Aβ IMMUNOGENIC PEPTIDE CARRIER CONJUGATES AND METHODS OF PRODUCING SAME

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application Serial No. 60/530,481, filed December 17, 2003, which is incorporated herein by reference in its entirety for all purposes

BACKGROUND OF THE INVENTION

[0002] The essence of adaptive immunity is the ability of an organism to react to the presence of foreign substances and produce components (antibodies and cells) capable of specifically interacting with and protecting the host from their invasion. An "*antigen*" or "*immunogen*" is a substance that is able to elicit this type of immune response and also is capable of interacting with the sensitized cells and antibodies that are manufactured against it.

[0003] Antigens or immunogens are usually macromolecules that contain distinct antigenic sites or "*epitopes*" that are recognized and interact with the various components of the immune system. They can exist as individual molecules composed of synthetic organic chemicals, proteins, lipoproteins, glycoproteins, RNA, DNA, or polysaccharides, or they may be parts of cellular structures (bacteria or fungi) or viruses (Harlow and Lane 1988a,b, c; Male *et al.,* 1987).

[0004] Small molecules like short peptides, although normally able to interact with the products of an immune response, often cannot cause a response on their own. These peptide immunogens or "*haptens*" as they are also called, are actually incomplete antigens, and, although not able by themselves to cause immunogenicity or to elicit antibody production, can be made immunogenic by coupling them to a suitable carrier. Carriers typically are protein antigens of higher molecular weight that are able to cause an immunological response when administered *in vivo*.

[0005] In an immune response, antibodies are produced and secreted by the B-lymphocytes in conjunction with the T-helper (T_H) cells. In the majority of hapten-carrier systems, the B cells produce antibodies that are specific for both the hapten and the carrier. In these cases, the T lymphocytes will have specific binding domains on the carrier, but will not recognize the hapten alone. In a kind of synergism, the B and T cells cooperate to induce a hapten-

specific antibody response. After such an immune response has taken place, if the host is subsequently challenged with only the hapten, usually it will respond by producing hapten-specific antibodies from memory cells formed after the initial immunization.

[0006] Synthetic haptens mimicking some critical epitopic structures on larger macromolecules are often conjugated to carriers to create an immune response to the larger "parent" molecule. For instance, short peptide segments can be synthesized from the known sequence of a protein and coupled to a carrier to induce immunogenicity toward the native protein. This type of synthetic approach to the immunogen production has become the basis of much of the current research into the creation of vaccines. However, in many instances, merely creating a B-cell response by using synthetic peptide-carrier conjugates, however well designed, will not always guarantee complete protective immunity toward an intact antigen. The immune response generated by a short peptide epitope from a larger viral particle or bacterial cell may only be sufficient to generate memory at the B cell level. In these cases it is generally now accepted that a cytotoxic T-cell response is a more important indicator of protective immunity. Designing peptide immunogens with the proper epitopic binding sites for both B-cell and T-cell recognition is one of the most challenging research areas in immunology today.

[0007] The approach to increasing immunogenicity of small or poorly immunogenic molecules by conjugating these molecules to large "carrier" molecules has been utilized successfully for decades (see, *e.g.*, Goebel *et al.* (1939) *J. Exp. Med.* 69: 53). For example, many immunogenic compositions have been described in which purified capsular polymers have been conjugated to carrier proteins to create more effective immunogenic compositions by exploiting this "carrier effect." Schneerson *et al.* (1984) *Infect. Immun.* 45: 582-591). Conjugation has also been shown to bypass the poor antibody response usually observed in infants when immunized with a free polysaccharide (Anderson *et al.* (1985) *J. Pediatr.* 107: 346; Insel *et al.* (1986) *J. Exp. Med.* 158: 294).

[0008] Hapten-carrier conjugates have been successfully generated using various cross-linking/coupling reagents such as homobifunctional, heterobifunctional, or zero-length cross linkers. Many such methods are currently available for coupling of saccharides, proteins, and peptides to peptide carriers. Most methods create amine, amide, urethane, isothiourea, or disulfide bonds, or in some cases thioethers. A disadvantage to the use of coupling reagents, which introduce reactive sites in to the side chains of reactive amino acid molecules on carrier and/or hapten molecules, is that the reactive sites if not neutralized are free to react

with any unwanted molecule either *in vitro* (thus adversely affecting the functionality or stability of the conjugate(s)) or *in vivo* (thus posing a potential risk of adverse events in persons or animals immunized with the preparations). Such excess reactive sites can be reacted or "capped", so as to inactivate these sites, utilizing various known chemical reactions, but these reactions may be otherwise disruptive to the functionality of the conjugates. This may be particularly problematic when attempting to create a conjugate by introducing the reactive sites into the carrier molecule, as its larger size and more complex structure (relative to the hapten) may render it more vulnerable to the disruptive effects of chemical treatment. In fact, no examples are known of methods whereby a conjugate is made by first activating the carrier, then reacting with the hapten in a conjugation reaction, and finally "capping" the remaining reactive sites, while preserving the ability of the resulting conjugate to function as an immunogenic composition having the desired properties of the "carrier effect".

BRIEF SUMMARY OF THE INVENTION

[0009] The present invention is directed to methods of producing an immunogenic conjugate of a peptide immunogen comprising Aβ peptide or fragments of Aβ or analogs thereof with a protein/polypeptide carrier, wherein the Aβ peptide or fragments of Aβ or analogs thereof is conjugated to the carrier via derivatized functional groups of amino acid residues of the carrier such as lysine residues, and wherein any unconjugated, derivatized functional groups of the amino acid residues are inactivated via capping to block them from reacting with other molecules, including proteins/polypeptides thereby preserving the functionality of the carrier, such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier. Furthermore, the invention also relates to conjugates produced by the above methods, and to immunogenic compositions containing such conjugates.

[0010] In one embodiment, the invention is directed to a first method for conjugating a peptide immunogen comprising Aβ peptide or fragments of Aβ or analogs thereof via a reactive group of an amino acid residue of the peptide immunogen to a protein/polypeptide carrier having one or more functional groups, the method comprising the steps of: (a) derivatizing one or more of the functional groups of the protein/polypeptide carrier to generate a derivatized molecule with reactive sites; (b) reacting the derivatized protein/polypeptide carrier of step (a) with a reactive group of an amino acid residue of the

peptide immunogen under reaction conditions such that the peptide immunogen is conjugated to the derivatized protein/polypeptide carrier via the functional groups; and (c) further reacting the conjugate with a capping reagent to inactivate free, reactive functional groups on the activated protein/polypeptide carrier, thereby preserving the functionality of the carrier such that itretains its abilityto elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier.

[0011] In one embodiment, the protein/polypeptide carrier is selected from the group consisting of human serum albumin, keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, ovalbumin, influenza hemagglutinin, PAN-DR binding peptide (PADRE polypeptide), malaria circumsporozite (CS) protein, hepatitis B surface antigen (HB_sAg_{19-28}), Heat Shock Protein (HSP) 65, Bacillus Calmette-Guerin (BCG), cholera toxin, cholera toxin mutants with reduced toxicity, diphtheria toxin, CRM_{197} protein that is cross-reactive with diphtheria toxin, recombinant Streptococcal C5a peptidase, *Streptococcus pyogenes* ORF1224, *Streptococcus pyogenes* ORF1664, *Streptococcus pyogenes* ORF 2452, *Streptococcus pneumoniae* pneumolysin, pneumolysin mutants with reduced toxicity, *Chlamydia pneumoniae* ORF T367, *Chlamydia pneumoniae* ORF T858, Tetanus toxoid, HIV gp120 T1, microbial surface components recognizing adhesive matrix molecules (MSCRAMMS), growth factor / hormone, cytokines and chemokines.

[0012] In another embodiment, the protein/polypeptide carrier contains a T-cell epitope.

[0013] In yet another embodiment, the protein/polypeptide carrier is a bacterial toxoid such as a tetanus toxoid, cholera toxin or cholera toxin mutant as described above. In a preferred embodiment, the protein/polypeptide carrier is CRM_{197}.

[0014] In still yet another embodiment, the protein/polypeptide carrier may be an influenza hemagglutinin, a PADRE polypeptide, a malaria CS protein, a Hepatitis B surface antigen ($HSBAg_{19-28}$), a heat shock protein 65 (HSP 65), or a polypeptide from *Mycobacterium tuberculosis* (BCG).

[0015] In a preferred embodiment, the protein/polypeptide carrier is selected from Streptococcal rC5a peptidase, *Streptococcus pyogenes* ORF1224, *Streptococcus pyogenes* ORF1664 or *Streptococcus pyogenes* ORF2452, *Streptococcus pneumoniae* pneumolysin, pneumolysin mutants with reduced toxicity, *Chlamydia pneumoniae* ORF T367, and *Chlamydia pneumoniae* ORF T858.

[0016] In one embodiment, protein/polypeptide carrier is a growth factor or hormone, which stimulates or enhances immune response and is selected from the group consisting of IL-1, IL-2, γ-interferon, IL-10, GM-CSF, MIP-1α, MIP-1β, and RANTES.

[0017] In one aspect, the invention provides a peptide immunogen comprising Aβ peptide or fragments of Aβ or analogs thereof eliciting an immunogenic response against certain epitopes within Aβ. Immunogenic peptides of the invention include immunogenic heterologous peptides. In some immunogenic peptides, an Aβ fragment is linked to a carrier to form an immunogenic heterologous peptide, and then this heterologous peptide is linked to a carrier using a method of the present invention to form a conjugate.

[0018] In another aspect of the invention, the peptide immunogen is a polypeptide comprising an N-terminal segment of at least residues 1-5 of Aβ, the first residue of Aβ being the N-terminal residue of the polypeptide, wherein the polypeptide is free of a C-terminal segment of Aβ. In yet another aspect of the invention, the peptide immunogen is a polypeptide comprising an N-terminal segment of Aβ, the segment beginning at residue 1-3 of Aβ and ending at residues 7-11 of Aβ. In some aspects of the invention, the peptide immunogen is an agent that induces an immunogenic response against an N-terminal segment of Aβ, the segment beginning at residue 1-3 of Aβ and ending at residues 7-11 of Aβ without inducing an immunogenic response against an epitope within residues 12-43 of Aβ43. In another aspect of the invention, the peptide immunogen is a heterologous polypeptide comprising a segment of Aβ linked to a heterologous amino acid sequence that induces a helper T-cell response against the heterologous amino acid sequence and thereby a B-cell response against the N-terminal segment.

[0019] In some peptide immunogens, the N-terminal segment of Aβ is linked at its C-terminus to a heterologous polypeptide. In some peptide immunogens, the N-terminal segment of Aβ is linked at its N-terminus to a heterologous polypeptide. In some peptide immunogens, the N-terminal segment of Aβ is linked at its N and C termini to first and second heterologous polypeptides. In some peptide immunogens, the N-terminal segment of Aβ is linked at its N terminus to a heterologous polypeptide, and at its C-terminus to at least one additional copy of the N-terminal segment. In some peptide immunogens, the polypeptide comprises from N-terminus to C-terminus, the N-terminal segment of Aβ, a plurality of additional copies of the N-terminal segment, and the heterologous amino acid segment.

[0020] In some of the above peptide immunogens, the polypeptide further comprises at least one additional copy of the N-terminal segment. In some of the above peptide immunogens, the fragment is free of at least the 5 C-terminal amino acids in Aβ43.

[0021] In some aspects of the above peptide immunogens, the fragment comprises up to 10 contiguous amino acids from Aβ.

[0022] In another aspect, the invention provides a peptide immunogen comprising Aβ peptide or fragments of Aβ or analogs thereof eliciting an immunogenic response against certain epitopes within Aβ may be in a configuration referred to as a multiple antigenic peptide (MAP) configuration.

[0023] In some of the above aspects of the invention, the peptide immunogen from the N-terminal half of Aβ. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-3, 1-4, 1-5, 1-6, 1-7, 1-10, 1-11, 1-12, 1-16, 3-6, and 3-7. In some of the above aspects of the invention, the peptide immunogen is from the internal region of Aβ. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ13-28, 15-24, 17-28, and 25-35. In some of the above aspects of the invention, the peptide immunogen from the C-terminal end of Aβ. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ33-42, 35-40, and 35-42. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-3, 1-4, 1-5, 1-6, 1-7, 1-10, 1-11, 1-12, 1-16, 1-28, 3-6, 3-7, 13-28, 15-24, 17-28, 25-35, 33-42, 35-40, and 35-42. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5, Aβ1-7, Aβ1-9, and Aβ1-12. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5-L, Aβ1-7-L, Aβ1-9-L, and Aβ1-12-L, where L is a linker. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5-L-C, Aβ1-7-L-C, Aβ1-9-L-C, and Aβ1-12-L-C, where C is a cysteine amino acid residue.

[0024] In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ16-22, Aβ16-23, Aβ17-23, Aβ17-24, Aβ18-24, and Aβ18-25. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ16-22-C, Aβ16-23-C, Aβ17-23-C, Aβ17-24-C, Aβ18-24-C, and Aβ18-25-C, where C is a cysteine amino acid residue. In other aspects of the invention, the peptide

immunogen is an Aβ fragment selected from the group consisting of C-Aβ16-22, C-Aβ16-23, C-Aβ17-23, C-Aβ17-24, C-Aβ18-24, and C-Aβ18-25, where C is a cysteine amino acid residue.

[0025] In some of the above peptide immunogens, the heterologous polypeptide is selected from the group consisting of peptides having a T-cell epitope, a B-cell epitope and combinations thereof.

[0026] In one embodiment, the functional group of one or more amino acid molecules of the protein/polypeptide carrier or of the optionally attached polypeptide linker is derivatized using a cross-linking reagent. In another embodiment, the derivatizing reagent is a zero-length cross-linking reagent. In another embodiment, the derivatizing reagent is a homobifunctional cross-linking reagent. In yet another embodiment, the derivatizing reagent is a heterobifunctional cross-linking reagent.

[0027] In a preferred embodiment, the heterobifunctional reagent is a reagent that reacts with a primary or a ϵ-amine functional group of one or more amino acid molecules of the protein/polypeptide carrier and a pendant thiol group of one or more amino acid molecules of the peptide immunogen. In one embodiment, the heterobifunctional reagent is N-succinimidyl bromoacetate.

[0028] In another embodiment, the primary or ϵ-amine functional group is lysine. In yet another embodiment, the derivatization of the primary or ϵ-amine functional group of the lysine of the protein/polypeptide carrier with N-succinimidyl bromoacetate results in the bromoacetylation of the primary or ϵ-amine residues on lysine molecules on the protein/polypeptide carrier. In a more preferred embodiment, the pendant thiol group is a cysteine residue of the peptide immunogen, which may be localized at the amino-terminus of the peptide immunogen, at the carboxy-terminus of the peptide immunogen or internally in the peptide immunogen.

[0029] In another embodiment, the pendant thiol group is generated by a thiolating reagent such as N-acetyl homocysteinethio lactone, Traut's reagent (2-iminothilane) SATA (N-Succinimidyl S-acetylthioacetate), SMPT (4-Succinimidyloxycarbonyl-methyl2-pyridyldithio toluene), Sulfo LC SPDP (Sulfo Succinimidyl pyridyl dithio propionamido hexanoate), SPDP (Succinimidyl pyridyl dithio propionate). In a preferred embodiment, the capping reagent that is used to inactivate free reactive, functional groups on the activated protein/polypeptide

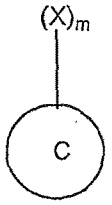
carrier is selected from the reagent group consisting of cysteamine, *N*-acetylcysteamine, and ethanolamine.

[0030] In a particularly preferred embodiment, the capping reagent that is used to inactivate free reactive functional groups on the activated protein/polypeptide carrier is selected from the reagent group consisting of sodium hydroxide, sodium carbonate, ammonium bicarbonate and ammonia.

[0031] In one embodiment, the reactive group of the amino acid residue of the peptide immunogen is a free sulfhydryl group.

[0032] In another embodiment, one or more of the functional groups are on a linker, which is optionally attached to the protein/polypeptide carrier. In a preferred embodiment, the linker is a peptide linker. In a more preferred embodiment, the peptide linker is polylysine.

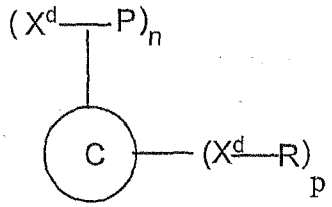
[0033] In another embodiment, the invention is directed to a second method for conjugating a peptide immunogen comprising Aβ peptide or fragments of Aβ or analogs thereof Aβ or analogs thereof with a protein/polypeptide carrier having the structure:



wherein,

[0034] C is a protein/polypeptide carrier and X is a derivatizable functional group of an amino acid residue on the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to the protein/polypeptide carrier, and wherein m is an integer greater than 0, but less than or equal to 85, the method comprising the steps of: (a) derivatizing one or more of the functional groups of the protein/polypeptide carrier or of the optionally attached linker molecule to generate a derivatized molecule with reactive sites; (b) reacting the derivatized protein/polypeptide carrier of step (a) with a reactive group of an amino acid residue of the peptide immunogen to form a covalently coupled peptide immunogen-protein/polypeptide carrier conjugate; and (c) further reacting the said conjugate with a capping reagent to inactive the free reactive functional groups on the activated protein/polypeptide carrier, such that the capped groups are not free to react with other molecules, including proteins/polypeptides thereby preserving the functionality of the carrier,

such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier so as to generate a capped peptide immunogen-protein/polypeptide carrier conjugate having the formula:



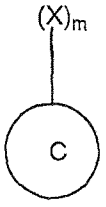
wherein,

[0035] C is the protein/polypeptide carrier and X^d is a derivatized functional group of an amino acid residue of the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to the protein/polypeptide carrier, and, wherein,

[0036] P is the peptide immunogen molecule covalently attached to the derivatized functional group on the amino acid residue on the protein carrier or optionally on an amino acid residue on a peptide linker covalently attached to a protein/polypeptide carrier, R is a capping molecule covalently attached to the derivatized functional group on an amino acid residue on the protein/polypeptide carrier or optionally on an amino acid residue on a peptide linker covalently attached to a protein/polypeptide carrier, n is an integer greater than 0, but less than or equal to 85, and p is an integer greater than 0, but less than 85.

[0037] The detailed embodiments for the first method described above are also applicable to the conjugates just described prepared by the second method.

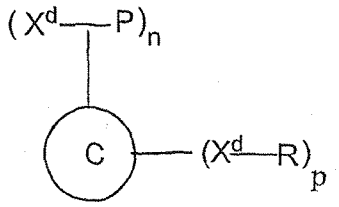
[0038] In one embodiment, the invention is directed to peptide immunogen-comprising Aβ peptide or fragments fo Aβ or analogs thereof/polypeptide carrier conjugates wherein the protein/polypeptide carrier has the formula:



wherein,

[0039] C is a protein/polypeptide carrier and X is a derivatizable functional group of an amino acid residue on the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to the protein/polypeptide carrier, and, wherein, m is

an integer greater than 0, but less than or equal to 85, and wherein the capped peptide immunogen-protein/polypeptide carrier conjugate has the formula:

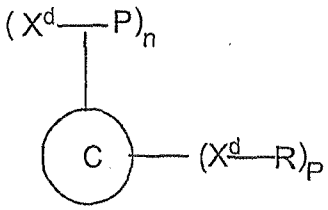


wherein,

[0040] C is the protein/polypeptide carrier and X^d is a derivatized functional group of an amino acid residue of the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to the protein/polypeptide carrier, and, wherein, P is the peptide immunogen molecule covalently attached to the derivatized functional group of the amino acid residue of the protein carrier or optionally of an amino acid residue of a peptide linker covalently attached to a protein/polypeptide carrier, R is a capping molecule covalently attached to the derivatized functional group of an amino acid residue of the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to a protein/polypeptide carrier, thereby preserving the functionality of the carrier, such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier., n is an integer greater than 0, but less than or equal to 85, and p is an integer greater than 0, but less than 85.

[0041] The detailed embodiments for the first and second methods described above are also applicable to the conjugates just described.

[0042] In another embodiment, the invention is directed to peptide immunogen- comprising Aβ peptide or fragments of Aβ or analogs thereof/polypeptide carrier conjugates generated according to the second method of the invention and having the formula:



wherein,

[0043] C is the protein/polypeptide carrier and X^d is a derivatized functional group of an amino acid residue of the protein/polypeptide carrier or optionally of an amino acid residue of

a peptide linker covalently attached to the protein/polypeptide carrier, and, wherein, P is the peptide immunogen molecule covalently attached to the derivatized functional group of the amino acid residue of the protein carrier or optionally of an amino acid residue of a peptide linker covalently attached to a protein/polypeptide carrier, R is a capping molecule covalently attached to the derivatized functional group of an amino acid residue of the protein/polypeptide carrier or optionally of an amino acid residue of a peptide linker covalently attached to a protein/polypeptide carrier thereby preserving the functionality of the carrier, such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier., n is an integer greater than 0, but less than or equal to 85, and p is an integer greater than 0, but less than 85.

[0044] The detailed embodiments for the second method described above are also applicable to the conjugates generated by the second method, as just described.

[0045] In another embodiment, the invention is directed to immunogenic compositions comprising a conjugate of a peptide immunogen with a protein/polypeptide carrier generated by the second method of the invention, together with one or more pharmaceutically acceptable excipients, diluents, and adjuvants.

[0046] The detailed embodiments for the second method and the conjugates generated thereby described above are also applicable to immunogenic compositions containing those conjugates as just described.

[0047] In another embodiment, the invention is directed to a method for inducing an immune response in a mammalian subject, which comprises administering an effective amount of an immunogenic composition of the present invention to the subject.

[0048] The detailed embodiments applicable to the immunogenic composition containing the conjugates of the present invention are also applicable to the embodiment of the invention directed to the method of use of these immunogenic compositions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] Figure 1: Flow chart depicting the process chemistry used for conjugation of Aβ peptide fragments to protein/polypeptide carrier CRM_{197} to form the Aβ / CRM_{197} conjugate.

[0050] Figure 2: Flow chart depicting acid hydrolysis chemistry used for quantitative determination of S-carboxymethylcysteine and S-carboxymethylcysteamine as evaluation of

the degree of conjugation of peptide immunogen-protein/polypeptide conjugates such as the Aβ/CRM_{197} conjugate.

[0051] Figure 3: This figure depicts the pH dependence of the Aβ peptide/CRM conjugation reaction.

[0052] Figure 4: This figure depicts the dependence of Aβ-peptide/CRM conjugation on peptide: CRM ratio.

[0053] Figure 5: Verification of capping process for Aβ1-7/CRM conjugation. The pH of the reaction was 9.15. Reaction time with peptide was 16 hrs, capping with *N*-acetylcysteamine was 8 hrs.

[0054] Figure 6: Conjugation and capping with various peptide: CRM ratios with peptide. The pH of the reaction was 9.0. Reaction time with peptide was 16 hrs, capping with *N*-acetylcysteamine was 8 hrs.

[0055] Figure 7: Day 36 titers of primate sera following immunization of primates with Aβ peptide conjugates with various adjuvants.

[0056] Figure 8: Day 64 titers of primate sera following immunization of primates with Aβ-peptide conjugates with various adjuvants.

[0057] Figure 9: Primate titers by day and treatment group. Primates were immunized with Aβ 1-7 or Aβ 1-5 CRM_{197} conjugates with alum or RC529 as adjuvants and titers of anti-Aβ antibodies were measured at day 29, 36, 57 and 54.

[0058] Figure 10: Peptide-protein conjugates were characterized using SDS-PAGE Western blot analysis with a tris-tricine precast gel. The lanes are: marker (lane 1); L-28375 24/01 (lane 2); L-28375 24/02 (lane 3); L-28375 24/03 (lane 4); L-28375 24/04 (lane 5); L-28375 24/05 (lane 6); L-28375 24/06 (lane 7) L-28375 24/07 (lane 8); L-28375 24/08 (lane 9); L-28375 24/09 (Mock) (lane 10); and, Br$AcCRM_{197}$ (lane 11).

BRIEF DESCRIPTION OF SEQUENCES

SEQ ID NO:	Sequence	Description
1	DAEFR-C	Aβ1-5-C
2	DAEFRHD-C	Aβ 1-7-C
3	DAEFRHDSG-C	Aβ 1-9-C

SEQ ID NO:	Sequence	Description
4	DAEFRHDSGYEV-C	Aβ1-12-C
5	DAEFR-GAGA-C	Aβ1-5-L-C
6	DAEFRHD-GAGA-C	Aβ1-7-L-C
7	DAEFRHDSG-GAGA-C	Aβ1-9-L-C
8	DAEFRHDSGYEV-GAGA-C	Aβ1-12-L-C
9	VEYGSDHRFEAD-C	Aβ12-1-C
10	GAGA	Linker peptide
11	PKYVKQNTLKLAT	Influenza Hemagglutinin: $HA_{307-319}$
12	AKXVAAWTLKAAA	PAN-DR Peptide (PADRE peptide)
13	EKKIAKMEKASSVFNV	Malaria CS: T3 epitope
14	FELLTRILTI	Hepatitis B surface antigen: HB_sAg_{19-28}
15	DQSIGDLIAEAMDKVGNEG	Heat Shock Protein 65: $hsp65_{153-171}$
16	QVHFQPLPPAVVKL	Bacillus Calmette-Guerin (BCG)
17	QYIKANSKFIGITEL	Tetanus toxoid: $TT_{830-844}$
18	FNNFTVSFWLRVPKVSASHLE	Tetanus toxoid: $TT_{947-967}$
19	KQIINMWQEVGKAMY	HIV gp120 T1
20	DAEFRHD-QYIKANSKFIGITEL-C-FNNFTVSFWLRVPKVSASHLE-DAEFRHD	$Aβ_{1-7}/TT_{830-844}/C/TT_{947-967}/Aβ_{1-7}$
21	DAEFRHDSGYEVHHQKLVFFAEDVGSNKGAIIGLMVGGVVIA	$Aβ_{1-42}$
22	DAEFRHDQYIKANSKFIGITEL	AN90549: $Aβ_{1-7}/TT_{830-844}$ (used in a MAP4 configuration)
23	DAEFRHDFNNFTVSFWLRVPKVSASHLE	AN90550: $Aβ_{1-7}/TT_{947-967}$ (used in a MAP4 configuration)
24	DAEFRHD-QYIKANSKFIGITELFNNFTVSFWLRVPKVSASHLE	AN90542: $Aβ_{1-7}/TT_{830-844} + TT_{947-967}$ (used in a linear configuration)
25	EFRHDSG-QYIKANSKFIGITEL	AN90576: $Aβ_{3-9}/TT_{830-844}$ (used in a MAP4 configuration)

SEQ ID NO:	Sequence	Description
26	AKXVAAWTLKAAA-DAEFRHD	AN90562: $A\beta_{1-7}$/PADRE
27	DAEFRHD-DAEFRHDD-AEFRHDAKXVAAWTLKAAA	AN90543: $A\beta_{1-7}$ x 3/PADRE
28	AKXVAAWTLKAAA-DAEFRHD-DAEFRHD-DAEFRHD	PADRE/$A\beta_{1-7}$ x 3
29	DAEFRHD-AKXVAAWTLKAAA	$A\beta_{1-7}$ x 3/PADRE
30	DAEFRHD-ISQAVHAAHAEINEAGR	$A\beta_{1-7}$/albumin fragment
31	FRHDSGY-ISQAVHAAHAEINEAGR	$A\beta_{4-10}$/ albumin fragment
32	EFRHDSG-ISQAVHAAHAEINEAGR	$A\beta_{3-9}$/ albumin fragment
33	PKYVKQNTLKLAT-DAEFRHD-DAEFRHD-DAEFRHD	$HA_{307-319}$/$A\beta_{1-7}$ x 3
34	DAEFRHD-PKYVKQNTLKLAT-DAEFRHD	$A\beta_{1-7}$/$HA_{307-319}$/$A\beta_{1-7}$
35	DAEFRHD-DAEFRHD-DAEFRHD-PKYVKQNTLKLAT	$A\beta_{1-7}$ x 3/ $HA_{307-319}$
36	DAEFRHD-DAEFRHD-PKYVKQNTLKLAT	$A\beta_{1-7}$ x 2/ $HA_{307-319}$
37	DAEFRHD-PKYVKQNTLKLAT-EKKIAKMEKASSVFNV-QYIKANSKFIGITEL-FNNFTVSFWLRVPKVSASHLE-DAEFRHD	$A\beta_{1-7}$/$HA_{307-319}$/Malaria CS/ $TT_{830-844}$/$TT_{947-967}$/$A\beta_{1-7}$
38	DAEFRHD-DAEFRHD-DAEFRHD-QYIKANSKFIGITEL-C-FNNFTVSFWLRVPKVSASHLE	$A\beta_{1-7}$ x 3/$TT_{830-844}$/C/$TT_{947-967}$
39	DAEFRHD-QYIKANSKFIGITEL-C-FNNFTVSFWLRVPKVSASHLE	$A\beta_{1-7}$/$TT_{830-844}$/C/$TT_{947-967}$
40	GADDVVDSSKSFVMENFSSYHGTKPGY VDSIQKGIQKPKSGTQGNYDDDWKEFY STDNKYDAAGYSVDNENPLSGKAGGVV KVTYPGLTKVLALKVDNAETIKKELGLS LTEPLMEQVGTEEFIKRFGDGASRVVLS LPFAEGSSSVEYINNWEQAKALSVELEIN FETRGKRGQDAMYEYMAQACAGNRVR RSVGSSLSCINLDWDVIRDKTKTKIESLK EHGPIKNKMSESPNKTVSEEKAKQYLEE	$CRM\beta_{197}$

SEQ ID NO:	Sequence	Description
	FHQTALEHPELSELKTVTGTNPVFAGAN YAAWAVNVAQVIDSETADNLEKTTAAL SILPGIGSVMGIADGAVHHNTEEIVAQSI ALSSLMVAQAIPLVGELVDIGFAAYNFV ESIINLFQVVHNSYNRPAYSPGHKTQPFL HDGYAVSWNTVEDSIIRTGFQGESGHDI KITAENTPLPIAGVLLPTIPGKLDVNKSK THISVNGRKIRMRCRAIDGDVTFCRPKSP VYVGNGVHANLHVAFHRSSSEKIHSNEI SSDSIGVLGYQKTVDHTKVNSKLSLFFEI KS	
41	ISQAVHAAHAEINEAGR	Albumin fragment
42	DAEFGHDSGFEVRHQKLVFFAEDVGSNKG AIIGLMVGGVVIA	Murine A(1-42
43	VFFAEDVG-C	A(18-25 -C
44	LVFFAEDV-C	A(17-24 -C
45	KLVFFAED-C	A(16-23 -C
46	C-VFFAEDVG	C-A(18-25
47	C-LVFFAEDV	C-A(17-24
48	C-KLVFFAED	C-A(16-23
49	VFFAEDV-C	A(18-24 -C
50	LVFFAED-C	A(17-23 -C
51	KLVFFAE-C	A(16-22 -C
52	C-VFFAEDV	C-$A\beta_{18-24}$
53	C-LVFFAED	C-$A\beta_{17-23}$
54	C-KLVFFAE	C-$A\beta_{16-22}$

DETAILED DESCRIPTION OF THE INVENTION

[0059] The present invention is directed to methods of generating peptide immunogen-carrier conjugates wherein the unreacted active functional groups on the carrier which are generated during activation are inactivated by using capping reagents such as *N*-Acetylcysteamine in order to prevent them from reacting further. The present invention is

also directed to capped carrier-peptide immunogen conjugates generated by those methods and to immunogenic compositions comprising said conjugates.

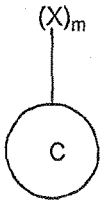
[0060] The approach of increasing immunogenicity of small or poorly immunogenic molecules, such as saccharides, through conjugation has been utilized successfully for decades (see, *e.g.*, Goebel *et al.* (1939) *J. Exp. Med.* 69: 53), and many immunogenic compositions have been described in which purified capsular polymers have been conjugated to carrier proteins to create more effective immunogenic compositions by exploiting this "carrier effect". For example, Schneerson *et al.* (*J. Exp. Med.* 152: 361-376, 1980), describe *Haemophilus influenzae* b polysaccharide protein conjugates that confer immunity to invasive diseases caused by that microorganism. Conjugates of PRP (polyribosylribitol phosphate, a capsular polymer of *H. influenzae* b) have been shown to be more effective than immunogenic compositions based on the polysaccharide alone (Chu *et al.*, (1983) *Infect. Immun.* 40: 245; Schneerson *et al.* (1984), *Infect. Immun.* 45: 582-591). Conjugation has also been shown to bypass the poor antibody response usually observed in infants when immunized with a free polysaccharide (Anderson *et al.* (1985) *J. Pediatr.* 107: 346; Insel *et al.* (1986) *J. Exp. Med.* 158: 294).

[0061] A further advantage of using as the protein carrier a bacterial toxin or toxoid against which routine immunization of humans (*e.g.*, tetanus or diphtheria) is a standard practice is that a desired immunity to the toxin or toxoid is induced along with immunity against the pathogens associated with the capsular polymer.

[0062] Antigenic determinant/hapten-carrier conjugates also are being used to produce highly specific monoclonal antibodies that can recognize discrete chemical epitopes on the coupled hapten. The resulting monoclonals often are used to investigate the epitopic structure and interactions between native proteins. In many cases, the antigenic determinants/haptens used to generate these monoclonals are small peptide segments representing crucial antigenic sites on the surface of larger proteins. The criteria for a successful carrier to be used in generating an antigenic determinant/hapten-carrier conjugate are the potential for immunogenicity, the presence of suitable functional groups for conjugation with an antigenic determinant/hapten, reasonable solubility properties even after derivatization and lack of toxicity *in vivo*.

[0063] These criteria are met by the conjugates generated by the methods of the instant invention. The conjugates may be any stable peptide immunogen-carrier conjugates generated using the conjugation process described herein. The conjugates are generated using

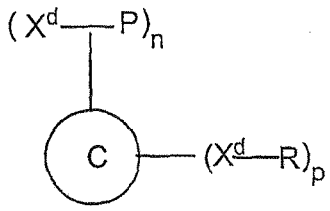
a process of the instant invention wherein a protein/polypeptide carrier having the following structure:



is covalently attached to a protein/polypeptide carrier,

wherein,

[0064] C is a protein/polypeptide carrier and X is a derivatizable functional group on an amino acid residue on the protein/polypeptide carrier or optionally on an amino acid residue on a peptide linker covalently attached to the protein/polypeptide carrier, and wherein m is an integer greater than 0, but less than or equal to 85, is covalently attached to a peptide immunogen and wherein the peptide immunogen-protein/polypeptide carrier conjugate has the following formula, is represented by the following formula:



wherein,

[0065] C is the protein/polypeptide carrier and X^d is a derivatized functional group on an amino acid residue on the protein/polypeptide carrier or optionally on an amino acid residue on a peptide linker covalently attached to the protein/polypeptide carrier, P is a peptide immunogen covalently attached to the derivatized functional group on the amino acid residue on the protein/polypeptide carrier or optionally on an amino acid residue on a peptide linker covalently attached to a protein/polypeptide carrier, R is a capping molecule covalently attached to the derivatized functional group on an amino acid residue on the protein/polypeptide carrier or optionally on an amino acid residue on a peptide linker covalently attached to a protein/polypeptide carrier thereby preserving the functionality of the carrier, such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier., n is an integer greater than 0, but less than or equal to 85, and p is an integer greater than 0, but less than 85.

Selection Of Carriers

[0066] Some peptide immunogens contain the appropriate epitope for inducing an immune response, but are too small to be immunogenic. In this situation, the peptide immunogens are linked to a suitable carrier to help elicit an immune response. In the above schematic representation of the peptide immunogens-carrier conjugate generated by a process of the present invention, C, is a protein/polypeptide carrier to which peptide immunogens are conjugated directly via derivatized functional groups on amino acid residues on the carrier themselves or indirectly via derivatized functional groups on peptide linkers covalently attached to the carriers. Suitable protein/polypeptide carriers include, but are not limited to, albumin (including humanserum albumin), keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, ovalbumin, MSCRAMMS, tetanus toxoid, or a toxoid from other pathogenic bacteria having reduced toxicity, including mutants, such as diphtheria, *E. coli,* cholera, or *H. pylori,* or an attenuated toxin derivative. One such carrier is the CRM_{197} protein (SEQ ID NO.:40) that is cross-reactive with diphtheria toxin.

[0067] Other carriers include T-cell epitopes that bind to multiple MHC alleles, *e.g.*, at least 75% of all human MHC alleles. Such carriers are sometimes known in the art as "universal T-cell epitopes." Exemplary carriers with universal T-cell epitopes include:

Influenza Hemagglutinin: $HA_{307-319}$	PKYVKQNTLKLAT (SEQ. ID NO. 11)
PAN-DR Peptide (PADRE peptide)	AKXVAAWTLKAAA (SEQ. ID NO. 12)
Malaria CS: T3 epitope	EKKIAKMEKASSVFNV (SEQ. ID NO. 13)
Hepatitis B surface antigen: HB_sAg_{19-28}	FELLTRILTI (SEQ. ID NO. 14)
Heat Shock Protein 65: $hsp65_{153-171}$	QSIGDLIAEAMDKVGNEG (SEQ. ID NO. 15)
Bacillus Calmette-Guerin (BCG)	QVHFQPLPPAVVKL (SEQ. ID NO. 16)
Tetanus toxoid: $TT_{830-844}$	QYIKANSKFIGITEL (SEQ. ID NO. 17)
Tetanus toxoid: $TT_{947-967}$	NNFTVSFWLRVPKVSASHLE (SEQ. ID NO. 18)
HIV gp120 T1:	KQIINMWQEVGKAMY (SEQ. ID NO. 19)

CRM_{197}	*See* the Brief Description of the Sequences (SEQ ID NO.:40)
Albumin fragment	ISQAVHAAHAEINEAGR (SEQ ID NO: 41)

[0068] Other carriers for stimulating or enhancing an immune response and to which a peptide immunogen or a hapten can be conjugated include cytokines such as IL-1, IL-1 α and β peptides, IL-2, γINF, IL-10, GM-CSF, and chemokines, such as MIP 1α and β and RANTES. Immunogenic peptides can also be linked to proteins/peptide carriers that enhance transport across tissues, as described in O'Mahony, WO 97/17163 and WO 97/17614, which are hereby incorporated by reference in their entirety for all purposes.

[0069] Still further carriers include recombinant Streptococcal C5a peptidase, *Streptococcus pyogenes* ORFs 1224, 1664 and 2452, *Chlamydia pneumoniae* ORFs T367 and T858, *Streptococcus pneumonia* pneumolysin, pneumolysin mutants with reduced toxicity, growth factors, and hormones.

[0070] In one preferred embodiment of the present invention, the carrier protein is CRM_{197}, a non-toxic mutant of diphtheria toxin with one amino acid change in its primary sequence. The glycine present at the amino acid position 52 of the molecule is replaced with a glutamic acid due to a single nucleic acid codon change. Due to this change, the protein lacks ADP-ribosyl transferase activity and becomes non-toxic. It has a molecular weight of 58,408 Da. CRM_{197} is produced in large quantities by recombinant expression in accordance with U.S. Patent 5,614,382, which is hereby incorporated by reference. Conjugations of saccharides as well as peptides to CRM_{197} are carried out by linking through the ε-amino groups of lysine residues. It has been well established through several commercial products that CRM_{197} is an excellent and safe carrier for B-cell epitopes.

Immunogenic Peptides

[0071] As used herein, the term *"peptide immunogen" or "hapten"* is any protein or subunit structure/fragment/analog derived therefrom that can elicit, facilitate, or be induced to produce an immune response on administration to a mammal. In particular, the term is used to refer to a polypeptide antigenic determinant from any source (bacteria, virus or eukaryote), which may be coupled to a carrier using a method disclosed herein. Such polypeptide immunogen/antigenic determinants may be of viral, bacterial or eukaryotic cell origin.

[0072] Peptide immunogens can be conjugated to a carrier for use as an immunotherapeutic in the prevention, treatment, prophylaxis or amelioration of various human diseases. Such peptide immunogens include those derived from Aβ a peptide of 39-43 amino acids, preferably 42 amino acids, which is the principal component of characteristic plaques of Alzheimer's disease (AD) (*see* US 4,666,829; Glenner & Wong (1984) *Biochem. Biophys. Res. Commun.* 120: 1131, Hardy (1984) *TINS* 20: 1131; Hardy (1977) *TINS* 20: 154), those derived from amyloid peptides of amylin, a polypeptide material produced by pancreatic islet cells that has been implicated in type II diabetes, peptides derived from low density lipoprotein gene products, which have been implicated in atherosclerosis and antigenic peptides derived from inflammatory cytokines and growth factors such as interleukin 6 (IL-6), tumor necrosis factor α (TNF-α) and GDF-8. Such eukaryotic peptide immunogens may include either T-cell (CTL) or B-cell epitope, also known as β-amyloid protein, or A4 peptide.

[0073] Aβ, also known as β-amyloid peptide, or A4 peptide (*see* US 4,666,829; Glenner & Wong, *Biochem. Biophys. Res. Commun.*, 120, 1131 (1984)), is a peptide of 39-43 amino acids, which is the principal component of characteristic plaques of Alzheimer's disease. Aβ is generated by processing of a larger protein APP by two enzymes, termed β and γ secretases (*see* Hardy, TINS 20, 154 (1997)). Known mutations in APP associated with Alzheimer's disease occur proximate to the site of β or γ secretase, or within Aβ. For example, position 717 is proximate to the site of γ-secretase cleavage of APP in its processing to Aβ, and positions 670/671 are proximate to the site of β-secretase cleavage. It is believed that the mutations cause AD by interacting with the cleavage reactions by which Aβ is formed so as to increase the amount of the 42/43 amino acid form of Aβ generated.

[0074] Aβ has the unusual property that it can fix and activate both classical and alternate complement cascades. In particular, it binds to Clq and ultimately to C3bi. This association facilitates binding to macrophages leading to activation of B cells. In addition, C3bi breaks down further and then binds to CR2 on B cells in a T cell dependent manner leading to a 10,000-fold increase in activation of these cells. This mechanism causes Aβ to generate an immune response in excess of that of other antigens.

[0075] Aβ has several natural occurring forms. The human forms of Aβ are referred to as Aβ39, Aβ40, Aβ41, Aβ42 and Aβ43. The sequences of these peptides and their relationship

to the APP precursor are illustrated by Figure 1 of Hardy et al., TINS 20, 155-158 (1997). For example, Aβ42 has the sequence:

H_2N-Asp-Ala-Glu-Phe-Arg-His-Asp-Ser-Gly-Tyr-Glu-Val-His-
His-Gln-Lys-Leu-Val-Phe-Phe-Ala-Glu-Asp-Val-Gly-Ser-Asn-
Lys-Gly-Ala-Ile-Ile-Gly-Leu-Met-Val-Gly-Gly-Val-Val-Ile-
Ala-OH (SEQ ID NO. 21).

Aβ41, Aβ40 and Aβ39 differ from Aβ42 by the omission of Ala, Ala-Ile, and Ala-Ile-Val respectively from the C-terminal end. Aβ43 differs from Aβ42 by the presence of a threonine residue at the C-terminus.

[0076] Peptide immunogens which are fragments of Aβ are advantageous relative to the intact molecule for use in the present methods for several reasons. First, because only certain epitopes within Aβ induce a useful immunogenic response for treatment of Alzheimer's disease, an equal dosage of mass of a fragment containing such epitopes provides a greater molar concentration of the useful immunogenic epitopes than a dosage of intact Aβ. Second, certain peptide immunogens of Aβ generate an immunogenic response against amyloid deposits without generating a significant immunogenic response against APP protein from which Aβ derives. Third, peptide immunogens of Aβ are simpler to manufacture than intact Aβ due to their shorter size. Fourth, peptide immunogens of Aβ do not aggregate in the same manner as intact Aβ, simplifying preparation of conjugates with carriers.

[0077] Some peptide immunogens of Aβ have a sequence of at least 2, 3, 5, 6, 10, or 20 contiguous amino acids from a natural peptide. Some peptide immunogens have no more than 10, 9, 8, 7, 5 or 3 contiguous residues from Aβ. In a preferred embodiment, peptide immunogens from the N-terminal half of Aβ are used for preparing conjugates. Preferred peptide immunogens include Aβ1-5, 1-6, 1-7, 1-10, 1-11, 3-7, 1-3, and 1-4. The designation Aβ1-5 for example, indicates an N-terminal fragment including residues 1-5 of Aβ. Aβ fragments beginning at the N-terminus and ending at a residue within residues 7-11 of Aβ are particularly preferred. The fragment Aβ1-12 can also be used but is less preferred. In some methods, the fragment is an N-terminal fragment other than Aβ1-10. Other preferred fragments include Aβ13-28, 15-24, 1-28, 25-35, 35-40, 35-42 and other internal fragments and C-terminus fragments.

[0078] Some Aβ peptides of the invention are immunogenic peptides that on administration to a human patient or animal generate antibodies that specifically bind to one or more

epitopes between residues 16 and 25 of Aβ. Preferred fragments include Aβ16-22, 16-23, 17-23, 17-24, 18-24, and 18-25. Antibodies specifically binding to epitopes between residues 16 and 25 specifically bind to soluble Aβ without binding to plaques of Aβ. These types of antibody can specifically bind to soluble Aβ in the circulation of a patient or animal model without specifically binding to plaques of Aβ deposits in the brain of the patient or model. The specific binding of antibodies to soluble Aβ inhibits the Aβ from being incorporated into plaques thus either inhibiting development of the plaques in a patient or inhibiting a further increase in the size or frequency of plaques if such plaques have already developed before treatment is administered.

[0079] Preferably, the fragment of Aβ administered lacks an epitope that would generate a T-cell response to the fragment. Generally, T-cell epitopes are greater than 10 contiguous amino acids. Therefore, preferred fragments of Aβ are of size 5-10 or preferably 7-10 contiguous amino acids or most preferably 7 contiguous amino acids; *i.e.*, sufficient length to generate an antibody response without generating a T-cell response. Absence of T-cell epitopes is preferred because these epitopes are not needed for immunogenic activity of fragments, and may cause an undesired inflammatory response in a subset of patients (Anderson et al., (2002) *J. Immunol.* 168, 3697-3701; Senior (2002) Lancet *Neurol.* 1, 3).

[0080] Fragment Aβ15-25 and subfragments of 7-8 contiguous amino acids thereof are preferred because these peptides consistently generate a high immunogenic response to Aβ peptide. These fragments include Aβ16-22, Aβ16-23, Aβ16-24, Aβ17-23, Aβ17-24, Aβ18-24, and Aβ18-25. Particularly preferred Aβ15-25 subfragments are 7 contiguous amino acids in length. The designation Aβ15-21 for example, indicates a fragment including residues 15-21 of Aβ and lacking other residues of Aβ. and preferably 7-10 contiguous amino acids. These fragments can generate an antibody response that includes end-specific antibodies.

[0081] Peptide immunogens of Aβs require screening for activity in clearing or preventing amyloid deposits (*see* WO 00/72880, which is incorporated herein in its entirety for all purposes). Administration of N-terminal fragments of Aβ induces the production of antibodies that recognize Aβ deposits *in vivo* and *in vitro*. Fragments lacking at least one, and sometimes at least 5 or 10 C-terminal amino acids present in naturally occurring forms of Aβ are used in some methods. For example, a fragment lacking 5 amino acids from the C-terminal end of Aβ43 includes the first 38 amino acids from the N-terminal end of Aβ.

[0082] Unless otherwise indicated, reference to Aβ includes the natural human amino acid sequences indicated above as well as analogs including allelic, species and induced variants. Analogs typically differ from naturally occurring peptides at one, two or a few positions, often by virtue of conservative substitutions. Analogs typically exhibit at least 80 or 90% sequence identity with natural peptides. Some analogs also include unnatural amino acids or modifications of N- or C-terminal amino acids at one, two, or a few positions. For example, the natural aspartic acid residue at position 1 and/or 7 of Aβ can be replaced with iso-aspartic acid.

[0083] Examples of unnatural amino acids are D, alpha, alpha-disubstituted amino acids, N-alkyl amino acids, lactic acid, 4-hydroxyproline, gamma-carboxyglutamate, epsilon-N,N,N-trimethyllysine, epsilon-N-acetyllysine, O-phosphoserine, N-acetylserine, N-formylmethionine, 3-methylhistidine, 5-hydroxylysine, omega-N-methylarginine, β-alanine, ornithine, norleucine, norvaline, hydroxproline, thyroxine, gamma-amino butyric acid, homoserine, citrulline, and isoaspartic acid. Immunogenic peptides also include analogs of Aβ and fragments thereof. Some therapeutic agents of the invention are all-D peptides, *e.g.*, all-D Aβ, all-D Aβ fragment, or analogs of all-D Aβ or all-D Aβ fragment. Fragments and analogs can be screened for prophylactic or therapeutic efficacy in transgenic animal models in comparison with untreated or placebo controls as described in WO 00/72880.

[0084] Peptide immunogens also include longer polypeptides that include, for example, an immunogenic of Aβ peptide, together with other amino acids. For example, preferred immunogenic peptides include fusion proteins comprising a segment of Aβ linked to a heterologous amino acid sequence that induces a helper T-cell response against the heterologous amino acid sequence and thereby a B-cell response against the Aβ segment. Such polypeptides can be screened for prophylactic or therapeutic efficacy in animal models in comparison with untreated or placebo controls as described in WO 00/72880.

[0085] The Aβ peptide, analog, immunogenic fragment or other polypeptide can be administered in disaggregated or aggregated form. Disaggregated Aβ or fragments thereof means monomeric peptide units. Disaggregated Aβ or fragments thereof are generally soluble, and are capable of self-aggregating to form soluble oligomers, protofibrils and ADDLs. Oligomers of Aβ and fragments thereof are usually soluble and exist predominantly as alpha-helices or random coils. Aggregated Aβ or fragments thereof means oligomers of Aβ or fragments thereof that have associate into insoluble beta-sheet assemblies. Aggregated Aβ or fragments thereof also means fibrillar polymers. Fibrils are usually insoluble. Some

antibodies bind either soluble Aβ or fragments thereof or aggregated Aβ or fragments thereof. Some antibodies bind both soluble Aβ or fragments thereof and aggregated Aβ or fragments thereof.

[0086] Immunogenic peptides also include multimers of monomeric immunogenic peptides. Immunogenic peptides other than Aβ peptides should induce an immunogenic response against one or more of the preferred fragments of Aβ listed above (e.g., Aβ1-3, 1-7, 1-10, and 3-7).

[0087] Immunogenic peptides of the present invention are linked to a carrier using a method of the present invention to form a conjugate. The immunogenic peptide can be linked at its amino terminus, its carboxyl terminus, or both to a carrier to form a conjugate. Optionally, multiple repeats of the immunogenic peptide can be present in the conjugate.

[0088] An N-terminal fragment of Aβ can be linked at its C-terminus to a carrier peptide to form a conjugate. In such conjugates, the N-terminal residue of the fragment of Aβ constitutes the N-terminal residue of the conjugate. Accordingly, such conjugates are effective in inducing antibodies that bind to an epitope that requires the N-terminal residue of Aβ to be in free form. Some immunogenic peptides of the invention comprise a plurality of repeats of an N-terminal segment of Aβ linked at the C-terminus to one or more copy of a carrier peptide to form a conjugate. The N-terminal fragment of Aβ incorporated into such conjugates sometimes begins at Aβ1-3 and ends at Aβ7-11. Aβ1-7, 1-3, 1-4, 1-5, and 3-7 are preferred N-terminal fragment of Aβ. Some conjugates comprise different N-terminal segments of Aβ in tandem. For example, a conjugate can comprise Aβ1-7 followed by Aβ1-3 linked to a carrier.

[0089] In some conjugates, an N-terminal segment of Aβ is linked at its N-terminal end to a carrier peptide. The same variety of N-terminal segments of Aβ can be used as with C-terminal linkage. Some conjugates comprise a carrier peptide linked to the N-terminus of an N-terminal segment of Aβ, which is in turn linked to one or more additional N-terminal segments of Aβ in tandem. Preferably, such immunogenic Aβ fragments, once conjugated to an appropriate carrier, induce an immunogenic response that is specifically directed to the Aβ fragment without being directed to other fragments of Aβ.

[0090] Immunogenic peptides of the invention include immunogenic heterologous peptides. In some immunogenic peptides, an Aβ fragment is linked to a carrier to form an

immunogenic heterologous peptide. This heterologous peptide is linked to a carrier using a method of the present invention to form a conjugate. Some of these immunogenic heterologous peptides comprise fragments of Aβ linked to tetanus toxoid epitopes such as described in US 5,196,512, EP 378,881 and EP 427,347. Optionally, an immunogenic peptide can be linked to one or multiple copies of a carrier, for example, at both the N and C termini of the carrier to form an immunogenic heterologous peptide. Other of these immunogenic heterologous peptides comprise fragments of Aβ linked to carrier peptides described in US 5,736,142. For example, an immunogenic heterologous peptide can comprise Aβ1-7 followed by Aβ1-3 followed by a carrier. Examples of such immunogenic heterologous peptides include:

Aβ 1-7/Tetanus toxoid 830-844 + 947-967 in a linear configuration
DAEFRHD-QYIKANSKFIGITELFNNFTVSFWLRVPKVSASHLE
(SEQ ID NO.:24)

[0091] Peptides described in US 5,736,142 (all in linear configurations):

PADRE/Aβ 1-7:
AKXVAAWTLKAAA-DAEFRHD (SEQ ID NO.:26)

Aβ1-7 x 3/PADRE:
DAEFRHD-DAEFRHD-DAEFRHD-AKXVAAWTLKAAA (SEQ ID NO.:27)

PADRE/Aβ1-7 x 3:
AKXVAAWTLKAAA-DAEFRHD-DAEFRHD-DAEFRHD (SEQ ID NO.:28)

Aβ1-7/PADRE:
DAEFRHD-AKXVAAWTLKAAA (SEQ ID NO.:29)

Aβ1-7/albumin fragment:
DAEFRHD-ISQAVHAAHAEINEAGR (SEQ ID NO.:30)

Aβ4-10/albumin fragment:
FRHDSGY-ISQAVHAAHAEINEAGR (SEQ ID NO.:31)

Aβ3-9/albumin fragment:
EFRHDSG-ISQAVHAAHAEINEAGR (SEQ ID NO.:32)

$HA_{307-319}/A\beta_{1-7}$ x 3:

PKYVKQNTLKLAT-DAEFRHD-DAEFRHD-DAEFRHD (SEQ ID NO.:33)

$A\beta_{1-7}/HA_{307-319}/A\beta_{1-7}$:

DAEFRHD-PKYVKQNTLKLAT-DAEFRHD (SEQ ID NO.:34)

$A\beta_{1-7}$x 3/$HA_{307-319}$:

DAEFRHD-DAEFRHD-DAEFRHD-PKYVKQNTLKLAT (SEQ ID NO.:35)

$A\beta_{1-7}$x 2/$HA_{307-319}$:

DAEFRHD-DAEFRHD-PKYVKQNTLKLAT (SEQ ID NO.:36)

$A\beta_{1-7}/HA_{307-319}$/Malaria CS/$TT_{830-844}/TT_{947-967}/A\beta_{1-7}$

DAEFRHD-PKYVKQNTLKLAT-EKKIAKMEKASSVFNV-QYIKANSKFIGITEL-FNNFTVSFWLRVPKVSASHLE-DAEFRHD (SEQ ID NO.:37)

$A\beta_{1-7}$ x 3/$TT_{830-844}$/C/$TT_{947-967}$

DAEFRHD-DAEFRHD-DAEFRHD-QYIKANSKFIGITEL-C-FNNFTVSFWLRVPKVSASHLE (SEQ ID NO.:38)

$A\beta_{1-7}/TT_{830-844}$/C/$TT_{947-967}$

DAEFRHD-QYIKANSKFIGITELCFNNFTVSFWLRVPKVSASHLE (SEQ ID NO.:39)

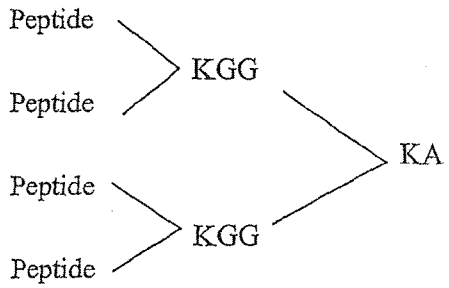
$A\beta_{1-7}/TT_{830-844}$/C/$TT_{947-967}/A\beta_{1-7}$

DAEFRHD-QYIKANSKFIGITEL-C-FNNFTVSFWLRVPKVSASHLE-DAEFRHD (SEQ ID NO.:20)

[0092] Some immunogenic heterologous peptides comprise a multimer of immunogenic peptides represented by the formula 2^x, in which x is an integer from 1-5. Preferably x is 1, 2 or 3, with 2 being most preferred. When x is two, such a multimer has four immunogenic peptides linked in a preferred configuration referred to as MAP4 (*see* US 5,229,490). Such immunogenic peptides are then linked to a carrier using a method of the present invention to form a conjugate.

[0093] The MAP4 configuration is shown below, where branched structures are produced by initiating peptide synthesis at both the N-terminal and side chain amines of lysine. Depending upon the number of times lysine is incorporated into the sequence and allowed to branch, the resulting structure will present multiple N-termini. In this example, four identical

N-termini have been produced on the branched lysine-containing core. Such multiplicity greatly enhances the responsiveness of cognate B cells.



[0094] Examples of such immunogenic heterologous peptides include:

Aβ 1-7/Tetanus toxoid 830-844 in a MAP4 configuration:

DAEFRHD-QYIKANSKFIGITEL (SEQ ID NO.:22)

Aβ 1-7/Tetanus toxoid 947-967 in a MAP4 configuration:

DAEFRHD-FNNFTVSFWLRVPKVSASHLE (SEQ ID NO.:23)

Aβ 3-9/Tetanus toxoid 830-844 in a MAP4 configuration:

EFRHDSG-QYIKANSKFIGITEL (SEQ ID NO.:25)

DAEFRHD-QYIKANSKFIGITEL on a 2 branched resin



[0095] The Aβ peptide, analog, active fragment or other polypeptide can be administered in associated or multimeric form or in dissociated form. Therapeutic agents also include multimers of monomeric immunogenic agents. Agents other than Aβ peptides should induce an immunogenic response against one or more of the preferred fragments of Aβ listed above (e.g., 1-10, 1-7, 1-3, and 3-7), and can also be conjugated to a carrier using a method of the present invention. Preferably, such agents, once conjugated to an appropriate carrier, induce an immunogenic response that is specifically directed to one of these fragments without being directed to other fragments of Aβ. To facilitate the conjugation of an peptide immunogen with a carrier, additional amino acids can be added to the termini of the antigenic determinants. The additional residues can also be used for modifying the physical or chemical properties of the peptide immunogen. Amino acids such as tyrosine, cysteine, lysine, glutamic or aspartic acid, or the like, can be introduced at the C- or N- terminus of the peptide immunogen. Additionally, peptide linkers containing amino acids such as glycine and alanine

can also be introduced. In addition, the antigenic determinants can differ from the natural sequence by being modified by terminal NH_2-group acylation, e.g., by alkanoyl (C1-C20) or thioglycolyl acetylation, terminal-carboxy amidation, e.g., ammonia, methylamine, etc. In some instances these modifications may provide sites for linking to a support or other molecule.

[0096] The peptide immunogens used to generate conjugates of the present invention using a process disclosed herein can be combined via linkage to form polymers (multimers), or can be formulated in a composition without linkage, as an admixture. Where a peptide is linked to an identical peptide, thereby forming a homopolymer, a plurality of repeating epitopic units are presented. For example, multiple antigen peptide (MAP) technology is used to construct polymers containing both CTL and/or antibody peptides and peptides. A "CTL epitope" is one derived from selected eptiopic regions of potential target antigens. When the peptides differ, *e.g.*, a cocktail representing different viral subtypes, different epitopes within a subtype, different HLA restriction specificities, or peptides which contain T-helper epitopes, heteropolymers with repeating units are provided. In addition to covalent linkages, noncovalent linkages capable of forming intermolecular and intrastructural bonds are also contemplated.

[0097] Such peptide immunogens and their analogs are synthesized by solid phase peptide synthesis or recombinant expression, or are obtained from natural sources. Automatic peptide synthesizers are commercially available from numerous suppliers, such as Applied Biosystems, Foster City, California.

[0098] Recombinant expression can be in bacteria (such as *E. coli*), yeast, insect cells or mammalian cells. Procedures for recombinant expression are described by Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual* (Cold Spring Harbor Press, NY, 2nd ed., 1989). Some immunogenic peptides are also available commercially (*e.g.*, American Peptides Company, Inc., Sunnyvale, CA, and California Peptide Research, Inc., Napa, CA).

[0099] Random libraries of peptides or other compounds can also be screened for suitability as a peptide immunogen. Combinatorial libraries can be produced for many types of compounds that can be synthesized in a step-by-step fashion. Such compounds include polypeptides, beta-turn mimetics, hormones, oligomeric *N*-substituted glycines, and oligocarbamates and the like. Large combinatorial libraries of the compounds can be constructed by the encoded synthetic libraries (ESL) method described in WO 95/12608, WO 93/06121, WO 94/08051, WO 95/35503 and WO 95/30642 (each of which is incorporated by

reference for all purposes). Peptide libraries can also be generated by phage display methods (*see, e.g.*, Devlin, WO 91/18980).

Derivatization and Conjugation of an Immunogenic Peptide to a Protein Carrier

[0100] The site of attachment of a peptide immunogen to a protein/polypeptide carrier, and the nature of the cross-linking agent that is used to attach a peptide immunogen to the carrier are both important to the specificity of the resultant antibody generated against it. For proper recognition, the peptide immunogen must be coupled to the carrier with the appropriate orientation. For an antibody to recognize subsequently the free peptide immunogens without carrier, the peptide immunogen-protein/polypeptide carrier conjugate must present the peptide immunogens in an exposed and accessible form. Optimal orientation is often achieved by directing the cross-linking reaction to specific sites on the peptide immunogens. One way to achieve this with a peptide immunogen is by attaching a terminal cysteine residue during peptide synthesis. This provides a sulfhydryl group on one end of the peptide for conjugation to the carrier. Cross-linking through this group provides attachment of the peptide immunogen only at one end, thereby ensuring consistent orientation.

[0101] In peptide immunogen-carrier conjugation, the goal is not to maintain the native state or stability of the carrier, but to present the hapten in the best possible way to the immune system. In reaching this goal, the choice of conjugation chemistry may control the resultant titer, affinity, and specificity of the antibodies generated against the hapten. It may be important in some cases to choose a cross-linking agent containing a spacer arm long enough to present the antigen in an unrestricted fashion. It also may be important to control the density of the peptide immunogen on the surface of the carrier. Too little peptide immunogen substitution may result in little or no response. A peptide immunogen density too high actually may cause immunological suppression and decrease the response. In addition, the cross-linker itself may generate an undesired immune response. These issues need to be taken into consideration in selecting not only the appropriate cross-linking reagents, but also the appropriate ratios of protein/polypeptide carrier and peptide immunogen.

[0102] A variety of means of attaching the protein/peptide carriers to the peptide immunogens are possible. Ionic interactions are possible through the termini or through the ε-amino group of lysine. Hydrogen bonding between the side groups of the residues and the peptide immunogen are also possible. Finally, conformation interactions between the protein/peptide carriers and the immunogenic peptide may give rise to a stable attachment.

[0103] Peptide immunogens-carrier conjugates have been successfully generated using various cross-linking reagents such as zero-length, homobifunctional or heterobifunctional cross linkers. The smallest available reagent systems for bioconjugation are the so-called zero-length cross-linkers. These compounds mediate the conjugation of two molecules by forming a bond containing no additional atoms. Thus, one atom of a molecule is spacer. In many conjugation schemes, the final complex is bound together by virtue of chemical components that add foreign structures to the substances being cross-linked. In some applications, the presence of these intervening linkers may be detrimental to the intended use. For instance, in the preparation of peptide immunogen-carrier conjugates the complex is formed with the intention of generating an immune response to the attached hapten. Occasionally, a portion of the antibodies produced by this response will have specificity for the cross-linking agent used in the conjugation procedure. Zero-length cross-linking agents eliminate the potential for this type of cross-reactivity by mediating a direct linkage between two substances.

[0104] Homobifunctional reagents, which were the first cross-linking reagents used for modification and conjugation of macromolecules, consisted of bireactive compounds containing the same functional group at both ends (Hartman and Wold, 1966). These reagents could tie one protein to another by covalently reacting with the same common groups on both molecules. Thus, the lysine ε-amines or N-terminal amines of one protein could be cross-linked to the same functional groups on a second protein simply by mixing the two together in the presence of the homobifunctional reagent.

[0105] Heterobifunctional conjugation reagents contain two different reactive groups that can couple to two different functional targets on proteins and other macromolecules. For example, one part of a cross-linker may contain an amine-reactive group, while another portion may consist of a sulfhydryl-reactive group. The result is the ability to direct the cross-linking reaction to selected parts of target molecules, thus garnering better control over the conjugation process.

[0106] Heterobifuntional reagents are used to cross-link proteins and other molecules in a two-or three-step process that limits the degree of polymerization often obtained using homobifunctional cross-linkers.

[0107] Many methods are currently available for coupling of peptide immunogens to protein/polypeptide carriers using zero-length, homobifunctional or heterobifunctional crosslinkers. Most methods create amine, amide, urethane, isothiourea, or disulfide bonds,

or in some cases thioethers. The more general method of coupling proteins or peptides to peptides utilizes bifunctional crosslinking reagents. These are small spacer molecules having active groups at each end. The spacer molecules can have identical or different active groups at each end. The most common active functionalities, coupling groups, and bonds formed are:

1. Aldehyde - amino → secondary amine
2. Maleimido - sulfhydryl (thioether
3. Succinimido - amino (amide
4. Imidate esters - amino (- amide
5. Phenyl azides - amino (phenyl amine
6. Acyl halide - sulfhydryl (thioether
7. Pyridyldisulfides - sulfhydryl (disulfide
8. Isothiocyanate - amino (isothiourea.

[0108] The reactivity of a given carrier protein, in terms of its ability to be modified by a cross-linking agent such that it can be conjugated to an peptide immunogen, is determined by its amino acid composition and the sequence location of the individual amino acids in the three dimensional structure of the molecule, as well as by the amino acid composition of the peptide immunogen.

[0109] In the case of linkers ("L") between protein/peptide carriers and other peptides (e.g., a protein/peptide carriers and an peptide immunogen), the spacers are typically selected from Ala, Gly, or other neutral spacers of nonpolar amino acids or neutral polar amino acids. In certain embodiments the neutral spacer is Ala. It will be understood that the optionally present spacer need not be comprised of the same residues and thus may be a hetero- or homo-oligomer. Exemplary spacers include homo-oligomers of Ala. When present, the spacer will usually be at least one or two residues, more usually three to six residues. In other embodiments the protein/polypeptide carrier is conjugated to an peptide immunogen, preferably with the protein/peptide carrier positioned at the amino terminus. The peptide may be joined by a neutral linker, such as Ala-Ala-Ala or the like, and preferably further contain a lipid residue such palmitic acid or the like which is attached to alpha and epsilon amino groups of a Lys residue ((PAM)2Lys), which is attached to the amino terminus of the peptide conjugate, typically via Ser-Ser linkage or the like.

[0121] In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5-L, Aβ1-7-L, Aβ1-9-L, and Aβ1-12-L. In some aspects of the invention the linker is GAGA (SEQ ID NO:10).

[0122] To facilitate the conjugation of a peptide immunogen with a carrier, additional amino acids can be added to the termini of the antigenic determinants. The additional residues can also be used for modifying the physical or chemical properties of the peptide immunogen. Amino acids such as tyrosine, cysteine, lysine, glutamic or aspartic acid, or the like, can be introduced at the C- or N- terminus of the peptide immunogen. Additionally, peptide linkers containing amino acids such as glycine and alanine can also be introduced. In addition, the antigenic determinants can differ from the natural sequence by being modified by terminal NH_2-group acylation, *e.g.*, by alkanoyl (C1-C20) or thioglycolyl acetylation, terminal-carboxy amidation, *e.g.*, ammonia, methylamine, etc. In some instances these modifications may provide sites for linking to a support or other molecule.

[0110] In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5-C, Aβ1-7-C, Aβ1-9-C, and Aβ1-12-C, where C is a cysteine amino acid residue. In some aspects of the invention, the peptide immunogen is an Aβ fragment selected from the group consisting of Aβ1-5-L-C, Aβ1-7-L-C, Aβ1-9-L-C, and Aβ1-12-L-C.

[0111] The peptide immunogen is linked to the protein/peptide carrier either directly or via a linker either at the amino or carboxy terminus of the peptide immunogen. The amino terminus of either the peptide immunogen or the protein/peptide carrier may be acylated. In addition, the peptide immunogen -protein/peptide carrier conjugate may be linked to certain alkanyol (C_1-C_{20}) lipids via one or more linking residues such as Gly, Gly-Gly, Ser, Ser-Ser as described below. Other useful lipid moieties include cholesterol, fatty acids, and the like.

[0112] Peptide immunogens can be linked to a carrier by chemical crosslinking. Techniques for linking an immunogen to a carrier include the formation of disulfide linkages using *N*-succinimidyl-3-(2-pyridyl-thio) propionate (SPDP) (Carlsson, J *et al.* (1978) *Biochem J*, 173: 723,) and succinimidyl 4-(*N*-maleimidomethyl) cyclohexane-1-carboxylate (SMCC) (if the peptide lacks a sulfhydryl group, this can be provided by addition of a cysteine residue to the hapten). These reagents create a disulfide linkage between themselves and peptide cysteine resides on one protein and an amide linkage through the ε-amino on a lysine, or other free amino group in other amino acids. A variety of such disulfide/amide-forming agents are described in Immuno. Rev. 62: 85 (1982). Other bifunctional coupling

agents form a thioether rather than a disulfide linkage. The thioether forming agents include reactive ester of 6-maleimidocaproic acid, 2-bromoacetic acid, and 2-iodoacetic acid, 4-(*N*-maleimido-methyl) cyclohexane-1-carboxylic acid. The carboxyl groups can be activated by combining them with succinimide or 1-hydroxyl-2-nitro-4-sulfonic acid, sodium salt.

[0113] Most frequently, lysine residues are the most abundant amino acid residues found on carrier proteins, and these residues are modified using cross-linking reagents to generate neucleophilic sites that are then coupled to a hapten. This coupling is achieved via any of the hydrophilic side chains on the hapten molecules that are chemically active. These include the guanidyl group of arginine, the (-carboxyl groups of glutamate and aspartic acid, the sulfhydryl group of cysteine, and the ε-amino group of lysine, to name a few. Modification of proteins such that they can now be coupled to other moieties is achieved using crosslinking reagents, which react with any of the side chains on the protein carrier or hapten molecules.

[0114] In one aspect of the present invention, the carrier protein with or without a linker molecule is functionalized (derivatized) with a reagent that introduces reactive sites into the carrier protein molecule that are amenable to further modification to introduce nucleophilic groups. In one embodiment, the carrier is reacted with a haloacetylating reagent, which preferentially reacts with a number of functional groups on amino acid residues of proteins such as the sulfhydryl group of cysteine, the primary ϵ-amine group of lysine residue, the α terminal of α-amines, the thioether of methionine and both imidazoyl side chain nitrogens of histidine (Gurd, 1967). In a preferred embodiment, the primary ϵ-amine groups on lysine residues of the carrier protein are derivatized with b N-hydroxysuccinimidyl bromoacetate to generate a bromoacetylated carrier. Conjugation of peptide immunogen and the activated protein carrier was carried out by slowly adding the activated carrier to the solution containing the peptide immunogen.

[0115] By using the process of this invention, the peptide immunogens discussed in section B, above, may be conjugated to any of the carriers discussed in section A, above. The conjugates resulting from the process of this invention are used as immunogens for the generation of antibodies against Aβ for use in passive/active immunotherapy. Furthermore, Aβ or an Aβ fragment linked to a carrier can be administered to a laboratory animal in the production of monoclonal antibodies to Aβ.

[0116] In one aspect of the invention, the conjugate is a conjugate selected from the group consisting of Aβ1-7-CRM_{197}, (Aβ1-7 x 3)-CRM_{197}, and (Aβ1-7 x 5)-CRM_{197}. In one aspect

of the invention, the conjugate is a conjugate selected from the group consisting of CRM_{197}-Aβ1-5, CRM_{197}-Aβ1-7, CRM_{197}-Aβ1-9, and CRM_{197}-Aβ1-12. In another aspect of the invention, the conjugate is a conjugate selected from the group consisting of Aβ1-5-C-CRM_{197}, Aβ1-7-C-CRM_{197}, Aβ1-9-C-CRM_{197}, and Aβ1-12-C-CRM_{197}, Aβ16-23-C-CRM_{197}, Aβ17-24-C-CRM_{197}, Aβ18-25-C-CRM_{197}, CRM_{197}-C-Aβ16-23, CRM_{197}-C-Aβ17-24, CRM_{197}-C-Aβ18-25, Aβ16-22-C-CRM_{197}, Aβ17-23-C-CRM_{197}, Aβ18-24-C-CRM_{197}, CRM_{197}-C-Aβ16-22, CRM_{197}-C-Aβ17-23, and CRM_{197}-C-Aβ18-24. Aβ1-9-C-CRM_{197}, and Aβ1-12-C-CRM_{197}. In yet another aspect of the invention, the conjugate is a conjugate selected from the group consisting of selected from the group consisting of Aβ1-5-L-C-CRM_{197}, Aβ1-7-L-C-CRM_{197}, Aβ1-9-L-C-CRM_{197}, and Aβ1-12-L-C-CRM_{197}.

Capping

[0117] A disadvantage to the use of coupling reagents, which introduce reactive sites into the side chains of reactive amino acid molecules on carrier and /or hapten molecules, is that the reactive sites if not neutralized are free to react with any unwanted molecule either *in vitro* or *in vivo*. In the process of the present invention, capping of the unreacted functional groups is accomplished by reaction of the conjugates with pendant reactive groups with reagents which inactivate/cap the reactive groups. Exemplary inactivating/capping reagents for use with the conjugation process of the present invention include cysteamine, *N*-acetylcysteamine, and ethanolamine. Alternatively, capping is accomplished by reaction with ammonia or ammonium bicarbonate, either of which converts the haloacetyl groups to aminoacetyl groups. Capping is also accomplished at alkaline pH (9.0–9.8) using sodium hydroxide or sodium carbonate, which converts the haloacetyl groups to hydroxyacetyl groups. One potential advantage of converting the haloacetyl groups to aminoacetyl or hydroxyacetyl groups, as opposed to the reaction with cysteamine derivatives, ethanolamine etc., is the introduction of relatively smaller size chemical functionalities, by reaction with ammonia or hydroxide/carbonate. The resulting capped functional groups, e.g. aminoacetyl or hydroxyacetyl, provide relatively less perturbance in the carrier protein portion of the conjugate. The capped peptide immunogen-carrier protein is purified as necessary using known methods, such as chromatography (gel filtration, ion exchange, hydrophobic interaction or affinity), dialysis, ultrafiltration-diafiltration, selective precipitation using ammonium sulfate or alcohol, and the like.

Immunogenic Conjugates and Compositions

[0118] The capped peptide immunogen-carrier protein conjugates are administered in an immunogenic composition to mammals, particularly humans, for prophylactic and/or therapeutic purposes. The conjugates of the present invention are used to elicit and/or enhance immune responses against immunogens. For instance, CTL-carrier conjugates are used to treat and/or prevent viral infection, amyloidogenic diseases, cancer etc. Alternatively, polypeptide immunogen-carrier conjugates, which induce antibody responses, are also used.

[0119] In therapeutic applications, a conjugate of the present invention is administered to an individual already suffering from an amyloidogenic disease such as Alzheimer's disease. Those in the incubation phase or the acute phase of the disease may be treated with the conjugate of the present invention separately or in conjunction with other treatments, as appropriate.

[0120] In therapeutic applications, an immunogenic composition of the present invention is administered to a patient in an amount sufficient to elicit an effective CTL response or humoral response to the amyloid plaque, and to cure, or at least partially arrest disease progression, symptoms and/or complications. An amount adequate to accomplish this is defined as "therapeutically effective dose." Amounts effective for this use will depend in part on the peptide composition, the manner of administration, the stage and severity of the disease being treated, the weight and general state of health of the patient, and the judgment of the prescribing physician.

[0121] Therapeutically effective amounts of the immunogenic compositions of the present invention generally range for the initial immunization for therapeutic or prophylactic administration, from about 0.1 μg to about 10,000 μg of peptide for a 70 kg patient, usually from about 0.1 to about 8000 μg, preferably between about 0.1 to about 5000 μg, and most preferably between 0.1 to about 1,000 μg. These doses are followed by boosting dosages of from about 0.1 μg to about 1000 μg of peptide pursuant to a boosting regimen over weeks to months depending upon the patient's response and condition by measuring specific immune responses.

[0122] Further, the present invention is used prophylactically to prevent and/or ameliorate amyloidogenic disease. Effective amounts are as described above. Additionally, one of ordinary skill in the art would also know how to adjust or modify prophylactic treatments, as appropriate, for example by boosting and adjusting dosages and dosing regimes.

[0123] Therapeutic administration may begin at the first sign of the disease. This is followed by boosting doses until the disease progression is halted or reversed or the symptoms are substantially abated and for a period thereafter.

[0124] Immunogenic compositions of the present invention for therapeutic or prophylactic treatment can be administered by parenteral, topical, intravenous, oral, subcutaneous, intra-arterial, intra-cranial, intra-peritoneal, intra-nasal or intra-muscular means for prophylactic and/or therapeutic treatment. One typical route of administration of an immunogenic agent is subcutaneous, although other routes can be equally effective. Another common route is intra-muscular injection. This type of injection is most typically performed in the arm or leg muscles. In some methods, agents are injected directly into a particular tissue where deposits have accumulated, for example intra-cranial injection. Intra-muscular injection or intravenous infusion is preferred for administration of antibody. In some methods, particular therapeutic antibodies are injected directly into the cranium. Because of the ease of administration, the immunogenic compositions of the invention are particularly suitable for oral administration. The invention further provides immunogenic compositions for parenteral administration, which comprise a solution of the peptides or conjugates, dissolved or suspended in an acceptable carrier, preferably an aqueous carrier.

[0125] A variety of diluents, excipients and buffers may be used, e.g., water, buffered water, phosphate buffered saline, 0.3% glycine, hyaluronic acid and the like. These compositions may be sterilized by conventional, well-known sterilization techniques, or may be sterile filtered. The resulting aqueous solutions may be packaged for use as is, or lyophilized, the lyophilized preparation being combined with a sterile solution prior to administration. The compositions may contain pharmaceutically acceptable auxiliary substances as required to approximate physiological conditions, such as buffering agents, tonicity adjusting agents, wetting agents and the like, for example, sodium acetate, sodium lactate, sodium chloride, potassium chloride, calcium chloride, sorbitan monolaurate, triethanolamine oleate, etc.

[0126] For solid compositions, conventional nontoxic solid carriers may be used. These may include, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharin, talcum, cellulose, glucose, sucrose, magnesium carbonate, and the like. For oral administration, a pharmaceutically acceptable nontoxic composition is formed by incorporating any of the normally employed excipients, such as those carriers previously

listed, and generally 10-95% of active ingredient, that is, one or more conjugates of the invention, and more preferably at a concentration of 25-75%.

[0127] The concentration of immunogenic compositions of the present invention in the pharmaceutical formulations can vary widely, i.e., from less than about 0. 1%, usually at or at least about 2% to as much as 20% to 50% or more by weight, and will be selected primarily by fluid volumes, viscosities, etc. , in accordance with the particular mode of administration selected.

[0128] The conjugates of the present invention may also be administered via liposomes, which serve to target the conjugates to a particular tissue, such as lymphoid tissue, or targeted selectively to infected cells, as well as increase the half-life of the peptide composition. Liposomes include emulsions, foams, micelles, insoluble monolayers, liquid crystals, phospholipid dispersions, lamellar layers and the like. In these preparations the composition to be delivered is incorporated as part of a liposome, alone or in conjunction with a molecule, which binds to, for example, a receptor prevalent among lymphoid cells. These molecules would include monoclonal antibodies, which bind to the CD45 antigen, or with other therapeutic or immunogenic compositions. Thus, liposomes filled with a desired composition of the present invention can be directed to the site of lymphoid cells, where the liposomes then deliver the selected therapeutic/immunogenic peptide compositions. Liposomes for use in the invention are formed from standard vesicle-forming lipids, which generally include neutral and negatively charged phospholipids and a sterol, such as cholesterol. The selection of lipids is generally guided by consideration of liposome size, acid lability and stability of the liposomes in the blood stream. A variety of methods are available for preparing liposomes, as described in, e.g., Szoka, et al., *Ann. Rev. Biophys. Bioeng* . 9:467 (1980), U.S. Pat. Nos. 4,235,871, 4,501,728, 4,837,028, and 5,019,369, incorporated herein by reference.

[0129] For aerosol administration, the compositions of the present invention are preferably supplied in finely divided form along with a surfactant and propellant. Typical percentages of the composition are 0.01-20% by weight, preferably 1-10%. The surfactant must, of course, be nontoxic, and preferably soluble in the propellant. Representative of such agents are the esters or partial esters of fatty acids containing from 6 to 22 carbon atoms, such as caproic, octanoic, lauric, palmitic, stearic, linoleic, linolenic, olesteric and oleic acids with an aliphatic polyhydric alcohol or its cyclic anhydride. Mixed esters, such as mixed or natural glycerides may be employed. The surfactant may constitute 0.1- 20% by weight of the

composition, preferably 0.25-5%. The balance of the composition is ordinarily propellant. A carrier can also be included, if desired, as with lecithin for intranasal delivery.

[0130] Conjugates of the present invention can optionally be administered in combination with other agents that are at least partly effective in treatment and/or amelioration of a an amyloid disease and/or its symptoms. In the case of Alzheimer's and Down's syndrome, in which amyloid deposits occur in the brain, the conjugates of the invention can be administered in conjunction with other agents that increase passage of the agents of the invention across the blood-brain barrier.

[0131] The immunogenic composition typically contains an adjuvant. An adjuvant is a substance that enhances the immune response when administered together with an immunogen or antigen. A number of cytokines or lymphokines have been shown to have immune modulating activity, and thus may be used as adjuvants, including, but not limited to, the interleukins 1-α, 1-β, 2, 4, 5, 6, 7, 8, 10, 12 (see, e.g., U.S. Patent No. 5,723,127), 13, 14, 15, 16, 17 and 18 (and its mutant forms), the interferons-α, β and γ, granulocyte-macrophage colony stimulating factor (see, e.g., U.S. Patent No. 5,078,996) macrophage colony stimulating factor, granulocyte colony stimulating factor, GSF, and the tumor necrosis factor α and β. Still other adjuvants useful in this invention include a chemokine, including without limitation, MCP-1, MIP-1α, MIP-1β, and RANTES. Adhesion molecules, such as a selectin, e.g., L-selectin, P-selectin and E-selectin may also be useful as adjuvants. Still other useful adjuvants include, without limitation, a mucin-like molecule, e.g., CD34, GlyCAM-1 and MadCAM-1, a member of the integrin family such as LFA-1, VLA-1, Mac-1 and p150.95, a member of the immunoglobulin super family such as PECAM, ICAMs, e.g., ICAM-1, ICAM-2 and ICAM-3, CD2 and LFA-3, co-stimulatory molecules such as CD40 and CD40L, growth factors including vascular growth factor, nerve growth factor, fibroblast growth factor, epidermal growth factor, B7.2, PDGF, BL-1, and vascular endothelial growth factor, receptor molecules including Fas, TNF receptor, Flt, Apo-1, p55, WSL-1, DR3, TRAMP, Apo-3, AIR, LARD, NGRF, DR4, DR5, KILLER, TRAIL-R2, TRICK2, and DR6. Still another adjuvant molecule includes Caspase (ICE). See, also International Patent Publication Nos. WO98/17799 and WO99/43839, which are incorporated herein by reference in their entirety for all purposes.

[0132] Suitable adjuvants used to enhance an immune response include, without limitation, MPL™ (3-O-deacylated monophosphoryl lipid A; Corixa, Hamilton, MT), which is described in U.S. Patent No. 4,912,094, which is hereby incorporated by reference for all

purposes. Also suitable for use as adjuvants are synthetic lipid A analogs or aminoalkyl glucosamine phosphate compounds (AGP), or derivatives or analogs thereof, which are available from Corixa (Hamilton, MT), and which are described in U.S. Patent No. 6,113,918, which is hereby incorporated by reference. One such AGP is 2-[(R)-3-Tetradecanoyloxytetradecancylamino] ethyl 2-Deoxy-4-O-phosphono-3-O-[(S)-3-tetradecanoyoxytetradecanoyl]-2-[(R)-3-tetradecanoyloxy-tetradecanoyl-amino]-b-D-glycopyranoside, which is known as 529 (also known as RC529; Corixa). This 529 adjuvant is formulated as an aqueous form (529 AF) or as a stable emulsion (529 SE).

[0133] Still other adjuvants include mineral oil and water emulsions, calcium salts such as calcium phosphate, aluminum salts (alum), such as aluminum hydroxide, aluminum phosphate, etc., Amphigen, Avridine, L121/squalene, D-lactide-polylactide/glycoside, pluronic acids, polyols, muramyl dipeptide, killed *Bordetella*, saponins, such as Stimulon™ QS-21 (Antigenics, Framingham, MA), described in U.S. Patent No. 5,057,540, which is hereby incorporated by reference3, and particles generated therefrom such as ISCOMS (immunostimulating complexes), *Mycobacterium tuberculosis*, bacterial lipopolysaccharides, synthetic polynucleotides such as oligonucleotides containing a CpG motif (U.S. Patent No. 6,207,646, which is hereby incorporated by reference), a pertussis toxin (PT), or an *E. coli* heat-labile toxin (LT), particularly LT-K63, LT-R72, PT-K9/G129; see, e.g., International Patent Publication Nos. WO 93/13302 and WO 92/19265, which are/ incorporated herein by reference for all purposes.

[0134] Also useful as adjuvants are cholera toxins and mutants thereof, including those described in published International Patent Application No.WO 00/18434 (wherein the glutamic acid at amino acid position 29 is replaced by another amino acid (other than aspartic acid, preferably a histidine). Similar CT toxins or mutants are described in published International Patent Application number WO 02/098368 (wherein the isoleucine at amino acid position 16 is replaced by another amino acid, either alone or in combination with the replacement of the serine at amino acid position 68 by another amino acid; and/or wherein the valine at amino acid position 72 is replaced by another amino acid). Other CT toxins are described in published International Patent Application number WO 02/098369 (wherein the arginine at amino acid position 25 is replaced by another amino acid; and/or an amino acid is inserted at amino acid position 49; and/or two amino acids are inserted at amino acid position 35 and 36).

[0135] It is to be understood that reference throughout this specification to any theory to explain the results described is not to limit the scope of the invention. Independent of the method by which the invention functions, the results and advantages described herein may be achieved by reference to the following examples of the invention.

[0136] It will be apparent to one of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the appended claims. All publications, patents and patent applications mentioned in this specification are incorporated by reference in their entirety for all purposes to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference.

EXAMPLE 1

Conjugation Of CRM_{197} To Aβ Peptide

[0137] Conjugation of haptens/antigenic peptides was carried out by reacting activated carrier CRM_{197}, which has thirty-nine lysine residues, to a hapten/antigenic peptide having a pendant thiol-group using the method described below (Figure 1). All the Aβ peptides contained a cysteine residue at the carboxy terminus to facilitate the conjugation of these peptides through the cysteinyl sulfhydryl group to the carrier protein. These peptides were produced by solid phase synthesis.

I. Activation

[0138] Free amino groups of CRM_{197} were bromoacteylated by reaction with an excess of bromoacetic acid *N*-hydroxysuccinimide ester (Sigma Chemical Co., St. Louis, MO) (Bernatowicz and Matsueda, 1986). To an ice-cold solution of CRM_{197} (~15 mg), 10% (v/v) 1.0 M $NaHCO_3$ (pH 8.4) was added. Bromoacetic acid *N*-hydroxysuccinimide ester, equal in weight to that of CRM_{197} used, was dissolved in 200 μL dimethylformamide (DMF), added slowly to the CRM_{197}, and gently mixed at room temperature in the dark for 1 hour. The resulting bromoacetylated (activated) protein was purified by passage through a desalting (P6-DG) column using PBS / 1 mM EDTA (pH 7.0) as the eluent. Following purification, the fractions corresponding to activated CRM_{197} were pooled and the protein concentration was estimated by BCA protein assay. The protein amino groups, both before and after treatment with bromoacetic acid *N*-hydroxysuccinimide ester, were reacted with 2,4,6-trinitrobenzenesulfonic acid (TNBSA), which served as an indicator of bromoacetylation (Means *et al.*, 1972).

II. Conjugation

[0139] Prior to conjugation, the peptides were reacted with 5,5'-dithio-bis(2-nitrobenzoic acid) [Ellman's reagent] to verify the content of free-SH groups (between 62-88% reduced). For the first four Aβ peptides (amino acids 1-7 without linker, amino acids 1-12 with GAGA (SEQ ID NO.:10) linker, amino acids 1-9 with GAGA (SEQ ID NO.: 10) linker, and amino acids 1-7 with GAGA (SEQ ID NO.: 10) linker), approximately 8.0 – 10.0 mg of peptide was dissolved in sterile distilled water to an approximate concentration of 20 mg/ml. The peptide was slowly added to cold activated CRM_{197} in a 1:1 ratio (w/w) and the pH was adjusted to approximately 7.0-7.2 with the addition of 20-36 μl of 1 N NaOH. The resulting material was gently mixed overnight at 4°C in the dark followed by dialysis in the dark against two 1L changes of PBS, pH 7.2. For the next four Aβ peptides (amino acids 1-5 without linker, amino acids 1-9 without linker, amino acids 1-12 without linker, and amino acids 1-5 with linker), reaction with Ellman's reagent was used to verify the free -SH groups. CRM_{197} was bromoacetylated, purified, and reacted with TNBSA as previously described. The pH of each peptide was adjusted to 7.0 with the addition of 0.1 M $NaPO_4$ (pH 8.5) at 2.2x the volume of the dissolved peptide. The peptide was slowly added to cold activated CRM_{197} in a 1:1 ratio and allowed to react overnight at 4°C in the dark. The resulting material was dialyzed. A final control peptide (1-12mer in reverse orientation) was conjugated to CRM_{197} as described above with the following modification. Rather than adjusting the pH of the peptide to 7.0, the pH of the activated CRM_{197} was adjusted to approximately 7.5 with the addition of 20% (v/v) 0.5 M $NaPO_4$ (pH 8.0). Each conjugate, after dialysis, was transferred into a sterile 15mL polypropylene tube, wrapped in aluminum foil, and stored at 4°C. Activation of the reactive amino residues on the carrier was then subsequently verified using mass spectrometry.

Conjugate	Immunogenic Peptide
A□1-5-C-CRM_{197}	DAEFR-C (SEQ. ID. NO.:1)
A□1-7-C-CRM_{197}	DAEFRHD-C (SEQ. ID NO.:2)
Aβ1-9-C-CRM_{197}	DAEFRHDSG-C (SEQ ID NO:3)
Aβ1-12-C-CRM_{197}	DAEFRHDSGYEV-C (SEQ ID NO:4)
Aβ1-5-L-C-CRM_{197}	DAEFR-GAGA-C (SEQ ID NO.:5)

Aβ 1-7-L-C-CRM_{197}	DAEFRHD-GAGA-C (SEQ ID NO.:6)
Aβ1-9-L-C-CRM_{197}	DAEFRHDSG-GAGA-C (SEQ ID NO.:7)
Aβ1-12-L-C-CRM_{197}	DAEFRHDSGYEV-GAGA-C (SEQ ID NO.:8)
Aβ12-1-C-CRM_{197} (-VE CONTROL)	VEYGSDHRFEAD-C (SEQ ID NO.: 9)

L= linker (GAGA) (SEQ ID NO.:10)

EXAMPLE 2

Preparation of Aβ Peptide-CRM_{197} Conjugate and Purification By Ultrafiltration

Bromoacetylation of CRM_{197}

[0140] CRM_{197} (100 mg) in 0.01 M sodium phosphate buffer, 0.9% NaCl, pH 7.0, was reacted with bromoacetic acid *N*-hydroxysucinimide ester (dissolved to 20 mg/mL in DMSO) at a 1:1 weight ratio under an argon atmosphere. The reaction was titrated as needed to maintain the pH at 7.0. The mixture was stirred in dark for 1.5 hours at room temperature. The reaction mixture was 1.2μm filtered into the retentate reservoir of a UF/DF system (Millipore Labscale TFF, Billerica, MA). Purification was done using a 10K or 30K UF membrane by diafiltration (30-fold) against 0.01 M sodium phosphate buffer / 0.9% NaCl, pH 7.0. The bromoacetylated CRM_{197} was filtered by passing through a 0.2μm filter. The degree of bromoacetylation was determined by reacting the activated CRM_{197} with cysteine, followed by amino acid analysis and quantitation of the resulting carboxymethylcysteine (CMC).

Conjugation of Aβ Peptide and Bromoacetylated CRM_{197} and Capping with N-Acetylacysteamine

[0141] Bromoacetylated CRM_{197} (50 mg) was transferred to a reaction vessel. To the stirred solution, maintained at 2-8°C, was added 1 M sodium carbonate/bicarbonate. Titration was performed to achieve a target pH of 9.0, under argon atmosphere. Separately, 50 mg of Aβ peptide was weighed out and dissolved in water for injection (WFI) to 20 mg/mL. To this solution was added 1 M sodium carbonate/bicarbonate until pH 9.0 was attained. The peptide solution was added to the bromoacetylated CRM_{197} solution, and the mixture was stirred at 2-8°C for 14-18 hours. The remaining bromoacetyl groups were capped with a 20-fold molar excess of *N*-acetylcysteamine for 3-6 hours at 2-8°C.

[0142] The reaction mixture was filtered through 1.2μm filter into the retentate reservoir of a UF/DF system (Millipore XL), and the conjugate was purified at room temperature by 30-fold diafiltration on a 10K or 30K MWCO membrane (Millipore) by diafiltering against 0.01 M sodium phosphate buffer / 0.9% NaCl, pH 7.0. The retentate was collected and 0.2μm filtered and analyzed for protein content (Lowry or Micro-BCA colorimetric assay), by SDS-PAGE, by amino acid analysis, and for immunogenicity in mice.

EXAMPLE 3

Conversion by Capping of the Unreacted Bromoacetyl Groups to Aminoacetyl Groups

[0143] Bromoacetylated CRM_{197} (50 mg), prepared as described above in Example 2, was transferred to a reaction vessel. To the stirred solution, maintained at 2-8°C, was added 1M sodium carbonate/bicarbonate. Titration was performed to achieve a target pH of 9.0, under argon atmosphere. Separately, 50 mg of Aβ peptide was weighed out and dissolved in WFI to 20 mg/mL. To this solution was added 1 M sodium carbonate/bicarbonate until pH 9.0 was attained. The peptide solution was added to the bromoacetylated CRM_{197} solution, and the mixture was stirred at 2-8°C for 14-18 hours. The remaining bromoacetyl groups were capped using 8% ammonium bicarbonate solution for 4 hours at 2-8°C.

[0144] The reaction mixture was 1.2μm filtered into the retentate reservoir of a UF/DF system (Millipore XL), and the conjugate was purified at room temperature by 30-fold diafiltration on a 10K or 30K MWCO membrane by diafiltering *vs* 0.01 M sodium phosphate buffer / 0.9% NaCl, pH 7.0. The retentate was collected and 0.2μm filtered and analyzed for protein content (Lowry or Micro-BCA colorimetric assay), by SDS-PAGE, by amino acid analysis, and for immunogenicity in mice.

EXAMPLE 4

Quantitative Determination of *S*-Carboxymethylcysteine and *S*-Carboxymethylcysteamine as Evaluation of Degree of Conjugation and Capping of Peptide Immunogen-Protein/Polypeptide Conjugates

[0145] Acid hydrolysis of protein-peptide conjugates generated using bromoacetyl activation chemistry resulted in the formation of acid stable S-carboxymethylcysteine (CMC) from the cysteines at the conjugated sites and the formation of acid stable S-carboxymethylcysteamine (CMCA) from the cysteamine at the capped sites (Figure 2). All of the conjugated and capped lysines were converted back to lysine and detected as such. All other amino acids were hydrolyzed back to free amino acids except for tryptophan and

cysteine, which were destroyed by the hydrolysis conditions. Asparagine and glutamine were converted to aspartic acid and glutamic acid respectively.

[0146] Conjugate samples were diluted with deionized water to a total protein concentration of less then 1 mg/mL. Two 10 microgram aliquots of each conjugate were dried and resuspended in 100 µL of 6N HCl [Pierce], 5 µL of melted phenol [Sigma-Aldrich], and 1 µL of 2-mercaptoethanol [Sigma-Aldrich]. The samples were then incubated under vacuum (100 mT) at 110 °C for 22 hours. The resulting hydrolysates were dried, resuspended in 250 µL of Beckman Na-S sodium citrate sample dilution buffer (pH 2.2) [Beckman Instruments, Inc., Fullerton, CA], and filtered using Whatman 0.2 µm nylon syringe tip filters and 1mL syringes.

[0147] Each sample was then loaded into a Beckman 6300 amino acid analyzer sample loop and placed in the analyzer. The amino acids of each hydrolyzed sample and control were separated using ion exchange chromatography followed by reaction with Beckman Ninhydrin NinRX solution at 135 °C. The derivatized amino acids were then detected in the visible range at 570 nm and 440 nm (*see* Table 1). A standard set of amino acids [Pierce Amino Acid Standard H] containing 500 picomoles of each amino acid was run along with the samples and controls for each set of analysis. S-carboxymethylcysteine [Sigma-Aldrich] was added to the standard.

Table 1
Retention Times for Amino Acids
Using Gradient Program 1 on the Beckman 6300 Amino Acid Analyzer

Retention Time (min.)	Amino Acid		Wavelength used for Detection
8.3	Carboxymethylcysteine	CMC	570
9.6	Aspartic Acid & Asparagine	Asx	570
11.3	Threonine	Thr	570
12.2	Serine	Ser	570
15.8	Glutamic Acid & Glutamine	Glx	570 & 440
18.5	Proline	Pro	440
21.8	Glycine	Gly	570
23.3	Alanine	Ala	570

Retention Time (min.)	Amino Acid		Wavelength used for Detection
29.0	Valine	Val	570
32.8	Methionine	Met	570
35.5	Isoleucine	Ile	570
36.8	Leucine	Leu	570
40.5	Tyrosine	Tyr	570
42.3	Phenylalanine	Phe	570
45.4	Carboxymethylcysteamine	CMCA	570
48.8	Histidine	His	570
53.6	Lysine	Lys	570
70.8	Arginine	Arg	570

[0148] The areas of each standard peak were used as a quantitative equivalence for proportional evaluation of each sample. Proline was determined from 440 nm and was converted to an equivalence in 570 nm using Glutamic acid, the closest amino acid.

[0149] Each of these picomole values was converted to a molar ratio of amino acid residues using a comparison of picomoles of lysine to the theoretical lysine value present in the protein. Lysine was chosen for this evaluation based on its covalent attachment to Cysteine and Cysteamine and the expected similar hydrolysis. The resulting numbers of moles of amino acids were then compared to the amino acid composition of the protein and reported along with the values for CMC and CMCA. The CMC value was used directly for evaluation of the degree of conjugation and the CMCA value was used directly for evaluation of the degree of capping.

EXAMPLE 5

Characterization and Optimization of Aβ-CRM_{197} Peptide Conjugates

[0150] To verify conjugation, all peptide-CRM_{197} conjugates were analyzed by amino acid analysis and matrix-assisted laser desorption ionization-time of flight (MALDI-TOF)mass spectrometry. For each conjugate, the moles of peptide conjugated to each mole CRM_{197} was determined by amino acid analysis (number of S-carboxymethylcysteine residues) and

MALDI-TOF mass spectrometry. The values determined by each method were generally in agreement.

I. Size exclusion chromatography:

[0151] Batch concentrate samples were removed from storage and allowed to warm to room temperature. The Aβ peptide conjugate sample was gently mixed to insure a homogeneous preparation. The Aβ peptide conjugate sample was spun in an Eppendorf micro-centrifuge to remove any particulates. The supernatant was withdrawn for TosoHaas TSK-Gel G3000SW chromatography (TosoHaas, Stuttgart, Germany). A TosoHaas TSK-Gel G3000SW column was connected to a HPLC system and the pressure limit was set to 1.4 MPa. The column was equilibrated with at least 30 mL of PBS (10 mM sodium phosphate, 150 mM NaCl, pH 7.2 ± 0.1) at a flow rate of 0.75 mL/min. The Aβ peptide conjugate sample was loaded onto the TosoHaas TSK-Gel G3000SW column using the following parameters:

Concentration of Aβ peptide conjugate sample: 1.5 ± 1.0 mg/mL
Flow rate: 0.75 mL/min
Sample Volume: 0.1 mL
Run Time: 30 minutes

[0152] The absorbance was monitored at both 280nm and 210nm. For long term storage, the TosoHaas TSK-Gel G3000SW column was equilibrated with at least 50 mL of 20% ethanol at a flow rate of 0.5 – 1.0 mL/min.

II. PAGE (Polyacrylamide Gel Electrophoresis):

[0153] The activated (bromoacetylated) CRM_{197} and the Aβ peptide-CRM_{197} conjugates were examined by SDS-Gels using a NuPAGE Bis-Tris Electrophoresis (Novex, Frankfurt, Germany) with a neutral pH, pre-cast polyacrylamide mini-gel system and NuPAGE MES SDS Running Buffer. An 8ug aliquot of each activated CRM or conjugate was mixed with reducing sample buffer and heated at 100°C for 5 minutes. The conjugates and molecular weight (MW) standards (Invitrogen, Carlsbad, CA) were loaded on a 10% (w/v, acrylamide) NuPage gel (Novex) based upon a Bis-Tris-HCl buffered system and run on MES SDS Running Buffer-PAGE (Laemmli). Following SDS-PAGE, the gel was stained with Pierce Gel Code Blue (Pierce, Rockford, IL). Aβ peptide-CRM_{197} conjugate was represented by a major band around 66 kDa, above the band of native CRM and a dimer band around 120 kDa, along with minor multimer bands (data not shown).

III. MALDI-TOF Mass Spectrometry Analysis of Peptide-CRM_{197} Conjugates:

[0154] Mass spectrometry was used for immediate approximation of the degree of conjugation. Suitable aliquots of activated CRM_{197} and conjugate samples were analyzed by MALDI-TOF mass spectrometry using 3,5-dimethoxy-4-hydroxy-cinnamic acid (sinapinic acid) as the matrix. The molecular weight of activated CRM_{197} determined by MALDI-TOF mass spectrometry (Finnigan MAT Lasermat 2000 Mass Spectrometer, Ringoes, NY) was found to be centered around 60.5kDa and for conjugates varied from 65kDa to 74kDa depending on the degree of conjugation (data not shown). Up to 22 of the lysines (~50%) in CRM_{197} were found to be modified at 1:1 ratio.

IV. Optimization Experiments:

[0155] The degree of activation and conjugation are a function of reagent:protein ratio, temperature of the reaction and pH of the reaction buffer. Some examples are given below to illustrate the optimal conjugation conditions carried out to identify the optimal pH conditions in order to have reproducible process control parameters for conjugation reactions. Results (Figure 3) showed that the conjugation reaction to Aβ 5mer (DAEFRC)(SEQ ID NO:1) as well as Aβ 7mer (DAEFRHDC)(SEQ ID NO:2) is pH dependent and yields a higher degree of modification/conjugation when the pH of the reaction condition is increased. Using the TFA salt of 5mer and 7mer peptides, the degree of conjugation was evaluated at pH 9.0 with varying amounts of peptide load (Figure 4). It is evident from these results that peptide conjugates with a defined number of peptide copies per CRM molecule can be generated by varying the peptide /activated CRM ratio during the conjugation process. Similar experiments were done using acetate salt of Aβ 7mer peptide.

[0156] For the Aβ1-7/CRM conjugation, the capping process was evaluated by comparing the moles of CMCA per CRM to the moles of CMC per CRM. Since the total of the CMC and CMCA was constant for each peptide:CRM ratio tested, the capping process was presumed to be complete (Figure 5). The total modification in the conjugate stayed between 19 and 21, comparable to the number of lysines bromoacetylated (Figure 5). These experiments were done with TFA as the counterion for the peptide. The Aβ1-7/CRM conjugation was repeated using the acetate salt of the peptide rather than the TFA salt, and these data are shown in Figure 5 and 6. The capping process appeared to go to completion, with the total of the CMC and CMCA for each point staying between 20 and 22. The conditions for the Aβ-CRM conjugation reaction have been optimized at pH 9.0, with the

degree of conjugation controlled by the peptide to CRM ratio in the reaction. By varying the ratio from 0.1 to 1.5, the degree of conjugation can be varied (Figure 6).

[0157] The degree of activation and conjugation are a function of reagent:protein ratio, temperature of the reaction and pH of the reaction buffer. The degree of modification (conjugation) for each conjugate was calculated by subtracting the mass value of activated CRM_{197} from the mass value of each conjugate and dividing by the mass of the peptide used to prepare the conjugate. The degree of modification (conjugation) for all of the conjugates is described in the Table 2.

[0158] The degree of conjugation was also compared to the values determined by the estimated amount of S-carboxymethylcysteine residues formed per mole of CRM_{197} (also shown in Table 2).

Table 2
Degree of Modification: Comparison of MALDI-TOF and AAA Data

Sample	Da (From Mass Spectrometry)	Degree of conjugation (From Mass Spectrometry)	Degree of conjugation (From CMC-Amino Acid Analysis)
CRM_{197}	58,408	----	----
BrAc-CRM	60,752	19	----
Aβ1-7/CRM	74,463	14	15
Aβ1-7/CRM	72,375	12	14
Aβ1-5/CRM	75,425	20	21
Aβ1-5/CRM	71,690	15	18

EXAMPLE 6

Immunogenicity Studies of Aβ Peptide Conjugates

[0159] Peptides spanning N-terminal residues 1-5, 1-7, 1-9, and 1-12 of Aβ (with and without the linker sequence GAGAC) and a peptide corresponding to the N-terminus of Aβ in reverse sequence from amino acid twelve to amino acid one (1-12mer in reverse sequence), each conjugated to CRM_{197}, were used to immunize mice along with an unconjugated Aβ 1-12 mer peptide in a formulation with STIMULON™ QS-21. Each group of mice was immunized subcutaneously with a dose of either 30 μg or 5 μg of one of the samples formulated with 20 μg of the adjuvant STIMULON™ QS-21, at the beginning of the study (week 0) and subsequently at weeks 3 and 6. The study protocol is illustrated in Table 3.

[0160] As shown in Table 3, peptides spanning N-terminal residues 1-5, 1-7, 1-9, and 1-12 of Aβ (with and without the linker sequence GAGAC) and a peptide corresponding to the N-terminus of Aβ in reverse sequence from amino acid twelve to amino acid one (1-12mer in reverse) conjugated to CRM_{197} were used to immunize mice along with unconjugated Aβ 1-12 mer peptide in a formulation with QS-21. Each group of mice was vaccinated subcutaneously with a dose of either 30 μg or 5 μg of one of the samples formulated with 20 μg of the adjuvant QS-21, at the beginning of the study (week 0) and subsequently at weeks 3 and 6. Swiss Webster mice were used for the entire study with 5 mice in each group. Injection volume = 100 μl; B = Bleed; V = vaccinate; E = exsanguinate.

[0161] Anti-Aβ titers were measured by ELISA against Aβ and CRM_{197} as described below. Briefly, Costar 96 well plates (#3591) were coated overnight at room temperature with 2 μg/mL Aβ1-42 in sterile carbonate/bicarbonate buffer, pH 9.6. Plates were emptied and blocked for two hours at room temperature with 200 μl/well of 0.05% BSA in 1X PBS/0.05% Tween 20. Blocked plates were emptied and washed with a plate washer containing TBS, 0.1% Brij-35 (without azide) wash buffer. All primary antisera were serially diluted with 0.05% BSA in 1X PBS containing 0.05% Tween 20/0.02% Azide and 100 μL of each dilution was then transferred to the appropriate plate wells and incubated at room temperature for 2 hours. Plates were then emptied/washed as described above. Alkaline phosphatase conjugated goat anti-mouse IgG secondary antibody from Southern Biotech (city, state) was diluted 1:1000 with 0.05% BSA in PBS containing 0.05% Tween 20/0.02% Azide and 100 μL was added to each well and incubated at room temperature for 1 hour. Plates were then emptied/washed as described above and finally incubated at room temperature for 1 hour with 100 μL/well of a 1 mg/mL solution of p-nitrophenyl phosphate substrate prepared in diethanolamine/$MgCl_2$, pH 9.8. The color development was stopped with the addition of 50 μL/well of 3 N NaOH. Plates were read at 405 nM with a 690 nM reference. Endpoint titers were calculated at an O.D. of 0.1 AU.

Table 3
Mouse Immunization Study Protocol

Group Code	Description	Dose (µg)	Wk 0	Wk 3	Wk 6	Wk 8	Wk 13	Wk 16
AE488	CRM/1-7 w/o linker	30	B, V	B, V	B, V	B	B	E
AE489	CRM/1-12 with linker	30	B, V	B, V	B, V	B	B	E
AE490	CRM/1-9 with linker	30	B, V	B, V	B, V	B	B	E
AE491	CRM/1-7 with linker	30	B, V	B, V	B, V	B	B	E
AE492	CRM/1-5 w/o linker	30	B, V	B, V	B, V	B	B	E
AE493	CRM/1-9 w/o linker	30	B, V	B, V	B, V	B	B	E
AE494	CRM/1-12 w/o linker	30	B, V	B, V	B, V	B	B	E
AE495	CRM/1-5 with linker	30	B, V	B, V	B, V	B	B	E
AE496	CRM/1-7 w/o linker	5	B, V	B, V	B, V	B	B	E
AE497	CRM/1-12 with linker	5	B, V	B, V	B, V	B	B	E
AE498	CRM/1-9 with linker	5	B, V	B, V	B, V	B	B	E
AE499	CRM/1-7 with linker	5	B, V	B, V	B, V	B	B	E
AE500	CRM/1-5 w/o linker	5	B, V	B, V	B, V	B	B	E
AE501	CRM/1-9 w/o linker	5	B, V	B, V	B, V	B	B	E

Table 3
Mouse Immunization Study Protocol - Continued

Group Code	Description	Dose (µg)	Wk 0	Wk 3	Wk 6	Wk 8	Wk 13	Wk 16
AE502	CRM/1-12 w/o linker	5	B, V	B, V	B, V	B	B	E
AE503	CRM/1-5 with linker	5	B, V	B, V	B, V	B	B	E
AE504	CRM_{197} C1-6151	30	B, V	B, V	B, V	B	B	E
AE505	CRM_{197} C1-6151	5	B, V	B, V	B, V	B	B	E
AE506	CRM/12-1mer	30	B, V	B, V	B, V	B	B	E
AE507	CRM/12-1mer	5	B, V	B, V	B, V	B	B	E
AE508	1-12mer peptide	30	B, V	B, V	B, V	B	B	E
AE509	1-12mer peptide	5	B, V	B, V	B, V	B	B	E
AE510	Ab	30	B, V	B, V	B, V	B	B	E
AE511	Ab	5	B, V	B, V	B, V	B	B	E

CRM_{197} ELISA

[0162] Greiner 96 well plates (#650011) were coated at 37°C for 90 minutes with 5.0 μg/mL (100 μl/well) of CRM_{197} in sterile carbonate/bicarbonate buffer, pH 9.6. Plates were emptied and washed with a plate washer containing 1X TBS, 0.1% Brij-35 wash buffer. All primary antisera were serially diluted with 1X PBS containing 0.3% Tween 20/EDTA and 100 μL of each dilution was then transferred to the appropriate plate wells and incubated at 37°C for 1 hour. The plates were then emptied/washed as described above. Alkaline phosphatase conjugated goat anti-mouse IgG secondary antibody from Southern Biotech was diluted 1:1000 with 1X PBS containing 0.05% Tween 20/0.02% Azide and 100 μL was added to each well and incubated at 37°C for 1 hour. Plates were then emptied/washed as described above and finally incubated at room temperature for 1 hour with 100 μL/well of a 1 mg/mL solution of p-nitrophenyl phosphate substrate prepared in diethanolamine/$MgCl_2$, pH 9.8. The development was stopped with the addition of 50 μL/well of 3 N NaOH. Plates were read at 405 nM with a 690 nM reference. Endpoint titers were calculated at an O.D. of 0.1 AU.

[0163] Tables 4-6 illustrate end point ELISA titers against Aβ. Following primary immunization, all eight conjugates (excluding the negative control) induced measurable anti-Aβ IgG immune responses. However, the 30μg dose, but not the 5μg dose, of Aβ gave a positive response at week 3 following primary immunization. Among all the conjugates, it appears that Aβ 1-7 peptide conjugated without linker elicited as good as or better response than other conjugates studied. At 5μg dose, Aβ 1-5C did better at weeks 8-16. Aβ 1-7C was best at 30μg dose. Analysis of antibody titers after second and third immunization with either 5 or 30μg dose indicate that the maximal immune response to Aβ for most of the conjugates was seen after the second immunization. At least in mice, the third immunization did not appear to enhance the immune response. Aβ peptide however, needed three immunizations with the 30μg dose to reach maximal immune response against the peptide (Table 5). In terms of antibody decay over an extended period of time, the antibody level from the groups immunized with conjugates was reduced by 2 to 3 fold as compared to the highest level within that group. Individual samples from weeks 6 and 8 were analyzed to calculate GMTs against Aβ for each of the group (Table 6) to see if any conjugate group was substantially better than the others. Statistical analysis of week 6 titers from Aβ1-5C, Aβ 1-7C and Aβ 1-9C conjugates indicated that the Aβ 1-7 conjugate induced a significantly higher titer. It is also evident from this experiment that the linker sequence GAGAC did not contribute to enhancing the immune response to the peptide.

Table 4

Group		Week 3	Week 6	Week 8	Week 13	Week 16
1-5C	<100	14,960	687,691	882,012	625,208	771,828
1-7C	<100	51,253	1,280,181	860,463	520,060	571,043
1-9C	<100	18,615	1,008,872	622,325	348,967	380,755
1-12C	<100	615	132,009	390,624	166,162	184,170
1-5LC	<100	4,999	458,075	454,631	237,573	220,091
1-7LC	<100	17,693	849,170	842,402	446,089	400,536
1-9LC	<100	18,544	1,465,115	1,180,347	571,127	579,477
1-12LC	<100	12,664	908,360	598,867	368,101	316,075
CRM_{197}	<100	<100	<100	<100	<100	<100
1-42	<100	<100	<100	<100	<100	<100
1-12	<100	<100	<100	<100	<100	<100
12-1C	<100	<100	<100	<100	<100	<100

Table 4. Weeks 0, 3, 6, 8, 13, and 16 ELISA endpoint titers against Aβ using antiserum from 5 μg dose of peptide conjugates spanning varying lengths of the N-terminus of Amyloid Aβ peptide. Ref: Elan hyperimmune polyclonal #592 = 3,073,307. Endpoint at O.D. 0.1 AU. Swiss Webster mice were immunized SC-N with 5 μg of above antigens formulated with 20 μg STIMULON™ QS-21 at weeks 0, 3, and 6.

Table 5

Group	Week 0	Week 3	Week 6	Week 8	Week 13	Week 16
1-5C	<100	18,150	590,355	332,832	204,645	176,159
1-7C	<100	100,672	1,840,741	647,470	592,638	779,072
1-9C	<100	18,520	1,184,696	713,494	363,459	327,065
1-12C	<100	7,837	1,325,725	1,126,389	681,268	577,604
1-5LC	<100	16,347	469,191	184,077	177,358	164,680
1-7LC	<100	47,866	971,229	462,200	463,466	529,726
1-9LC	<100	59,002	921,544	787,273	405,023	500,468
1-12LC	<100	27,348	697,150	483,320	284,800	397,816
CRM_{197}	<100	<100	<100	<100	<100	<100
1-42	<100	160	3,327	109,718	48,646	27,901
1-12	<100	<100	<100	<100	<100	<100
12-1C	<100	<100	<100	<100	<100	<100

Table 5. Weeks 0, 3, 6, 8, 13, and 16 ELISA endpoint titers against Aβ using antiserum from 30 μg dose of peptide conjugates spanning varying lengths of the N-terminus of Amyloid Aβ peptide. Ref: Elan hyperimmune polyclonal #592 = 3,073,307. Endpoint at O.D. 0.1 AU. Swiss Webster mice were immunized SC-N with 30 μg of above antigens formulated with 20 μg STIMULON™ QS-21 at weeks 0, 3, and 6.

Table 6

Group	Week 6	Week 8
1-5C	237,668 [a]	161,671 [b]
1-7C	1,866,702 [a]	881,146 [b]
1-9C	963,323 [a]	595,414 [b]
1-12C	940,260	955,470
1-5LC	395,553	141,084
1-7LC	516,921	394,521
1-9LC	826,773	562,458
1-12LC	544,768	376,952
1-42	365	4,565

Table 6. Weeks 6 and 8 ELISA endpoint GMTs against Aβ using antisera from 30 μg dose of peptide conjugates spanning varying lengths of the N-terminus of Amyloid-Aβ. Ref: Elan Hyperimmune Polyclonal #592 = 3,073,307. Endpoint at O.D. 0.1 AU. Swiss Webster mice were immunized SC-N with 30 μg of above antigens formulated with 20 μg STIMULON™ QS-21 at weeks 0, 3, and 6

a. Statistical analysis of week 6 titers from 1-5C, 1-7C, and 1-9C using Tukey-Kramer show a statistical difference between 1-5C vs 1-7C only, whereas, analysis using Student's T-test shows a statistical difference between 1-5C vs 1-7C and 1-5C vs 1-9C.

b. Statistical analysis of week 8 titers from 1-5C, 1-7C, and 1-9C does not show a statistical difference among the three groups. However, there appears to be a trend that may indicate a difference between 1-5C vs 1-7C.

PDAPP Mouse Brain Tissue Staining

[0164] The PDAPP brain tissue staining assay provides an indication of the functionality of the Aβ peptide conjugates and/or Aβ 1-42 antiserum. Serum samples from individual mouse groups were separately analyzed for their ability to recognize PDAPP mouse brain tissue plaques containing amyloid peptide. The results are shown in Table 7A and 7B. With the exception of the Aβ 5mer conjugate antisera, there was a dose-related response in recognizing the plaques. Independent of the linker, 30μg conjugate-induced antisera had better reactivity patterns as compared to that of 5μg conjugate antisera. However, with the Aβ 5mer conjugate antisera, there seems be similar or better reactivity for the 5μg group. Comparing all these results, it is concluded that conjugates made from Aβ 1-5 mer through Aβ 1-9 mer are sufficient in eliciting plaques recognizing immune response in mice and the presence of linker is not essential. The following conclusions can be drawn from this study: (a) All of

the peptide conjugates induced high titered antiserum against the carrier protein CRM_{197} to equal or slightly higher levels as compared to the unconjugated CRM_{197} control (not shown). (b) The conjugates with the GAGAC linker did not enhance immunogenicity or functionality compared to conjugates without the linker. (c) The immunogenicity data and PDAPP brain tissue staining (an initial indication of functional antibody) show that the Aβ 1-5mer and Aβ 1-7mer conjugates appeared to be the preferred immunogens for further development.

Table 7A. PDAPP mouse brain tissue staining.

5 µg Dose					
Without Linker			**With Linker**		
Vaccine	**Animal #**	**PDAPP Staining**	**Vaccine**	**Animal #**	**PDAPP Staining**
CRM/ Aβ 1-5	1	+(no diffuse)	CRM/ Aβ 1-5	1	-
	2	++/+++		2	-
	3	++/+++		3	±
	4	++		4	±
	5	++		5	±
CRM/ Aβ 1-7	1	++	CRM/ Aβ 1-7	1	+
	2	++		2	++
	3	++		3	++
	4	++		4	+
	5	++		5	++
CRM/ Aβ 1-9	1	+	CRM/ Aβ 1-9	1	++
	2	+/++		2	++
	3	±		3	+
	4	±		4	+
	5	±		5	+
CRM/ Aβ 1-12	1	-	CRM/ Aβ 1-12	1	+
	2	?		2	+
	3	±		3	++
	4	-		4	-
	5	±		5	±
CRM/ Aβ 12-1mer	1	-	Aβ42	1	-
	2	-		2	-
	3	±		3	-
	4	-		4	-
	5	±		5	-

All antiserum diluted 1:1000 for staining procedure.

Table 7B. PDAPP mouse brain tissue staining.

30 µg Dose					
Without Linker			**With Linker**		
Vaccine	**Animal #**	**PDAPP Staining**	**Vaccine**	**Animal #**	**PDAPP Staining**
CRM/ Aβ 1-5	1	-	CRM/ Aβ 1-5	1	+
	2	+/++		2	-
	3	-		3	-
	4	±		4	±
	5	++		5	-
CRM/ Aβ 1-7	1	+/++	CRM/ Aβ 1-7	1	+
	2	++		2	±/+
	3	++		3	+/++
	4	++		4	±/+
	5	++/+++		5	+/++
CRM/ Aβ 1-9	1	++/+++	CRM/ Aβ 1-9	1	+/++
	2	++		2	++
	3	++		3	++
	4	+		4	±
	5	+		5	+/++
CRM/ Aβ 1-12	1	-	CRM/ Aβ 1-12	1	+/++
	2	+/++		2	+
	3	+/++		3	-
	4	±		4	+/++
	5	±		5	+
CRM/ Aβ 12-1mer	1	-	Aβ 42	1	±
	2	-		2	-
	3	-		3	-
	4	-		4	-
	5	-		5	-

All antiserum diluted 1:1000 for staining procedure.

EXAMPLE 7

Immunogenicity Studies in Monkeys

[0165] Groups of 6 monkeys received 30 ug of 7mer conjugate (total conjugate) adjuvanted with either STIMULON™ QS-21, alum or RC529 SE formulation at days 0, 29 and 58. Additional groups included were 30 ug 5mer conjugate with either alum ($Al(OH)_3$) or RC529 SE, 75 and 300µg of Aβ with STIMULON™ QS-21 as positive controls. Positive controls were immunized every two weeks. At day 36 and 64 the anti-Aβ antibody titers were determined (Figures 7 - 9). On day 36, 7mer/CRM conjugates with STIMULON™ QS-21,

Alum and RC529 SE elicited GMT titers of 10110, 13330 and 17090 respectively (Figure 7). In contrast, Aβ 1-42 plus STIMULON™ QS-21 elicited GMTs of 223 and 1734 at 75 and 300μg dose levels, respectively. The Aβ 5mer conjugate elicited a titer of 2134 with alum and 15980 with RC529 SE. On day 64, i.e. after 3 doses of conjugates with either STIMULON™ QS21 or RC-529 SE induced substantially higher titers than post second dose (GMTs 69910 for 7 mer/RC-529 SE; 21640 for Aβ 5mer/RC-529 SE and 30310 for Aβ 7mer/STIMULON™ QS-21) (Figure 8). Conjugates with alum elicited reduced titers at post third immunization compared to post second immunization. It appears that the Aβ 7mer conjugate elicited a better response as compared to the Aβ 5mer conjugate. In monkeys, adjuvanting Aβ 7mer conjugate with RC-529 SE or STIMULON™ QS-21 elicited the highest response (Figure 9). The response to the Aβ 7mer conjugate with alum was moderate and similar to that of 300ug Aβ 1-42 with STIMULON™ QS-21.

[0166] Several conclusions can be drawn from the current example. First, both conjugates are very immunogenic in primate species. Second, the presence of adjuvants in the immunization formulation significantly influences the immune response. Third, except for the aluminum adjuvant, RC-529 SE and STIMULON™ QS-21 enhance the immune response after each dose of immunization at least up to three doses (Figures 9). Overall, Aβ 7mer conjugate induced higher antibody response in the presence of 529, followed by STIMULON™ QS-21 (*see* Figure 9).

EXAMPLE 8

Preparation of Multiple Antigenic Peptide (MAP) Conjugates and their Immunogenicity Study

[0167] Several methods are available for generating multiple antigenic sites on the carriers. In the previous examples, each antigenic site is separately conjugated to the carrier by defined conjugation and capping chemistries. In this example, multiple antigenic sites are constructed by solid phase synthesis of tandem repeats of Aβ1-7 mer. Alternatively these tandem repeats can be coupled with T-cell epitopes with or without linking through a lysine core as described elsewhere. These multiple antigenic peptides were synthesized with an additional cysteinyl residue for conjugation to the carrier protein. Peptides containing one repeat unit (1-7), three repeat units $(1\text{-}7)_3$ and five repeat units $(1\text{-}7)_5$ with an additional cysteinyl residue at the carboxyl end were synthesized. These peptides were covalently attached to bromoacetylated CRM overnight through their C-terminal cysteine residues. The reaction was carried out at pH 9.0-9.2 with peptide:CRM ratios added as outlined in Table 8.

Bromoacetyl groups, which did not react with peptide, were capped with N-acetylcysteamine. These lots represent conjugates containing one single copy, three tandem copies, and five tandem copies of the Aβ1-7 peptide conjugated to CRM, respectively. Table 8 briefly outlines the properties of the samples.

Table 8
Multiple Antigenic Peptide (MAP) Conjugate Samples

Conjugate	Peptide: CRM (w/w)	pH of reaction
$Ab(1-7)_1$/CRM	0.37	8.99
$Ab(1-7)_3$/CRM	1.02	8.95
$Ab(1-7)_5$/CRM	1.67	9.17

[0168] Peptide load (the average number of Aβ 1-7 peptides per carrier) and capping numbers (Table 9) are the numbers of unique amino acids (CMC or CMCA) per carrier as determined by amino acid analysis. The CMC and CMCA values were referenced to lysine.

Table 9
Degree of Conjugation and Capping of Each Conjugate

CONJUGATE	Peptide Load (CMC)	Capping (CMCA)
$Aβ(1-7)_1$/CRM	12.5	11.7
$Aβ(1-7)_3$/CRM	10.4	15.2
$Aβ(1-7)_5$/CRM	9.8	15.9

[0169] Swiss-Webster mice (10 per group) were immunized subcutaneously with 1 or 0.1 μg Aβ/CRM conjugated peptide. Half of the mice were immunized with the composition formulated with 100 μg of the adjuvant $Al(OH)_3$, and half were immunized without adjuvant. Immunizations were scheduled at weeks 0 and 3. Bleeds were scheduled for weeks 0, 3, and 6. Serum samples were analyzed for antibody response against Aβ1-42 mer peptide. The results are shown in Table 10.

Table 10

Anti-Aβ Endpoint Titers for Multiple Antigenic Peptide (MAP) Conjugates

Group Code	Sample Description	Adjuvant	Wk 0 Pool	Wk 3 GMT	Wk 6 GMT
AG332	1 μg Aβ $(1\text{-}7)_1$/CRM	$Al(OH)_3$	<100	18,096	100,279
AG333	1 μg Aβ $(1\text{-}7)_3$/CRM	$Al(OH)_3$	<100	44,911	420,235
AG334	1 μg Aβ $(1\text{-}7)_5$/CRM	$Al(OH)_3$	<100	27,032	394,488
AG335	0.1 μg Aβ $(1\text{-}7)_1$/CRM	$Al(OH)_3$	<100	19,350	66,834
AG336	0.1 μbg Aβ $(1\text{-}7)_3$/CRM	$Al(OH)_3$	<100	13,307	208,272
AG337	0.1 μg Aβ $(1\text{-}7)_5$/CRM	$Al(OH)_3$	<100	1,196	22,665
AG338	1 μg Aβ $(1\text{-}7)_1$/CRM	None	<100	5,273	370,980
AG339	1 μg Aβ $(1\text{-}7)_3$/CRM	None	<100	9,299	541,093
AG340	1 μg Aβ $(1\text{-}7)_5$/CRM	None	<100	3,100	185,272
AG341	0.1 μg Aβ $(1\text{-}7)_1$/CRM	None	<100	340	25,839
AG342	0.1 μg Aβ $(1\text{-}7)_3$/CRM	None	<100	128	5,553
AG343	0.1 μg Aβ $(1\text{-}7)_5$/CRM	None	<100	668	2,098

[0170] All conjugates induced anti-Aβ 1-42 antibody titer after primary immunization and the levels were substantially increased after the booster dose. In the absence of aluminum adjuvant, the differences in dose response were evident both at week 3 and week 6 bleeds. The higher dose elicited high-titered antibody response. Aluminum adjuvant elicited substantially higher antibody response at week 3 at both dose levels (0.1 and 1 μg) as compared to the unadjuvanted groups. After secondary immunization, conjugates given at 1 μg dose elicited 5 to 10 fold increase in antibody levels. At this dose level peptide conjugates with 3 and 5 repeats induced higher antibody response than a single repeat containing conjugate. The titers against the CRM carrier were also determined, and these are listed in Table 11.

Table 11
Anti-CRM Endpoint Titers for Multiple Antigenic Peptide (MAP) Conjugates

Group Code	Sample Description	Adjuvant	Wk 0 Pool	Wk 3 GMT	Wk 6 GMT
AG332	1 μg $A\beta(1\text{-}7)_1$/CRM	$Al(OH)_3$	<50	10,531	114,602
AG333	1 μg $A\beta(1\text{-}7)_3$/CRM	$Al(OH)_3$	<50	4,274	83,065
AG334	1 μg $A\beta(1\text{-}7)_5$/CRM	$Al(OH)_3$	<50	1,680	49,320
AG335	0.1 μg $A\beta(1\text{-}7)_1$/CRM	$Al(OH)_3$	<50	1,114	13,231
AG336	0.1 μg $A\beta(1\text{-}7)_3$/CRM	$Al(OH)_3$	<50	197	1,484
AG337	0.1 μg $A\beta(1\text{-}7)_5$/CRM	$Al(OH)_3$	<50	65	222
AG338	1 μg $A\beta(1\text{-}7)_1$/CRM	None	<50	35	309
AG339	1 μg $A\beta(1\text{-}7)_3$/CRM	None	<50	29	1,085
AG340	1 μg $A\beta(1\text{-}7)_5$/CRM	None	<50	29	542
AG341	0.1 μg $A\beta(1\text{-}7)_1$/CRM	None	<50	25	55
AG342	0.1 μg $A\beta(1\text{-}7)_3$/CRM	None	<50	25	34
AG343	0.1 μg $A\beta(1\text{-}7)_5$/CRM	None	<50	29	ND

Animals were immunized at weeks 0 and 3 and bled at weeks 0, 3, and 6. Adjuvant: 100 μg $Al(OH)_3$ or none. ND=Not Determined.

[0171] Data in Table 11 indicates that the unadjuvanted groups induced very low levels of anti-CRM antibody response at both 1μg as well as 0.1μg dose levels even after two immunizations. However conjugates with aluminum hydroxide adjuvant induced substantial levels of anti-CRM antibody response at 1μg dose and much lower response at 0.1μg dose. In the presence of the adjuvant, CRM titers were highest for the single repeat conjugate, intermediate for the triple repeat conjugate, and lowest for the quintuple repeat conjugate. This is as expected, since the CRM dose per peptide dose is lowest for $A\beta(1\text{-}7)_5$/CRM, and highest for $A\beta(1\text{-}7)_1$/CRM. The differences were only statistically significant at week 6 for the 0.1μ μg dose.

[0172] The objective of the current invention is to elicit high titered immunogenic response against the antigenic hapten and not necessarily against the carrier protein. Under certain

circumstances it is desirable to elicit optimal immune response against the hapten antigenic determinant with least or no immune response against the carrier protein. For such applications, conjugates with tandem repeats of multiple antigenic determinants with unadjuvanted formulation will serve the need.

EXAMPLE 9

Preparation of Aβ-Peptide Conjugates with Various Carrier Proteins and their Immunogenicity

[0173] This example compares the immunogenicity of conjugates using six different carrier proteins. The acetate salt of Aβ1-7 was added to bromoacetylated carriers in a 1:1 ratio by weight at pH 9. All conjugates except Aβ1-7/rC5ap were capped with N-acetylcysteamine. All of the alternative carriers are recombinant bacterial proteins, including CRM (diphtheria toxoid), recombinant C5a peptidase (rC5ap; cloned from *Streptococcus agalactiae,* includes D130A and S512A mutations), ORFs 1224, 1664, 2452 (all cloned from *Streptococcus pyogenes*), and T367, T858 (each cloned from *Chlamydia pneumoniae*). A summary of the carriers used is found in Table 12. The degree of conjugation and capping of each Aβ 1-7 conjugate to these carriers are presented in Table 13.

[0174] This study showed that the recombinant C5a peptidase conjugate induced higher titers against Aβ than most of the other carriers tested, including CRM. This difference was statistically significant for week 6 titers of groups that received aluminum hydroxide. In addition, the Aβ1-7/T858 conjugate was significantly more immunogenic than most other conjugates in the absence of adjuvant. The only conjugate that performed poorly relative to the CRM control conjugate was Aβ1-7/T367, a conjugate that also did not react with an Aβ specific monoclonal antibody by Western blot. This study confirms that numerous other carriers can be successfully used to immunize against the Aβ peptide.

Table 12

List of Carriers and Conjugate Properties

CARRIER PROTEIN	MW of carrier (Da)	# of lysines
CRM	58, 408	39
rC5ap	108, 560	85
ORF1224	30, 950	18
ORF1664	31, 270	38
ORF2452	31, 790	29
T367	49, 700	29
T858	37, 190	23

Table 13

Degree Of Conjugation and Capping of Each Conjugate

CONJUGATE	Peptide load (CMC)	Capping (CMCA)
Aβ1-7/rC5ap	25.9	-
Aβ1-7/ORF1224	12.8	5.7
Aβ1-7/ORF1664	13.4	10.8
Aβ1-7/ORF2452	12.03	10.5
Aβ1-7/T367	13.2	8.2
Aβ1-7/T858	5.2	1.7

Conjugation results: Peptide load (the average number of Aβ1-7 peptides per carrier) and capping number are the numbers of unique amino acids (CMC or CMCA) per carrier as determined by amino acid analysis. The CMC and CMCA values were referenced to lysine.

Immunization Results

[0175] The geometric mean titer for each group in this study is listed in Table 14. At week 3, regardless of the presence of adjuvant, Aβ1-7/rC5ap induced significantly higher anti-Aβ titers than the corresponding conjugates prepared with *Streptococcus pyogenes* ORFs 1224, 1664, 2452, or *Chlamydia pneumoniae* ORFs T367 and T858. At week 3 in the absence of

adjuvant, Aβ1-7/rC5ap was also more immunogenic than all other conjugates except Aβ1-7/T858. The T858 conjugate without $Al(OH)_3$ induced higher titers than the ORF1224, ORF1664, ORF2452, and CRM conjugates without adjuvant. The only conjugate that was significantly less immunogenic than Aβ1-7/CRM was Aβ1-7/T367 ($p< 0.00002$). The T367 carrier performed poorly with or without adjuvant at both weeks 3 and 6. At week 6, the rC5ap conjugate with aluminum hydroxide was more immunogenic ($p<0.04$) than all the other conjugates except Aβ 1-7/ORF2452. In the absence of adjuvant, both Aβ1-7/rC5ap and Aβ1-7/T858 induced significantly higher titers than the ORF1224, ORF1664, or T367 conjugates. Aβ1-7/CRM without aluminum hydroxide induced higher titers than either Aβ1-7/ORF1664 or Aβ1-7/T367.

TABLE 14

Anti-Aβ1-42 Endpoint Titers.

GROUP CODE	SAMPLE DESCRIPTION	ADJUVANT	WK 0 POOL	WK 3 GMT	WK 6 GMT
AG344	5 μg Aβ1-7/CRM	$Al(OH)_3$	<100	21,404	54,157
AG345	5 μg Aβ1-7/rC5ap	$Al(OH)_3$	<100	61,967	402,972
AG346	5 μg Aβ1-7/ORF1224	$Al(OH)_3$	<100	10,711	30,084
AG347	5 μg Aβ1-7/ORF1664	$Al(OH)_3$	<100	7,188	43,226
AG348	5 μg Aβ1-7/ORF2452	$Al(OH)_3$	<100	11,437	109,091
AG349	5 μg Aβ1-7/T367	$Al(OH)_3$	<100	321	5,139
AG350	5 μg Aβ1-7/T858	$Al(OH)_3$	<100	16,656	33,328
AG351	5 μg Aβ1-7/CRM	None	<100	2,615	119,488
AG352	5 μg Aβ1-7/rC5ap	None	<100	11,858	279,113
AG353	5 μg Aβ1-7/ORF1224	None	<100	1,674	18,719
AG354	5 μg Aβ1-7/ORF1664	None	<100	119	9,832
AG355	5 μg Aβ1-7/ORF2452	None	<100	2,493	76,038
AG356	5 μg Aβ1-7/T367	None	<100	50	620
AG357	5 μg Aβ1-7/T858	None	<100	28,820	275,202

Animals were immunized at weeks 0 and 3 and bled at weeks 0, 3, and 6. Dose is based on the total amount of conjugate. Adjuvant: 100 μg $Al(OH)_3$ or none.

EXAMPLE 10

Preparation of Additional Aβ Peptide-Protein Conjugates

I. Activation

[0176] Thawed CRM_{197} (8 mL, 59.84 mg, at 7.48mg/mL) was dissolved in 0.1 M borate buffer (pH 9, 3.968 mL) to bring the concentration to 5 mg/mL. The solution was cooled in

an ice bath to 0-5°C. Bromoacetic acid N-hydroxysuccinimide (59.9mg) (Aldrich-Sigma) was dissolved in DMF (100 µL) (Aldrich-Sigma) and added dropwise, to the solution of CRM_{197}. Upon addition of the bromoacetic acid N-hydroxysuccinimide, a precipitate was observed. When the pH was checked, it decreased to pH 6. The pH of the reaction mixture was brought back to pH 9 by adding more 0.1 M borate buffer. Reaction mixture was then stirred at 4°C for 1 hr, with gentle swirling. The mixture was purified and concentrated using YM-10 centriprep centrifugal concentration and repurified on Sephadex G-25 using 10 mM borate as the eluent. Fractions positive to Bradford Reagent were pooled and concentrated using centriprep YM-10. The degree of bromoacetylation was determined by Bradford assay (linear). The concentration was found to be 5.36 mg/mL (Yielded 30mg). The final concentration was then adjusted to be 5 mg/mL and was stored in the freezer in 5% sucrose until further use.

II. Conjugation

[0177] For each conjugation, thawed bromoacetylated CRM_{197} was used. Peptides were dissolved in borate buffer (2.5mg in 125 ml of 0.1 M borate buffer). Slight insolubility was observed with Aβ peptides KLVFFAEDC (SEQ ID NO:45), CLVFFAEDV (SEQ ID NO:47), CKLVFFAED (SEQ ID NO:48), and LVFFAEDC (SEQ ID NO:50). Bromoacetylated CRM_{197} (5mg/mL) was treated with the peptide solutions/suspensions. The ratio of the peptide and protein in the mixture was 1:2. Turbidity was observed in the conjugate mixtures with peptides KLVFFAEDC (SEQ ID NO:45), CLVFFAEDV (SEQ ID NO:47), CKLVFFAED (SEQ ID NO:48), and KLVFFAEDC (SEQ ID NO:45). The mixtures were then checked for pH (pH 9) and incubated at 4°C overnight with slow swirling. Final concentrations of the mixtures were made to 3 mg/mL before incubation. The turbidity of the conjugate mixtures with peptides CLVFFAEDV (SEQ ID NO:47) and LVFFAEDC (SEQ ID NO:50) disappeared after incubation. However, KLVFFAEDC (SEQ ID NO:45) and CKLVFFAED (SEQ ID NO:48) were still slightly turbid. Soluble mock protein conjugate was also prepared with cysteamine at a ratio of 1: 1 (w/w). Synthesized peptides were obtained from BIOSOURCE with about 95% purity.

Octamers:

LVFFAEDVC (SEQ ID NO:44)

KLVFFAEDC (SEQ ID NO:45)

VFFAEDVGC (SEQ ID NO:43)

CLVFFAEDV (SEQ ID NO:47)

CKLVFFAED (SEQ ID NO:48)

CVFFAEDVG (SEQ ID NO:46)

Heptamers:

VFFAEDVC (SEQ ID NO:49)

LVFFAEDC (SEQ ID NO:50)

III. Capping Unreacted Lysine Groups on Protein:

[0178] The unreacted lysines were capped with N-acetylcysteamine (CMCA; Aldrich-Sigma) at a ratio of 1/1 (w/w) for 4 hr at 4°C while swirling in the dark. The unreacted peptides and capping reagents were removed from the conjugates by dialysis using Slide-A-Lyzer cassette (M_w cut off 10,000) (Pierce) against PBS buffer (2 L) overnight (13 hr). Buffer exchange and dialysis was done twice (2 x 14 hr). Slight insolubility was observed in the conjugates with peptides KLVFFAEDC (SEQ ID NO:45) and CKLVFFAED (SEQ ID NO:48). All conjugates were then stored in the refrigerator at 4°C in a perservative.

IV. Characterization of the Protein Carrier:

[0179] MALDI-TOF MS was used to determine the mass of bromoacetylated CRM_{197} and the mass of the mock conjugate N-acetylcysteamine-CRM_{197}.

Based on the masses of the CRM_{197} and bromoacetylated CRM_{197}, 11 lysine residues were modified.

(59941.46- 58590.29)/122 = 11

Where; Mw of CRM_{197} is 58624.29

Mw of bromoacetylated CRM_{197} is 59941.46

Mw of bromoacetate is 122

[0180] The degree of bromoacetylation was more than 28%. (The total number of lysines in CRM_{197} was 39). From these 11 modified lysine residues, 10 were coupled with cysteamine. The coupling efficiency was 90%.

(61143- 59941)/119 = 10

Where; Mw of bromoacetylated CRM_{197} is 59941.46

Mw of mock conjugate is 61143

Mw of the N-acetylcysteamine is 119

(10/11) x 100 = 90

V. Characterization of the Peptide-Protein Conjugates by SDS-PAGE Western Blot Analysis with Tris-Tricine Precast Gel:

[0181] The protein-peptide conjugates were analyzed by Western blot. The lanes are: marker (lane 1); L-28375 24/01 (lane 2); L-28375 24/02 (lane 3); L-28375 24/03 (lane 4); L-28375 24/04 (lane 5); L-28375 24/05 (lane 6); L-28375 24/06 (lane 7) L-28375 24/07 (lane 8); L-

28375 24/08 (lane 9); L-28375 24/09 (Mock) (lane 10); and, $BrAcCRM_{197}$ (lane 11). A peptide specific monoclonal antibody from mice (248 – 6H9 – 806 Aβ 17-28) was used as the primary antibody (antisera) (1:3000 dilution was found to be the best). Goat-Anti mouse IgG (H+L)-HPR was the secondary antibody (1:1000 dilution). It was observed that all the conjugates were recognized by the primary antibody, except for the mock conjugate and the activated CRM_{197}. (*See* Figure 10.)

Protein Concentration

[0182] Protein concentrations of the conjugate samples were determined by the Pierce BCA assay. (*See* Table 15.)

Amino Acid Analysis

[0183] Amino acid analysis was carried out to determine the degree of conjugation. T degree of conjugation was calculated based on the CMCA (carboxymethylcycteamine) residues found in the conjugates. CMCA was used to cap the unreacted activated sites after conjugation with the peptides. (*See* Table 15.)

Table 15

Degree of Conjugation of Peptides with $BrAcCRM_{197}$

Conjugate Code	Peptide Sequence (SEQ ID NO:)	Final Concentration (mg/mL)	Degree of Conjugation (Based on CMCA)
L-28375 24/01	LVFFAEDV-C (SEQ ID NO:44)	1.67	8/10
L-28375 24/02	KLVFFAED-C (SEQ ID NO:45)	0.82	5/10
L-28375 24/03	VFFAEDVG-C (SEQ ID NO:43)	1.43	8/10
L-28375 24/04	C-LVFFAEDV (SEQ ID NO:47)	1.04	9/10
L-28375 24/05	C-KLVFFAED (SEQ ID NO:48)	0.78	1/10
L-28375 24/06	C-VFFAEDVG (SEQ ID NO:46)	0.97	9/10
L-28375 24/07	VFFAEDV-C (SEQ ID NO:49)	1.00	7/10
L-28375 24/08	LVFFAED-C	0.99	8/10

Conjugate Code	Peptide Sequence (SEQ ID NO:)	Final Concentration (mg/mL)	Degree of Conjugation (Based on CMCA)
	(SEQ ID NO:50)		
L-28375 24/09 (Mock)		1.89	10/11

[0184] All colorimetric assays were performed using microplate spectrophotometer and SOFTmax Pro.

EXAMPLE 11

Immunogenic Studies of Aβ Peptide Conjugates in Swiss Webster Mice

[0185] Outbred Swiss Webster mice were immunized with VFFAEDVG-C (SEQ ID NO:43), LVFFAEDV-C (SEQ ID NO:44), KLVFFAED-C (SEQ ID NO:45), C-VFFAEDVG (SEQ ID NO:46), C-LVFFAEDV (SEQ ID NO:47), C-KLVFFAED (SEQ ID NO:48), VFFAEDV-C (SEQ ID NO:49), LVFFAED-C (SEQ ID NO:50) each conjugated to CRM_{197}, or with Aβ1–7CRM_{197}, all formulated with the adjuvant RC 529 SE. Nine groups of 10 animals per group were immunized subcutaneously with one of the Aβ peptide conjugates at the beginning of the study (week 0) and subsequently at week 4. Serum was collected prior to, but on the same days as immunization.

Immunogenic Studies of Aβ Peptide Conjugates in Inbred Balb/c Mice

[0186] Inbred Balb/c mice were immunized as in the preceding paragraph, but were also boosted with conjugate and adjuvant at week 12.

Results

[0187] Sera from both studies are being collected for analysis of $A\beta_{13-28}$ peptide-specific IgG antibody titer. Sera from Balb/c mice are also collected for analysis one day prior to the week 12 boost, and one week thereafter. Spleen cells from animals used in Example 11 are evaluated for their potential to respond *in-vitro* to stimulation with an overlapping pool of peptides spanning $A\beta_{1-42}$, full length $A\beta_{1-42}$, CRM_{197}, or polyclonal activators. Analysis is comprised of Elispot readout for interleukins 4 and 5, and interferon-gamma. Upon completion, the Aβ peptide conjugates are be evaluated as described above and as described in Example 6.

EXAMPLE 12

Immunogenic Studies of Aβ Peptide Conjugates in PSAPP Mice

[0188] PSAPP mice are immunized with VFFAEDVG-C (SEQ ID NO:43), LVFFAEDV-C (SEQ ID NO:44), KLVFFAED-C (SEQ ID NO:45), C-VFFAEDVG (SEQ ID NO:46), C-LVFFAEDV (SEQ ID NO:47), C-KLVFFAED (SEQ ID NO:48), VFFAEDV-C (SEQ ID NO:49), LVFFAED-C (SEQ ID NO:50). The PSAPP mouse, a doubly transgenic mouse (PSAPP) overexpressing mutant APP and PS1 transgenes, is described in Holcomb, *et al.* (1998) *Nature Medicine* 4:97-11.

Immunogenic Studies of Aβ Peptide Conjugates in PDAPP Mice

[0189] PDAPP mice are immunized with VFFAEDVG-C (SEQ ID NO:43), LVFFAEDV-C (SEQ ID NO:44), KLVFFAED-C (SEQ ID NO:45), C-VFFAEDVG (SEQ ID NO:46), C-LVFFAEDV (SEQ ID NO:47), C-KLVFFAED (SEQ ID NO:48), VFFAEDV-C (SEQ ID NO:49), LVFFAED-C (SEQ ID NO:50) The PDAPP mouse expresses a mutant form of human APP (APP^{V71F}) and develops Alzheimer's disease at a young age (Bard, *et al.* (2000) *Nature Medicine* 6:916-919; Masliah E, *et al.* (1996) *J Neurosci.* 15;16(18):5795-811).

Results

[0190] Sera from both studies are collected for analysis of $A\beta_{13-28}$ peptide-specific IgG antibody titer. Upon completion, the Aβ peptide conjugates will be evaluated as described above and as described in Examples 6 and 11, as well as in the contextual fear conditioning (CFC) assay.

[0191] Contextual fear conditioning is a common form of learning that is exceptionally reliable and rapidly acquired in most animals, for example, mammals. Test animals learn to fear a previously neutral stimulus and/or environment because of its association with an aversive experience. (*see, e.g.*, Fanselow, *Anim. Learn. Behav.* 18:264-270 (1990); Wehner *et al.*, *Nature Genet.* 17:331-334. (1997); Caldarone *et al.*, *Nature Genet.* 17:335-337 (1997)).

[0192] Contextual fear conditioning is especially useful for determining cognitive function or dysfunction, *e.g.*, as a result of disease or a disorder, such as a neurodegenerative disease or disorder, an Aβ-related disease or disorder, an amyloidogenic disease or disorder, the presence of an unfavorable genetic alteration effecting cognitive function (*e.g.*, genetic mutation, gene disruption, or undesired genotype), and/or the efficacy of an agent, *e.g.*, an Aβ conjugate agent, on cognitive ability. Accordingly, the CFC assay provides a method for independently testing and/or validating the therapeutic effect of agents for preventing or treating a cognitive disease or disorder, and in particular, a disease or disorder affecting one or more regions of the brains, *e.g.*, the hippocampus, subiculum, cingulated cortex, prefrontal cortex, perirhinal cortex, sensory cortex, and medial temporal lobe.

[0193] Typically, the CFC assay is performed using standard animal chambers and the employment of conditioning training comprising a mild shock (*e.g.*, 0.35mA foot shock) paired with an auditory (*e.g.*, a period of 85 db white noise), olfactory (*e.g.*, almond or lemon extract), touch (*e.g.*, floor cage texture), and/or visual cue (light flash). The response to the aversive experience (shock) is typically one of freezing (absence of movement except for respiration) but may also include eye blink, or change in the nictitating membrane reflex, depending on the test animal selected. The aversive response is usually characterized on the first day of training to determine a baseline for unconditioned fear, with aversive response results on subsequent test days, *e.g.*, freezing in presence of the context and/or cue but in the absence of the aversive experience, being characterized as context and cue conditioned fear, respectively. For improved reliability, test animals are typically tested separately by independent technicians and scored over time. Additional experimental design details can be found in the art, for example, in Crawley, JN, *What's Wrong with my Mouse; Behavioral Phenotyping of Transgenic and Knockout Mice*, Wiley-Liss, NY (2000).

[0194] Exemplary test animals (*e.g.*, model animals) include mammals (*e.g.* rodents or non-human primates) that exhibit prominent symptoms or pathology that is characteristic of an amyloidogenic disorder such as Alzheimer's. Model animals may be created by selective inbreeding for a desired or they may genetically engineered using transgenic techniques that are well-known in the art, such that a targeted genetic alteration (*e.g.* a genetic mutation, gene disruption) in a gene that is associated with the dementia disorder, leading to aberrant expression or function of the targeted gene. For example, several transgenic mouse strains are available that overexpress APP and develop amyloid plaque pathology and/or develop cognitive deficits that are characteristic of Alzheimer's disease (see for example, Games *et al.*, *supra*, Johnson-Wood *et al.*, *Proc. Natl. Acad. Sci. USA* 94:1550 (1997); Masliah E and Rockenstein E. (2000) *J Neural Transm Suppl.*;59:175-83).

[0195] Alternatively, the model animal can be created using chemical compounds (*e.g.* neurotoxins, anesthetics) or surgical techniques (*e.g.* stereotactic ablation, axotomization, transection, aspiration) that ablate or otherwise interfere with the normal function of an anatomical brain region (*e.g.* hippocampus, amygdala, perirhinal cortex, medial septal nucleus, locus coeruleus, mammalary bodies) or specific neurons (*e.g.* serotonergic, cholinergic, or dopaminergic neurons) that are associated with characteristic symptoms or pathology of the amyloidogenic disorder. In certain preferred embodiments, the animal model exhibits a prominent cognitive deficit associated with learning or memory in addition

to the neurodegenerative pathology that associated with a amyloidogenic disorder. More preferably, the cognitive deficit progressively worsens with increasing age, such that the disease progression in the model animal parallels the disease progression in a subject suffering from the amyloidogenic disorder.

[0196] Contextual fear conditioning and other *in vivo* assays to test the functionality of the conjugates described herein may be performed using wild-type mice or mice having a certain genetic alteration leading to impaired memory or mouse models of neurodegenerative disease, *e.g.*, Alzheimer's disease, including mouse models which display elevated levels of soluble Aβ in the cerebrospinal fluid (CSF) or plasma. For example, animal models for Alzheimer's disease include transgenic mice that overexpress the "Swedish" mutation of human amyloid precursor protein (*hAPPswe;* Tg2576) which show age-dependent memory deficits and plaques (Hsiao *et al.* (1996) *Science* 274:99-102). The *in vivo* functionality of the conjugates described herein can also be tested using the PS-1 mutant mouse, described in Duff, *et al.* (1996) *Nature* 383, 710-713. Other genetically altered transgenic models of Alzheimer's disease are described in Masliah E and Rockenstein E. (2000) *J Neural Transm Suppl.* 59:175-83.

[0197] In various aspects, the methods of the invention comprise the administration of an Aβ conjugate that is capable of improving cognition in a subject wherein the Aβ conjugate has been identified in using an assay which is suitably predictive of immunotherapeutic efficacy in the subject. In exemplary embodiments, the assay is a model animal assay that is based, at least in part, on comparing cognition, as determined from a contextual fear conditioning study, of an animal after administration of a test immunological reagent to the animal, as compared to a suitable control. The CFC assay evaluates changes in cognition of an animal (typically a mouse or rat) upon treatment with a potential therapeutic compound. In certain embodiments, the change in cognition evaluated is an improvement in memory impairment status or a reversal of memory deficit. Accordingly, the CFC assay provides a direct method for determining the therapeutic effect of agents for preventing or treating cognitive disease, and in particular, a disease or disorder affecting one or more regions of the brains, e.g., the hippocampus, subiculum, cingulated cortex, prefrontal cortex, perirhinal cortex, sensory cortex, and medial temporal lobe. Such CFC assays are discussed in copending U.S. Patent Application Serial No. 60/XXX,XXX entitled "Contextual Fear Conditioning for Predicting Immunotherapeutic Efficacy" (bearing Attorney Docket No. ELN-058-1), filed on December 15, 2004, and U.S. Patent Application Serial No. 60/XXX,XXX entitled "Contextual Fear

Conditioning for Predicting Immunotherapeutic Efficacy" (bearing Attorney Docket No. ELN-058-2) the entire contents of which are hereby incorporated by reference.

BIBLIOGRAPHY

Bernatowicz, M.S., and Matsueda, G.R. (1986) *Analytical Biochemistry* 155: 95-102.

Kniskern, P.J., and Marburg, S. (1994) *Development and Clinical Uses of Haemophilus b Conjugate Vaccines: Conjugation: Design, Chemistry, and Analysis* Ellis, R.W., and Granoff, D.M., Eds; Marcel Dekker, Inc: New York, NY, 37-70

Arrizon, V., Biechler, R., Cummings, J., and Harbaugh, J. (1991) *High-Performance Liquid Chromatography of Peptide and Proteins: Separation, Analysis, and Conformation* Mant, C.T. and Hodges, R.S., Eds; CRC Press: Boca Raton, FL, 859-863.

Carlsson, J. *et al.* (1978) *Biochem J*, 173: 723.

Means, G.E., Cangdon, W.I., and Bender, M.I. (1972) *Biochemistry* 11: 3564-3574.

Glenner & Wong (1984) *Biochem. Biophys. Res. Commun.* 120: 1131

Hardy (1984) *Trends in Neurosciences* 20: 1131.

Hardy (1977) *Trends in Neurosciences* 20: 154.

Stoute *et al.* (1997) *N. Engl. J. Med.* 336: 86-91.

Goebel *et al.*, (1939) *J. Exp. Med.* 69: 5 3.

Schneerson *et al.* (1980) *J. Exp. Med.* 152: 361-376.

Chu *et al.* (1983) *Infect. Immun.* 40: 245.

Schneerson *et al.* (1984) *Infect. Immun.* 45: 582-591.

Anderson *et al.* (1985) *J. Pediatr.* 107: 346.

Insel *et al.* (1986) *J. Exp. Med.* 158: 294.

U.S. Patent No. 4,673,574 Jun., 1987 Anderson

U.S. Patent No. 4,902,506 Feb., 1990 Anderson et al

U.S. Patent No. 5,192,540 Mar., 1993 Kuo et al.

U.S. Patent No. 5,306,492 Apr., 1994 Porro

U.S. Patent No. 5,360,897 Nov., 1994 Anderson et al.

U.S. Patent No. 5,785,973 Jul., 1998 Bixler et al

U.S. Patent No. 6,361,777 Mar., 2002 Hoogerhout

Sambrook *et al.*, *Molecular Cloning: A Laboratory Manual* (C.S.H. P. Pres, NY 2d ed., 1989)

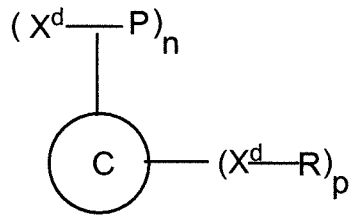
Bernatowicz, M. S., and Matsueda, G. R. (1986) *Analytical Biochemistry* 155, 95-102.

Kniskern, P.J., and Marburg, S. (1994) *Development and Clinical Uses of Haemophilus b Conjugate Vaccines: Conjugation: Design, Chemistry, and Analysis* Ellis, R.W., and Granoff, D.M., Eds; Marcel Dekker, Inc: New York, NY, 37-70

Arrizon, V., Biechler, R., Cummings, J., and Harbaugh, J. (1991) *High-Performance Liquid Chromatography of Peptide and Proteins: Separation, Analysis, and Conformation* Mant, C.T. and Hodges, R.S., Eds; CRC Press: Boca Raton, FL, 859-863.

Claims:

1. A peptide immunogen-protein/polypeptide carrier conjugate having the formula:



wherein,

C is a CRM_{197} protein/polypeptide carrier,

X^d is a derivatized functional group of an amino acid residue of the protein/polypeptide carrier,

P is a peptide immunogen molecule comprising a fragment of Aβ covalently attached to the derivatized functional group of the amino acid residue of the protein/polypeptide carrier, wherein the Aβ fragment is selected from the group consisting of residues 1-3, 1-4, 1-5, 1-6, 1-7, 1-9, 1-10, 1-11, 1-12, 1-16, 1-28, 3-6, 3-7, 13-28, 15-24, 16-22, 16-23, 17-23, 17-24, 18-24, 18-25, 17-28, 25-35, 33-42, 35-40, and 35-42 of Aβ (SEQ ID NO:21),

R is a capping molecule covalently attached to the derivatized functional group of an amino acid residue of the protein/polypeptide carrier, thereby preserving the functionality of the carrier such that it retains its ability to elicit the desired immune responses against the peptide immunogen that would otherwise not occur without a carrier,

n is an integer greater than 0, but less than or equal to 85, and

p is an integer greater than 0, but less than 85.

2. The conjugate of claim 1, wherein the peptide immunogen further comprises a terminal cysteine residue and the peptide immunogen is covalently attached to the derivatized functional group of the amino acid residue of the protein/polypeptide carrier via the terminal cysteine residue.

3. The conjugate of claim 2, wherein the terminal cysteine residue is located at the carboxy-terminus or the amino-terminus of the peptide immunogen.

4. The conjugate of claim 3, wherein the terminal cysteine residue is located at the carboxy-terminus of the peptide immunogen.

5. The conjugate of any one of claims 1-4, wherein the Aβ fragment comprises residues 1-7 of Aβ (SEQ ID NO:21).

6. The conjugate of any one of claims 1-5, wherein the capping molecule is formed by reaction of the conjugate with a capping reagent selected from the group consisting of cysteamine, N-acetylcysteamine, ethanolamine, ammonia, ammonium bicarbonate, sodium hydroxide and sodium carbonate.

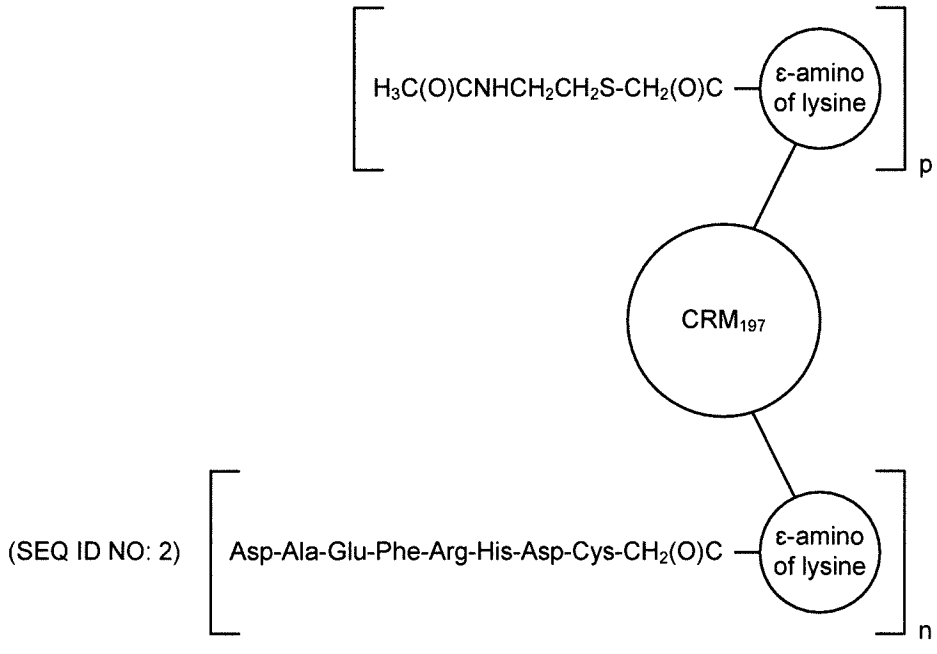
7. The conjugate of claim 5, wherein the Aβ fragment is residues 1-7 of Aβ (SEQ ID NO:21).

8. The conjugate of claim 7, wherein the peptide immunogen is DAEFRHD-C (SEQ ID NO:2).

9. The conjugate of any one of claims 1-8, wherein the capping molecule is formed by reaction of the conjugate with N-acetylcysteamine.

10. The conjugate of any one of claims 1-9, wherein X^d is a derivatized functional group of a lysine residue.

11. The conjugate of claim 1 having the formula:



12. The conjugate of claim 11, wherein n is 12, 14 or 15.

13. An immunogenic composition, comprising a conjugate of a peptide immunogen with a protein/polypeptide carrier according to any one of the preceding claims, together with one or more pharmaceutically acceptable excipients, diluents, and/or adjuvants.

14. The immunogenic composition of claim 13, wherein one or more adjuvants are selected from the group consisting of GM-CSF, 529 SE, IL-12, aluminum phosphate, aluminum hydroxide, *Mycobacterium tuberculosis*, *Bordetella pertussis*, bacterial lipopolysaccharides, aminoalkyl glucosamine phosphate compounds, MPL™ (3-O-deacylated monophosphoryl lipid A), a polypeptide, Quil A, STIMULON™ QS-21, a pertussis toxin (PT), an *E. coli* heat-labile toxin (LT), IL-1 α, IL-1 β, IL-2, IL-4, IL-5, IL-6, IL-7, IL-8, IL-10, IL-13, IL-14, IL-15, IL-16, IL-17, IL-18, interferon-α, interferon-β, interferon-γ, G-CSF, TNF-α and TNF-β.