPLC analysis (C18 column, mobile phase A: 0.1% TFA in water, mobile phase B: 0.1 % TFA in CH3CN, gradient).

Example 6: Conjugation of Immunomodulatory Agent

PLA (R202H) (2.0 g, 0.42 mmol, 1.0 eq), DCC (260 mg, 1.26 mmol, 3.0 eq), NHS (145 mg, 1.26 mmol, 3.0 eq), R848 (200 mg, 0.63 mmol, 1.5 eq), DMAP (77 mg, 0.63 mmol, 1.5 eq) and DIPEA (0.223 mL, 1.26 mmol, 3.0 eq) were dissolved in 4 mL of dry DMF. The mixture was heated at 50-55 C for 3 days. The mixture was cooled to rt and diluted with DCM. The DCC-urea was filtered off and the filtrate was concentrated to remove DCM. The resulting residue in DMF was added to water (40 mL) to precipitate out the polymer product which was washed with water (40 mL), ether/DCM (40 mL/4 mL) and ether (40 mL). After drying under vacuum at 30 C, the desired PLA-R848 conjugate was obtained as a white foamy solid (1.5 g).

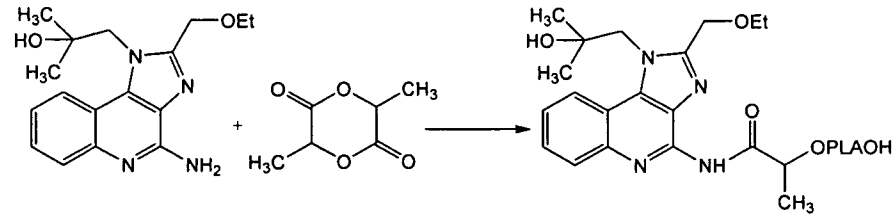
Example 7: Conjugation of Immunomodulatory Agent

PLA (R202H) (2.0 g, 0.42 mmol, 1.0 eq), EDC (242 mg, 1.26 mmol, 3.0 eq), HOAt (171 mg, 1.26 mmol, 3.0 eq), R848 (200 mg, 0.63 mmol, 1.5 eq), and DIPEA (0.223 mL, 1.26 mmol, 3.0 eq) were dissolved in 4 mL of dry DMF. The mixture was heated at 50-55 C for 2 days. The solution was cooled to rt and added to water (40 mL) to precipitate out the polymer product which was washed with water (40 mL), ether/MeOH (40 mL/2 mL) and ether (40 mL). The orange colored polymer was dissolved in 4 mL of DCM and the resulting solution was added to 40 mL of ether to precipitate out the polymer without much of the orange color. The light colored polymer was washed with ether (40 mL). After drying under vacuum at 30 C, the desired PLA-R848 conjugate was obtained as a light brown foamy solid (1.5 g).

Example 8: Conjugation of Immunomodulatory Agent

PLA (R202H) (1.0 g, 0.21 mmol, 1.0 eq), EDC (161 mg, 0.84 mmol, 4.0 eq), HOBt.H2O (65 mg, 0.42 mmol, 2.0 eq), R848 (132 mg, 0.42 mmol, 2.0 eq), and DIPEA (0.150 mL, 0.84 mmol, 4.0 eq) were dissolved in 2 mL of dry DMF. The mixture was heated at 50-55 °C for 2 days. The solution was cooled to room temperature and added to water (40 mL) to precipitate out the polymer product. The orange colored polymer was dissolved in 2 mL of DCM and the resulting solution was added to 40 mL of ether to precipitate out the polymer which was washed with water/acetone (40 mL/2 mL) and ether (40 mL). After drying under vacuum at 30 °C, the desired PLA-R848 conjugate was obtained as an off-white foamy solid (1.0 g, loading of R848 on polymer was about 45 mg/g based on HPLC analysis and confirmed by ^{1}H NMR). In the same manner, PLGA (75% Lactide)-R848 and PLGA (50% lactide)-R848 were prepared.

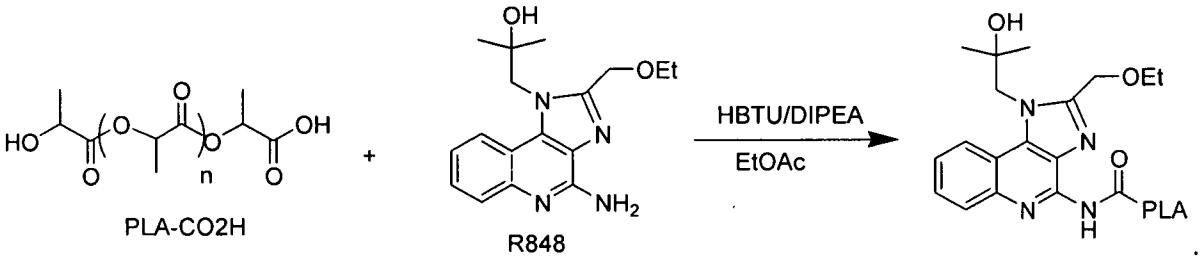
Example 9: Conjugation of Immunomodulatory Agent



To a round bottom flask equipped with a stir bar and condenser was added the imidazoquinoline, resiquimod (R-848, 218 mg, 6.93 X 10^{-4} moles), D/L lactide (1.0 g, 6.93 X

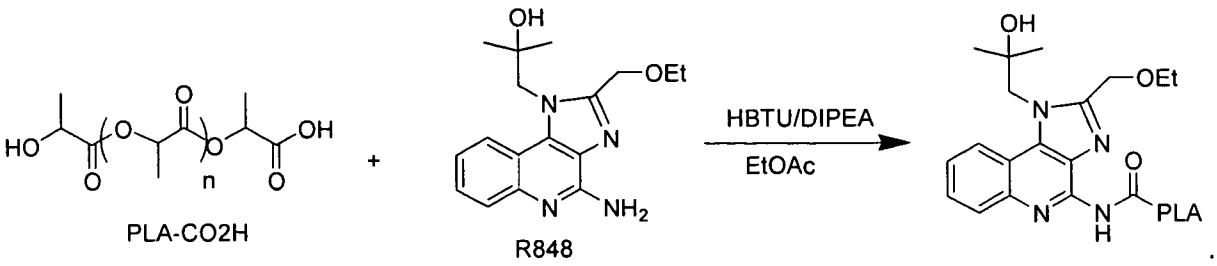
10^{-3} moles) and anhydrous sodium sulfate (800 mg). The flask and contents were dried under vacuum at 55 °C for 8 hours. After cooling, the flask was then flushed with argon and toluene (50 mL) was added. The reaction was stirred in an oil bath set at 120 °C until all of the lactide had dissolved and then tin ethylhexanoate (19 mg, 15μL) was added via pipette. Heating was continued under argon for 16 hours. After cooling, the reaction was diluted with ether (200 mL) and the solution was washed with water (200 mL). The solution was dried over magnesium sulfate, filtered and evaporated under vacuum to give 880 mg. of crude polylactic acid-R-848 conjugate. The crude polymer was chromatographed on silica using 10% methanol in methylene chloride as eluent. The fractions containing the conjugate were pooled and evaporated to give the purified conjugate. This was dried under high vacuum to provide the conjugate as a solid foam in a yield of 702 mg (57.6%). By integrating the NMR signals for the aromatic protons of the quinoline and comparing this to the integrated intensity of the lactic acid CH proton it was determined that the molecular weight of the conjugate was approximately 2KD. GPC showed that the conjugate contained less than 5% of free R848.

Example 10: Preparation Of Low MW PLA-R848 Conjugate



A solution of PLA-CO2H (average MW: 950, DPI:1.32; 5.0 g, 5.26 mmol) and HBTU (4.0 g, 10.5 mmol) in EtOAc (120 mL) was stirred at room temperature under argon for 45 min. Compound R848 (1.65 g, 5.26 mmol) was added, followed by DIPEA (5.5 mL, 31.6 mmol). The mixture was stirred at room temperature for 6 h and then at 50-55 °C for 15 h. After cooling, the mixture was diluted with EtOAc (150 mL) and washed with 1% citric acid solution (2x40 mL), water (40 mL) and brine solution (40 mL). The solution was dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Methyl *t*-butyl ether (MTBE) (150 mL) was then added and the polymer conjugate precipitated out of solution. The polymer was then washed with MTBE (50 mL) and dried under vacuum at room temperature for 2 days as a white foam (5.3 g, average MW by GPC is 1200, PDI: 1.29; R848 loading is 20% by HPLC).

Example 11: Preparation Of Low MW PLA-R848 Conjugate



A solution of PLA-CO2H (average MW: 1800, DPI:1.44; 9.5 g, 5.26 mmol) and HBTU (4.0 g, 10.5 mmol) in EtOAc (120 mL) was stirred at room temperature under argon for 45 min. Compound R848 (1.65 g, 5.26 mmol) was added, followed by DIPEA (5.5 mL, 31.6 mmol). The mixture was stirred at room temperature for 6 h and then at 50-55 °C for 15 h. After cooling, the mixture was diluted with EtOAc (150 mL) and washed with 1% citric acid solution (2 x 40 mL), water (40 mL) and brine solution (40 mL). The solution was dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Methyl *t*-butyl ether (MTBE) (150 mL) was then added and the polymer conjugate precipitated out of solution. The polymer was then washed with MTBE (50 mL) and dried under vacuum at room temperature for 2 days as a white foam (9.5 g, average MW by GPC is 1900, PDI: 1.53; R848 loading is 17% by HPLC).

Example 12: Conjugation Of R848 To PCADK Via Imide Ring Opening

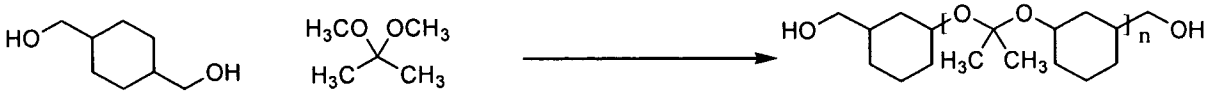
The following example describes the synthesis of a polyketal, PCADK, according to a method provided in Pulendran et al, WO 2008/127532, as illustrated in step 1 below.

PCADK is synthesized in a 50 mL two-necked flask, connected to a short-path distilling head. First, 5.5 mg of re-crystallized p-toluenesulfonic acid (0.029 mmol, Aldrich, St. Louis, MO), is dissolved in 6.82 mL of ethyl acetate, and added to a 30 mL benzene solution (kept at 100°C), which contains 1 ,4-cyclohexanedimethanol (12.98 g, 90.0 mmol, Aldrich). The ethyl acetate is allowed to boil off, and distilled 2,2-dimethoxypropane (10.94 mL, 90.0 mmol, Aldrich) is added to the benzene solution, initiating the polymerization reaction. Additional doses of 2,2-dimethoxypropane (5 mL) and benzene (25 mL) are subsequently added to the reaction every hour for 6 hours via a metering funnel to compensate for 2,2-dimethoxypropane and benzene that is distilled off. After 8 hours, the reaction is stopped by addition of 500 μL of triethylamine. The polymer is isolated by precipitation in cold hexane (stored at -20°C) followed by vacuum filtration. The molecular weight of PCADK is determined by gel permeation chromatography (GPC) (Shimadzu, Kyoto, Japan) equipped with a UV detector. THF is used as the mobile phase at a flow rate

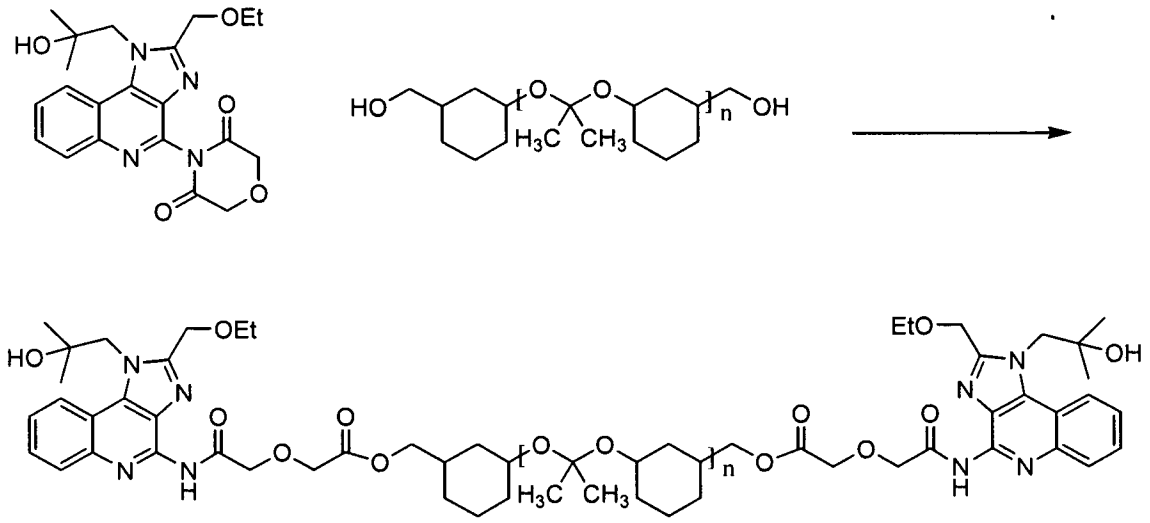
of 1 ml/min. Polystyrene standards from Polymer Laboratories (Amherst, MA) are used to establish a molecular weight calibration curve. This compound is used to generate the PCADK particles in all subsequent experiments.

R848 may be conjugated to the terminal alcohol groups of the PCADK having molecular weight 6000 via imide ring opening, according to the step 2 shown below.

Step 1: Preparation of PCADK



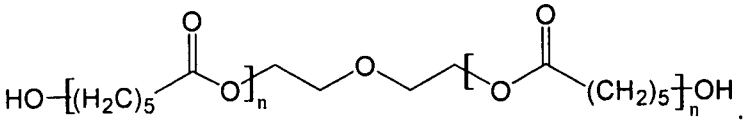
Step 2: Conjugation of PCADK to R848



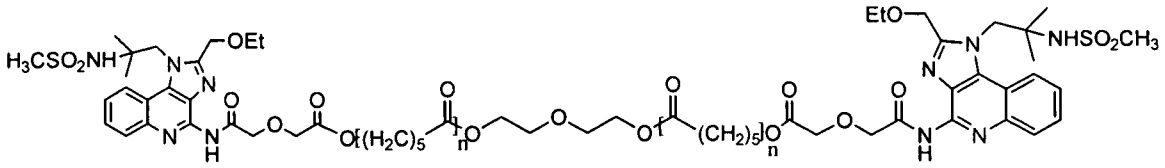
In step 2, the polymer from step 1 (12 g, 2.0 x 10^{-3} moles) is dissolved in methylene chloride 100 mL, and the lactam of R848 (3.3 g, 8.0 x 10^{-3} moles) is added. This slurry is stirred as 1,5,7-triazabicyclo-[4,4,0]dec-5-ene (TBD, 0.835 g, 6 X 10^{-3} moles) is added in a single portion. After stirring at room temperature overnight, a clear solution forms. The solution is diluted with methylene chloride (100 mL) and the solution is washed with 5% citric acid. This solution is dried over sodium sulfate after which it is filtered and evaporated under vacuum. After drying under high vacuum there is obtained 11.3 grams (81%) of polymer. A portion is hydrolyzed in acid and the R848 content is determined to be 9% by weight.

Example 13: Conjugation Of R848 To Poly-Caprolactonediol Via Imide Ring Opening

Imide ring opening is used to attach R854 to the terminal alcohol groups of poly-caprolactonediol of molecular weight 2000. The polycaprolactone diol is purchased from Aldrich Chemical Company, Cat. #189421 and has the following structure:



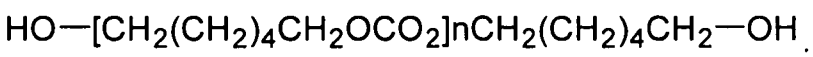
The polycaprolactone diol-R854 conjugate has the following structure:



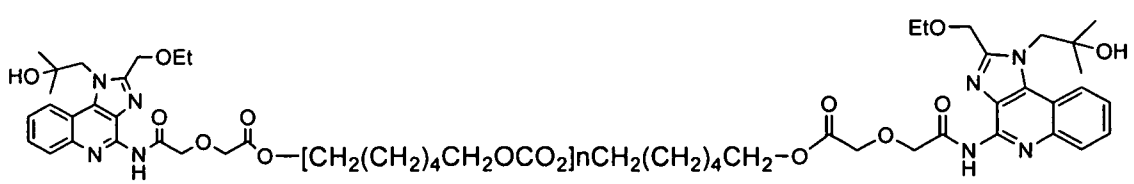
The polymer (5 g, 2.5 x 10^{-3} moles) is dissolved in methylene chloride 25 mL and the lactam of R854 (2.4 g, 5.0 x 10^{-3} moles) is added. This slurry is stirred as 1,5,7-triazabicyclo-[4,4,0]dec-5-ene (TBD, 0.557 g, 4 X 10^{-3} moles) is added in a single portion. After stirring at room temperature for 15 minutes, a clear pale yellow solution forms. The solution is diluted with methylene chloride (100 mL) and the solution is washed with 5% citric acid. This solution is dried over sodium sulfate after which it is filtered and evaporated under vacuum. After drying under high vacuum there is obtained 5.2 grams (70%) of polymer. A portion is hydrolyzed in acid and the R848 content is determined to be 18.5% by weight.

Example 14: Conjugation Of R848 To Poly-(Hexamethylene Carbonate)Diol Via Imide Ring Opening

Imide ring opening is used to attach R848 to the terminal alcohol groups of poly-(hexamethylene carbonate)diol of molecular weight 2000. The poly(hexamethylene carbonate) diol is purchased from Aldrich Chemical Company, Cat # 461164, and has the following structure:

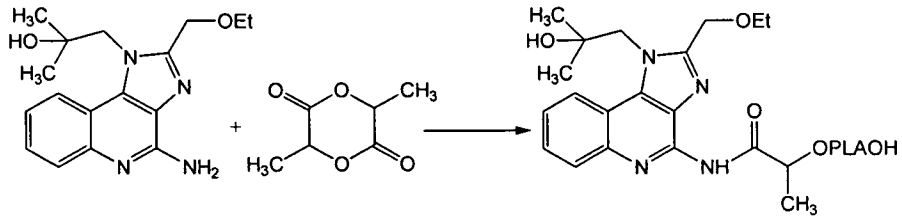


The poly(hexamethylene carbonate) diol-R848 conjugate has the following structure:



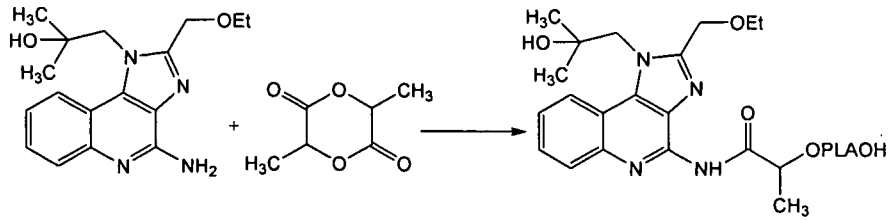
The polymer (5 g, 2.5 x 10^{-3} moles) is dissolved in methylene chloride 25 mL and the lactam of R848 (2.06 g, 5.0 X 10^{-3} moles) is added. This slurry is stirred as 1,5,7-triazabicyclo-[4,4,0]dec-5-ene (TBD, 0.557 g, 4 X 10^{-3} moles) is added in a single portion. After stirring at room temperature overnight a clear pale yellow solution forms. The solution is diluted with methylene chloride (100 mL) and the solution is washed with 5% citric acid. This solution is dried over sodium sulfate after which it is filtered and evaporated under vacuum. After drying under high vacuum there is obtained 5.9 grams (84%) of polymer. NMR is used to determine the R848 content which is determined to be 21%.

Example 15: Polylactic Acid Conjugates Of An Imidazoquinoline Using A Tin Ethylhexanoate Catalyst



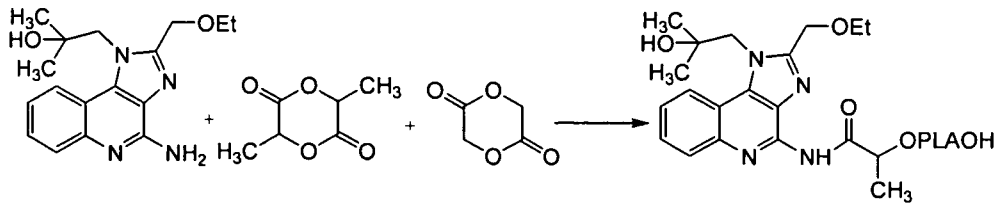
To a two necked round bottom flask equipped with a stir bar and condenser was added the imidazoquinoline resiquimod (R-848, 100 mg, 3.18 X 10^{-4} moles), D/L lactide (5.6 g, 3.89 X 10^{-2} moles) and anhydrous sodium sulfate (4.0 g). The flask and contents were dried under vacuum at 50 °C for 8 hours. The flask was then flushed with argon and toluene (100 mL) was added. The reaction was stirred in an oil bath set at 120 °C until all of the lactide had dissolved and then tin ethylhexanoate (75 mg, 60 μL) was added via pipette. Heating was continued under argon for 16 hours. After cooling, water (20 mL) was added and stirring was continued for 30 minutes. The reaction was diluted with additional toluene (200 mL) and was then washed with water (200 mL). The toluene solution was then washed in turn with 10% sodium chloride solution containing 5% conc. Hydrochloric acid (200 mL) followed by saturated sodium bicarbonate (200 mL). TLC (silica, 10% methanol in methylene chloride) showed that the solution contained no free R-848. The solution was dried over magnesium sulfate, filtered and evaporated under vacuum to give 3.59 grams of polylactic acid-R-848 conjugate. A portion of the polymer was hydrolyzed in base and examined by HPLC for R-848 content. By comparison to a standard curve of R-848 concentration vs. HPLC response, it was determined that the polymer contained 4.51 mg of R-848 per gram of polymer. The molecular weight of the polymer was determined by GPC to be about 19,000.

Example 16: Low Molecular Weight Polylactic Acid Conjugates Of An Imidazoquinoline



To a round bottom flask equipped with a stir bar and condenser was added the imidazoquinoline, resiquimod (R-848, 218 mg, 6.93 X 10^{-4} moles), D/L lactide (1.0 g, 6.93 X 10^{-3} moles) and anhydrous sodium sulfate (800 mg). The flask and contents were dried under vacuum at 55 °C for 8 hours. After cooling, the flask was then flushed with argon and toluene (50 mL) was added. The reaction was stirred in an oil bath set at 120 °C until all of the lactide had dissolved and then tin ethylhexanoate (19 mg, 15μL) was added via pipette. Heating was continued under argon for 16 hours. After cooling, the reaction was diluted with ether (200 mL) and the solution was washed with water (200 mL). The solution was dried over magnesium sulfate, filtered and evaporated under vacuum to give 880 mg. of crude polylactic acid-R-848 conjugate. The crude polymer was chromatographed on silica using 10% methanol in methylene chloride as eluent. The fractions containing the conjugate were pooled and evaporated to give the purified conjugate. This was dried under high vacuum to provide the conjugate as a solid foam in a yield of 702 mg (57.6%). By integrating the NMR signals for the aromatic protons of the quinoline and comparing this to the integrated intensity of the lactic acid CH proton it was determined that the molecular weight of the conjugate was approximately 2KD. GPC showed that the conjugate contained less than 5% of free R848.

Example 17: Low Molecular Weight Polylactic Acid Co-Glycolic Acid Conjugates Of An Imidazoquinoline



To a round bottom flask equipped with a stir bar and condenser was added the imidazoquinoline, resiquimod (R-848, 436 mg, 1.39 X 10^{-3} moles), glycolide (402 mg, 3.46 X 10^{-3} moles), D/L lactide (2.0 g, 1.39 X 10^{-2} moles) and anhydrous sodium sulfate (1.6 g).

The flask and contents were dried under vacuum at 55 °C for 8 hours. After cooling, the flask was then flushed with argon and toluene (60 mL) was added. The reaction was stirred in an oil bath set at 120°C until all of the R848, glycolide and lactide had dissolved and then tin ethylhexanoate (50 mg, 39 μL) was added via pipette. Heating was continued under argon for 16 hours. After cooling, the reaction was diluted with ethyl acetate (200 mL) and the solution was washed with water (200 mL). The solution was dried over magnesium sulfate, filtered and evaporated under vacuum to give crude PLGA-R-848 conjugate. The crude polymer was chromatographed on silica using 10% methanol in methylene chloride as eluent. The fractions containing the conjugate were pooled and evaporated to give the purified conjugate. This was dried under high vacuum to provide the conjugate as a solid foam in a yield of 1.55 g (54.6%). By integrating the NMR signals for the aromatic protons of the quinoline and comparing this to the integrated intensity of the lactic acid CH proton it was determined that the molecular weight of the conjugate was approximately 2KD. GPC showed that the conjugate contained no detectable free R848.

Example 18: Polylactic Acid Conjugates Of An Imidazoquinoline Using A Lithium Diisopropylamide Catalysis

The imidazoquinoline (R-848), D/L lactide, and associated glassware were all dried under vacuum at 50 °C for 8 hours prior to use. To a round bottom flask equipped with a stir bar and condenser was added the R-848 (33 mg, 1.05 x 10^{-4} moles), and dry toluene (5 mL). This was heated to reflux to dissolve all of the R-848. The solution was stirred under nitrogen and cooled to room temperature to provide a suspension of finely divided R-848. To this suspension was added a solution of lithium diisopropyl amide (2.0 M in THF, 50μL, 1.0 x 10^{-4} moles) after which stirring was continued at room temperature for 5 minutes. The pale yellow solution that had formed was added via syringe to a hot (120 °C) solution of D/L lactide (1.87 g, 1.3 x 10^{-2} moles) under nitrogen. The heat was removed and the pale yellow solution was stirred at room temperature for one hour. The solution was diluted with methylene chloride (200 mL) and this was then washed with 1% hydrochloric acid (2 x 50 mL) followed by saturated sodium bicarbonate solution (50 mL). The solution was dried over magnesium sulfate, filtered and evaporated under vacuum to give the polylactic acid-R-848 conjugate. TLC (silica, 10% methanol in methylene chloride) showed that the solution contained no free R-848. The polymer was dissolved in methylene chloride (10 mL) and the solution was dripped into stirred hexane (200 mL). The precipitated polymer was isolated by decantation and was dried under vacuum to give 1.47 grams of the polylactic acid – R-848

conjugate as a white solid. A portion of the polymer was hydrolyzed in base and examined by HPLC for R-848 content. By comparison to a standard curve of R-848 concentration vs. HPLC response, it was determined that the polymer contained 10.96 mg of R-848 per gram of polymer.

Example 19: Attachment Of Immunomodulatory Agent To Low MW PLA

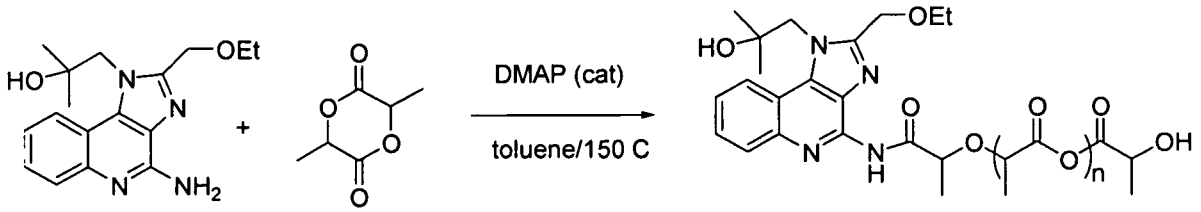
PLA (D/L-polylactide) with MW of 5000 (10.5 g, 2.1 mmol, 1.0 eq) is dissolved in dichloromethane (DCM) (35 mL). EDC (2.0 g, 10.5 mmol, 5 eq) and NHS (1.2 g, 10.5 mmol, 5 eq) are added. The resulting solution is stirred at room temperature for 3 days. The solution is concentrated to remove most of DCM and the residue is added to a solution of 250 mL of diethyl ether and 5 mL of MeOH to precipitate out the activated PLA-NHS ester. The solvents are removed and the polymer is washed twice with ether (2 x 200 mL) and dried under vacuum to give PLA-NHS activated ester as a white foamy solid (~ 8 g recovered, H NMR can be used to confirm the presence of NHS ester). The PLA-NHS ester is stored under argon in a below -10 °C freezer before use.

Alternatively, the reaction can be performed in DMF, THF, dioxane, or CHCl3 instead of DCM. DCC can be used instead of EDC (resulting DCC-urea is filtered off before precipitation of the PLA-NHS ester from ether). The amount of EDC or DCC and NHS can be in the range of 2-10 eq of the PLA.

Example 20: Attachment Of Immunomodulatory Agent To Low MW PLGA

In the same manner as provided above for polymer activation, low MW PLGA with 50% to 75% glycolide is converted to the corresponding PLGA-NHS activated ester and is stored under argon in a below -10 °C freezer before use.

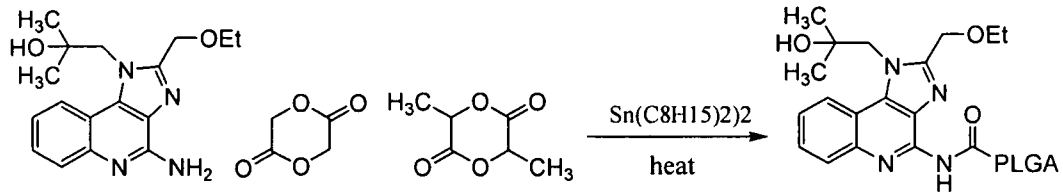
Example 21: One-Pot Ring-Opening Polymerization Of R848 With D/L-Lactide In The Presence Of A Catalyst



R848 dl-lactide R848-PLA (R848 loading 3 mg/g)

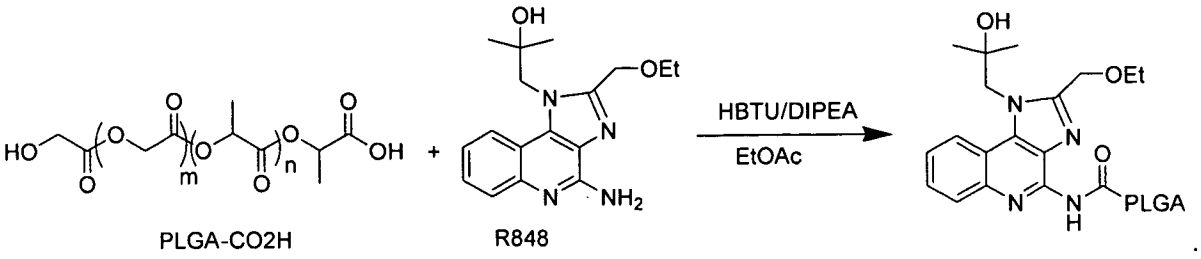
A mixture of R848 (0.2 mmol, 63 mg), D/L-lactide (40 mmol, 5.8 g), and 4-dimethylaminopyridine (DMAP) (50 mg, 0.4 mmol) in 2 mL of anhydrous toluene was heated slowly to 150 °C (oil bath temperature) and maintained at this temperature for 18 h (after 3 hr, no R848 was left). The mixture was cooled to ambient temperature and the resulting mixture was quenched with water (50 mL) to precipitate out the resulting polymer, R848-PLA. The polymer was then washed sequentially with 45 mL each of MeOH, iPrOH, and ethyl ether. The polymer was dried under vacuum at 30 °C to give an off-white puffy solid (5.0 g). Polymeric structure was confirmed by ^{1}H NMR in $CDCl_3$. A small sample of the polymer was treated with 2 N NaOH aq in THF/MeOH to determine the loading of R848 on the polymer by reverse phase HPLC. The loading of R848 is 3 mg per gram of polymer (0.3% loading - 27.5% of theory).

Example 22: Two Step Ring Opening Polymerization Of R848 With D/L-Lactide And Glycolide



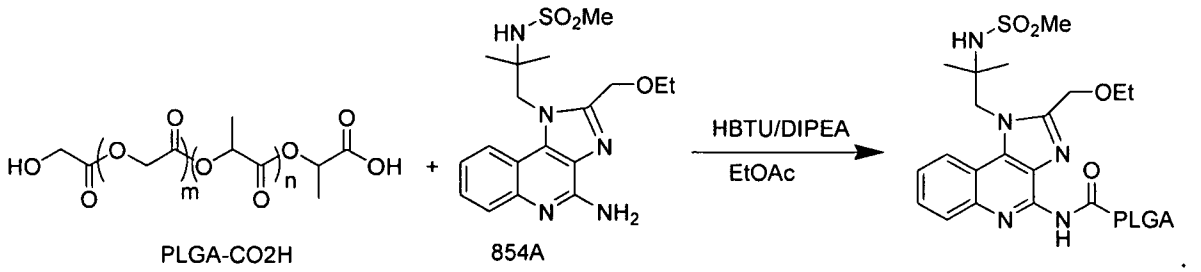
A mixture of D/L-lactide (10.8 g, 0.075 moles) and glycolide (2.9 g, 0.025 moles) was heated to 135 °C under argon. Once all of the materials had melted and a clear solution had resulted, R848 (1.08 g, 3.43 X 10^{-3} moles) was added. This solution was stirred at 135 °C under a slow stream of argon for one hour. Tin ethylhexanoate (150 µL) was added and heating was continued for 4 hours. After cooling, the solid pale brown mass was dissolved in methylene chloride (250 mL) and the solution was washed with 5% tartaric acid solution (2 x 200 mL). The methylene chloride solution was dried over magnesium sulfate, filtered, and then concentrated under vacuum. The residue was dissolved in methylene chloride (20 mL) and 2-propanol (250 mL) was added with stirring. The polymer that separated was isolated by decantation of the 2-propanol and was dried under high vacuum. NMR showed that the polymer was 71.4% lactide and 28.6% glycolide with a molecular weight of 4000. The loading of R848 was close to theoretical by NMR.

Example 23: Preparation Of PLGA-R848 Conjugate



A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 10 g, 7.0 mmol) and HBTU (5.3 g, 14 mmol) in anhydrous EtOAc (160 mL) was stirred at room temperature under argon for 50 minutes. Compound R848 (2.2 g, 7 mmol) was added, followed by diisopropylethylamine (DIPEA) (5 mL, 28 mmol). The mixture was stirred at room temperature for 6 h and then at 50-55 °C overnight (about 16 h). After cooling, the mixture was diluted with EtOAc (200 mL) and washed with saturated NH_4Cl solution (2 x 40 mL), water (40 mL) and brine solution (40 mL). The solution was dried over Na_2SO_4 (20 g) and concentrated to a gel-like residue. Isopropyl alcohol (IPA) (300 mL) was then added and the polymer conjugate precipitated out of solution. The polymer was then washed with IPA (4 x 50 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 3 days as a white powder (10.26 g, MW by GPC is 5200, R848 loading is 12% by HPLC).

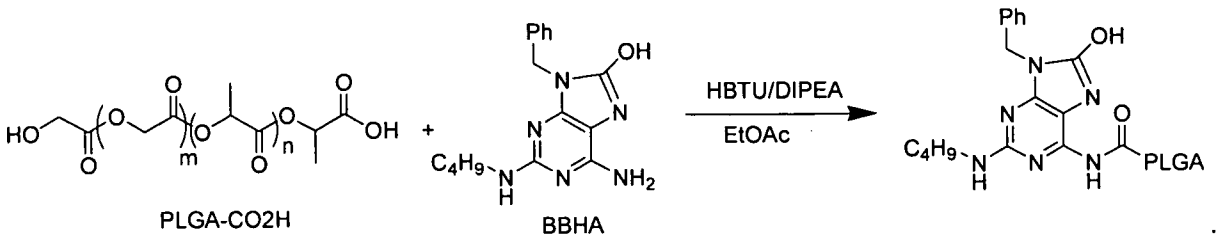
Example 24: Preparation Of PLGA-854A Conjugate



A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 1.0 g, 7.0 mmol) and HBTU (0.8 g, 2.1 mmol) in anhydrous EtOAc (20 mL) was stirred at room temperature under argon for 45 minutes. Compound 845A (0.29 g, 0.7 mmol) was added, followed by diisopropylethylamine (DIPEA) (0.73 mL, 4.2 mmol). The mixture was stirred at room temperature for 6 h and then at 50-55 °C overnight (about 15 h). After cooling, the mixture was diluted with EtOAc (100 mL) and washed with saturated NH4Cl solution (2 x 20 mL), water (20 mL) and brine solution (20 mL). The solution was dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Isopropyl alcohol (IPA) (40 mL) was then added and the polymer conjugate precipitated out of solution. The polymer was then

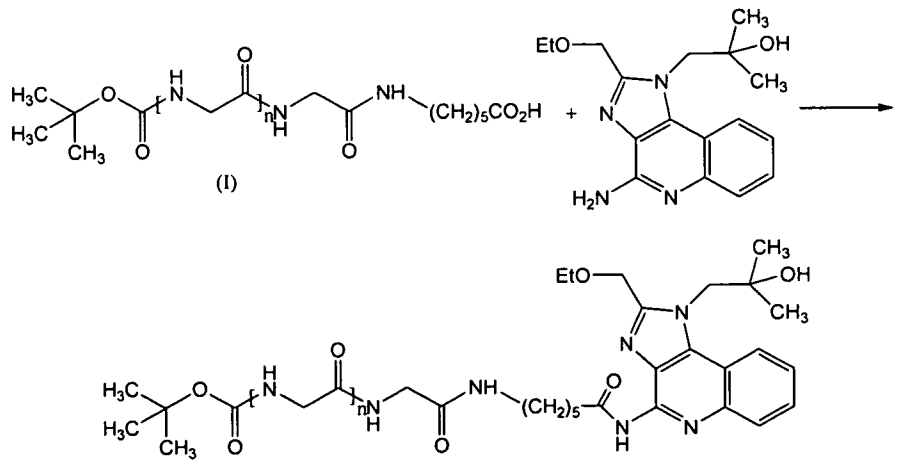
washed with IPA (4 x 25 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 2 days as a white powder (1.21 g, MW by GPC is 4900, 854A loading is 14% by HPLC).

Example 25: Preparation Of PLGA-BBHA Conjugate



A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 1.0 g, 7.0 mmol) and HBTU (0.8 g, 2.1 mmol) in anhydrous EtOAc (30 mL) was stirred at room temperature under argon for 30 minutes. Compound BBHA (0.22 g, 0.7 mmol) in 2 mL of dry DMSO was added, followed by diisopropylethylamine (DIPEA) (0.73 mL, 4.2 mmol). The mixture was stirred at room temperature for 20 h. Additional amounts of HBTU (0.53 g, 1.4 mmol) and DIPEA (0.5 mL, 2.8 mmol) were added and the mixture was heated at 50-55 °C for 4 h. After cooling, the mixture was diluted with EtOAc (100 mL) and washed with saturated NH4Cl solution 20 mL), water (2 x 20 mL) and brine solution (20 mL). The solution was dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Isopropyl alcohol (IPA) (35 mL) was then added and the brownish polymer conjugate precipitated out of solution. The polymer was then washed with IPA (2 x 20 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 2 days as a brownish powder (1.1 g).

Example 26: Conjugation Of R848 To Polyglycine, A Polyamide



The *t*-butyloxycarbonyl (tBOC) protected polyglycine carboxylic acid (I) is prepared by ring opening polymerization of glycine N-carboxyanhydride (Aldrich cat #369772) using 6-aminohexanoic acid benzyl ester (Aldrich cat #S33465) by the method of Aliferis et al. (*Biomacromolecules*, 5, 1653, (2004)). Protection of the end amino group as the *t*-BOC carbamate followed by hydrogenation over palladium on carbon to remove the benzyl ester completes the synthesis of BOC protected polyglycine carboxylic acid (I).

A mixture of BOC-protected polyglycine carboxylic acid (5 gm, MW = 2000, 2.5 x 10^{-3} moles) and HBTU (3.79 gm, 1.0 x 10^{-2} moles) in anhydrous DMF (100 mL) is stirred at room temperature under argon for 50 minutes. Then R848 (1.6 gm, 5.0 X 10^{-3} moles) is added, followed by diisopropylethylamine (4 mL, 2.2 x 10^{-2} moles). The mixture is stirred at RT for 6 h and then at 50-55 °C overnight (16 h). After cooling, the DMF is evaporated under vacuum and the residue is triturated in EtOAc (100 mL). The polymer is isolated by filtration and the polymer is then washed with 2-propanol (4 x 25 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 3 days. The polymer is isolated as an off white solid in a yield of 5.1 g (88%). The R848 loading can be determined by NMR is 10.1%.

The *t*-BOC protecting group is removed using trifluoroacetic acid and the resulting polymer is grafted to PLA with carboxyl end groups by conventional methods.

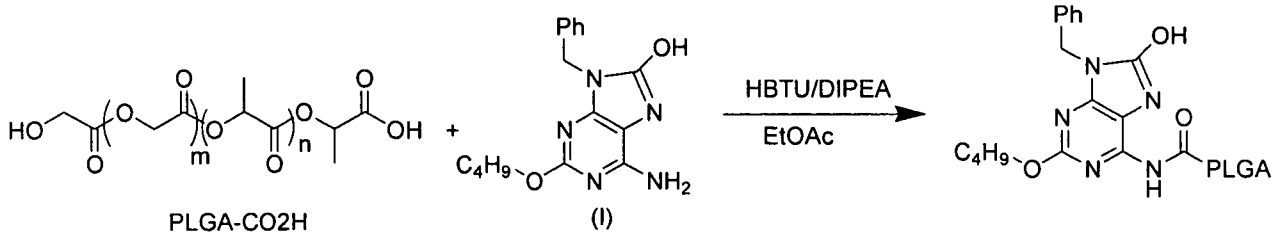
Example 27: Preparation Of A PLGA Conjugate Of The Polyglycine/R848 Polymer

Step 1: A t-BOC protected polyglycine/R848 conjugate (5 g) is dissolved in trifluoroacetic acid (25 mL) and this solution is warmed at 50°C for one hour. After cooling, the trifluoroacetic acid is removed under vacuum and the residue is triturated in ethyl acetate (25 mL). The polymer is isolated by filtration and is washed well with 2-propanol. After drying under vacuum there is obtained 4.5 grams of polymer as an off white solid.

Step 2: A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 10 g, 7.0 mmol) and HBTU (5.3 g, 14 mmol) in anhydrous DMF (100 mL) is stirred at RT under argon for 50 minutes. The polymer from above (1.4 g, 7 mmol) dissolved in dry DMF (20 mL) is added, followed by diisopropylethylamine (DIPEA) (5 mL, 28 mmol). The mixture is stirred at RT for 6 h and then at 50-55° C overnight (16 h). After cooling, the DMF is evaporated under vacuum, and the residue is dissolved in methylene chloride (50 mL). The polymer is precipitated by the addition of 2-propanol (200 mL). The polymer is isolated by decantation and is washed with 2-propanol (4 x 50 mL) to remove

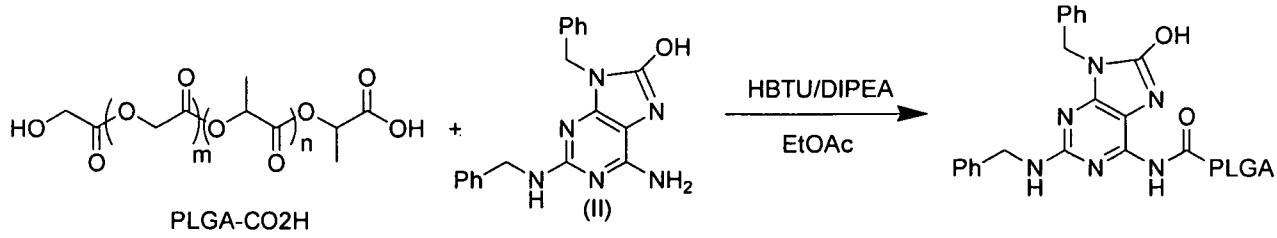
residual reagents and then dried under vacuum at 35-40 C overnight. There is obtained 9.8 g (86%) of the block copolymer.

Example 28: Preparation Of PLGA-2-Butoxy-8-Hydroxy-9-Benzyl Adenine Conjugate



A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 1.0 g, 7.0 mmol) and HBTU (0.8 g, 2.1 mmol) in anhydrous EtOAc (30 mL) is stirred at RT under argon for 30 minutes. Compound (I) (0.22 g,0.7 mmol) in 2 mL of dry DMSO is added, followed by diisopropylethylamine (DIPEA) (0.73 mL, 4.2 mmol). The mixture is stirred at room temperature for 20 h. Additional amounts of HBTU (0.53 g, 1.4 mmol) and DIPEA (0.5 mL, 2.8 mmol) are added and the mixture is heated at 50-55 °C for 4 h. After cooling, the mixture is diluted with EtOAc (100 mL) and washed with saturated NH_4Cl solution 20 mL), water (2 x 20 mL) and brine solution (20 mL). The solution is dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Isopropyl alcohol (IPA) (35 mL) is then added and the brownish polymer conjugate precipitates out of solution. The polymer is then washed with IPA (2 x 20 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 2 days as a brownish powder (1.0 g).

Example 29: Preparation Of PLGA-2,9-Dibenzyl-8-Hydroxyadenine Conjugate



A mixture of PLGA (Lakeshores Polymers, MW ~5000, 7525DLG1A, acid number 0.7 mmol/g, 1.0 g, 7.0 mmol) and HBTU (0.8 g, 2.1 mmol) in anhydrous EtOAc (30 mL) is stirred at RT under argon for 30 minutes. Compound (II) (0.24 g,0.7 mmol) in 2 mL of dry DMSO is added, followed by diisopropylethylamine (DIPEA) (0.73 mL, 4.2 mmol). The mixture is stirred at RT for 20 h. Additional amounts of HBTU (0.53 g, 1.4 mmol) and

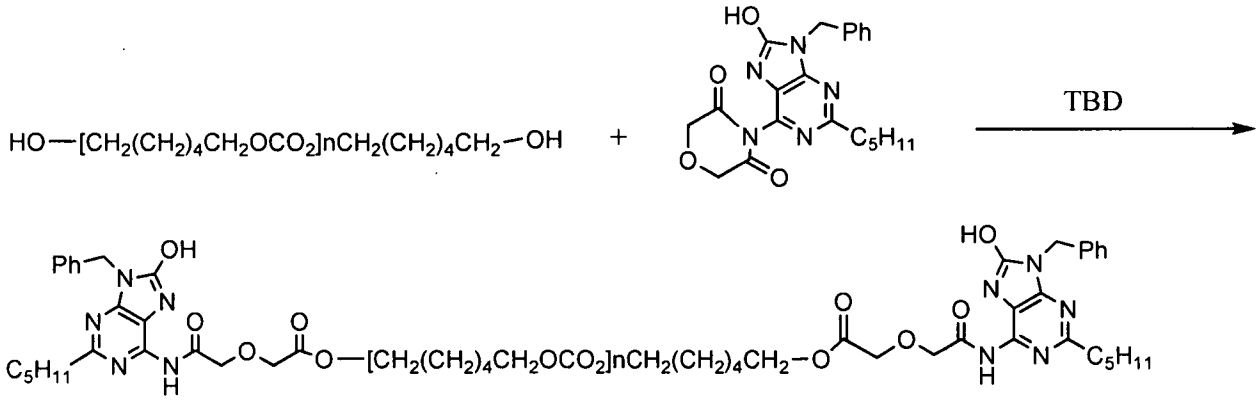
DIPEA (0.5 mL, 2.8 mmol) are added and the mixture is heated at 50-55 °C for 4 h. After cooling, the mixture is diluted with EtOAc (100 mL) and washed with saturated NH_4Cl solution 20 mL), water (2 x 20 mL) and brine solution (20 mL). The solution is dried over Na_2SO_4 (10 g) and concentrated to a gel-like residue. Isopropyl alcohol (IPA) (35 mL) is then added and the brownish polymer conjugate precipitated out of solution. The polymer is then washed with IPA (2 x 20 mL) to remove residual reagents and dried under vacuum at 35-40 °C for 2 days as a brownish powder (1.2 g).

Example 30: Imide Ring Opening Used To Attach 2-Pentyl-8-Hydroxy-9-Benzyladenine To The Terminal Alcohol Groups Of Poly-Hexamethylene Carbonate) Diol Of Molecular Weight 2000

The poly(hexamethylene carbonate) diol is purchased from Aldrich Chemical Company, Cat # 461164.

Poly(hexamethylene carbonate) diol:

Poly(hexamethylene carbonate) diol – 8-oxoadenine conjugate:



The polymer (5 g, 2.5 x 10^{-3} moles) is dissolved in methylene chloride 25 mL and the lactam of 2-pentyl-8-hydroxy-9-benzyladenine (2.05 g, 5.0 x 10^{-3} moles) is added. This slurry is stirred as 1,5,7-triazabicyclo-[4,4,0]dec-5-ene (TBD, 0.557 g, 4 x 10^{-3} moles) is added in a single portion. After stirring at room temperature overnight a clear pale yellow solution forms. The solution is diluted with methylene chloride (100 mL), and the solution is washed with 5% citric acid. This solution is dried over sodium sulfate after which it is filtered and evaporated under vacuum. After drying under high vacuum there is obtained 5.5 grams (78%) of polymer. NMR is used to determine the benzyladenine content which is 18%.

Example 31: Nicotine-PEG-PLA Conjugates

A 3-nicotine-PEG-PLA polymer was synthesized as follows:

First, monoamino poly(ethylene glycol) from JenKem® with a molecular weight of 3.5KD (0.20 gm, 5.7 X 10-5moles) and an excess of 4-carboxycotinine (0.126 gm, 5.7 X 10-4 moles) were dissolved in dimethylformamide (5.0 mL). The solution was stirred and dicyclohexylcarbodiimide (0.124 gm, 6.0 X 10-4 moles) was added. This solution was stirred overnight at room temperature. Water (0.10 mL) was added and stirring was continued for an additional 15 minutes. The precipitate of dicyclohexylurea was removed by filtration and the filtrates were evaporated under vacuum. The residue was dissolved in methylene chloride (4.0 mL) and this solution was added to diethyl ether (100 mL). The solution was cooled in the refrigerator for 2 hours and the precipitated polymer was isolated by filtration. After washing with diethyl ether, the solid white polymer was dried under high vacuum. The yield was 0.188 gm. This polymer was used without further purification for the next step.

The cotinine/PEG polymer (0.20 gm, 5.7 X 10-5 moles) was dissolved in dry tetrahydrofuran (10 mL) under nitrogen and the solution was stirred as a solution of lithium aluminum hydride in tetrahydrofuran (1.43 mL of 2.0M, 2.85 X 10-3 moles) was added. The addition of the lithium aluminum hydride caused the polymer to precipitate as a gelatinous mass. The reaction was heated to 80°C under a slow stream of nitrogen and the tetrahydrofuran was allowed to evaporate. The residue was then heated at 80°C for 2 hours. After cooling, water (0.5 mL) was cautiously added. Once the hydrogen evolution had stopped, 10% methanol in methylene chloride (50 mL) was added and the reaction mixture was stirred until the polymer had dissolved. This mixture was filtered through Celite® brand diatomaceous earth (available from EMD Inc. as Celite® 545, part # CX0574-3) and the filtrates were evaporated to dryness under vacuum. The residue was dissolved in methylene chloride (4.0 mL) and this solution was slowly added to diethyl ether (100 mL). The polymer separated as a white flocculent solid and was isolated by centrifugation. After washing with diethyl ether, the solid was dried under vacuum. The yield was 0.129 gm.

Next, a 100 mL round bottom flask, equipped with a stir bar and reflux condenser was charged with the PEG/nicotine polymer (0.081 gm, 2.2 X 10-5 moles), D/L lactide (0.410 gm, 2.85 X 10-3 moles) and anhydrous sodium sulfate (0.380 gm). This was dried under vacuum at 55°C for 8 hours. The flask was cooled and flushed with argon and then dry toluene (10 mL) was added. The flask was placed in an oil bath set at 120°C, and once the

lactide had dissolved, tin ethylhexanoate (5.5 mg, 1.36 X 10-5 moles) was added. The reaction was allowed to proceed at 120°C for 16 hours. After cooling to room temperature, water (15 mL) was added and stirring was continued for 30 minutes. Methylene chloride (200 mL) was added, and after agitation in a separatory funnel, the phases were allowed to settle. The methylene chloride layer was isolated and dried over anhydrous magnesium sulfate. After filtration to remove the drying agent, the filtrates were evaporated under vacuum to give the polymer as a colorless foam. The polymer was dissolved in tetrahydrofuran (10 mL) and this solution was slowly added to water (150 mL) with stirring. The precipitated polymer was isolated by centrifugation and the solid was dissolved in methylene chloride (10 mL). The methylene chloride was removed under vacuum and the residue was dried under vacuum. 3-nicotine-PEG-PLA polymer yield was 0.38 gm.

Example 32: Synthetic Nanocarrier Formulation

For encapsulated adjuvant formulations, Resiquimod (aka R848) was synthesized according to the synthesis provided in Example 99 of US Patent 5,389,640 to Gerster et al.

R848 was conjugated to PLA by a method provided above, and the PLA structure was confirmed by NMR.

PLA-PEG-nicotine conjugate was prepared according to Example 31.

PLA was purchased (Boehringer Ingelheim Chemicals, Inc., 2820 North Normandy Drive, Petersburg, VA 23805). The polyvinyl alcohol (Mw = 11 KD - 31 KD, 85-89% hydrolyzed) was purchased from VWR scientific. Ovalbumin peptide 323-339 was obtained from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505. Part # 4064565).

The above materials were used to prepare the following solutions:

1. Resiquimod (R848) @ 10 mg/mL and PLA @ 100 mg/mL in methylene chloride or PLA-R848 conjugate @ 100 mg/mL in methylene chloride
2. PLA-PEG-nicotine in methylene chloride @ 100 mg/mL
3. PLA in methylene chloride @ 100 mg/mL
4. Ovalbumin peptide 323 – 339 in water @ 10 or 69 mg/mL
5. Polyvinyl alcohol in water @50 mg/mL.

Solution #1 (0.25 to 0.75 mL), solution #2 (0.25 mL), solution #3 (0.25 to 0.5 mL) and solution #4 (0.1mL) were combined in a small vial and the mixture was sonicated at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. To this emulsion was added solution #5 (2.0 mL) and sonication at 35% amplitude for 40 seconds using the Branson Digital Sonifier 250 forms the second emulsion. This was added to a beaker containing

phosphate buffer solution (30 mL) and this mixture was stirred at room temperature for 2 hours to form the nanoparticles.

To wash the particles a portion of the nanoparticle dispersion (7.4 mL) was transferred to a centrifuge tube and spun at 5,300g for one hour, supernatant was removed, and the pellet was re-suspended in 7.4 mL of phosphate buffered saline. The centrifuge procedure was repeated and the pellet was re-suspended in 2.2 mL of phosphate buffered saline for a final nanoparticle dispersion of about 10 mg/mL.

Example 33: Double Emulsion with Multiple Primary Emulsions

Materials

Ovalbumin peptide 323-339, a 17 amino acid peptide known to be a T cell epitope of Ovalbumin protein, was purchased from Bachem Americas Inc. (3132 Kashiwa Street, Torrance CA 90505.)

Resiquimod (aka R848) was synthesized according to a method provided in US Patent 6,608,201.

PLA-R848, resiquimod, was conjugated to PLA with a molecular weight of approximately 2,500 Da according to a method provided above.

PLGA-R848, resiquimod, was conjugated to PLGA with a molecular weight of approximately 4,100 Da according to a method provided above.

PS-1826 DNA oligonucleotide with fully phosphorothioated backbone having nucleotide sequence 5'-TCC ATG ACG TTC CTG ACG TT-3' with a sodium counter-ion was purchased from Oligos Etc (9775 SW Commerce Circle C-6, Wilsonville, OR 97070.)

PO-1826 DNA oligonucleotide with phosphodiester backbone having nucleotide sequence 5'-TCC ATG ACG TTC CTG ACG TT-3' with a sodium counter-ion was purchased from Oligos Etc. (9775 SW Commerce Circle C-6, Wilsonville, OR 97070.)\

PLA with an inherent viscosity of 0.21 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211. Product Code 100 DL 2A.)

PLA with an inherent viscosity of 0.71 dL/g was purchased from SurModics Pharmaceuticals (756 Tom Martin Drive, Birmingham, AL 35211. Product Code 100 DL 7A.)

PLA with an inherent viscosity of 0.19 dL/g was purchased from Boehringer Ingelheim Chemicals, Inc. (Petersburg, VA. Product Code R202H.)

PLA-PEG-nicotine with a molecular weight of approximately 18,500 to 22,000 Da was prepared according to a method provided above.

PLA-PEG-R848 with a molecular weight of approximately 15,000 Da was synthesized was prepared according to a method provided above.

Polyvinyl alcohol (Mw = 11,000 – 31,000, 87-89% hydrolyzed) was purchased from J.T. Baker (Part Number U232-08).

Batches were produced using a double emulsion process with multiple primary emulsions. The table below references the solution suffix (e.g., B in Solution #1 column indicates Solution #1B was used) and volume of solution used.

Sample Number	Solution #1 (Volume)	Solution #2 (Volume)	Solution #3 (Volume)	Solution #4 (Volume)	Solution #5 (Volume)
1	B (0.1 ml)	C (1.0 ml)	A (0.1 ml)	C (1.0 ml)	A (2.0 ml)
2	A (0.2 ml)	A (1.0 ml)	A (0.1 ml)	A (1.0 ml)	A (3.0 ml)
3	A (0.2 ml)	B (1.0 ml)	A (0.1 ml)	B (1.0 ml)	A (3.0 ml)
4	A (0.2 ml)	B (1.0 ml)	A (0.1 ml)	B (1.0 ml)	A (3.0 ml)

Solution 1A: Ovalbumin peptide 323 – 339 @ 35 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13N hydrochloric acid solution at room temperature.

Solution 1B: Ovalbumin peptide 323 – 339 @ 70 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13N hydrochloric acid solution at room temperature.

Solution 2A: 0.21-IV PLA @ 75 mg/mL and PLA-PEG-nicotine @ 25 mg/ml in methylene chloride. The solution was prepared by first preparing two separate solutions at room temperature: 0.21-IV PLA @ 100 mg/mL in pure methylene chloride and PLA-PEG-nicotine @ 100 mg/mL in pure methylene chloride. The final solution was prepared by adding 3 parts PLA solution for each part of PLA-PEG-nicotine solution.

Solution 2B: 0.71-IV PLA @ 75 mg/mL and PLA-PEG-nicotine @ 25 mg/ml in methylene chloride. The solution was prepared by first preparing two separate solutions at room temperature: 0.71-IV PLA @ 100 mg/mL in pure methylene chloride and PLA-PEG-nicotine @ 100 mg/mL in pure methylene chloride. The final solution was prepared by adding 3 parts PLA solution for each part of PLA-PEG-nicotine solution.

Solution 2C: 0.19-IV PLA @ 75 mg/mL and PLA-PEG-nicotine @ 25 mg/ml in methylene chloride. The solution was prepared by first preparing two separate solutions at room temperature: 0.19-IV PLA @ 100 mg/mL in pure methylene chloride and PLA-PEG-nicotine @ 100 mg/mL in pure methylene chloride. The final solution was prepared by adding 3 parts PLA solution for each part of PLA-PEG-nicotine solution.

Solution 3A: Oligonucleotide (either PS-1826 or PO-1826) @ 200 mg/ml in purified water. The solution was prepared by dissolving oligonucleotide in purified water at room temperature.

Solution 4A: Same as Solution #2A.

Solution 4B: Same as Solution #2B.

Solution 4C: Same as Solution #2C.

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

Two separate primary water in oil emulsions were prepared. W1/O2 was prepared by combining solution 1 and solution 2 in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. W3/O4 was prepared by combining solution 3 and solution 4 in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. A third emulsion with two inner emulsion ([W1/O2,W3/O4]/W5) emulsion was prepared by combining 0.5 ml of each primary emulsion (W1/O2 and W3/O4) and solution 5 and sonicating at 30% amplitude for 40 to 60 seconds using the Branson Digital Sonifier 250.

The third emulsion was added to a beaker containing 70mM phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow for 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 spinning at 13,823g 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 nanocarrier dispersion of about 10 mg/mL.

The amounts of oligonucleotide and peptide in the nanocarrier were determined by HPLC analysis.

Example 34: Standard Double Emulsion

Materials

As provided in Example 33 above.

Batches were produced using a standard double emulsion process. The table below references the solution suffix (e.g., B in Solution #1 column indicates Solution #1B was used) and volume of solution used.

Sample Number	Solution #1 (Volume)	Solution #2 (Volume)	Solution #3 (Volume)	Solution #4 (Volume)	Solution #5 (Volume)
1	A (0.1 ml)	A (0.75 ml)	A (0.25 ml)	None	A (2.0 ml)
2	A (0.1 ml)	None	A (0.25 ml)	A (0.75 ml)	A (2.0 ml)
3	A (0.1 ml)	B (0.75 ml)	A (0.25 ml)	None	A (2.0 ml)
4	B (0.1 ml)	C (0.75 ml)	A (0.25 ml)	None	B (2.0 ml)
5	B (0.1 ml)	D (0.25 ml)	A (0.25 ml)	A (0.50 ml)	B (2.0 ml)
6	C (0.2 ml)	None	A (0.25 ml)	A (0.75 ml)	B (2.0 ml)
7	D (0.1 ml)	None	A (0.25 ml)	A (0.75 ml)	B (2.0 ml)

Solution 1A: Ovalbumin peptide 323 – 339 @ 69 mg/mL in de-ionized water. The solution was prepared by slowly adding ovalbumin peptide to the water while mixing at room temperature.

Solution 1B: Ovalbumin peptide 323 – 339 @ 70 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide in 0.13N hydrochloric acid solution at room temperature.

Solution 1C: Oligonucleotide (PS-1826) @ 50 mg/ml in purified water. The solution was prepared by dissolving oligonucleotide in purified water at room temperature.

Solution 1D: Ovalbumin peptide 323 – 339 @ 17.5 mg/mL in dilute hydrochloric acid aqueous solution. The solution was prepared by dissolving ovalbumin peptide @ 70 mg/ml in 0.13N hydrochloric acid solution at room temperature and then diluting the solution with 3 parts purified water per one part of starting solution.

Solution 2A: R848 @ 10 mg/ml and 0.19-IV PLA @ 100 mg/mL in pure methylene chloride prepared at room temperature.

Solution 2B: PLA-R848 @ 100 mg/ml in pure methylene chloride prepared at room temperature.

Solution 2C: PLGA-R848 @ 100 mg/ml in pure methylene chloride prepared at room temperature.

Solution 2D: PLA-PEG-R848 @ 100 mg/ml in pure methylene chloride prepared at room temperature.

Solution 3A: PLA-PEG-nicotine @ 100 mg/ml in pure methylene chloride prepared at room temperature.

Solution 4A: 0.19-IV PLA @ 100 mg/mL in pure methylene chloride prepared at room temperature.

Solution 5A: Polyvinyl alcohol @ 50 mg/mL in de-ionized water.

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

The water in oil (W/O) primary emulsion was prepared by combining solution 1 and solution 2, solution 3, and solution 4 in a small pressure tube and sonicating at 50% amplitude for 40 seconds using a Branson Digital Sonifier 250. The water/oil/water (W/O/W) double emulsion was prepared by adding solution 5 to the primary emulsion and sonicating at 30% to 35% amplitude for 40 seconds using the Branson Digital Sonifier 250.

The double emulsion was added to a beaker containing phosphate buffer solution (30 mL) and stirred at room temperature for 2 hours to allow for 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 spinning at 5,000 to 9,500 RPM 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 nanocarrier dispersion of about 10 mg/mL.

Example 35: Determination Of Amount Of Agents

Method for R848 and peptides (e.g., ova peptide, human peptide, TT2pDT5t)

The amount of R848 (immunostimulatory agent) and ova peptide (T cell antigen) was measured using reverse phase HPLC on an Agilent 1100 system at appropriate wavelengths (λ = 254 nm for R848 and 215 nm for ova peptide) equipped with an Agilent Zorbax SB-C18 column (3.5μm. 75 x 4.6 mm. Column Temp = 40°C (part no. 866953-902)) using Mobile Phase A (MPA) of 95% water/5% acetonitrile/0.1% TFA and Mobile Phase B (MPB) of 90 % acetonitrile/10% water/0.09% TFA (Gradient: B = 5 to 45 % in 7 minutes; ramp to 95% B to 9 min; decrease back to 5% B to 9.5 min and kept equilibrating to end. Total run time was 13 minute with flow rate of 1 mL/min).

Method for CpG

The amount of CpG (immunostimulatory agent) was measured using reverse phase HPLC on Agilent 1100 system at 260 nm equipped with Waters XBridge C-18 (2.5 micron

particle, 50x 4.6 mm ID (part No. 186003090), column temp. 600C) using mobile phase A of 2% acetonitrile in 100 mM TEA- acetic acid buffer, pH about 8.0 and mobile B as 90% acetonitrile, 10% water (column equilibrated at 5% B, increased to 55% B in 8.5 min, then ramped to 90% B to 12 minutes. Strength of B was rapidly decreased to 5% in one minute and equilibrated until stop time, 16 minutes. The flow rate was 1 mL/min until end of the method, 16 minutes).

Method for Nicotine analog

Nicotine analog was measured using reverse phase HPLC on Agilent 1100 system at 254 nm equipped with Waters X-Bridge C-18 (5 micron particle, 100 x 4.6 mm ID, column temp at 400C) using Mobile Phase A (MPA) of 95% water/5% acetonitrile/0.1% TFA and Mobile Phase B (MPB) of 90 % acetonitrile/10% water/0.09% TFA (gradient: column was equilibrated at 5% B increased to 45% B in 14 minutes. Then ramped up to 95% B from 14 to 20 minutes. Mobile B strength was quickly decreased back to 5% and requilibrated until the end of the method. The flow rate of the method was maintained at 0.5 ml/min with total run time of 25 minutes. The NC suspension was centrifuged @14000 rpm for about 15-30 minutes depending on particle size. The collected pellets were treated with 200 uL of conc. NH_4OH (8 M) for 2h with agitation until the solution turns clear. A 200 uL of 1% TFA was added to neutralize the mixture solution, which brought the total volume of the pellet solution to 200 uL. An aliquot of 50 uL of the solution was diluted with MPA(or water) to 200 uL and analyzed on HPLC as above to determine the amount present in the pellets.

Encapsulated free R848 in nanocarrier

0.5 mL of the NC suspension was centrifuged @14000rpm for about 15 minutes. The collected pellet was dissolved with 0.3 mL of acetonitrile and centrifuged briefly @ 14000rpm to remove any residual insolubles. The clear solution was further diluted with 4 times equivalent volume of MPA and assayed on reverse phase HPLC described above.

Encapsulated CpG in nanocarrier

330 uL of NC suspension from the manufacture (about 10 mg/mL suspension in PBS) was spun down at 14000rpm for 15 to 30 minutes depending on particle size. The collected pellets were re-suspended with 500 uL of water and sonicated for 30 minutes to fully disperse the particles. The NC was then heated at 600°C for 10 minutes. Additional 200 uL of 1 N NaOH was added to the mixture, heated for another 5 minutes where the mixture becomes

clear. The hydrolyzed NC solution was centrifuged briefly at 14000 rpm. A final 2x dilution of the clear solution using water was then made and assayed on the reverse HPLC described above.

Encapsulated T cell antigens (e.g., ova peptide, or human peptide, TT2pDT5t)

330 uL of NC suspension from the manufacture (about 10 mg/mL suspension in PBS) was spun down at 14000rpm for 15 to 30 minutes. 100 uL of acetonitrile was added to the pellets to dissolve the polymer components of the NC. The mixture was vortexed and sonicated for 1 to 5 minutes. 100 uL 0.2% TFA was added to the mixture to extract the peptides and sonicated for another 5 minutes to ensure the break down of the aggregates. The mixture was centrifuged at 14000rpm for 15 minutes to separate any insoluble materials (e.g., polymers). A 50 uL aliquot of the supernatant diluted with 150 uL of MPA (or water) was taken and assayed on the reverse phase HPLC as described above.

Amount of conjugated nicotine analog (B cell antigen) in nanocarriers

1.5 mL of NC suspension was spun down @ 14000rpm for about 15 minutes, the pellets were hydrolyzed using 150 uL of concentrated NH_4OH (8M) for about 2-3 h until the solution turns clear. A 150 uL of 2% TFA(aq) solution was added to the pellet mixture to neutralize the solution. A 100 uL aliquot of the mixture was diluted with 200 uL of water and assayed on reverse phase HPLC described above and quantified based on the standard curve established using the precursor (PEG-nicotine) of the PLA-PEG-nicotine used in the manufacture.

Example 36: Release Rate Testing

The release of the antigen (a nicotine analog) and the immunostimulatory agent (R848) from synthetic nanocarriers in phosphate buffered saline solution (PBS) (100mM, pH=7.4) and citrate buffer (100 mM, pH=4.5) at 37 °C are performed as follows:

Analytical Method: The amount of R848 and nicotine analog released is measured using reverse phase HPLC on a Agilent 1100 system at λ = 215 nm equipped with an Agilent Zorbax SB-C18 column (3.5µm. 75 x 4.6 mm. Column Temp = 40°C (part no. 866953-902)) using Mobile Phase A (MPA) of 98% water/2% acetonitrile/0.1% TFA and Mobile Phase B (MPB) of 90 % acetonitrile/10% water/0.09% TFA (Gradient: B = 5 to 45 % in 7 minutes; ramp to 95% B to 9 min; re-equilibrate to end. Total run time is 13 minute with flow rate of 1 mL/min).

The total amount of R848 and nicotine analog present in the synthetic nanocarriers is first estimated based on the loading of R848 and nicotine analog in the synthetic nanocarriers. An aqueous suspension of the tested synthetic nanocarriers is then diluted to a final stock volume of 4.4 mL with PBS.

In vitro release rate measurement in PBS (pH=7.4):

For T0 sample, a 200 μL aliquot is immediately removed from each of the NC sample and centrifuged @ 14000 rpm in microcentrifuge tubes using a microcentrifuge (Model: Galaxy 16). 100 μL of the supernatant is removed and diluted to 200 μL with HPLC Mobile Phase A (MPA) and assayed for the amount of R848 and nicotine analog released on the reverse phase HPLC.

For time point measurements: 9 x 200 μL of each of the samples are added to microcentrifuge tubes (3 x 200 for unconjugated) and 300 μL of 37 Deg C PBS is added to each above aliquot and the samples are placed immediately in a 37 Deg C oven. At the following time points: 2h, 12 h, 24 h, 48 h, 96 h and 144 h (for conjugated R848) or 2 h, 12 h, 16h and 24 h (for unconjugated (encapsulated) R848), the samples are centrifuged and are assayed for the amount of R848 and nicotine analog released in the same manner as for T0 sample.

In vitro release rate measurement in Citrate Buffer (pH=4.5):

For T0 sample, a 200 μL aliquot is removed from each of the samples and centrifuged @ 6000 rpm for 20 minutes and the supernatant is removed. The residual synthetic nanocarriers are resuspended in 200 uL of citrate buffer and centrifuged @ 14000 rpm for 15 minutes. 100 uL of the supernatant is removed and diluted to 200 uL with MPA and assayed for R848 and nicotine analog as above.

For time point measurements: 9 x 200 uL of each of the samples are added to microcentrifuge tubes (3 x 200 for unconjugated) and centrifuged for 20 minutes @ 6000 rpm and the supernatants are removed. The residual NCs are then resuspended in 500 uL of citrate buffer and placed in a 37 Deg C oven. At the following time points: 12 h, 24 h, 48 h, 96 h and 144 h (for conjugated R848) or 2 h, 12 h, 16h and 24 h (for unconjugated (encapsulated) R848), the samples are centrifuged and assayed for the amount of R848 and nicotine analog relased as above for T0 sample.

In order to complete the mass balance from above measurements in PBS and Citrate buffer, the remaining pellets from each sample are treated with 200 uL of conc. NH4OH (8 M) for 3h with mixing. After the mixture is settled, 200 uL of 1% TFA is added to bring total volume of the pellet solution to 400 uL. An aliquot of 50 uL of the solution is diluted with

MPA to 200 uL and analyzed on HPLC as above to determine the amount of unreleased R848 and nicotine analog remaining in the pellets after in vitro release to close the mass balance. For unconjugated samples, the sample is diluted with TFA in acetonitrile and assayed as above for R848 and nicotine analog.

Example 37: Release Rate Testing

The release of antigen (e.g., ova peptide, T cell antigen) and immunostimulatory agents (e.g., R848, CpG) from synthetic nanocarriers in phosphate buffered saline solution (PBS) (100mM, pH=7.4) and citrate buffer (100 mM, pH=4.5) at 37 °C was determined as follows:

The release of R848 from the nanocarrier composed of conjugated R848 and the ova peptide was achieved by exchanging desired amount of the aqueous suspension of the tested synthetic nanocarriers obtained from the manufacture (e.g., about 10 mg/mL in PBS) into the same volume of the appropriate release media (Citrate buffer 100mM) via centrifugation and re-suspension.

In vitro release rate measurement in PBS (pH=7.4)

1 mL of the PBS suspension NC was centrifuged @ 14000 rpm in microcentrifuge tubes generally from 15-30 minutes depending on particle size. The collected supernatant was then diluted with equal volume of the mobile phase A (MPA) or water and assayed on reverse phase HPLC for the amount of the R848 release during the storage. The remaining pellet was re-suspended to homogeneous suspension in 1mL of PBS and placed to 37°C thermal chamber with constant gentle agitation

For T0 sample, a 150 μL aliquot was immediately removed from NC suspension prior placing the NC suspension to 37°C thermal chamber and centrifuged @ 14000 rpm in microcentrifuge tubes using a microcentrifuge (Model: Galaxy 16). 100 μL of the supernatant was removed and diluted to 200 μL with HPLC Mobile Phase A (MPA) or water and assayed for the amount of R848 and ova peptide released on the reverse phase HPLC.

For time point measurements, 150 μL aliquot was removed from the 37°C NC sample suspension, and the samples were centrifuged and assayed for the amount of R848 and ova peptide released in the same manner as for T0 sample. The R848 and ova peptide released was tested at 6h, 24h for routine monitoring with additional 2h, 48h, 96h and 144h for complete release profile establishment.

In vitro release rate measurement in Citrate Buffer (pH=4.5)

A 100 mM sodium citrate buffer (pH= 4.5) was applied to exchange the original NC storage solution (e.g., PBS) instead of the PBS buffer, pH= 7.4. In order to complete the mass balance from above measurements in PBS and Citrate buffer, the remaining pellets from each time point were treated with 100 uL of NH_4OH (8 M) for 2h (or more) with agitation until solution turn clear. A 100 uL of 1% TFA was added to neutralize the mixture, which brought the total volume of the pellet solution to 200 uL. An aliquot of 50 uL of the mixture was diluted with MPA (or water) to 200 uL and analyzed on HPLC as above to determine the amount of unreleased R848 remaining in the pellets after in vitro release to close the mass balance. For unconjugated samples, the sample was diluted with TFA in acetonitrile and assayed as above for R848.

The release of CpG was determined similar to the measurement of R848 and ova peptide in terms of sample preparation and monitored time points. However, the amount of the CpG in the release media was assayed by the reverse phase HPLC method described above.

Example 38: Immunization with NC-Nic Carrying R848

A group of five mice was immunized three times (subcutaneously, hind limbs) at 2-week intervals (days 0, 14 and 28) with 100 μg of NC-Nic. The nanocarriers were made using a formulation strategy as described above and contained ova peptide and polymers 50% of which were PLGA-R848, 25% of which were PLA, and 25% of which were PLA-PEG-Nic. Serum anti-nicotine antibodies were then measured on days 26, 40, 54 and 69. EC_{50} values for anti-nicotine antibodies as measured in standard ELISA against polylysine-nicotine are shown in **Fig. 1**.

The release rate of R848 from NC-Nic was 19.8 μg per 1 mg of NC-Nic at 24 hours of incubation at 37°C (pH=4.5). Similar treatment did not result in any detectable release of PEG-nicotine antigen from NC-Nic. PEG-nicotine was released from NC-Nic only at extreme pH values (upon treatment with NH_4OH or with TFA) showing 5.2% release (52 μg per 1 mg of NC-Nic).

This experiment demonstrates that utilization of NC-Nic carrying R848 (a Th1 adjuvant, TLR7/8 agonist), which was released from NC-Nic much faster at physiological conditions (pH=4.5) than the antigen (PEG-nicotine), generates a strong and long-term humoral immune response against NC-carried antigen. Antibody induction after

immunization with NC-Nic (nanocarrier exhibiting nicotine on the outer surface in the form of PLA-PEG-nicotine) also carrying adjuvant R848.

CLAIMS

What is claimed is:

1. A composition comprising:

synthetic nanocarriers that comprise:

(a) an immunomodulatory agent coupled to the synthetic nanocarrier; and

(b) an antigen coupled to the synthetic nanocarrier;

wherein the immunomodulatory agent and antigen dissociates from the synthetic nanocarrier according to the following relationship:

$$IA(rel)\ \% / A(rel)\ \% \geq 1.2$$

wherein IA(rel) % is defined as a weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours divided by the sum of the weight of immunomodulatory agent released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours plus a weight of immunomodulatory agent retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers; and

wherein A(rel) % is defined as a weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours divided by the sum of the weight of antigen released upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours plus a weight of antigen retained in the synthetic nanocarrier upon exposure of the synthetic nanocarrier to an in vitro aqueous environment at a pH = 4.5 for 24 hours, expressed as weight percent, and taken as an average across a sample of the synthetic nanocarriers.

2. The composition of claim 1, wherein the immunomodulatory agent is coupled to the synthetic nanocarrier via an immunomodulatory agent coupling moiety.

3. The composition of claim 2, wherein the immunomodulatory agent is covalently coupled to the synthetic nanocarrier.

4. The composition of claim 1 or 2, wherein the immunomodulatory agent is encapsulated within the synthetic nanocarrier.

5. The composition of any of claims 1-4, wherein the antigen is coupled to the synthetic nanocarrier via an antigen coupling moiety.

6. The composition of claim 5, wherein the antigen is covalently coupled to the synthetic nanocarrier.

7. The composition of claim 1 or 5, wherein the antigen is encapsulated within the synthetic nanocarrier.

8. The composition of any of claims 1-7, wherein the antigen is a B cell antigen.

9. The composition of claim 8, wherein the B cell antigen is an antigen derived from an infectious agent.

10. The composition of claim 8, wherein the B cell antigen is a poorly immunogenic antigen.

11. The composition of claim 8, wherein the B cell antigen is an abused substance or a portion thereof or an addictive substance or a portion thereof.

12. The composition of claim 8, wherein the B cell antigen is a toxin or hazardous environmental agent.

13. The composition of claim 8, wherein the B cell antigen is an allergen, a degenerative disease antigen, a cancer antigen, an atopic disease antigen, or a metabolic disease antigen.

14. The composition of any of claims 1-7, wherein the antigen is a T cell antigen.

15. The composition of claim 14, wherein the T cell antigen is a MHC class I antigen.

16. The composition of any of claims 1-15, wherein the immunomodulatory agent is an adjuvant.

17. The composition of claim 16, wherein the adjuvant comprises a Toll-like receptor (TLR) agonist.

18. The composition of claim 17, wherein the TLR agonist is a TLR 3 agonist, TLR 7 agonist, TLR 8 agonist, TLR 7/8 agonist, or a TLR 9 agonist.

19. The composition of claim 17 or 18, wherein the TLR agonist is an imidazoquinoline.

20. The composition of claim 19, wherein the imidazoquinoline is resiquimod or imiquimod.

21. The composition of claim 17 or 18, wherein the TLR agonist is an immunostimulatory nucleic acid.

22. The composition of claim 21, wherein the immunostimulatory nucleic acid is an immunostimulatory DNA or immunostimulatory RNA.

23. The composition of claim 21 or 22, wherein the immunostimulatory nucleic acid is a CpG-containing immunostimulatory nucleic acid.

24. The composition of claim 16, wherein the adjuvant comprises a universal T-cell antigen.

25. The composition of any of claims 1-24, wherein the synthetic nanocarriers comprise one or more biodegradable polymers.

26. The composition of claim 25, wherein the immunomodulatory agent is coupled to the one or more biodegradable polymers via the immunomodulatory agent coupling moiety.

27. The composition of claim 26, wherein the immunomodulatory agent is covalently coupled to the one or more biodegradable polymers.

28. The composition of claim 27, wherein the immunomodulatory agent coupling moiety comprises an amide bond.

29. The composition of claim 27, wherein the immunomodulatory agent coupling moiety comprises an ester bond.

30. The composition of claim 26, wherein the immunomodulatory agent coupling moiety comprises an electrostatic bond.

31. The composition of any of claims 25-29, wherein the biodegradable polymers comprise poly(lactide), poly(glycolide), or poly(lactide-co-glycolide).

32. The composition of any of claims 25-29 and 31, wherein the biodegradable polymers have a weight average molecular weight ranging from 800 Daltons to 10,000 Daltons, as determined using gel permeation chromatography.

33. The composition of any of claims 1-32, wherein the synthetic nanocarriers further comprise an antigen presenting cell (APC) targeting feature.

34. The composition of any of claims 1-33, wherein the synthetic nanocarriers comprise lipid-based nanoparticles, polymeric nanoparticles, metallic nanoparticles, surfactant-based emulsions, dendrimers, buckyballs, nanowires, virus-like particles, peptide or protein-based particles, nanoparticles that comprise a combination of nanomaterials, spheroidal nanoparticles, cubic nanoparticles, pyramidal nanoparticles, oblong nanoparticles, cylindrical nanoparticles or toroidal nanoparticles.

35. The composition of any of claims 1-34, further comprising a pharmaceutically acceptable excipient.

36. A composition comprising a vaccine comprising the composition of any of claims 1-35.

37. A method comprising:

administering the composition of any of claims 1-36 to a subject.

38. The method of claim 37, wherein the composition is in an amount effective to induce or enhance an immune response.

39. The method of claim 38, wherein the subject has cancer, an infectious disease, a non-autoimmune metabolic disease, a degenerative disease, or an addiction.

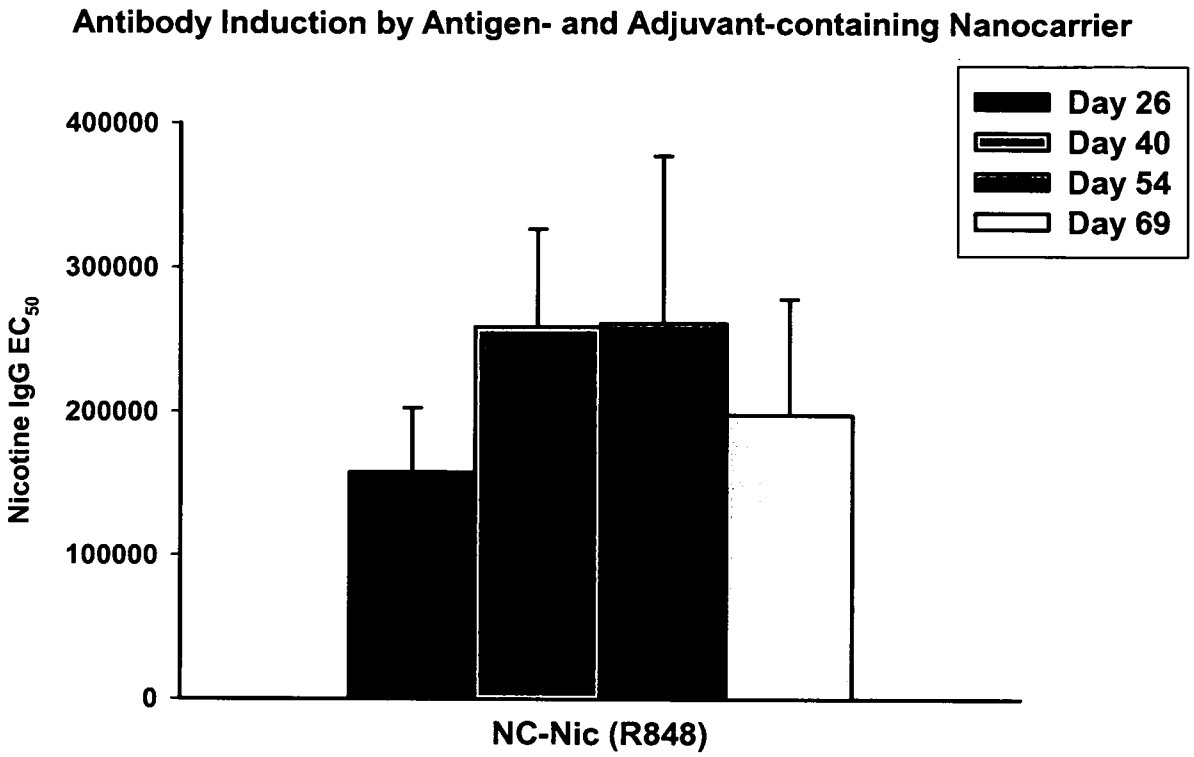

Antibody Induction by Antigen- and Adjuvant-containing Nanocarrier
Day 26
Day 40
Day 54
Day 69
400000
300000
200000
100000
0
Nicotine IgG EC50
NC-Nic (R848)

FIG. 1