[0005] The carbohydrate-modified particles disclosed herein are relatively small and have an effective average diameter within a microscale or a nanoscale. Specifically, the carbohydrate-modified particles may be referred to as "carbohydrate-enhanced nanoparticles" or "CENPs." The particles are modified via attachment of one or more carbohydrate moieties at the surface of the particles. Preferably, the particles are modified via covalent attachment of one or more carbohydrate moieties at the surface of the particles. The carbohydrate moieties may be attached directly to the surface of the particles or via one or more linker molecules. The carbohydrate moieties preferably function as immune modulators, for example, modulators that induce immune tolerance.

[0005a] In one aspect, there is provided carbohydrate-modified particles encapsulating an antigen, the particles comprising a biodegradable polymeric base material having an effective average diameter of 0.01-500 μm and a carbohydrate moiety that is an immune modulator covalently attached at the surface of the particles, wherein the particles induce tolerance and/or an anti-inflammatory response to an antigen, and wherein the carbohydrate moiety is selected from the group consisting of Heparin disaccharide I-A, Heparin disaccharide II-A, Heparin disaccharide III-A, Heparin disaccharide IV-A, Heparin disaccharide IV-S, Heparin unsaturated disaccharide I-H, Heparin unsaturated disaccharide II-H, Heparin unsaturated disaccharide II-H, Heparin unsaturated disaccharide I-P, Chondroitin disaccharide Δdi-0S, Chondroitin disaccharide Δdi-4S, Chondroitin disaccharide Δdi-6S, Chondroitin disaccharide ΔDi-diSB, Chondroitin disaccharide ΔDi-diSE, Chondroitin disaccharide ΔDi-triS, Chondroitin disaccharide ΔDi-UA2S, Neocarradecaose-41,3,5,7,9-penta-O-sulphate, neocarrahexadecaose-41,3,5,7,9,11,13,15-octa-O-sulfate, GalNAcβ1-4Gal (receptor for pili of *Pseudomonas aeruginosa*), Blood group B type 2 linear trisaccharide, P1 Antigen, Tn Antigen, Sialyl-Lewis A, Sialyl-Lewis X, Sialyl-Lewis X β-methyl glycoside, Sulfo-Lewis A, Sulfo-Lewis X, α1-2-Mannobiose, α1-3-Mannobiose, α1-6-Mannobiose, Mannotetraose, α1-3, α1-3, α1-6-Mannopentose, β1-2-N-Acetylglucosamine-mannose, LS-Tetrasaccharide a (LSTa), LS-tetrasaccharide c (LSTc), α-D-N-Acetylgalactosaminyl 1-3 galactose, α-D-N-Acetylgalactosaminyl 1-3 galactose β1-4 glucose, D-Galactose-4-O-sulfate, Glycyl-lactose (Lac-gly), Glycyl-lacto-N-tetraose (LNT-gly), 2'-Fucosyllactose, Lacto-N-neotetraose (LNnT), Lacto-N-tetraose (LNT), Lacto-N-difucohexaose I

(LNDFH I), Lacto-N-difucohexaose II (LNDFHII), Lacto-N-neohexaose (LNnH), 3'-Sialyllactose (3'-SL), 6'-Sialyllactose (6'-SL), 3'-Sialyl-N-acetyllactosamine, 6'-Sialyl-N-acetyllactosamine (6'-SLN), 3-Fucosyllactose (3FL), Fucoidan, 4-β-Galactobiose, 1-3 Galactodiosyl β-methyl glycosie, α1-3, β1-4, α1-3 Galactotetraose, β-Galactosyl 1-3 N-acetyl galactosamine methyl glycoside, β1-3 Gal-N-acetyl galactosaminyl-β1-4 Gal-β1-4-Glc, β1-6 Galactobiose, Globotriose, β-D-N-Acetylglactosaminyl 1-3 galactose (terminal disaccharide of globotriose), 1-Deoxynojirimyncin (DNJ), D-Fucose, L-Fucose, D-Talose, Calystegine A3, Calystegine B3, N-methyl cis-4-hydroxymehtyl-L-proline, 2,5-dideoxy-2,5-imino-D-mannitol, Castanospermine, 6-epi-Castanospermine, and combinations thereof.

[0006] The disclosed particles of the compositions and formulations preferably are biodegradable and are formed from a polymeric base material. In some examples, the particles comprise polymeric base material formed from carbohydrate monomers or pre-polymers.

[0007] In addition to the carbohydrate moiety, the disclosed carbohydrate-modified particles may include additional components for modulating an immune response. In particular, the disclosed carbohydrate-modified particles may include an antigen, for example, a peptide, polypeptide, or protein that is utilized as an antigen and administered to a subject in order to desensitize the subject to the antigen and or to induce tolerance in the subject. Suitable antigens for inclusion in the disclosed carbohydrate-modified particle may include autoantigens associated with autoimmune disease (*e.g.*, peptides, polypeptides, or proteins that are associated with autoimmune disease). Suitable antigens may include autoantigens associated with type 1 diabetes (T1D). Suitable antigens also may include antigens associated with allergic reactions (*i.e.*, allergens).

[0008] The disclosed particles may be prepared by methods that include one or more of the following steps: (a) screening a library of carbohydrate moieties for immune-modulator activity by contacting the library with an immune cell and measuring the effect of the library on stimulating the immune cell (*e.g.*, by measuring cytokine production over baseline and in particular IL-10, TGFβ, and/or CCL4 production versus IL-6 production); (b) selecting a

CLAIMS

We claim:

1. Carbohydrate-modified particles encapsulating an antigen, the particles comprising a biodegradable polymeric base material having an effective average diameter of 0.01-500 µm and a carbohydrate moiety that is an immune modulator covalently attached at the surface of the particles, wherein the particles induce tolerance and/or an anti-inflammatory response to an antigen, and

wherein the carbohydrate moiety is selected from the group consisting of Heparin disaccharide I-A, Heparin disaccharide II-A, Heparin disaccharide III-A, Heparin disaccharide IV-A, Heparin disaccharide IV-S, Heparin unsaturated disaccharide I-H, Heparin unsaturated disaccharide II-H, Heparin unsaturated disaccharide II-H, Heparin unsaturated disaccharide I-P, Chondroitin disaccharide Adi-OS, Chondroitin disaccharide Adi-4S, Chondroitin disaccharide Adi-6S, Chondroitin disaccharide ADi-diSB, Chondroitin disaccharide ADi-diSE, Chondroitin disaccharide ADi-triS, Chondroitin disaccharide ADi-UA2S, Neocarradecaose-41,3,5 ,7,9-penta-0-sulphate, neocarrahexadecaose-41 ,3 ,5,7,9, 11 , 13 ,15 -octa-0-sulfate, GalNAc131-4Gal (receptor for pili of Pseudomonas aeruginosa), Blood group B type 2 linear trisaccharide, P1 Antigen, Tn Antigen, Sialyl-Lewis A, Sialyl-Lewis X, Sialyl-Lewis X 13-methyl glycoside, Sulfo-Lewis A, Sulfo-Lewis X, al-2-Mannobiose, a 1-3-Mannobiose, al -6-Mannobiose, Mannotetraose, al-3, al-3, al-6-Mannopentose, 131-2-N-Acetylglucosamine-mannose, LS-Tetrasaccharide a (LSTa), LS-tetrasaccharide c (LSTc), a-D-N-Acetylgalactosaminyl 1-3 galactose, a-D-N-Acetylgalactosaminyl 1-3 galactose 131-4 glucose, D-Galactose-4-O-sulfate, Glycyl-lactose (Lac-gly), Glycyl-lacto-N-tetraose (LNT-gly), 2'-Fucosyllactose, Lacto-N-neotetraose (LNnT), Lacto-N-tetraose (LNT), Lacto-N-difucohexaose I (LNDFH I), Lacto-N-difucohexaose II (LNDFHII), Lacto-N-neohexaose (LNnH), 3'-Sialyllactose (3'-SL), 6'-Sialyllactose (6'-SL), 3'-Sialyl-N-acetyllactosamine, 6'-Sialyl-N-acetyllactosamine (6'-SLN), 3-Fucosyllactose (3FL), Fucoidan, 4-13-Galactobiose, 1-3 Galactodiosyl 13-methyl glycosie, al-3, 131-4, al-3 Galactotetraose, 13-Galactosyl 1-3 N-acetyl galactosamine methyl glycoside, 131-3 Gal-N-acetyl galactosaminyl-f31-4 Gal-f31-4-Glc, 131-6 Galactobiose, Globotriose, f3-D-N-Acetylglactosaminyl 1-3 galactose (terminal disaccharide of globotriose), 1-Deoxynojirimyncin (DNJ), D-Fucose, L-Fucose, D-Talose, Calystegine A3, Calystegine B3, N-methyl cis-4-

hydroxymehtyl-L-proline, 2,5-dideoxy-2,5-imino-D-mannitol, Castanospermine, 6-epi-Castanospermine, and combinations thereof.

2. The particles of claim 1, wherein the polymeric base material comprises a co-polymer of polylactic acid (PLA) and polyglycolic acid (PGA) (i.e., PLGA).

3. The particles of claim 1, wherein the carbohydrate moiety is covalently attached to the surface of the particles via a linker.

4. The particles of claim 3, wherein the linker comprises: (1) an electrophile that reacts with a free hydroxyl group of the carbohydrate moiety; and (2) a nucleophile that reacts with a free carboxyl group of the polymeric base material.

5. The particles of claim 4, wherein the carbohydrate moiety is covalently attached to the surface of the particles via carbodiimide crosslinking.

6. The particles of claim 1, further comprising an additional immunomodulator other than the carbohydrate moiety.

7. The particles of claim 1, wherein the immune modulator induces desensitization or tolerance and/or the immune modulator induces an anti-inflammatory response.

8. The particles of claim 6, wherein the additional immunomodulator is an antigen associated with an autoimmune disease or disorder.

9. The particles of claim 8, wherein the antigen is associated with type-1 diabetes.

10. A pharmaceutical composition comprising the particles of claim 1 together with a suitable carrier, excipient, or diluent.

11. Use of the composition of claim 10 in the manufacture of a medicament for treating a disease or disorder in a subject in need thereof.

12. The use of claim 11, wherein the subject has or is at risk for developing an immune disease or disorder.

13. The use of claim 12, wherein the immune disease or disorder is an allergic reaction and the method induces tolerance in the subject.

14. The use of claim 12, wherein the immune disease or disorder is an autoimmune disease or disorder.

15. The use of claim 14, wherein the immune disease or disorder is diabetes mellitus type 1.

16. A method for preparing the particles of claim 1, the method comprising one or more of the following steps:

(a) screening a library of carbohydrate moieties for immune modulator activity by contacting the library with an immune cell and measuring the effect of the library on stimulating the immune cell;

(b) selecting a carbohydrate moiety based on its effect on stimulating the immune cell; and

(c) attaching the carbohydrate moiety to particles formed from a polymeric base material.

17. The method of claim 16, wherein measuring the effect of the library on stimulating the immune cell comprising measuring cytokine production.

18. The method of claim 17, wherein measuring cytokine production comprises measuring IL-10 production over baseline and measuring IL-6 production over baseline, and selecting a carbohydrate moiety based on its effect on stimulating the immune cell comprises selected a carbohydrate moiety that increases IL-10 secretion over baseline while not changing IL-6 secretion or while decreasing IL-6 secretion.

19. The method of claim 16, wherein attaching the carbohydrate moiety is attached covalently to particles formed from a polymeric base material.