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(54) Title: NOVEL IMMUNOTHERAPEUTIC COMPOSITION AND USES THEREOF

(57) Abstract: The present invention relates generally to an immunotherapeutic composition. More particularly, the present invention relates to an immunotherapeutic composition which interacts immunologically with T lymphocytes in subjects having peanut allergy or allergy to other tree nuts. This composition is preferably immunointeractive with T cells in subjects having an allergy to the Ara h 1 and/or Ara h 2 allergens. The composition of the present invention is useful in the therapeutic or prophylactic treatment of conditions characterised by an aberrant, inappropriate or otherwise unwanted immune response to peanut, Ara h1 and/or Ara h 2 or derivative or homologue thereof.



NOVEL IMMUNOTHERAPEUTIC COMPOSITION AND USES THEREOF

FIELD OF THE INVENTION

The present invention relates generally to an immunotherapeutic composition. More particularly, the present invention relates to an immunotherapeutic composition which interacts immunologically with T lymphocytes in subjects having peanut allergy or allergy to other tree nuts. This composition is preferably immunointeractive with T cells in subjects having an allergy to the Ara h 1 and/or Ara h 2 allergens. The composition of the present invention is useful in the therapeutic or prophylactic treatment of conditions characterised by an aberrant, inappropriate or otherwise unwanted immune response to peanut, Ara h1 and/or Ara h 2 or derivative or homologue thereof.

BACKGROUND OF THE INVENTION

Bibliographic details of the publications referred to by author in this specification are collected alphabetically at the end of the description.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that that prior art forms part of the common general knowledge.

Peanut allergy is a life-threatening and incurable disorder, affecting approximately 1% of the general population (Husain *et al. J Am Acad Dermatol.* 66(1):136-43, 2012; Burks, *Lancet.* 371(9623):1538-46, 2008). It is characterised by the sudden onset of anaphylaxis, which may occur with exposure to minute quantities of peanut proteins (Hourihane *et al., J Allergy Clin Immunol* 100: 596-600, 1997; Pumphrey, *Current Opinion in Allergy & Immunology.* 4(4):285-90, 2004). Peanut induced anaphylaxis is that most frequently associated with mortality or with life-threatening features (Bock *et al. J Allergy Clin Immunol.* 119(4):1016-8, 2007; Burks 2008, *supra*). Peanut proteins are frequently concealed within apparently safe food sources, such that accidental contact occurs for up to 50% of sufferers over a 5 year period (Sicherer *et al., Paediatrics* 102: e6, 1998). Not surprisingly, peanut and tree nut allergy is associated with significant psychological morbidity for sufferers and carers alike, akin to that suffered by those with chronic debilitating illnesses such as rheumatoid arthritis (Primeau *et al., Clin Exp Allergy* 30: 1135-43, 2000; Kemp *et al. Med. J. Aust.* 188(9):503-4, 2008). Cure, while being an imperative to remove peanut and tree nut allergy as a cause of mortality, is also necessary to remove the chronic psychological burden that peanut allergic subjects carry.

To date, efforts at immunotherapy for peanut allergy have been met by extremely limited success. Nelson *et al.* have shown that clinical desensitisation of peanut can be induced using a rush immunotherapy protocol with an unfractionated peanut extract, but that clinical desensitisation

is lost in approximately half of the subjects during maintenance dosing and additionally that injections are associated with frequent episodes of anaphylaxis in the majority of subjects during both the buildup and maintenance phases (Nelson *et al.*, *J Allergy Clin Immunol* 99: 744-51, 1997). Oppenheimer *et al.* demonstrated similar findings within their study, again showing that active
5 therapy with unfractionated peanut extract is associated with a high rate of systemic anaphylaxis. Data collection in that study was terminated after the administration of peanut extract to a placebo randomised subject resulted in their death, highlighting the dangerous nature of this condition (Oppenheimer *et al.*, *J Allergy Clin Immunol* 90: 256-62, 1992). Recent studies of oral immunotherapy with whole peanut flour provide encouragement that desensitization is feasible, but
10 the observed adverse reactions highlight major safety concerns (Hofmann *et al.* *J. Allergy Clin. Immunol.* 124, 286, 2009; Jones *et al.* *J. Allergy Clin. Immunol.* 24, 292, 2009; Clark *et al.* *Allergy* 64, 1218, 2009; Varshney *et al.* *J Allergy Clin Immunol.* 127(3):654-60, 2011; Varshney *et al.* *J Allergy Clin Immunol.* 124(6):1351-2, 2009; Anagnostou *et al.* *Clin Exp Allergy.* 41(9):1273-81, 2011; Allen & O'Hehir. *Clin Exp Allergy.* 41(9):1172-4, 2011; Yu *et al.* *Int Arch Allergy Immunol.*
15 159(2):179-182, 2012; Thyagarajan *et al.* *J Allergy Clin Immunol.* 126(1):31-2, 2010; Blumchen *et al.* *J Allergy Clin Immunol.* 126(1):83-91, 2010). Even with the exclusion of children prone to severe symptoms or asthma, two studies reported an anaphylactic episode, in one case during an initial food challenge (Clark *et al.* *Allergy* 64, 1218, 2009) and in the other during treatment of a child who had not previously experienced anaphylaxis (Hofmann *et al.* *J. Allergy Clin. Immunol.*
20 124, 286, 2009).

Development of novel strategies to overcome the morbidity associated with allergen immunotherapy depends on an accurate understanding of the immunological basis to successful immunotherapy, as well as its side-effects. It has long been established that morbidity due to allergen immunotherapy is due to the cross-linking of IgE, and that this action is not required for
25 such therapy to be efficacious (Litwin *et al.*, *Int Arch Allergy Appl Immunol* 87: 361-61, 1998). It is also known that one of the critical actions of conventional (subcutaneous injection or sublingual or oral with unfractionated allergen extract) immunotherapy in producing tolerance is its ability to change the predominant specific T cell phenotype from a T_H2 to a regulatory phenotype. These regulatory T cells act via production of the anti-inflammatory cytokines IL-10 and/or TGF β .
30 (Akdis & Akdis, *J Allergy Clin Immunol.* 123:735-46, 2009; Akdis & Akdis, *Nature Reviews: Drug Discovery.* 8:645-60, 2009; Akdis & Akdis, *J Allergy Clin Immunol.* 127:18-27, 2011).

A key difference in antibody and lymphocyte responses is in antigen recognition, antibodies recognising conformational B cell epitopes dependent on molecular tertiary structure, while CD4+ T cells recognise short linear peptides. This difference in antigen recognition is the
35 basis to many novel strategies of immunotherapy, including that using peptides based upon T cell

epitopes, B cell epitope mutants and altered peptide ligands (Rolland *et al. Pharmacology & Therapeutics* 121:273-284, 2009). Such methods all depend on the alteration or absence of molecular tertiary structure, so that IgE cross-linking and effector cell activation is lost. Peptide immunotherapy is a method in respect of which evidence of efficacy exists, being documented for both cat dander allergy and bee venom allergy. Three different studies showed that, in the absence of any systemic side-effects, clinical and immunological tolerance could be achieved for the major bee venom allergen Phospholipase A2 (PLA2) using T cell epitope-containing sequences (Muller *et al. J Allergy Clin Immunol.* 101: 747-54, 1998; Tarzi *et al. Clin Exp Allergy.* 36: 465-74, 2006; Fellrath *et al. J Allergy Clin Immunol.* 111: 854-61, 2003), while several studies have demonstrated that peptides based on the structure of the major cat allergen Fel d 1 can be used to induce diminished clinical responses (Norman *et al., Am J Respir Crit Care Med* 154: 1623-8, 1996; Marcotte *et al., J Allergy Clin Immunol* 101: 506-13, 1998; Pene *et al., J Allergy Clin Immunol* 102: 571-8, 1998; Oldfield *et al. Lancet* 360:47-53, 2002; Alexander *et al. Clin Exp Allergy* 35: 52-8, 2004; Alexander *et al. Allergy* 60:1269-74, 2005). Most recently, a phase IIa trial confirmed the safety, tolerability and potential efficacy of a seven-peptide mixture from Fel d 1 (Toleromune Cat[®], Cicassia Ltd., Oxford, UK) (Worm *et al. J Allergy Clin Immunol.* 127: 89-97, 2011) with Phase IIb trials now underway (Moldaver & Larche. *Allergy.* 66: 784-91, 2011; Worm *et al. Expert Opin. Investig. Drugs.* 22(10): 1347-1357, 2013). Crucial to the development of such strategies is the retention of T cell epitopes, so that T cell phenotypic change can be induced.

The ability to bind directly on to MHC class II molecules allows peptides to be presented by non-professional or immature APC without pro-inflammatory and co-stimulatory signals which promotes induction of tolerance, anergy and/or suppressive activity in responding T cells (Moldaver & Larche, *Allergy* 66: 784-91, 2011) and/or other CD4⁺ T cells that express MHC class II. This also allows peptides to be presented at higher frequency than peptides processed from the whole molecule (Santambrogio *et al. Proc Natl Acad Sci U S A.* 1999, 96:15056-61), and since they are also safer than whole allergen, peptides can be given at higher concentrations, thus repolarising T cell responses more effectively.

Importantly, targeting T cells specific for dominant T cell epitopes of major allergens can alter responses to whole allergen extracts (linked suppression). Many studies reporting successful peptide immunotherapy in murine models of allergy demonstrated that administration of dominant T-cell epitope peptides of major allergens induced tolerance not only to those peptides, but also to purified allergen and whole allergen extracts (Yang *et al. Clin Exp Allergy* 40(4):668-78, 2010; Yoshitomi *et al. J Pept Sci.* 13(8):499-503, 2007; Marazuela *et al. Mol Immunol.* 45(2):438-45, 2008; Rupa *et al. Allergy.* 67(1):74-82, 2012; Hoyne *et al. J Exp Med.* 178(5):1783-8, 1993; Hall *et al. Vaccine.* 21(5-6):549-61, 2003).

Accordingly, there is a need to both identify the major peanut allergens and, further, to identify the T cell epitopes of these allergens. The identification, characterisation, and analysis of these T cell epitopes is critical to the development of specific immunotherapeutic or prophylactic methodology. To this end, although the Ara h 1 and/or Ara h 2 peanut allergen molecules have previously been the subject of analysis, the identification of the T cell core epitopic regions is essential to the development of an effective vaccine.

In work leading up to the present invention, dominant, HLA-degenerate Ara h 1 and/or Ara h 2 core T cell epitopic regions have been identified. This group of core T cell epitopic regions is unique in terms of its high level of efficacy. Unlike the previously studied 20mer Ara h 1 and/or Ara h 2 peptides which were identified based only on their ability to exhibit some level of T cell reactivity, there have been identified a selected set of core T cell epitope regions which are both immunodominant, relative to other Ara h 1 and/or Ara h 2 peptide fragments, and are also HLA degenerate in that they bind to two or more HLA types. Still further, many of these T cell epitopic core regions are presented by HLA-DQ molecules. HLA-DQ molecules are more conserved in mixed populations than HLA-DR molecules. Accordingly, peptides presented on HLA-DQ enable broader population coverage.

In a still further finding, it has also been determined that a specific subgroup of seven of these peptides which contain both Ara h 1 and Ara h 2 T cell epitopes provides particularly effective immunological outcomes. Accordingly, the identification of this uniquely effective group of peptides has facilitated the development of particularly effective therapeutic prophylactic methods for the treatment of conditions characterised by aberrant, inappropriate or otherwise unwanted immune responses to Ara h 1 and/or Ara h 2 or derivative or homologue thereof, other tree nut allergies or allergens to a composition, such as foods, containing the Ara h 1 and/or Ara h 2 molecules.

SUMMARY OF THE INVENTION

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

As used herein, the term "derived from" shall be taken to indicate that a particular integer or group of integers has originated from the species specified, but has not necessarily been obtained directly from the specified source. Further, as used herein the singular forms of "a", "and" and "the" include plural referents unless the context clearly dictates otherwise.

Unless otherwise defined, all technical and scientific terms used herein have the same

meaning as commonly understood by one of ordinary skill in the art to which this invention belongs.

The subject specification contains amino acid sequence information prepared using the programme PatentIn Version 3.5, presented herein after the bibliography. Each amino acid
 5 sequence is identified in the sequence listing by the numeric indicator <210> followed by the sequence identifier (eg. <210>1, <210>2, etc). The length, type of sequence (protein, etc) and source organism for each sequence is indicated by information provided in the numeric indicator fields <211>, <212> and <213>, respectively. Amino acid sequences referred to in the specification are identified by the indicator SEQ ID NO: followed by the sequence identifier (eg.
 10 SEQ ID NO:1, SEQ ID NO:2, etc.). The sequence identifier referred to in the specification correlates to the information provided in numeric indicator field <400> in the sequence listing, which is followed by the sequence identifier (eg. <400>1, <400>2, etc). That is SEQ ID NO:1 as detailed in the specification correlates to the sequence indicated as <400>1 in the sequence listing.

One aspect of the present invention is directed to an immunomodulatory composition
 15 comprising at least five of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- 20 (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPXEQHLM (SEQ ID NO:7)
- (viii) ENNQRXMXEA (SEQ ID NO:8)

25 or functional derivatives or homologues thereof wherein residue X is cysteine or serine and said composition comprises at least one T cell epitopic region selected from SEQ ID NOS: 1-6 and at least one T cell epitopic region selected from SEQ ID NOS: 7-8.

In another aspect, said LRPXEQHLM is LRPSEQHLM (SEQ ID NO:137).

In still another aspect, said ENNQRXMXEA is ENNQRSMSEA (SEQ ID NO:138).

30 In accordance with these aspects and embodiments of the present invention, said composition comprises at least 6 of said T cell epitopic regions.

In a further aspect, said composition comprises at least 7 of said T cell epitopic regions.

In still a further aspect, said composition comprises each of said 8 T cell epitopic regions.

In another aspect there is provided an immunomodulatory composition comprising each of
 35 the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- 6 -

- (i) FQNLQNHHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- 5 (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPXEQHLM (SEQ ID NO:7)
- (viii) ENNQRXMXEA (SEQ ID NO:8)

or functional derivatives or homologues thereof wherein said residue X is cysteine or serine.

- 10 In yet another aspect there is provided an immunomodulatory composition comprising each of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- 15 (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPSEQHLM (SEQ ID NO:137)
- (viii) ENNQSRMSEA (SEQ ID NO:138)

- 20 or functional derivatives or homologues thereof.

In a related aspect the present invention is directed to an immunomodulatory composition comprising one or more peptides, each of which peptides is up to 60 contiguous amino acids in length and which peptides include each of the Ara h 1 and Ara h 2 T cell epitopic region combinations detailed hereinbefore.

- 25 In a further aspect the present invention is directed to an immunomodulatory composition comprising one or more peptides, each of which peptides is up to 60 contiguous amino acids in length and which peptides include each of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHHR (SEQ ID NO:1)
- 30 (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- 35 (vii) LRPSEQHLM (SEQ ID NO:7)

(viii) ENNQSRMSEA (SEQ ID NO:8)

or functional derivatives or homologues thereof.

In yet another aspect said peptides or T cell epitopic regions are capable of modifying T cell function when presented to T cells isolated from subjects having a condition characterised by an aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2 or to
5 an allergen present in a composition, such as food, comprising Ara h 1 and/or Ara h 2 but which peptides are unable to bind to Ara h 1-specific and/or Ara h 2 -specific IgE.

In accordance with these aspects, said peptides are selected from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- 10 (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPXEQHLM (SEQ ID NO:15)
- 15 (vii) EFENNQRXMXEALQ (SEQ ID NO:16)
- (viii) NNFGKLFVVKPDKKNPQLQ (SEQ ID NO:17)
- (ix) GDVFIMPAAHPVAINASSE (SEQ ID NO:18)
- (x) SQLERANLRPXEQHLM (SEQ ID NO:19)
- (xi) ELNEFENNQRXMXEALQ (SEQ ID NO:20)
- 20 (xii) FQNLQNHRIV (SEQ ID NO:21)
- (xiii) RIVQIEAKPNTLV (SEQ ID NO:22)
- (xiv) ENNEGVIVKVSKE (SEQ ID NO:23)
- (xv) EVKPDKKNPQLQD (SEQ ID NO:24)
- (xvi) EFENNQRXMXEALQQI (SEQ ID NO:25)
- 25 (xvii) NNFGKLFVVKPDKKNPQLQD (SEQ ID NO:26)
- (xviii) ELNEFENNQRXMXEALQQI (SEQ ID NO:27)
- (xx) WSTRSSENNEGVIVKVSKE (SEQ ID NO:28)
- (xxi) GDVFIMPAAHPVAINASS (SEQ ID NO:29)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

30 In one embodiment, said residue X is serine.

In a further aspect said peptides are selected from:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4)
- 35 (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)

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- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ ID NO:31)
- (vii) EFENNQRSMSEALQ (SEQ ID NO:32)
- (viii) EVKPDKKNPQLQD (SEQ ID NO:24)
- 5 (ix) EFENNQRSMSEALQQI (SEQ ID NO:33)

or functional derivatives or homologues thereof.

In another aspect, said immunomodulatory composition comprises each of the Ara h 1 and Ara h 2 T cell peptides from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11);
- 10 (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12);
- (iii) EVKPDKKNPQLQ (SEQ ID NO:34) and/or EVKPDKKNPQLQD (SEQ ID NO:24);
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13);
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14);
- (vi) ANLRPSEQHLM (SEQ ID NO:31); and
- 15 (vii) EFENNQRSMSEALQ (SEQ ID NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33).

or functional derivatives or homologues thereof.

- In a yet a further aspect, the inventors have designed a preferred set of seven peptides, five of which comprise Ara h 1 T cell epitopes and two of which comprise Ara h 2 T cell epitopes, which function particularly efficaciously, when administered together, to induce desensitisation or tolerance and thereby either prophylactically or therapeutically treat hypersensitivity to compositions, such as foods, comprising Ara h 1 and/or Ara h 2. These peptides are:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- 25 (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLQD (SEQ ID NO:24)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ ID NO:31)
- (vii) EFENNQRSMSEALQ (SEQ ID NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)

- 30 In still yet another aspect there is provided an immunomodulatory composition comprising each of the Ara h 1 and Ara h 2 T cell peptides from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLQD (SEQ ID NO:24)
- 35 (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)

- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ NO:31)
- (vii) EFENNQRSMSEALQ (SEQ NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)

In a yet still another aspect, there is provided a composition comprising each of the Ara h 1
 5 and Ara h 2 T cell peptides from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:30)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLD (SEQ ID NO:24)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- 10 (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ NO:31)
- (vii) EFENNQRSMSEALQ (SEQ NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)

which peptides are capable of reducing Ara h 1 and/or Ara h 2 hypersensitivity or hypersensitivity
 to a composition comprising Ara h 1 and/or Ara h 2 when administered to a subject having a
 15 condition characterised by said hypersensitivity.

The present invention is directed to a composition comprising the peptides hereinbefore
 defined. It should be understood, though, that the subject composition may comprise additional
 components, such as additional peptides. Examples of other peptides which may be included in the
 composition include, but are not limited to:

- 20 (i) ALMLPHFNSKAMVIVVV (SEQ ID NO:34)
- (ii) NNFGKLFEVKPDKKNPQ (SEQ ID NO:35)
- (iii) SQLERANLRPXEQ (SEQ ID NO:36)
- (iv) ELNEFENNQRXM (SEQ ID NO:37)
- (v) NNFGKLFEVKPDKKNPQLQD (SEQ ID NO:38)
- 25 (vi) NNFGKLFEVKPDKKNPQL (SEQ ID NO:40)
- (vii) SQLERANLRPXEQH (SEQ ID NO:41)
- (viii) KAMVIVVVNKG TGNLELVAV (SEQ ID NO:42)
- (ix) RELRNLPQQXGLRA (SEQ ID NO:43)
- (x) KAMVIVVVNKG (SEQ ID NO:44)
- 30 (xi) AMVIVVVNKG TGNLELV (SEQ ID NO:45)
- (xii) VVNKG TGNLELVAVRK (SEQ ID NO:46)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

In another aspect, the present invention provides a nucleic acid molecule composition
 comprising one or more nucleic acid molecules encoding or complementary to a sequence

encoding the T cell epitopes and peptides as hereinbefore defined or a derivative, homologue or analogue thereof.

In still another aspect the present invention provides a method for the treatment and/or prophylaxis of a condition in a subject, which condition is characterised by the aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2 or an allergen in a composition comprising Ara h 1 and/or Ara h 2, said method comprising administering to said subject an effective amount of an immunomodulatory composition as hereinbefore defined for a time and under conditions sufficient to remove or reduce the presence or function in said subject of T cells directed to said Ara h 1 and/or Ara h 2 or other allergen.

In a further aspect said condition is hypersensitivity to peanuts or tree nuts which contain Ara h 1 and Ara h 2 or Ara h 1-like or Ara h 2-like molecules, such as hazelnuts, almonds or Brazil nuts.

In another aspect, said method desensitises or induces immunological tolerance to Ara h 1 and/or Ara h 2 or other allergen of said composition.

In still another aspect, said desensitization or tolerance is achieved by inducing T cell anergy or apoptosis.

In yet still another aspect, said desensitisation or tolerance is achieved by inducing Ara h 1 or Ara h 2-specific Treg cells.

A further aspect of the present invention contemplates the use of an immunomodulatory composition as hereinbefore defined in the manufacture of a medicament for the treatment of a condition in a mammal, which condition is characterised by an aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2.

Preferably said condition is hypersensitivity to peanuts or a tree nut which contains Ara h 1 and/or Ara h 2 or Ara h 1-like and/or Ara h 2-like molecules, such as a hazelnut.

In yet another further aspect, the present invention contemplates a vaccine comprising the composition as hereinbefore defined together with one or more pharmaceutically acceptable carriers and/or diluents. Said composition is referred to as the active ingredient.

Yet another aspect of the present invention relates to the compositions, as hereinbefore defined, when used in the method of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graphical representation of a CFSE screen for peptide-specific PBMC T cells: (A) CFSE-labelled PBMC from a peanut-allergic subject incubated with whole peanut extract or the Vax (7 peptide compilation). Boxes show percent of activated proliferating CD4+ T cells (CD25+CFSElo). SI indicates fold increase in T cell activation above no antigen control. (B)

Confirmation of peanut-allergic donor PBMC CD4⁺ T-cell activation and proliferation in response to the Vax (7 peptide compilation) in 7 subjects (all have a positive SI>2.5).

Figure 2 is a graphical representation of a basophil activation test (BAT) (A) FACS plots showing blood from a peanut-allergic subject incubated with whole peanut extract or the Vax (7 peptide compilation). Basophils are identified as IgEhi cells (box, first plot) and activated basophils as CD63hi (boxes, plots 2-4). (B) BAT data and (C) Histamine release data (measured by commercial kit) from a peanut-allergic subject following incubation with increasing concentrations (g/ml) of whole peanut extract or the Vax. Positive controls are anti-IgE and fMLP. Whole peanut extract causes high basophil activation and histamine release but the Vax does not. Data are representative of 14 peanut-allergic subjects tested.

Figure 3 is a schematic representation of the method employed to identify the dominant epitopes of the major peanut allergens Ara h 1 and Ara h 2.

Figure 4 is a graphical representation of a 7-day CFSE assay designed to detect the ability of dominant 20-mer peptides to induce T cell proliferation in whole PBMC of peanut-allergic donors. The numbers in the boxes indicate % of dividing (CFSE low) CD4⁺ T cells SI = fold increase in dividing cells above unstimulated control.

Figure 5 is a graphical representation demonstrating responder frequency of T-cell lines to Ara h 1 20-mer peptides. Boxes indicate the 9 dominant 20-mers ultimately selected (based on multiple parameters).

Figure 6 is a graphical representation of PBMC screening with dominant Ara h 1 20-mers. The ability of dominant 20-mers to target specific CD4⁺ T-cells in PBMC from peanut-allergic donors was tested.

Figure 7 is a graphical representation demonstrating responder frequency of T-cell lines to Ara h 2 20-mer peptides and number of specific TCL per 20-mer. Boxes indicate 4 dominant 20-mer peptides ultimately selected based on multiple parameters.

Figure 8 is a graphical representation of the core T cell epitope mapping results.

Figure 9 is a graphical representation of the HLA restriction of the dominant Ara h 1 and Ara h 2 T cell epitopes.

Figure 10 is a graphical representation of T cell recognition of peptides in which selected cysteine residues were replaced with serine residues. TCL proliferation in response to 'parent' (cysteine containing) or serine-substituted Ara h 2 peptides as determined by ³H thymidine uptake. Graphs show representative TCL for each epitope (mean cpm replicate wells +SD). A) Ara h 2(32-44), B) Ara h 2(37-47); C) Ara h 2(91-102); D) Ara h 2(95-107); E) Ara h 2(128-141).

Figure 11 is a graphical representation of T cell cytokine production in response to peptides in which selected cysteine residues were replaced with serine residues. Cytokine secretion

in response to 'parent' or cysteine-substitute Ara h 2 peptides determined by ELISPOT. Graphs show representative TCL specific for each epitope (means spots of replicate wells +SD). IL-4, black bars; IL-5, hatched bars; IFN- γ , white bars; A) Ara h 2(32-44), B) Ara h 2(37-47); C) Ara h 2(91-102); D) Ara h 2(95-107); E) Ara h 2(128-141).

5 **Figure 12** is a graphical representation of PBMC responses to peptide pools vs whole peanut. Peptides included in each pool are shown in Table 23. P-values show Wilcoxon matched pairs signed rank test (for non-parametric data).

10 **Figure 13** is a graphical representation of PBMC responses to peptide pools vs whole peanut. Peptides included in each pool are shown in Table 23. P-values show Wilcoxon matched pairs signed rank test (for non-parametric data).

15 **Figure 14** is a graphical representation comprising PBMC T cell responses to the preferred 7-peptide pool. Stats: Kruskal-Wallis test for non-parametric data with Dunns post-hoc corrections to test for differences between multiple groups. *data normalised to % of response to whole peanut due to variation in magnitudes of responses in different subjects in the different cohorts analysed for the different pools.

Figure 15 is a graphical representation of Ara h 2 peptide-induced inhibition of T cell proliferation.

20 **Figure 16** is a graphical representation of Ara h 1 peptide-induced inhibition of T cell proliferation.

DETAILED DESCRIPTION OF THE INVENTION

25 The present invention is predicated, in part, on the identification of a group of Ara h 1 and Ara h 2 epitopes which, when administered together, in a group of at least five, produce more efficacious immunological outcomes than any of these epitopes used either alone or together with other combinations of these or other Ara h 1 or Ara h 2 peptides. In particular, it has been determined that the use of all eight epitopes produces particularly and exceptionally efficacious functional outcomes, most particularly when these eight epitopes are administered in the context of the seven peptides exemplified herein. The design of this composition has enabled the development of significantly more efficacious therapeutic and prophylactic compositions and treatment approaches, than have been available to date, for conditions such as, but not limited to, peanut allergy.

 Accordingly, one aspect of the present invention is directed to an immunomodulatory composition comprising at least five of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

35 (i) FQNLQNHR (SEQ ID NO:1)

- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- 5 (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPXEQHLM (SEQ ID NO:7)
- (viii) ENNQRXMXEA (SEQ ID NO:8)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine and said composition comprises at least one T cell epitopic region selected from SEQ ID NOS: 1-6 and at
 10 least one T cell epitopic region selected from SEQ ID NOS: 7-8.

In one embodiment, said LRPXEQHLM is LRPSEQHLM (SEQ ID NO:137).

In another embodiment, said ENNQRXMXEA is ENNQSRMSEA (SEQ ID NO:138).

In accordance with these aspects and embodiments of the present invention, said composition comprises at least 6 of said T cell epitopic regions.

15 In a further embodiment, said composition comprises at least 7 of said T cell epitopic regions.

In still a further embodiment, said composition comprises each of said 8 T cell epitopic regions.

According to this embodiment there is therefore provided an immunomodulatory
 20 composition comprising each of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- 25 (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPXEQHLM (SEQ ID NO:7)
- (viii) ENNQRXMXEA (SEQ ID NO:8)

30 or functional derivatives or homologues thereof wherein said residue X is cysteine or serine.

In another embodiment there is provided an immunomodulatory composition comprising each of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- 35 (iii) NEGVIVKVSK (SEQ ID NO:3)

- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPSEQHLM (SEQ ID NO:137)
- 5 (viii) ENNQSRMSEA (SEQ ID NO:138)

or functional derivatives or homologues thereof.

In a related aspect the present invention is directed to an immunomodulatory composition comprising one or more peptides, each of which peptides is up to 60 contiguous amino acids in length and which peptides include each of the Ara h 1 and Ara h 2 T cell epitopic region
10 combinations detailed hereinbefore.

In accordance with this aspect the present invention is directed to an immunomodulatory composition comprising one or more peptides, each of which peptides is up to 60 contiguous amino acids in length and which peptides include each of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- 15 (i) FQNLQNHHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVSK (SEQ ID NO:3)
- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- 20 (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPSEQHLM (SEQ ID NO:7)
- (viii) ENNQSRMSEA (SEQ ID NO:8)

or functional derivatives or homologues thereof.

In another embodiment of the preceding aspects of the invention, said peptides or T cell
25 epitopic regions are capable of modifying T cell function when presented to T cells isolated from subjects having a condition characterised by an aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2 or to an allergen present in a composition, such as food, comprising Ara h 1 and/or Ara h 2 but which peptides are unable to bind to Ara h 1-specific and/or Ara h 2 -specific IgE.

30 Without limiting the present invention in any way, peanuts contain many proteins, with the number of distinct bands visible on SDS-PAGE depending on the methodology used. Up to 53 bands are visible following high pressure liquid chromatography (de Jong *et al.*, *Clin Exp Allergy* 28: 743-51, 1998). Only two of these proteins warrant classification as major allergens using standard criteria, whereby IgE reactivity occurs within greater than 50% of the peanut allergic
35 population; these proteins are termed Ara h 1 and Ara h 2 (Burks *et al.*, *Allergy* 53: 725-30, 1998).

Although a number of studies have indicated Ara h 2 to be the more potent of these two allergens (Blanc *et al. Clin Exp Allergy*. 2009; 39(8):1277-85; Koppelman *et al. Clin Exp Allergy*. 2004; 34(4):583-90; Palmer *et al. Clin Immunol*. 2005; 115(3):302-12), Ara h 1 also plays a major role in the pathogenesis of peanut allergy, with numerous studies reporting strong correlations between symptom severity and IgE reactivity to both Ara h 1 and Ara h 2 (Glaumann *et al. Allergy*. 2012; 67(2):242-7; Chiang *et al. Pediatr Allergy Immunol*. 2009; 21(2 Pt 2):e429-38; Asarnoj *et al. Allergy*. 2010; 65(9):1189-95; Moverare *et al. Int Arch Allergy Immunol* 2011; 156(3):282-90; Lin *et al. J Microbiol Immunol Infect*. 2012; Peeters *et al. Clin Exp Allergy*. 2007; 37(1):108-15). Ara h 1 is the most abundant major allergen in peanut, accounting for 12-16% of total peanut protein (Koppelman *et al. Allergy*. 2001; 56(2):132-7).

Still without limiting the present invention in any way, the Ara h 1 allergen is a 7S seed storage glycoprotein or vicilin. The concentration of Ara h 1 in peanuts increases with the size of the kernel (4-16 mg extracted Ara h 1/g peanut), so expression of the protein is associated with peanut maturity (Pomés *et al.* 2006, *Clin. Exp. Allergy* 36(6):824-30). Ara h 1 is a homotrimer held together through hydrophobic areas at the distal ends of the monomers, where most of the IgE binding B cell epitopes are located. Each 64.5 kD monomer has a cupin motif which consists of two core β -barrels, each associated to a loop domain of α -helices.

Ara h 2 is a glycoprotein which has been identified as a member of the conglutin seed storage family. 20% of the Ara h 2 molecular mass represents carbohydrate side chains and it migrates as a doublet on SDS-PAGE with an average molecular mass of 17.5 kDa (Burks *et al. Int Arch Allergy Immunol* 119:165-172, 1992). It has been characterised as a major allergen, on the basis of its reactivity with 6 out of 6 sera tested (Burks *et al.* 1992, *supra*). Others have also confirmed its importance; Clarke demonstrated that 71% of subjects possessed specific IgE to Ara h 2 upon western blotting of crude peanut extract. Kleber-Janke *et al.* have demonstrated that 85% of subjects possessed IgE towards their recombinant form upon western blotting, and de Jong's group have shown that approximately 78% of their group demonstrate specific IgE to purified natural Ara h 2 (Clarke *et al.*, *Clin Exp Allergy* 28: 1251-7, 1998; de Jong *et al.* 1998 *supra*; Kleber-Janke *et al.*, *Int Arch Allergy Immunol* 119: 265-274, 1999).

Reference to "Ara h 1" should be understood as a reference to all forms of this molecule including reference to any isoforms which may arise from alternative splicing of Ara h 1 mRNA or functional mutant or polymorphic forms of Ara h 1. It should still further be understood to extend to any protein encoded by the Ara h 1 gene, any subunit polypeptide, such as precursor forms which may be generated, whether existing as a monomer, multimer or fusion protein. It also includes reference to analogues or equivalents of Ara h 1 such as may occur where a product which naturally comprises Ara h 1 is synthetically generated for the purpose of generating a product such

as a food additive. The present invention thereby provides T cell epitopes and methods for their use in the diagnosis and treatment of any condition characterised by hypersensitivity to an Ara h 1 or Ara h 1-like molecule, such as peanut allergy or a tree-nut allergy, or an allergy to an antigen present in a composition, such as food, which composition also comprises Ara h 1. Preferably, said
5 Ara h 1 comprises the sequence set forth in SEQ ID NO:9 and Ara h 2 comprises the sequence set forth in SEQ ID NO: 10.

Reference to "T cells" should be understood as a reference to any cell comprising a T cell receptor. In this regard, the T cell receptor may comprise any one or more of the α , β , or γ chains. The present invention is not intended to be limited to any particular functional sub-class of
10 T cells although in a preferred embodiment the subject T cell is a T helper cell and still more preferably a Th2-type cell and/or Treg cell. In this regard, reference to "modifying T cell function" should be understood as a reference to modifying any one or more functions which a T cell is capable of performing. For example, the subject function may be proliferation, differentiation or other form of cellular functional activity such as the production of cytokines. In one embodiment
15 the subject functional activity is proliferation.

In terms of "modifying the function" of T cells isolated from subjects having a condition characterised by an aberrant, unwanted or inappropriate immune response to Ara h 1 and/or Ara h 2 or to a composition which comprises Ara h 1 and/or Ara h 2, it should be understood that this is not necessarily a reference to modifying the function of all the T cells in a given biological sample but
20 is likely, in fact, to reflect the modification of functioning of only some of the T cells in the sample. For example, only a portion of the T helper cells in a given T cell sample may functionally respond to contact with the subject peptide. Such a partial response should be understood to fall within the scope of the present invention. It should also be understood that the T cells which are derived from the subject may be freshly harvested T cells or they may have undergone some form of *in vitro* or
25 *in vivo* manipulation prior to testing. For example, T cell lines may have been generated from the cell sample and it is these T cell lines which then form the subject derived T cell population which is tested in accordance with the present invention. To the extent that the subject functional activity is T cell proliferation, the T cell proliferation assay is preferably performed as disclosed herein. Still more preferably, the subject modification of T cell function is the induction of proliferation.
30 In this regard, reference to "Ara h 1-reactive" or "Ara h 2-reactive" T cells should be understood as a reference to a T cell which responds functionally to HLA presentation of an Ara h 1 and/or Ara h 2 T cell epitope, respectively. Similarly, reference to "Ara h 1-specific" or "Ara h 2-specific" IgE should be understood as a reference to IgE directed to Ara h 1 or Ara h 2 B cell epitopes, respectively.

35 Reference to an "aberrant, unwanted or otherwise inappropriate" immune response should

be understood as a reference to any form of physiological activity which involves the activation and/or functioning of one or more immune cells where that activity is inappropriate in that it is of an inappropriate type or proceeds to an inappropriate degree. It may be aberrant in that according to known immunological principles it either should not occur when it does so or else should occur

5 when it does not do so. In another example, the immune response may be inappropriate in that it is a physiologically normal response but which is unnecessary and/or unwanted, such as occurs with respect to type-I hypersensitivity responses to innocuous allergens. In the context of the present invention, this immune response may be directed to Ara h 1 and/or Ara h 2 or it may be directed to a different allergen which is present in a composition together with Ara h 1 and/or Ara h 2.

10 Without limiting the present invention to any one theory or mode of action, it has been determined that even where the hypersensitivity response is directed to an allergen other than Ara h 1 and/or Ara h 2, which allergen is present in a composition which nevertheless comprises Ara h 1 and/or Ara h 2, treatment via the method of the present invention which is directed to Ara h 1 and/or Ara h 2 nevertheless induces beneficial modulation of Th2 and Treg functionality such that the

15 hypersensitivity which exists to the unrelated allergen is nevertheless reduced. Preferably said immune response is peanut hypersensitivity.

By "peanut hypersensitivity" is meant the induction of clinical symptoms of IgE mediated peanut hypersensitivity. However, it should be understood that although clinical symptoms may be evident, not all such individuals would necessarily exhibit detectable levels of peanut specific

20 serum IgE which is measured using the Kallestad Allercoat EAST System (Sanofi-Pasteur Diagnostics, USA), although such individuals should nevertheless be understood to fall within the scope of the definition of those exhibiting "peanut hypersensitivity". Alternatively, testing may proceed utilising any of the EAST, Pharmacia or the UniCap systems or allergen skin prick testing. Reference to "Ara h 1 and/or Ara h 2 hypersensitivity" should be understood to have a

25 corresponding meaning in the context of reactivity to the Ara h 1 and/or Ara h 2 protein.

In accordance with the preceding aspects, said peptides are selected from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- 30 (iii) EVKPKDKKNPQLQ (SEQ ID NO:4)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPXEQHLM (SEQ ID NO:15)
- (vii) EFENNQRXMXEALQ (SEQ ID NO:16)
- 35 (viii) NNFGKLFVVKPKDKKNPQLQ (SEQ ID NO:17)

- 18 -

- (ix) GDVFIMPAAHPVAINASSE (SEQ ID NO:18)
- (x) SQLERANLRPXEQHLM (SEQ ID NO:19)
- (xi) ELNEFENNQRXMXEALQ (SEQ ID NO:20)
- (xii) FQNLQNHHRIV (SEQ ID NO:21)
- 5 (xiii) RIVQIEAKPNTLV (SEQ ID NO:22)
- (xiv) ENNEGVIVKVSKE (SEQ ID NO:23)
- (xv) EVKPDKKNPQLQD (SEQ ID NO:24)
- (xvi) EFENNQRXMXEALQQI (SEQ ID NO:25)
- (xvii) NNFGKLFVVKPDKKNPQLQD (SEQ ID NO:26)
- 10 (xviii) ELNEFENNQRXMXEALQQI (SEQ ID NO:27)
- (xx) WSTRSENNEGVIVKVSKE (SEQ ID NO:28)
- (xxi) GDVFIMPAAHPVAINASS (SEQ ID NO:29)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

In one embodiment, said residue X is serine.

- 15 Preferably, said peptides are selected from:
 - (i) FQNLQNHHRIVQIEAKPNTLV (SEQ ID NO:11)
 - (ii) STRSENNEGVIVKVSKE (SEQ ID NO:12)
 - (iii) EVKPDKKNPQLQ (SEQ ID NO:4)
 - (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
 - 20 (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
 - (vi) ANLRPSEQHLM (SEQ ID NO:31)
 - (vii) EFENNQRSMSEALQ (SEQ ID NO:32)
 - (viii) EVKPDKKNPQLQD (SEQ ID NO:24)
 - (ix) EFENNQRSMSEALQQI (SEQ ID NO:33)

- 25 or functional derivatives or homologues thereof.

In another embodiment, said immunomodulatory composition comprises each of the Ara h 1 and Ara h 2 T cell peptides from the list consisting of:

- (i) FQNLQNHHRIVQIEAKPNTLV (SEQ ID NO:11);
- (ii) STRSENNEGVIVKVSKE (SEQ ID NO:12);
- 30 (iii) EVKPDKKNPQLQ (SEQ ID NO:34) and/or EVKPDKKNPQLQD (SEQ ID NO:24);
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13);
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14);
- (vi) ANLRPSEQHLM (SEQ ID NO:31); and
- (vii) EFENNQRSMSEALQ (SEQ ID NO:32) and/or EFENNQRSMSEALQQI (SEQ ID
- 35 NO:33).

or functional derivatives or homologues thereof.

The reduction of peanut, Ara h 1 and Ara h 2 hypersensitivity (and allergen hypersensitivity more generally) is discussed in more detail hereafter. Briefly, however, this may take the form of either partially or completely desensitising or tolerising an individual to Ara h 1
5 and Ara h 2 specifically or peanut or other proteins more generally.

Reference to a "peptide" includes reference to a peptide, polypeptide or protein or parts thereof. The peptide may be glycosylated or unglycosylated and/or may contain a range of other molecules fused, linked, bound or otherwise associated to the protein such as amino acids, lipids, carbohydrates or other peptides, polypeptides or proteins. Reference hereinafter to a "peptide"
10 includes a peptide comprising a sequence of amino acids as well as a peptide associated with other molecules such as amino acids, lipids, carbohydrates or other peptides, polypeptides or proteins.

"Derivatives" include fragments, parts, portions and variants from natural, synthetic or recombinant sources including fusion proteins. Parts or fragments include, for example, active regions of the subject peptide. Derivatives may be derived from insertion, deletion or substitution
15 of amino acids. Amino acid insertional derivatives include amino and/or carboxylic terminal fusions as well as intrasequence insertions of single or multiple amino acids. Insertional amino acid sequence variants are those in which one or more amino acid residues are introduced into a predetermined site in the protein although random insertion is also possible with suitable screening of the resulting product. Deletional variants are characterized by the removal of one or more amino
20 acids from the sequence.

Substitutional amino acid variants are those in which at least one residue in the sequence has been removed and a different residue inserted in its place. An example of substitutional amino acid variants are conservative amino acid substitutions. Conservative amino acid substitutions typically include substitutions within the following groups: glycine and alanine; valine, isoleucine
25 and leucine; aspartic acid and glutamic acid; asparagine and glutamine; serine and threonine; lysine and arginine; and phenylalanine and tyrosine. Additions to amino acid sequences include fusions with other peptides, polypeptides or proteins. In one embodiment, cysteine residues are substituted with serine, as exemplified herein.

Chemical and functional equivalents of the subject peptide should be understood as
30 molecules exhibiting any one or more of the functional activities of these molecules and may be derived from any source such as being chemically synthesized or identified via screening processes such as natural product screening.

Homologues include peptides derived from varieties other than peanuts, such as peptides derived from other tree nuts.

35 Analogues contemplated herein include, but are not limited to, modification to side chains,

incorporating of unnatural amino acids and/or their derivatives during peptide, polypeptide or protein synthesis and the use of crosslinkers and other methods which impose conformational constraints on the proteinaceous molecules or their analogues. Mutants include molecules which exhibit modified functional activity (for example, Ara h 1 peptides which express one or more T cell epitopes but lack B cell reactivity).

Examples of side chain modifications contemplated by the present invention include modifications of amino groups such as by reductive alkylation by reaction with an aldehyde followed by reduction with NaBH_4 ; amidination with methylacetimidate; acylation with acetic anhydride; carbamoylation of amino groups with cyanate; trinitrobenzylation of amino groups with 2, 4, 6-trinitrobenzene sulphonic acid (TNBS); acylation of amino groups with succinic anhydride and tetrahydrophthalic anhydride; and pyridoxylation of lysine with pyridoxal-5-phosphate followed by reduction with NaBH_4 .

The guanidine group of arginine residues may be modified by the formation of heterocyclic condensation products with reagents such as 2,3-butanedione, phenylglyoxal and glyoxal. The carboxyl group may be modified by carbodiimide activation *via* O-acylisourea formation followed by subsequent derivatisation, for example, to a corresponding amide. Sulphydryl groups may be modified by methods such as carboxymethylation with iodoacetic acid or iodoacetamide; performic acid oxidation to cysteic acid; formation of mixed disulphides with other thiol compounds; reaction with maleimide, maleic anhydride or other substituted maleimide; formation of mercurial derivatives using 4-chloromercuribenzoate, 4-chloromercuriphenylsulphonic acid, phenylmercury chloride, 2-chloromercuri-4-nitrophenol and other mercurials; carbamoylation with cyanate at alkaline pH. Tryptophan residues may be modified by, for example, oxidation with N-bromosuccinimide or alkylation of the indole ring with 2-hydroxy-5-nitrobenzyl bromide or sulphenyl halides. Tyrosine residues on the other hand, may be altered by nitration with tetranitromethane to form a 3-nitrotyrosine derivative.

Modification of the imidazole ring of a histidine residue may be accomplished by alkylation with iodoacetic acid derivatives or N-carboethoxylation with diethylpyrocarbonate.

Examples of incorporating unnatural amino acids and derivatives during protein synthesis include, but are not limited to, use of norleucine, 4-amino butyric acid, 4-amino-3-hydroxy-5-phenylpentanoic acid, 6-aminoheptanoic acid, t-butylglycine, norvaline, phenylglycine, ornithine, sarcosine, 4-amino-3-hydroxy-6-methylheptanoic acid, 2-thienyl alanine and/or D-isomers of amino acids. A list of unnatural amino acids contemplated herein is shown in Table 1.

TABLE1

	Non-conventional amino acid	Code	Non-conventional amino acid	Code
5	-aminobutyric acid	Abu	L-N-methylalanine	Nmala
	-amino- -methylbutyrate	Mgab	L-N-methylarginine	Nmarg
	aminocyclopropane- carboxylate	Cpro	L-N-methylasparagine	Nmasn
			L-N-methylaspartic acid	Nmasp
10	aminoisobutyric acid	Aib	L-N-methylcysteine	Nmcys
	aminonorbonyl- carboxylate	Norb	L-N-methylglutamine	Nmgln
			L-N-methylglutamic acid	Nmglu
	cyclohexylalanine	Chexa	L-N-methylhistidine	Nmhis
	cyclopentylalanine	Cpen	L-N-methylisoleucine	Nmile
15	D-alanine	Dal	L-N-methylleucine	Nmleu
	D-arginine	Darg	L-N-methyllysine	Nmlys
	D-aspartic acid	Das	L-N-methylmethionine	Nmmet
	D-cysteine	Dcys	L-N-methylnorleucine	Nnmle
	D-glutamine	Dgln	L-N-methylnorvaline	Nmnva
20	D-glutamic acid	Dglu	L-N-methylornithine	Nmorn
	D-histidine	Dhis	L-N-methylphenylalanine	Nmphe
	D-isoleucine	Dile	L-N-methylproline	Nmpro
	D-leucine	Dleu	L-N-methylserine	Nmser
	D-lysine	Dlys	L-N-methylthreonine	Nmthr
25	D-methionine	Dmet	L-N-methyltryptophan	Nmtrp
	D-ornithine	Dorn	L-N-methyltyrosine	Nmtyr
	D-phenylalanine	Dphe	L-N-methylvaline	Nmval
	D-proline	Dpro	L-N-methylethylglycine	Nmetg
	D-serine	Dser	L-N-methyl-t-butylglycine	Nmtbug
30	D-threonine	Dthr	L-norleucine	Nle
	D-tryptophan	Dtrp	L-norvaline	Nva
	D-tyrosine	Dtyr	-methyl-aminoisobutyrate	Maib
	D-valine	Dval	-methyl- -aminobutyrate	Mgab
	D- -methylalanine	Dmala	-methylecyclohexylalanine	Mchexa
35	D- -methylarginine	Dmarg	-methylecyclopentylalanine	Mcpen

	D- -methylasparagine	Dmasn	-methyl- -naphthylalanine	Manap
	D- -methylaspartate	Dmasp	-methylpenicillamine	Mpen
	D- -methyleysteine	Dmcys	N-(4-aminobutyl)glycine	Nglu
	D- -methylglutamine	Dmgln	N-(2-aminoethyl)glycine	Naeg
5	D- -methylhistidine	Dmhis	N-(3-aminopropyl)glycine	Norn
	D- -methylisoleucine	Dmile	N-amino- -methylbutyrate	Nmaabu
	D- -methylleucine	Dmleu	-naphthylalanine	Anap
	D- -methyllysine	Dmlys	N-benzylglycine	Nphe
	D- -methylmethionine	Dmmet	N-(2-carbamylethyl)glycine	Ngln
10	D- -methylornithine	Dmorn	N-(carbamylmethyl)glycine	Nasn
	D- -methylphenylalanine	Dmphe	N-(2-carboxyethyl)glycine	Nglu
	D- -methylproline	Dmpro	N-(carboxymethyl)glycine	Nasp
	D- -methylserine	Dmser	N-cyclobutylglycine	Nebut
	D- -methylthreonine	Dmthr	N-cycloheptylglycine	Nchep
15	D- -methyltryptophan	Dmtrp	N-cyclohexylglycine	Nchex
	D- -methyltyrosine	Dmtty	N-cyclodecylglycine	Ncdec
	D- -methylvaline	Dmval	N-cylcododecylglycine	Ncdod
	D-N-methylalanine	Dnmala	N-cyclooctylglycine	Ncoct
	D-N-methylarginine	Dnmarg	N-cyclopropylglycine	Ncpro
20	D-N-methylasparagine	Dnmasn	N-cycloundecylglycine	Ncund
	D-N-methylaspartate	Dnmasp	N-(2,2-diphenylethyl)glycine	Nbbhm
	D-N-methyleysteine	Dnmcys	N-(3,3-diphenylpropyl)glycine	Nbhe
	D-N-methylglutamine	Dnmgln	N-(3-guanidinopropyl)glycine	Narg
	D-N-methylglutamate	Dnmglu	N-(1-hydroxyethyl)glycine	Nthr
25	D-N-methylhistidine	Dnmhis	N-(hydroxyethyl)glycine	Nser
	D-N-methylisoleucine	Dnmile	N-(imidazolylethyl)glycine	Nhis
	D-N-methylleucine	Dnmleu	N-(3-indolylethyl)glycine	Nhtrp
	D-N-methyllysine	Dnmlys	N-methyl- -aminobutyrate	Nmgabu
	N-methylcyclohexylalanine	Nmchexa	D-N-methylmethionine	Dnmmet
30	D-N-methylornithine	Dnmorn	N-methylcyclopentylalanine	Nmcpen
	N-methylglycine	Nala	D-N-methylphenylalanine	Dnmphe
	N-methylaminoisobutyrate	Nmaib	D-N-methylproline	Dnmpro
	N-(1-methylpropyl)glycine	Nile	D-N-methylserine	Dnmser
	N-(2-methylpropyl)glycine	Nleu	D-N-methylthreonine	Dnmthr
35	D-N-methyltryptophan	Dnmtrp	N-(1-methylethyl)glycine	Nval

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	D-N-methyltyrosine	Dnmtyr	N-methyl- α -naphthylalanine	Nmanap
	D-N-methylvaline	Dnmval	N-methylpenicillamine	Nmpen
	-aminobutyric acid	Gabu	N-(<i>p</i> -hydroxyphenyl)glycine	Nhtyr
	L- <i>t</i> -butylglycine	Tbug	N-(thiomethyl)glycine	Ncys
5	L-ethylglycine	Etg	penicillamine	Pen
	L-homophenylalanine	Hphe	L- α -methylalanine	Mala
	L- α -methylarginine	Marg	L- α -methylasparagine	Masn
	L- α -methylaspartate	Masp	L- α -methyl- <i>t</i> -butylglycine	Mtbug
	L- α -methylcysteine	Mcys	L-methylethylglycine	Metg
10	L- α -methylglutamine	Mgln	L- α -methylglutamate	Mglu
	L- α -methylhistidine	Mhis	L- α -methylhomophenylalanine	Mhphe
	L- α -methylisoleucine	Mile	N-(2-methylthioethyl)glycine	Nmet
	L- α -methylleucine	Mleu	L- α -methyllysine	Mlys
	L- α -methylmethionine	Mmet	L- α -methylnorleucine	Mnle
15	L- α -methylnorvaline	Mnva	L- α -methylornithine	Morn
	L- α -methylphenylalanine	Mphe	L- α -methylproline	Mpro
	L- α -methylserine	Mser	L- α -methylthreonine	Mthr
	L- α -methyltryptophan	Mtrp	L- α -methyltyrosine	Mtyr
	L- α -methylvaline	Mval	L-N-methylhomophenylalanine	Nmhpe
20	N-(N-(2,2-diphenylethyl) carbamylmethyl)glycine	Nnbhm	N-(N-(3,3-diphenylpropyl) carbamylmethyl)glycine	Nnbhe
	1-carboxy-1-(2,2-diphenyl-Nmbe		ethylamino)cyclopropane	

25 Crosslinkers can be used, for example, to stabilise 3D conformations, using homo-bifunctional crosslinkers such as the bifunctional imido esters having (CH₂)_n spacer groups with n=1 to n=6, glutaraldehyde, N-hydroxysuccinimide esters and hetero-bifunctional reagents which usually contain an amino-reactive moiety such as N-hydroxysuccinimide and another group specific-reactive moiety.

30 It is possible to modify the structure of a peptide according to the invention for various purposes such as for increasing solubility, enhancing therapeutic or preventative efficacy, enhancing stability or increasing resistance to proteolytic degradation. A modified peptide may be produced in which the amino acid sequence has been altered, such as by amino acid substitution, deletion or addition, to modify immunogenicity and/or reduce allergenicity. Similarly components may be added to peptides of the invention to produce the same result.

35 For example, a peptide can be modified so that it exhibits the ability to induce T cell

energy. In this instance, critical binding residues for the T cell receptor can be determined using known techniques (for example substitution of each residue and determination of the presence or absence of T cell reactivity). In one example, those residues shown to be essential to interact with the T cell receptor can be modified by replacing the essential amino acid with another, preferably similar amino acid residue (a conservative substitution) whose presence is shown to alter T cell reactivity or T cell functioning. In addition, those amino acid residues which are not essential for T cell receptor interaction can be modified by being replaced by another amino acid whose incorporation may then alter T cell reactivity or T cell functioning but does not, for example, eliminate binding to relevant MHC proteins. In yet another example, mutant peptides may be created which exhibit normal T cell binding but abrogated IgE binding.

Exemplary conservative substitutions are detailed, below, and include:

Original Residue	Exemplary Substitutions
Ala	Ser
Arg	Lys
Asn	Gln, His
Asp	Glu
Cys	Ser, Ala
Gln	Asn
Glu	Asp
Gly	Pro
His	Asn, Gln
Ile	Leu, Val
Leu	Ile, Val
Lys	Arg, Gln, Glu
Met	Leu, Ile
Phe	Met, Leu, Tyr
Ser	Thr
Thr	Ser
Trp	Tyr
Tyr	Trp, Phe
Val	Ile, Leu

Such modifications will result in the production of molecules falling within the scope of "mutants" of the subject peptide as herein defined. "Mutants" should be understood as a reference to peptides which exhibit one or more structural features or functional activities which are distinct from those exhibited by the non-mutated peptide counterpart.

Peptides of the invention may also be modified to incorporate one or more polymorphisms resulting from natural allelic variation and D-amino acids, non-natural amino acids or amino acid analogues may be substituted into the peptides to produce modified peptides which fall within the scope of the invention. Peptides may also be modified by conjugation with polyethylene glycol (PEG) by known techniques. Reporter groups may also be added to facilitate purification and potentially increase solubility of the peptides according to the invention. Other well known types of modification including insertion of specific endoprotease cleavage sites, addition of functional groups or replacement of hydrophobic residues with less hydrophobic residues as well as site-directed mutagenesis of DNA encoding the peptides of the invention may also be used to introduce modifications which could be useful for a wide range of purposes. The various modifications to peptides according to the invention which have been mentioned above are mentioned by way of example only and are merely intended to be indicative of the broad range of modifications which can be effected.

As detailed hereinbefore, the present invention provides peptides which retain all or some of their capacity to interact with T cells but exhibit partially or completely inhibited, abrogated or otherwise down-regulated antibody reactivity. Effecting the down-regulation of antibody reactivity can be achieved by any suitable method, which methods would be well known to those skilled in the art. For example, to the extent that a B cell epitope is defined by its linear amino acid sequence, one may add, delete or substitute one or more amino acid residues in order to render the mutated linear sequence distinct from the naturally occurring sequence. To the extent that an epitope may be additionally, or alternatively, defined by a conformational epitope, one may seek to disrupt that conformation by disrupting a 2° or, to the extent that homodimers or heterodimers exist, a 3° structure of the peptide. This may be achieved, for example, by disrupting the formation of bonds, such as disulphide bonds, which are known to stabilise 2° and/or 3° structures. In terms of the T cell epitopes hereinbefore defined, these T cells epitopic regions do not comprise B cell epitopes.

In a related aspect, the inventors have designed a preferred set of seven peptides, five of which comprise Ara h 1 T cell epitopes and two of which comprise Ara h 2 T cell epitopes, which function particularly efficaciously, when administered together, to induce desensitisation or tolerance and thereby either prophylactically or therapeutically treat hypersensitivity to compositions, such as foods, comprising Ara h 1 and/or Ara h 2. These peptides are:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLQD (SEQ ID NO:24)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)

- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ NO:31)
- (vii) EFENNQRSMSEALQ (SEQ NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)

Accordingly, in a preferred embodiment there is provided an immunomodulatory
 5 composition comprising each of the Ara h 1 and Ara h 2 T cell peptides from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLQD (SEQ ID NO:24)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)

- 10 (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ NO:31)
- (vii) EFENNQRSMSEALQ (SEQ NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)

In a further aspect, there is provided a composition comprising each of the Ara h 1 and
 Ara h 2 T cell peptides from the list consisting of:

- 15 (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4) and/or EVKPDKKNPQLQD (SEQ ID NO:24)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)

- 20 (vi) ANLRPSEQHLM (SEQ NO:31)
 - (vii) EFENNQRSMSEALQ (SEQ NO:32) and/or EFENNQRSMSEALQQI (SEQ ID NO:33)
- which peptides are capable of reducing Ara h 1 and/or Ara h 2 hypersensitivity or hypersensitivity
 to a composition comprising Ara h 1 and/or Ara h 2 when administered to a subject having a
 condition characterised by said hypersensitivity.

- 25 The peptides of the present invention may be prepared by recombinant or chemical
 synthetic means. According to a preferred aspect of the present invention, there is provided a
 recombinant peptide or mutant thereof which is preferentially immunologically reactive with T
 cells from individuals with peanut hypersensitivity, which is expressed by the expression of a host
 cell transformed with a vector coding for the peptide sequence of the present invention. The
 30 peptide may be fused to another peptide, polypeptide or protein. Alternatively, the peptide may be
 prepared by chemical synthetic techniques, such as by the Merrifield solid phase synthesis
 procedure. Furthermore, although synthetic peptides of the sequence given above represent a
 preferred embodiment, the present invention also extends to biologically pure preparations of the
 naturally occurring peptides or fragments thereof. By "biologically pure" is meant a preparation
 35 comprising at least about 60%, preferably at least about 70%, or preferably at least about 80% and

still more preferably at least about 90% or greater as determined by weight, activity or other suitable means.

The present invention should therefore be understood to encompass peptides that comprise at least one T cell core epitopic region of Ara h 1 and/or Ara h 2, as hereinbefore defined, in conjunction with other amino acids (which may or may not be naturally occurring) or other chemical species. In a preferred aspect of the invention such peptides may comprise one or more epitopes of Ara h 1 and/or Ara h 2, which epitopes are T cell core epitopic regions. Peptides with one or more T cell epitopes of Ara h 1 and/or Ara h 2 are desirable for increased therapeutic effectiveness.

As detailed hereinbefore, the present invention is directed to a composition comprising the peptides hereinbefore defined. It should be understood, though, that the subject composition may comprise additional components, such as additional peptides. These peptides may encompass, for example, partial regions of the core minimal epitope. Alternatively, they may not comprise any part of a T cell epitope as disclosed herein but may be incorporated for either reasons. Examples of other peptides which may be included in the composition include, but are not limited to:

- (i) ALMLPHFNSKAMVIVVV (SEQ ID NO:34)
- (ii) NNFGKLFVVKPDKKNPQ (SEQ ID NO:35)
- (iii) SQLERANLRPXEQ (SEQ ID NO:36)
- (iv) ELNEFENNQRXM (SEQ ID NO:37)
- (v) NNFGKLFVVKPDKKNPQLQD (SEQ ID NO:38)
- (vi) NNFGKLFVVKPDKKNPQL (SEQ ID NO:40)
- (vii) SQLERANLRPXEQH (SEQ ID NO:41)
- (viii) KAMVIVVVNKG TGNLELVAV (SEQ ID NO:42)
- (ix) RELRNLPQQXGLRA (SEQ ID NO:43)
- (x) KAMVIVVVNKG (SEQ ID NO:44)
- (xi) AMVIVVVNKG TGNLELV (SEQ ID NO:45)
- (xii) VVNKG TGNLELVAVRK (SEQ ID NO:46)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

One may also include still other peptides or molecules which may be advantageous given the particulars of a specific situation.

In another aspect, the present invention provides a nucleic acid molecule composition comprising one or more nucleic acid molecules encoding or complementary to a sequence encoding the T cell epitopes and peptides as hereinbefore defined or a derivative, homologue or analogue thereof.

It should be understood that reference to "peptides" includes reference to peptides comprising one or more T cell epitopes. A nucleic acid molecule encoding the subject peptide is preferably a sequence of deoxyribonucleic acids such as cDNA or a genomic sequence. A genomic sequence may comprise exons and introns. A genomic sequence may also include a promoter
5 region or other regulatory regions.

The nucleic acid molecule may be ligated to an expression vector capable of expression in a prokaryotic cell (eg. *E. coli*) or a eukaryotic cell (eg. yeast cells, fungal cells, insect cells, mammalian cells or plant cells). The nucleic acid molecule may be ligated or fused or otherwise associated with a nucleic acid molecule encoding another entity such as, for example, a signal
10 peptide. It may also comprise additional nucleotide sequence information fused, linked or otherwise associated with it either at the 3' or 5' terminal portions or at both the 3' and 5' terminal portions. The nucleic acid molecule may also be part of a vector, such as an expression vector. The latter embodiment facilitates production of recombinant forms of the subject peptide which forms are encompassed by the present invention.

15 Such nucleic acids may be useful for recombinant production of T cell epitopes of Ara h 1 and/or Ara h 2 or proteins comprising them by insertion into an appropriate vector and transfection into a suitable cell line. Such expression vectors and host cell lines also form an aspect of the invention.

In producing peptides by recombinant techniques, host cells transformed with a nucleic
20 acid having a sequence encoding a peptide according to the invention or a functional equivalent of the nucleic acid sequence are cultured in a medium suitable for the particular cells concerned. Peptides can then be purified from cell culture medium, the host cells or both using techniques well known in the art such as ion exchange chromatography, gel filtration chromatography, ultrafiltration, electrophoresis or immunopurification with antibodies specific for the peptide.

25 Nucleic acids encoding Ara h 1 and/or Ara h 2 or peptides comprising T cell core epitopic regions of Ara h 1 and/or Ara h 2 may be expressed in bacterial cells such as *E. coli*, insect cells, yeast or mammalian cells such as Chinese hamster ovary cells (CHO). Suitable expression vectors, promoters, enhancers and other expression control elements are referred to in Sambruck *et al* (1989). Other suitable expression vectors, promoters, enhancers and other expression elements are
30 well known to those skilled in the art. Examples of suitable expression vectors in yeast include Yep Sec 1 (Balderi *et al.*, 1987, *Embo J.*, 6:229-234); pMFa (Kurjan and Herskowitz., 1982, *Cell.*, 30:933-943); JRY88 (Schultz *et al.*, 1987, *Gene.*, 54:113-123) and pYES2 (Invitrogen Corporation, San Diego, CA). These vectors are freely available as are baculovirus and mammalian expression systems. For example, a baculovirus system is commercially available (ParMingen, San Diego,

CA) for expression in insect cells while the pMsg vector is commercially available (Pharmacia, Piscataway, NJ) for expression in mammalian cells.

For expression in *E. coli* suitable expression vectors include among others, pTrc (Amann *et al.*, 1998, *Gene.*, 69:301-315) pGex (Amrad Corporation, Melbourne, Australia); pMal (N.E. Biolabs, Beverley, MA); pRit5 (Pharmacia, , Piscataway, NJ); pEt-11d (Novagen, Maddison, WI) (Jameel *et al.*, 1990, *J. Virol.*, 64:3963-3966) and pSem (Knapp *et al.*, 1990, *Bio Techniques.*, 8:280-281). The use of pTRC, and pEt-11d, for example, will lead to the expression of unfused protein. The use of pMal, pRit5, pSem and pGex will lead to the expression of allergen fused to maltose E binding protein (pMal), protein A (pRit5), truncated β -galactosidase (PSEM) or glutathione S-transferase (pGex). When a T cell epitope of Ara h 1 or a peptide comprising it is expressed as a fusion protein, it is particularly advantageous to introduce an enzymatic cleavage site at the fusion junction between the carrier protein and the peptide concerned. The peptide of the invention may then be recovered from the fusion protein through enzymatic cleavage at the enzymatic site and biochemical purification using conventional techniques for purification of proteins and peptides. The different vectors also have different promoter regions allowing constitutive or inducible expression or temperature induction. It may additionally be appropriate to express recombinant peptides in different *E. coli* hosts that have an altered capacity to degrade recombinantly expressed proteins. Alternatively, it may be advantageous to alter the nucleic acid sequence to use codons preferentially utilised by *E. coli*, where such nucleic acid alteration would not effect the amino acid sequence of the expressed proteins.

Host cells can be transformed to express the nucleic acids of the invention using conventional techniques such as calcium phosphate or calcium chloride co-precipitation, DEAE-dextran-mediated transfection or electroporation. Suitable methods for transforming the host cells may be found in Sambrock *et al.* (1989), and other laboratory texts. The nucleic acid sequence of the invention may also be chemically synthesised using standard techniques.

In addition to recombinant production of peptides according to the invention, the nucleic acids may be utilised as probes for experimental or purification purposes.

Identification and synthesis of the peptides as disclosed herein now facilitates the development of a range of prophylactic and therapeutic treatment protocols for use with respect to peanut related immune conditions. Also facilitated is the development of reagents for use therein. Accordingly, the present invention should be understood to extend to the use of the peptides or functional derivatives, homologues or analogues thereof in the therapeutic and/or prophylactic treatment of patients. Such methods of treatment include, but are not limited to:

- (i) Administration of the subject peptides to a patient as a means of desensitising or inducing immunological tolerance to peanut, Ara h 1 and/or Ara h 2 or Ara h 1-like and/or Ara h 2-

like molecules. This may be achieved, for example, by inducing Ara h 1 and/or Ara h 2 directed Th2 anergy or apoptosis. In a preferred embodiment, such an outcome is achieved by the use of peptides which maintain T cell epitope reactivity but which are unable to undergo IgE binding. Alternatively, one may utilise treatment protocols which are based on the administration of specific concentrations of a given peptide in accordance with a specific regimen in order to induce tolerance. Such methodology may eliminate Ara h 1 and/or Ara h 2 hypersensitivity or it may reduce the severity of Ara h 1 and/or Ara h 2 hypersensitivity or sensitivity to an allergen present in a composition comprising Ara h 1 and/or Ara h 2, such as a peanut allergy. Reference herein to the treatment of Ara h 1 and/or Ara h 2 sensitivity should be understood to encompass within its scope the treatment of conditions characterised by sensitivity to compositions which comprise Ara h 1 and/or Ara h 2, such as peanuts generally, even if the sensitivity is directed to an allergen other than Ara h 1 and/or Ara h 2.

Preferably such treatment regimens are capable of modifying the T cell response or both the B and T cell response of the individual concerned. As used herein, modification of the allergic response of the individual suffering from peanut hypersensitivity can be defined as inducing either non-responsiveness or diminution in symptoms to the Ara h 1 molecule as determined by standard clinical procedures (Varney *et al.* 1991 *British Medical Journal* 302:265-269). Diminution in the symptoms includes any reduction in an allergic response in an individual to Ara h 1 after a treatment regimen has been completed. This diminution may be subjective or clinically determined, for example by using standard food challenge tests or standard skin tests known in the art.

Exposure of an individual to the peptides of the present invention may tolerise or anergise appropriate T cell subpopulations such that they become unresponsive to Ara h 1 and/or Ara h 2 and do not participate in stimulating an immune response upon such exposure. Preferably the peptides according to the invention will retain immunodominant T cell epitopes but possess abrogated IgE binding. Still further, even if the allergen in issue is not Ara h 1 and/or Ara h 2, but is directed to a different allergen which is present in the same composition as Ara h 1 and/or Ara h 2 (such as a different peanut allergen) immunisation with Ara h 1 and/or Ara h 2 may nevertheless induce a bystander suppressive effect which acts to reduce the degree of hypersensitivity to that allergen.

Administration of a peptide of the invention may modify the cytokine secretion profile as compared with exposure to naturally occurring Ara h 1 and/or Ara h 2 allergen. This exposure may also influence T cell subpopulations which normally participate in the allergic response to migrate away from the site or sites of normal exposure to the allergen

and towards the site or sites of therapeutic administration. This redistribution of T cell subpopulations may ameliorate or reduce the ability of an individual's immune system to stimulate the usual immune response at the site of normal exposure to the allergen, resulting in diminution of the allergic symptoms.

5 Modification of the B cell response may be achieved, for example, via modulation of the cytokine profile produced by T cells, as detailed above. Specifically, decreasing T cell derived IL-4 and IL-13 production thereby decreasing IgE synthesis.

(ii) The peptides of the present invention may be used in the capacity of an adsorbent to remove Ara h 1 and/or Ara h 2 directed T cells from a biological sample or from a patient.

10 Accordingly, in another aspect the present invention provides a method for the treatment and/or prophylaxis of a condition in a subject, which condition is characterised by the aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2 or an allergen in a composition comprising Ara h 1 and/or Ara h 2, said method comprising administering to said subject an effective amount of an immunomodulatory composition as hereinbefore defined for a
15 time and under conditions sufficient to remove or reduce the presence or function in said subject of T cells directed to said Ara h 1 and/or Ara h 2 or other allergen.

Preferably said condition is hypersensitivity to peanuts or tree nuts which contain Ara h 1 and Ara h 2 or Ara h 1-like or Ara h 2-like molecules, such as hazelnuts, almonds or Brazil nuts.

20 In one embodiment, said method desensitises or induces immunological tolerance to Ara h 1 and/or Ara h 2 or other allergen of said composition.

In another embodiment, said desensitization or tolerance is achieved by inducing T cell anergy or apoptosis.

In still another embodiment, said desensitisation or tolerance is achieved by inducing Ara h 1 or Ara h 2-specific Treg cells.

25 An "effective amount" means an amount necessary at least partly to attain the desired immune response, or to delay the onset or inhibit progression or halt altogether, the onset or progression of a particular condition being treated. The amount varies depending upon the health and physical condition of the individual to be treated, the taxonomic group of individual to be treated, the degree of protection desired, the formulation of the composition, the assessment of the
30 medical situation, and other relevant factors. It is expected that the amount will fall in a relatively broad range that can be determined through routine trials.

The subject of the treatment or prophylaxis is generally a mammal such as but not limited to human, primate, livestock animal (e.g. sheep, cow, horse, donkey, pig), companion animal (e.g. dog, cat), laboratory test animal (e.g. mouse, rabbit, rat, guinea pig, hamster), captive wild animal

(e.g. fox, deer). Preferably the mammal is a human or primate. Most preferably the mammal is a human.

Reference herein to "treatment" and "prophylaxis" is to be considered in its broadest context. The term "treatment" does not necessarily imply that a subject is treated until total
5 recovery. Similarly, "prophylaxis" does not necessarily mean that the subject will not eventually contract a disease condition. Accordingly, treatment and prophylaxis include amelioration of the symptoms of a particular condition or preventing or otherwise reducing the risk of developing a particular condition. The term "prophylaxis" may be considered as reducing the severity or onset of a particular condition. "Treatment" may also reduce the severity of an existing condition.

10 Administration of the composition of the present invention (herein referred to as "agent") in the form of a pharmaceutical composition, may be performed by any convenient means. The agent of the pharmaceutical composition is contemplated to exhibit therapeutic activity when administered in an amount which depends on the particular case. The variation depends, for example, on the human or animal and the agent chosen. A broad range of doses may be applicable.
15 Considering a patient, for example, from about 0.01 g to about 1 mg of an agent may be administered per dose. Dosage regimens may be adjusted to provide the optimum therapeutic response. For example, several divided doses may be administered daily, weekly, monthly or other suitable time intervals or the dose may be proportionally reduced as indicated by the exigencies of the situation. In another example, said composition is administered initially to induce tolerance
20 and then, if necessary, booster administrations of the composition are administered to maintain tolerance. These boosters may be administered monthly, for example, and may be administered for any period of time, including the life of the patient.

The agent may be administered in a convenient manner such as by the oral, intravenous (where water soluble), intraperitoneal, intramuscular, subcutaneous, intradermal (with or without
25 using a traditional needle or other transdermal delivery device), transdermal, intranasal, sublingual or suppository routes or implanting (e.g. using slow release molecules). Preferably, said composition is administered intradermally. The agent may be administered in the form of pharmaceutically acceptable nontoxic salts, such as acid addition salts or metal complexes, e.g. with zinc, iron or the like (which are considered as salts for purposes of this application).

30 Illustrative of such acid addition salts are hydrochloride, hydrobromide, sulphate, phosphate, maleate, acetate, citrate, benzoate, succinate, malate, ascorbate, tartrate and the like. If the active ingredient is to be administered in tablet form, the tablet may contain a binder such as tragacanth, corn starch or gelatin; a disintegrating agent, such as alginic acid; and a lubricant, such as magnesium stearate.

In accordance with these methods, the agent defined in accordance with the present invention may be coadministered with one or more other compounds or molecules. By “coadministered” is meant simultaneous administration in the same formulation or in two different formulations via the same or different routes or sequential administration by the same or different routes. By “sequential” administration is meant a time difference of from seconds, minutes, hours or days between the administration of the two types of molecules. These molecules may be administered in any order. It should also be understood that the peptides of the present invention may be themselves administered simultaneously or sequentially. They may be administered as one or more compositions, either simultaneously or sequentially. For example, one may formulate some of the peptides in one formulation and the others in a separate formulation; with these two formulations being given one in each arm. Alternatively, additional separate formulations could be generated and administered, either simultaneously to different sites or sequentially. It is well within the skill of the person in the art to design and generate the production of an appropriate formulation or mix of formulations.

Another aspect of the present invention contemplates the use of an immunomodulatory composition as hereinbefore defined in the manufacture of a medicament for the treatment of a condition in a mammal, which condition is characterised by an aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2.

Preferably said condition is hypersensitivity to peanuts or a tree nut which contains Ara h 1 and/or Ara h 2 or Ara h 1-like and/or Ara h 2-like molecules, such as a hazelnut.

In yet another further aspect, the present invention contemplates a vaccine comprising the composition as hereinbefore defined together with one or more pharmaceutically acceptable carriers and/or diluents. Said composition is referred to as the active ingredient.

The pharmaceutical forms suitable for injectable use include sterile aqueous solutions (where water soluble) or dispersions and sterile powders for the extemporaneous preparation of sterile injectable solutions or dispersion or may be in the form of a cream or other form suitable for topical application. It must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils. The proper fluidity can be maintained, for example, by the use of a coating such as lecithin, by the maintenance of the required particle size in the case of dispersion and by the use of surfactants. The preventions of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal and the like. Tonicity adjusting agents are useful to keep the preparation

isotonic with human plasma and thus avoid tissue damage. Commonly used tonicity agents include Dextrose, Trehalose, Glycerin and Mannitol. Glycerol and sodium chloride are other options but are less commonly used. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating the active compounds in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filtered sterilisation. Generally, dispersions are prepared by incorporating the various sterilised active ingredient into a sterile vehicle which contains the basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and the freeze-drying technique which yield a powder of the active ingredient plus any additional desired ingredient from previously sterile-filtered solution thereof.

When the active ingredients are suitably protected they may be orally administered, for example, with an inert diluent or with an assimilable edible carrier, or it may be enclosed in hard or soft shell gelatin capsule, or it may be compressed into tablets, or it may be incorporated directly with the food of the diet. For oral therapeutic administration, the active compound may be incorporated with excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. Such compositions and preparations should contain at least 1% by weight of active compound. The percentage of the compositions and preparations may, of course, be varied and may conveniently be between about 5 to about 80% of the weight of the unit. The amount of active compound in such therapeutically useful compositions is such that a suitable dosage will be obtained. Preferred compositions or preparations according to the present invention are prepared so that an oral dosage unit form contains between about 0.1 µg and 1000 µg of active compound.

The tablets, troches, pills, capsules and the like may also contain the components as listed hereafter: a binder such as gum, acacia, corn starch or gelatin; excipients such as dicalcium phosphate; a disintegrating agent such as corn starch, potato starch, alginic acid and the like; a lubricant such as magnesium stearate; and a sweetening agent such as sucrose, lactose or saccharin may be added or a flavouring agent such as peppermint, oil of wintergreen, or cherry flavouring. When the dosage unit form is a capsule, it may contain, in addition to materials of the above type, a liquid carrier. Various other materials may be present as coatings or to otherwise modify the physical form of the dosage unit. For instance, tablets, pills, or capsules may be coated with shellac, sugar or both. A syrup or elixir may contain the active compound, sucrose as a sweetening

agent, methyl and propylparabens as preservatives, a dye and flavouring such as cherry or orange flavour. Of course, any material used in preparing any dosage unit form should be pharmaceutically pure and substantially non-toxic in the amounts employed. In addition, the active compound(s) may be incorporated into sustained-release preparations and formulations.

5 The pharmaceutical composition may also comprise genetic molecules such as a vector capable of transfecting target cells where the vector carries a nucleic acid molecule encoding a modulatory agent. The vector may, for example, be a viral vector.

Routes of administration include, but are not limited to, respiratorally (eg. intranasally or orally via aerosol), intratracheally, nasopharyngeally, intravenously, intraperitoneally,
10 subcutaneously, intracranially, intradermally, transdermally, intramuscularly, intraocularly, intrathecally, intracerebrally, intranasally, infusion, orally, rectally, *via* IV drip patch, implant and sublingual. Preferably, said route of administration is subcutaneously, intradermally, transdermally or intranasally.

Yet another aspect of the present invention relates to the compositions, as hereinbefore
15 defined, when used in the method of the present invention.

The present invention is further described by reference to the following non-limiting examples.

EXAMPLE 1

Ara h 1 and Ara h 2 are the most allergenic and abundant proteins in peanut, making
20 peptides comprising their dominant T-cell epitopes essential for inclusion in a therapy. Another important consideration when selecting peptides for immunotherapy, is whether they can be presented by different MHC class II molecules (HLA molecules in humans) and therefore be suitable for treating a genetically diverse human population. The HLA-restriction of peptide presentation to T cells was tested using blocking antibodies and HLA-genotyping and showed that
25 every T cell epitope identified could be presented on two or more different HLA-molecules. Furthermore, it was demonstrated that the identified T cell epitopes were collectively presented on a combination of HLA-DR, HLA-DQ and HLA-DP molecules (Table 2). Inclusion of HLA-DQ and -DP-restricted T cell epitopes is particularly advantageous for a therapeutic since these HLA-types are more conserved in mixed populations than HLA-DR molecules, enabling broader
30 population coverage with fewer T cell epitope sequences.

Adjacent or overlapping T cell epitopes were combined into single peptides (<20 aa long) to minimise the number of peptides in the final therapeutic set resulting in three candidate peptides from Ara h 2 and seven from Ara h 1. Since cysteine residues can be problematic for peptide stability and biological reactivity, cysteine residues were substituted with structurally conserved
35 but less reactive serine residues. Minor changes were also made to two Ara h 1 peptides to improve

stability and/or solubility (Table 2). In all cases it has been confirmed that T-cell reactivity to the variant peptide has been retained.

Table 2: Therapeutic candidate peptides of Ara h 1 and Ara h 2

Sequence	HLA	Sequence	HLA
FQNLQNHRIVQIEAKPNTLV	DR	KAMVIVVVVNKGTGNLELVAVD	DR
*STRSSENNEGVIKVSKE ¹	DQ	*GDVFIMPAAHPVAINASSE ²	DQ+DR
NNFGKLPEVKPDKKNPQLQ	DR	*SQLERANLRPSEQHLM ³	DP+DQ+DR
VEIKEGALMLPHFNSKA	DQ+DR	*ELNEFENNQRSMSEALQ ³	DR+DQ
ALMLPHFNSKAMVIVVV	DR	*RELRLNPQQSGLRA ³	DR

Ara h 1 peptides shaded; Ara h 2 peptides unshaded. HLA column shows HLA types known to

- 5 *present T cell epitope(s) within the peptide. *Peptides altered to improve properties; ¹W' omitted from Nterminus. ²E' (from native sequence) added to C-terminus. ³Bolded serine replaced a cysteine.*

Preclinical screening of these peptides confirms PBMC T-cell reactivity (Fig 1), lack of inflammatory cell activation (Fig 2) and serum stability in an additional peanut-allergic cohort (n = 10 40). It has been confirmed that PBMC T-cell recognition of one or more of these ten peptides in 100% of subjects (n=20) analysed, with 50-90% responding to each peptide. The analyses to date clearly demonstrate that the ten peptides in Table 2 above, provide a sufficient, feasible and suitable mixture.

EXAMPLE 2

Brief overview of steps

1) Identification of dominant T cell epitopes of major peanut allergens Ara h 1 and Ara h 2 (Figures 3 and 4)
Isolated CD4+ T cells specific for Ara h 1 or Ara h 2 from PBMC of peanut-allergic subjects
Determined T cell specificity to overlapping 20-mer peptides spanning full Ara h 1 (Figures 5 and 6) or 2 (Figure 7) sequence
Selected dominant 20-mers and mapped core T cell epitope sequences within them (Figure 8)
2) Determining HLA-restriction of core T cell epitopes
Blocked T cell epitope presentation to specific T cells using anti-HLA antibodies (Figure 9)
HLA-genotyped subjects used for T cell epitope-mapping
Further assessed HLA-binding degeneracy of T cell epitopes with algorithms
3) Design of therapeutic candidate peptides

Replaced cysteine residues with serine residues
Combined overlapping T cell epitopes into single peptides 20 aa long (10 peptides) (Tables 16-18)
Designed shorter peptide variants based on single T cell epitopes (13 peptides)
Synthesised all 23 peptides to >95% GLP-grade purity & determined solutions for solubility
4) Selection and testing of final therapeutic mixture
Compared PBMC T cell reactivity to all 23 peptides in peanut-allergic cohort and selected final 7-peptide therapeutic
Assessed PBMC T cell response to 7-peptide mix at 2 therapeutic doses in peanut-allergic cohort
Tested basophil response to 7-peptide mix at 4-log dose range in peanut-allergic cohort

Materials and Methods

- Subjects:* Peanut-allergic adult subjects were recruited from The Alfred Allergy Clinic, Melbourne, Australia. Peanut-allergic subjects had clinical symptoms of IgE-mediated peanut allergy and peanut-specific IgE CAP score ≥ 2 (1.16 kUA/l; Pharmacia CAP SystemTM, Pharmacia Diagnostics, Uppsala, Sweden) and many had a history of anaphylaxis. Some subjects were genotyped (HLA-DRB1, -DQB1 and -DPB1, exon 2) by the Victorian Transplantation and Immunogenetics Service. The study was approved by The Alfred and Monash University Ethics Committees and informed written consent obtained from each subject.
- Antigens:* Crude peanut extract (CPE) was prepared from commercial unsalted, dry-roasted peanuts as described elsewhere, (de Leon *et al. Clin Exp Allergy*. 2003;33(9):1273-80) dialyzed against phosphate-buffered saline (PBS) and filter-sterilized (0.2 μ m). Natural Ara h 1 and Ara h 2 were enriched from CPE based on published methodology. (de Jong EC *et al. Clin Exp Allergy*. 1998;28(6):743-51) Briefly, CPE was buffer exchanged into 20 mM TRIS-bis-propane (TBP), pH 7.2, using Vivaspin columns (Sartorius Stedim Biotech S.A., Aubagne, France) and applied onto a 5 mL Mono-Q 10/10 column (Pharmacia FPLC System, St Albans, UK) equilibrated with TBP. After washing with TBP, a linear gradient of 30 mL 0-1 M NaCl/TBP was applied to elute bound proteins (1 mL/min). Fractions, 0.5 mL, were analyzed by SDS-PAGE and those containing Ara h 1 or Ara h 2 with minimal other proteins pooled and dialyzed against PBS. Endotoxin contents were 1.7, 4.0 and 78.0 EU/mg for CPE, Ara h 1 and Ara h 2 respectively (Endpoint Chromogenic LAL assay, Lonza, Walkersville, USA). Peptides (Mimotopes, Victoria, Australia and GenScript USA Inc, New Jersey, USA) were reconstituted at 1-4 mg/ml in 10% dimethyl sulfoxide/PBS (20-mers and truncated peptide sets) or PBS, 1-2% acetic acid or 0.1M ammonium bicarbonate buffers

as specified (custom-synthesized core epitope peptides). All antigens were confirmed to be neither mitogenic nor toxic as described (Eusebius NP *et al.*, *Int Arch Allergy Immunol.* 2002;127(3):234-44).

Generation of Ara h 1 and Ara h 2-specific CD4+ T-cell lines (TCL): Ara h 1 or Ara h 2-specific oligoclonal TCL were generated from peripheral blood mononuclear cells (PBMC) of peanut-allergic subjects using 5,6-carboxyfluorescein diacetate succinimidylester (CFSE)-based methodology. (Mannering SI *et al.*, *J Immunol Methods.* 2005;298(1-2):83-92; Prickett SR, *et al.*, *J Allergy Clin Immunol.* 2011;127(3):608-15 e1-5). Briefly, culturing was performed in RPMI-1640 containing 2 mM L-glutamine, 100 IU/mL penicillin-streptomycin and 5% human AB serum (Sigma-Aldrich, St Louis, USA) (cRPMI). PBMC were labelled with 0.1 μ M CFSE (Molecular Probes, Eugene, USA) and cultured (2.5×10^6 /mL) with cRPMI alone, CPE (100 μ g/mL), Ara h 1 or Ara h 2 (10 μ g/mL), Ara h 1 or Ara h 2 20-mer-peptide pools (10 μ g/mL/peptide) or as a control, tetanus toxoid (TT; 10 LfU/mL; Statens Serum Institute, Copenhagen, Denmark) for 7 days at 37°C. After staining with CD4-PE and 7AAD (BD Pharmingen, San Diego, USA), CD4+CFSEdim7AAD- cells were sorted (10 cells/well) into 96-U-well plates containing irradiated allogeneic feeder-cells, anti-CD3 (OKT-3), rIL-2 (Cetus, Emeryville, USA) and Fungizone (Invitrogen, Carlsbad, USA) as described. Cells were fed with rIL-2 as required and after 10-14 days, transferred to 48-well plates and tested for proliferation to Ara h 1 or Ara h 2 (10 μ g/mL). Ara h 1 or Ara h 2-positive TCL were expanded with anti-CD3 and rIL-2 in T25 culture flasks (BD, Franklin Lakes, USA) for 10-12 days then tested for specificity (proliferation) to overlapping 20-mer peptides spanning the respective sequence (10 μ g/mL). Core epitope sequences were mapped within selected 20-mers using peptide sets truncated from the N- or C-terminus of the 20-mer as described (Prickett SR, *et al.*, *J Allergy Clin Immunol.* 2011;127(3):608-15 e1-5).

T-cell assays: All culturing was performed in RPMI-1640 containing 2 mM L-glutamine, 100 IU/mL penicillin-streptomycin and 5% heat-inactivated human AB serum (Sigma-Aldrich, St Louis, USA) (cRPMI). Antigen-induced TCL proliferation was assessed by 3 H-thymidine (3 H-TdR) uptake assays as follows: assays were performed on 72-hour duplicate or triplicate cultures in 96-U-well plates containing 1×10^4 T cells/well, 1×10^4 irradiated (5000 rads) autologous EBV-transformed PBMC (EBV-B cells) as antigen presenting cells and antigens as specified. Negative control was cRPMI alone. Cells were pulsed with 3 H-thymidine (3 H-TdR; 0.5 Ci/well) for the last 16 hours and uptake recorded as mean counts per minute (cpm) of replicate cultures. A stimulation index (SI; cpm antigen-stimulated T cells/cpm unstimulated T cells) ≥ 2.5 was considered positive and all positive responses confirmed in ≥ 2 assays. To allow detection of peptide-induced CD4+ T-cell proliferation within whole PBMC, 7-day cultures of CFSE-labelled PBMC were set up as described for TCL generation, with addition of anti-CD25 antibodies (BD) to assess T cell

activation in addition to proliferation. At least 10,000 CD4⁺ T cells were analyzed per sample and SI calculated as percentage of CD4⁺CFSE^{lo} (proliferated), CD4⁺CD25⁺ (activated) or CD4⁺CD25⁺CFSE^{lo} (activated and proliferated) cells with antigen divided by the percentage of the same population without antigen (background). Analysing CD4⁺CD25⁺CFSE^{lo} (activated and proliferated) cells provided the most sensitive method for detection of T cell responses with designation of an SI ≥ 1.5 as positive.

HLA class II blocking assays: T cells and irradiated EBV-B cells (1×10^4 of each) were incubated with 0.1-10 μ g/mL blocking monoclonal antibody (mAb) against HLA-DR (L243, BD Pharmingen), HLA-DQ (SVP-L3) or HLA-DP (B7/21) or isotype-control antibodies (IgG2a: BD Pharmingen; IgG1: BioLegend, San Diego, USA) for 1 hour at 37°C prior to addition of peptides (2-10 μ g/mL) or CPE (100 μ g/mL) and testing proliferative response as above.

Cytokine ELISPOT assays: MAIP ELISPOT plates (Millipore, Billerica, USA) were coated overnight at 4°C with 10 μ g/mL IL-4, IFN- γ or IL-5 antibodies (eBioscience, San Diego, USA) in PBS. Wells were blocked (cRPMI, 1 hour, 37°C) then PBMC (3.5×10^5) or T cells and irradiated EBV-B cells (1×10^4 of each) added in duplicate 100 μ L cultures with CPE (100 μ g/mL), nAra h 2 (10 μ g/mL) or peptides (10 μ g/mL). Controls were cRPMI alone, TT (10 IU/ml) and phytohaemagglutinin (1 μ g/mL; Sigma-Aldrich). After 48 hours culture at 37°C, plates were incubated with biotinylated IL-4, IL-5 or IFN- γ antibodies (eBioscience) (1 μ g/ml PBS, 2 hours) followed by ExtrAvidin®-alkaline phosphatase (Sigma-Aldrich) (1/3,000 PBS, 2 hours) before developing with alkaline phosphatase substrate (Bio-Rad). When spots appeared in positive-control wells, plates were washed, air dried and read (AID ELISPOT 4.0 h reader, Autoimmun Diagnostika, Strassberg, Germany).

Basophil activation test: Basophil activation was assessed by CD63 upregulation detected by flow cytometry as described (Drew AC, *et al.*, *J Immunol.* 2004;173(9):5872-9). Positive controls were rabbit anti-human IgE antibody (7.5 μ g/mL; DAKO Corporation, CA, USA), N-formyl-methionine-leucine-phenylalanine (fMLP) (0.4 μ g/mL; Sigma) and CPE. CPE was tested over a 3 log concentration range (50, 5 and 0.5 μ g/mL) and the peptide pool was tested over a 4-log concentration range (50, 5, 0.5 and 0.05 μ g/mL). Histamine release was assessed using Histamine Release and the Histamine ELISA kits (IBL International GmbH, Hamburg, Germany) as per manufacturer's instructions.

Results

The factors considered in dominant 20-mer selection included:

- Responder frequency
- Number of specific TCL generated per patient/prevalence of specific T cells in patient PBMC
- Magnitude of T cell response

- Patterns of T cell responses (peptide combinations recognised within and between subjects)
- Ability to directly target specific T cells amongst the whole PBMC population with peptide (CFSE screening)
- Consistency of T cell responses
- 5 • Identification of core T cell epitope(s) within the 20-mer peptide

Ara h 1 dominant 20-mer selection

145 Ara h 1-specific T cells lines (TCL) were generated from 18 peanut-allergic donors and 65/69 overlapping 20-mer peptides spanning Ara h 1 were recognised by these TCL (see Table 3 and Figure 5). 14 of these 65 20-mers were selected as most frequently recognised (4-6
10 responders of 18; 22-33%) (peptide numbers 23, 24, 26, 38, 40, 44-51 and 57). Of these 14 peptides, 9 were selected for further analysis (peptide numbers 23, 24, 40, 46, 47, 49, 50, 51 and 57) (Table 4).

These selections were made based on number of specific TCL per subject, magnitude of TCL response, reproducibility of TCL response and ability to target specific T cells in PBMC. The 9
15 20-mers which were selected were:

- collectively recognised by TCL from 16 of 18 subjects (89%) in this cohort
- typically induced strong and consistent responses in specific TCL
- each recognised by multiple TCL from many responders
- each able to target specific T cells in donor PBMC (collectively inducing detectable PBMC

20 T cell responses in 18/20 additional subjects with 8-16 responders (40-80%) per 20-mer. One or more of the nine 20-mers was recognised by T cells in 35 (92%) of 38 subjects analysed by TCL isolation and/or CFSE-screening (Table 3).

Table 3

Proliferative responses (thymidine uptake) of TCL to Ara h 1 20-mer peptides. Table shows SI values (≈fold increase in TCL proliferation with peptide above proliferation in unstimulated TCL).
25 Only stimulation indices (SI) ≥2.5 are shown. For subjects with multiple TCL specific for a given 20-mer, the highest SI is shown. Dark grey, SI ≥2.5<5.0; SI ≥5.0. The 9 dominant peptides ultimately selected are shown in Table 4.

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Table 3

Subject		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
No. TCI/Subject		1	3	3	3	3	4	4	6	7	7	7	8	10	11	13	14	31	31
20-mer peptide residues	1	1-20																	
	2	15-20																	
	3	18-58																	
	4	38-47																	6.5
	5	37-55																	
	6	45-65																	
	7	25-74																	
	8	54-83																	
	9	78-93																	
	10	82-101																	
	11	21-130																	
	12	100-119																	
	13	109-128																	
	14	118-137																	
	15	130-146																	
	16	136-155																	
	17	145-164																	
	18	154-173																	
	19	185-192																	
	20	172-191																	
	21	181-200																	
	22	191-210																	
	23	199-218																	
	24	218-237																	
	25	247-266																	
	26	236-245																	
	27	229-254																	
	28	244-263																	
	29	235-272																	
	30	252-281																	
	31	275-299																	
	32	281-299																	
	33	309-308																	
	34	296-317																	
	35	307-336																	
	36	318-335																	
	37	325-344																	
	38	334-353																	
	39	345-364																	
Arch	40	372-371																	
	41	381-380																	
	42	373-389																	
	43	379-398																	
	44	385-407																	
	45	402-421																	
	46	413-438																	
	47	425-454																	
	48	439-459																	
	49	438-461																	
	50	451-470																	
	51	482-479																	
	52	489-488																	
	53	475-497																	
	54	487-506																	
	55	495-515																	
	56	505-524																	
	57	514-533																	
	58	525-542																	
	59	530-551																	
	60	540-560																	
	61	550-569																	
	62	559-578																	
	63	508-587																	
	64	575-596																	
	65	585-605																	
	66	595-614																	
	67	604-623																	
	68	607-626																	

Table 4: Summary of dominant Ara h 1 20-mer selection

Peptide No.	Residues	Sequence
23	199-218	FDQRSRQFQNLQNHRIQIE (SEQ ID NO:47)
24	208-227	NLQNHRIQIEAKPNTLVLP (SEQ ID NO:48)
40	352-371	RWSTRSSENNEGVIVKVSKE (SEQ ID NO:49)
46	406-425	DLSNNFGKLFVVKPDKKNPQ (SEQ ID NO:50)
47	415-434	FEVKPDKKNPQLQDLDMMLT (SEQ ID NO:51)
49	433-452	LTCVEIKEGALMLPHFNSKA (SEQ ID NO:52)
50	442-461	ALMLPHFNSKAMVIVVVNKG (SEQ ID NO:53)
51	451-470	KAMVIVVVNKG TGNLELVAV (SEQ ID NO:120)
57	505-524	KEGDVFIMPAAHPVAINASS (SEQ ID NO:55)

PBMC screening with dominant Ara h 1 20-mers

Table 5 shows that 1 dominant 20-mer peptide is recognised by 18/20 (or 22/24 of all data). Each
5 20-mer peptide is recognised by at least 7 subjects. CFSE and TCL data combined; recognition confirmed in 43/45 subjects.

Table 5

SIs of peptide-induced proliferation for 24 subjects. Upper panel shows new peanut-allergic donor cohort (distinct to cohort used for TCL). Lower panel shows 4 subjects from cohort used for TCL
10 generation with combined totals from upper and lower panels.

CPE, crude peanut extract; +ve, positive; nt, not tested (peptide stocks not available at time of testing); Grey, stimulation indices $1.1 < 2.5$; Black, stimulation indices ≥ 2.5 .

		Stimulation Indices (SI)										+ve 20-mers			
Sub- ject	No Antigen*	CPE	Ara h 1 20-mers									SI>1.1		SI>1.5	
			23	24	40	46	47	49	50	51	57	No.	%	No.	%
19	0.22	91.6	3.5	0.7	3.3	nt	nt	nt	0.7	3.2	36.0	4/6	67	4/6	67
20	0.08	1.4	1.1	1.4	0.0	nt	nt	nt	1.0	69.3	0.0	3/6	50	1/6	17
21	0.45	7.0	0.4	2.8	0.5	nt	nt	nt	0.3	1.0	0.4	1/6	17	1/6	17
22	0.27	54.6	0.4	0.9	0.2	nt	nt	nt	1.7	0.5	0.2	1/6	17	1/6	17
23	3.02	5.9	0.6	0.8	1.0	nt	nt	nt	1.2	0.4	2.0	2/6	33	1/6	17
24	0.26	6.8	0.5	0.5	0.6	nt	nt	nt	2.8	2.0	0.7	2/6	33	2/6	33
25	0.10	152.0	2.2	1.2	0.6	23.4	1.9	3.1	0.9	0.4	0.7	5/9	56	4/9	44
26	0.07	122.8	2.3	5.8	0.9	0.6	1.3	12.7	4.2	4.4	2.7	7/9	78	6/9	67
27	0.17	1.4	0.6	0.8	0.9	1.0	0.7	1.3	0.6	1.1	1.5	3/9	33	1/9	11
28	0.06	37.5	5.6	8.9	6.0	18.0	1.7	2.5	3.0	12.6	29.5	9/9	100	9/9	100
29	1.87	2.9	1.7	1.7	1.3	0.7	1.1	1.6	1.6	1.7	1.8	8/9	89	6/9	67
30	0.11	2.1	1.5	2.6	1.7	0.9	0.9	1.2	0.4	2.1	0.5	5/9	56	4/9	44
31	0.08	10.3	1.9	2.1	1.2	2.5	9.0	1.9	1.5	1.3	2.0	9/9	100	7/9	78
32	0.06	5.8	0.8	2.4	1.3	1.2	1.6	2.3	10.2	0.9	1.3	7/9	78	4/9	44
33	1.30	2.3	1.8	0.4	0.8	1.5	1.2	0.9	0.8	0.1	0.2	3/9	33	2/9	22
34	1.04	1.6^	2.1	1.0	2.8	2.4	2.3	1.5	0.3	2.0	4.1	6/9	66	6/9	66
35	0.08	8.2^	1.0	0.8	1.3	0.5	3.3	5.3	0.3	0.8	2.0	4/9	44	3/9	33
36	0.35	6.1^	1.6	1.4	1.6	1.7	4.8	2.6	0.8	1.2	1.5	8/9	89	7/9	78
37	1.05	7.8	0.3	0.3	0.3	0.6	0.2	0.9	0.7	0.9	0.3	0/9	0	0/9	0
38	0.78	1.3	0.8	0.9	0.8	0.7	0.9	0.9	0.7	0.7	0.8	0/9	0	0/9	0
Responders w SI>1.1	#	20/20	11/20	10/20	8/20	7/14	10/14	11/14	8/20	11/20	11/20				
	%	100	55	50	40	50	71	79	40	55	55				
Responders w SI>1.5	#	17/20	10/20	7/20	4/20	6/14	7/14	9/14	7/20	8/20	10/20				
	%	85	50	35	20	43	50	64	35	40	50				
1	0.17	7.1^	2.4	2.7	1.8	1.1	1.7	2.5	0.4	0.5	1.2	7/9	78	5/9	56
2	0.19	83.5	1.8	10.3	1.6	1.8	1.0	1.6	3.4	1.9	2.9	8/9	89	8/9	89
4	0.62	12.3	5.2	1.8	4.2	nt	nt	nt	4.7	6.5	9.7	6/6	100	6/6	100
10	0.23	44.4	14.4	5.3	5.3	nt	nt	nt	14.2	8.1	4.4	6/6	100	6/6	100
Responders w SI>1.1	#	24/24	15/24	14/24	12/24	9/16	11/16	13/16	11/24	14/24	15/24				
	%	100	63	58	50	56	69	81	46	58	63				
Responders w SI>1.5	#	21/24	14/24	11/24	8/24	7/16	8/16	11/16	10/24	11/24	13/24				
	%	88	58	46	33	44	50	69	42	46	54				

Ara h 2 dominant 20-mer selection

69 Ara h 2-specific T cells lines (TCL) were generated from 16 peanut-allergic donors and 16/17 overlapping 20-mer peptides spanning Ara h 2 were recognised by these TCL (Table 6). 4 of these

5 16 20-mers were selected as most frequently recognised (each with 7-9 responders of 16; 44-46%) (peptide numbers 4, 5, 11, 15) (Figure 7). These selections were made based on number of specific TCL per subject, magnitude of TCL response, reproducibility of TCL response and ability to target specific T cells in PBMC. The 4 20-mer peptides which were selected were:

- collectively recognised by TCL from all 16 subjects (100%) in this cohort
- typically induced strong and consistent responses in specific TCL
- each recognised by multiple TCL from many responders
- collectively recognised by ~80% of all 69 TCL

- each able to target specific T cells in donor PBMC (detectable PBMC T cell responses demonstrated in 6 subjects tested).

One or more of the four 20-mers was recognised by T cells in 16/16 (100%) of subjects analysed by TCL isolation and/or CFSE-screening (Table 6).

5 **Table 6**

Proliferative responses (thymidine uptake) of TCL to Ara h 2 20-mer peptides. Table shows SI values (=fold increase in TCL proliferation with peptide above proliferation in unstimulated TCL). Only positive stimulation indices (≥ 2.5) are shown: Grey, $2.5 \leq SI \leq 5.0$; Black, $SI > 5.0$. A) allergen-driven TCL; B) peptide-driven TCL. The dominant 20-mers are indicated in Table 7.

Ara h 2 20-mer peptides

			Peel 1			Peel 2		Peel 3		Peel 4		Peel 5		Peel 6	
Subject	Drug Allergen	PEL	area of oxidation(s) TCL (mean $\pm$ SE)	120	1028	1028	1047	1246	1048	1074	1081	1092	1092	1092	1092
A	1	CPE	1	261 $\pm$ 8											
		CPE	2	231 $\pm$ 303											
	2	CPE	3	292 $\pm$ 110											
		CPE	4	311 $\pm$ 23	308.7										
	3	CPE	5	213 $\pm$ 18											
		CPE	6	1123 $\pm$ 1106										21.6	
	4	CPE	7	279 $\pm$ 86	6.7	31.6	3.9								
		CPE	8	291 $\pm$ 28		2.7									
	5	CPE	9	154 $\pm$ 32			6.6								
		CPE	10	351 $\pm$ 29											
	6	ALL	1	182 $\pm$ 4											
		ALL	2	713 $\pm$ 716											
	7	ALL	3	416 $\pm$ 85											
		ALL	4	1367 $\pm$ 122											
	8	ALL	5	785 $\pm$ 14											
		ALL	6	1235 $\pm$ 115											
	9	ALL	7	895 $\pm$ 291											
		ALL	8	1071 $\pm$ 869											
	10	CPE	1	2245 $\pm$ 189											
		CPE	2	2323 $\pm$ 281											
	11	ALL	3	147 $\pm$ 117											
		ALL	4	169 $\pm$ 107											
	12	ALL	5	740 $\pm$ 107											
		ALL	6	4811 $\pm$ 1972											
	13	ALL	7	2310 $\pm$ 305											
		ALL	8	3003 $\pm$ 74											
	14	ALL	9	4968 $\pm$ 687											
		ALL	10	1319 $\pm$ 148											
	15	ALL	11	867 $\pm$ 156											
		ALL	12	351 $\pm$ 71											
B	1	CPE	1	1042 $\pm$ 12											
		CPE	2	1965 $\pm$ 4											
	2	CPE	3	474 $\pm$ 11											
		CPE	4	877 $\pm$ 263											
	3	ALL	5	407 $\pm$ 203											
		CPE	6	3795 $\pm$ 18											
	4	CPE	1	3795 $\pm$ 18											
		CPE	2	503 $\pm$ 159											
	5	CPE	3	1630 $\pm$ 321											
		CPE	4	871 $\pm$ 527	3.6	12	25.4	2.6	3.8						
	6	CPE	5	1783 $\pm$ 620											
		CPE	6	1567 $\pm$ 185											
	7	ALL	1	5173 $\pm$ 1133											
		ALL	2	127 $\pm$ 176											
	8	ALL	3	116 $\pm$ 38											
		ALL	4	1117 $\pm$ 1											
	9	ALL	5	1079 $\pm$ 33											
		ALL	6	1573 $\pm$ 211											
	10	CPE	1	285 $\pm$ 32											
		CPE	2	191 $\pm$ 26											
	11	CPE	1	182 $\pm$ 154											
		CPE	2	1605 $\pm$ 1904											
	12	ALL	3	69 $\pm$ 206											
		ALL	4	2213 $\pm$ 109											
	13	ALL	1	4927 $\pm$ 267											
		ALL	2	1456 $\pm$ 24											
	14	Peel 1	2	337 $\pm$ 3											
		Peel 1	10	7483 $\pm$ 1667											
	15	Peel 2	11	2395 $\pm$ 384											
		Peel 2	12	1725 $\pm$ 235											
	16	Peel 2	13	1297 $\pm$ 560											
		Peel 1	14	2493 $\pm$ 280											
	17	Peel 1	15	3638 $\pm$ 1233											
		Peel 1	16	2663 $\pm$ 83											
	18	Peel 1	6	732 $\pm$ 78											
		Peel 1	7	1921 $\pm$ 90											
	19	Peel 2	1	3613 $\pm$ 831											
		Peel 2	2	646 $\pm$ 61											
	20	Peel 2	2	268 $\pm$ 24											
		Peel 2	3	951 $\pm$ 62											

Table 7: Summary of dominant Ara h 2 20-mer selection

Name	Residues	Sequence
20-mer 4	28-47	RRCQSQLERANLRPCEQHLM (SEQ ID NO:56)
20-mer 5	37-56	ANLRPCEQHLMQKIQRDEDS (SEQ ID NO:57)
20-mer 11	91-110	ELNEFENNQRRCMCEALQQIM (SEQ ID NO:58)
20-mer 15	127-146	KRELRLNPQQCGLRAPQRCD (SEQ ID NO:59)

5 *Core T-cell Epitope Mapping*

Technical approach

TCL from different subjects were used to map each core T cell epitope. Exact T cell epitopes varied between TCL and subjects. The minimum T-cell stimulatory sequence (core epitope) within each selected 20-mer was determined by testing proliferation of reactive TCL from different subjects to truncated peptide sets (Figure 8). The number of residues required to induce maximal T-cell proliferation varied from 6-19 aa between different TCL and/or subjects (Tables 8 and 9). Due to variation in the number of flanking-residues required for optimal epitope recognition, TCL were considered to recognize the same epitope if peptides containing a common core sequence induced recognition. Based on this criterion, ten distinct Ara h 1 and 5 distinct Ara h 2 CD4⁺ T-cell epitopes were identified ('consolidated epitopes', Tables 8 and 9), with common 'minimal core epitope' sequences varying from 5-12 aa (underlined sequences, Tables 8 and 9). 'Consolidated epitope' sequences were the minimum sequences encompassing all residues required for optimal T cell reactivity across different subjects to ensure broadest possible recognition.

20 (i) Core T cell epitopes found in dominant Ara h 1 20-mers

Core T-cell epitope sequences were mapped within the dominant Ara h 1 20-mer peptides. 10 Ara h 1 T cell epitopes were identified ('consolidated T cell epitope'), including 4 pairs of overlapping T cell epitopes. (Table 8)

Table 8

20-mer peptide		Minimum sequence required for T-cell recognition		Consolidated epitope (common core underlined)		Confirmed Responders	
#	Residues	Residues	Sequence	Residues/aa	Sequence	TCL	Subjects
5	23 (199-218)	(206-212)	FQNIQNHR (SEQ ID NO:60)	(206-212)	FQNIQNHRIV	6	3
		(206-215)	FQNIQNHRIV (SEQ ID NO:61)	30 aa			
	24 (208-227)	(213-222)	RIVQIEAKPN (SEQ ID NO:62)	(213-225)	RIVQIEAKPNTLV	6	3
		(213-225)	RIVQIEAKPNTLV (SEQ ID NO:63)	13 aa			
		(214-219)	IVQIEA (SEQ ID NO:64)				
10	40 (352-371)	(353-371)	WSTRSSENNEGVIKVSKE (SEQ ID NO:65)	(353-371)	WSTRSSENNEGVIKVSKE*	3	3
		(SEQ ID NO:143)(359-371)	ENNEGVIKVSKE	19 aa			
		(SEQ ID NO:67)(361-370)	NEGVIKVSKE				
	46 (406-425)	(409-418)	NNFGKLFYK (SEQ ID NO:68)	(409-425)	NNFGKLFYKPDKENPQ	3	2
		(SEQ ID NO:69)	NNFGKLFYKPDKENPQ (SEQ ID NO:70)	17 aa			
15		(411-418)	FGKLFYK	(416-427)	FYKPDKENPQLQ	2	1
	47 (415-434)	(416-427)	FYKPDKENPQLQ (SEQ ID NO:71)	12 aa			
	49 (433-452)	(436-445)	VEIKEGALML (SEQ ID NO:72)	(436-452)	VEIKEGALMLPHFNSKA*	5	2
		(SEQ ID NO:73)(436-449)	VEIKEGALMLPHFN	17 aa	(SEQ ID NO:85)		
		(SEQ ID NO:74)(440-452)	EGALMLPHFNSKA				
20	50 (442-461)	(442-458)	ALMLPHFNSKAMVIVVV (SEQ ID NO:75)	(442-458)	ALMLPHFNSKAMVIVVV*	6	3
		(SEQ ID NO:76)(443-457)	LMLPHFNSKAMVIVV	17 aa			
		(SEQ ID NO:77)(446-456)	PHFNSKAMVIV				
		(SEQ ID NO:78)(451-459)	KAMVIVVVN	(451-461)	KAMVIVVVNKG (SEQ ID NO:86)	3	2
		(SEQ ID NO:79)(452-461)	AMVIVVVNKG	11 aa			
20		(SEQ ID NO:80)(455-461)	IVVVNKG				
	51 (451-470)	(452-467)	AMVIVVVNKGTONLELV (SEQ ID NO:81)	(452-470)	AMVIVVVNKGTONLELVAV	7	4
		(SEQ ID NO:82)(452-468)	AMVIVVVNKGTONLELV	19 aa	(SEQ ID NO:87)		
		(SEQ ID NO:83)(457-469)	VVNKGTONLELVAV				
		(SEQ ID NO:84)(457-470)	VVNKGTONLELVAV				
20	57 (505-524)	(507-524)	GDVFIMPAAHPVAINASS (SEQ ID NO:88)	(507-524)	GDVFIMPAAHPVAINASS*	12	4
		(SEQ ID NO:89)(509-524)	VFIMPAAHPVAINASS	18 aa			
		(SEQ ID NO:90)(510-521)	FIMPAAHPVAIN				
		(SEQ ID NO:91)(511-517)	IMPAAHP				
		(SEQ ID NO:92)(511-521)	IMPAAHPVAIN				

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(ii) Core T cell epitopes found in dominant Ara h 2 20-mers

Core T-cell epitope sequences were mapped within dominant Ara h 2 20-mer peptides. 5 Ara h 2 T cell epitopes were identified ('consolidated T cell epitopes'), including 2 pairs of overlapping T cell epitopes (Table 9)

Table 9

Dominant 20-mer			Minimum sequence required for T-cell recognition	Consolidated epitopes (common core underlined)		Confirmed Responders
Name	Residues	Sequence		Sequence	Residues	
20-mer 4	28-47	(SEQ ID NO 92) RRCGSGLERANLRPCEQHLM	(SEQ ID NO 94) SGLERANLRPCEQ	SGLERANLRPCEQ	32-44	2 patients, 5 TCI
		(SEQ ID NO 95) SGLERANLRPC				
		(SEQ ID NO 96) LERANLRPC				
		(SEQ ID NO 97) LERANLRPCEQ				
		(SEQ ID NO 98) ERANLRPCEQ				
		(SEQ ID NO 99) ANLRPCEQHLM				
20-mer 11	91-110	(SEQ ID NO 100) ELNEFENNQRCMCEALQIM	(SEQ ID NO 102) ELNEFENNQRCM	ELNEFENNQRCM	91-102	3 patients, 6 TCI
		(SEQ ID NO 103) LNEFENNQRCM				
		(SEQ ID NO 104) EFENNQRCMCEALQ				
		(SEQ ID NO 105) ENNQRCMCEA				
		(SEQ ID NO 106) NNQRCMCEALQ				
20-mer 15	127-146	(SEQ ID NO 107) KRELRLNPQCCGLRPFGRCD	(SEQ ID NO 108) RELRLNPQCCGL	(SEQ ID NO 113) RELRLNPQCCGLRA	128-141	5 peptides, 7 TCI
		(SEQ ID NO 109) ELRLNPQCCGLR				
		(SEQ ID NO 110) ELRLNPQCCGL				
		(SEQ ID NO 111) LRLNPQCCGL				
		(SEQ ID NO 112) LRLNPQCCG				

HLA-restriction of Ara h 1 and Ara h 2 T cell epitopes

T cell recognition of dominant T cell epitopes was blocked with monoclonal antibodies against HLA-DP, HLA-DQ or HLA-DR (Figure 9). Some T cell epitopes presented on both HLA-DR and HLA-DQ molecules while the T cell epitopes were collectively presented on HLA-DP, HLA-DQ and HLA-DR (Table 10).

Table 10

Peptide info	T cell Epitope Sequence	Residues	length	HLA-restriction
Ara h 1 dominant T cell epitopes				
23 core	FQNLQNHRIV	206-215	10 aa	HLA-DR
24 core	RIVQIEAKPNTLV	213-225	13 aa	HLA-DR
40 core	WSTRSSENEGVIKVSKE	353-371	19 aa	HLA-DQ
46 core	NNFGKLFVVKPDKKNPQ	409-425	17 aa	HLA-DR
47 core	EVKPDKKNPQLQ	416-427	12 aa	HLA-DR
core 49	VEIKEGALMLPHFNSKA	436-452	17 aa	HLA-DQ
50 core	ALMLPHFNSKAMVIVVV	442-458	17 aa	HLA-DR

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50/51 core	KAMVIVVVNKG	451-461	11 aa	HLA-DR
51 'core'	KAMVIVVVNKG TGNLELVAV	451-470	20 aa	HLA-DR
57 core	GDVFIMPAAHPVAINASS	507-525	19 aa	HLA-DR or HLA-DQ
Ara h 2 dominant T cell epitopes				
4 core	SQLERANLRPCEQ	32-44	13 aa	HLA-DP
4/5 core	ANLRPCEQHLM	37-47	11 aa	HLA-DR or HLA-DQ
10 core	ELNEFENNQRCM	91-102	12 aa	HLA-DR
10/11 core	EFENNQRCMCEALQ	94-107	14 aa	HLA-DQ
15 core	RELRNLPQQCGLRA	128-141	14 aa	HLA-DR

HLA-restriction of Ara h 1 and Ara h 2 T cell epitope presentation

HLA-typing was performed on subjects, with TCL recognising dominant T cell epitopes, in order to assess HLA-subtypes potentially able to T cell present epitopes. The absence of shared HLA alleles for subjects recognising a T cell epitope with confirmed HLA-DR/DQ/DP restriction indicated T cell epitope HLA-binding degeneracy. The Ara h 1 results are shown in Table 11 and the Ara h 2 results in Table 12.

Table 11

Grey shading indicates T cell epitopes included in current 7-peptide mix

20-mer	T cell Epitope	Subject	HLA-restriction	Corresponding HLA-allele(s)	
23	(206-215)	18	HLA-DR	DRB1 04:05	DRB1 15:01
		3	HLA-DR	DRB1 03:01	DRB1 08:01
24	(213-225)	12	HLA-DR	DRB1 08:01	DRB1 10:01
		10	HLA-DR	DRB1 11:01	DRB1 15:01
40	(353-371)	4	HLA-DQ	DQB1 03:01	DQB1 06:02
		13	HLA-DQ	DQB1 03:01	DQB1 06:02
		14	nt	DQB1 06:09	
46	(409-425)	16	HLA-DR	DRB1 04:04	DRB1 13:01
		15	nt	DRB1 03:01P	DRB1 04:01

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47	(416-427)	16	HLA-DR	DRB1 04:04	DRB1 13:01
		15	nt	DRB1 03:01P	DRB1 04:01
49	(436-452)	18	HLA-DQ	DQB1 03:02	DQB1 06:02
			HLA-DR	DRB1 04:05	DRB1 15:01
50	(442-458)	17	HLA-DR	DRB1 11:04	DRB1 15:01
		9	HLA-DR	DRB1 09:01	DRB1 13:01
50+51	(451-461)	12	HLA-DR	DRB1 08:01	DRB1 10:01
		6	HLA-DR	DRB1 04:01	DRB1 04:04
51	(452-470)	10	HLA-DR	DRB1 11:01	DRB1 15:01
		14	nt	DRB1 13:02	
57	(507-524)	17	HLA-DR	DRB1 11:04	DRB1 15:01
		13	HLA-DQ	DQB1 03:01	DQB1 06:02

Nt = HLA-restriction not tested

*HLA-restriction of Ara h 2 epitope presentation***Table 12**

T cell Epitope	HLA-genotyping for subjects recognising each T cell epitope						Known HLA
	DR B1		DQ B1		DP B1		Restriction
A: <u>SQLERANLRPCEQ</u>	1201G	1501	0301	0602	0902/1301	0401	DP
	1001	0801	0402	0501	0301G	0401	DP
	0301	0801	0201G	0402	0301G	0401	NT
	0404	0401	0302	0402	0902/1301	0401	NT
B: <u>ANLRPCEQHLM</u>	0901	1301	0303	0603	0301G	0402/0602	DR
	1201G	1501	0301	0602	1301/0902	0401	DR
	0301	1302	0201G	0609	0101	0401	DQ
		1302		0609	0501	0402/0602	DQ

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C: <u>ELNEFENNQRCM</u>	1201G	1501	0301	0602	1301/0902	0401	DR
	1101	1501	0301G	0602		0401	DR
D: <u>EFENNQRCMCEALQ</u>	1201G	1501	0301	0602	1301/0902	0401	DQ
	0103	0401	0302	0501	0301G	0201	DQ
	1001	0801	0402	0501	0301G	0401	NT
	0404	0401	0302	0402	0902/1301	0401	NT
		1302		0609	0501	0402/0602	NT
	0701	1501	0201G	0602	0201	0401	NT
	1101	1501	0301G	0602	0301G	0401	NT
E: <u>RELRLNPQQCGLRA</u>	1101	1501	0301G	0602		0401	DR
	0405	1501	NA	0602	0301G	0401	DR
	0404	1301	0302	0603	0201	0401	DR
	0901	1301	0303	0603	0301G	0402/0602	NT
		1302		0609	0501	0402/0602	NT
	1101	1501	0301G	0602		0401	NT
	0701	1501	0201G	0602	0201	0401	NT
	0404	0401	0301G	0302	0201	0401	NT

The absence of a shared *HLA-DQB1* allele between all subjects from whom recognition of Ara h 2 T cell epitope (95-107) was blocked by anti-*HLA-DQ* indicated that this T cell epitope must be presented by multiple *HLA-DQB1* molecules. Similarly, the diversity in *HLA-DRB1* alleles between subjects for whom recognition of Ara h 2 T cell epitopes (127-141) or (37-47) was blocked by anti-*HLA-DR* indicated binding-degeneracy of both T-cell epitopes for multiple *HLA-DRB1* molecules.

In addition to presentation by at least 2 *HLA-DR* molecules, Ara h 2 T cell epitope (37-47) was also presented by *HLA-DQB1*06:09* as both subjects who recognised this T cell epitope in the context of *HLA-DQ* had this allele, and for subject 9 it was the only *DQB1* allele present.

As *DPB1*04:01* or *DRB1*15:01* alleles were present in all subjects recognising Ara h 2 T cell epitopes (32-44) (blocked by anti-*HLA-DP*) or (95-107) (blocked by anti-*HLA-DR*) respectively, degeneracy of these T cell epitopes could not be determined. However, as *DPB1*0401* and *DRB1*1501* are prevalent in populations worldwide, T cell epitopes presented by these *HLA*-molecules would still be broadly recognized.

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There were no shared alleles between two or more subjects recognising the dominant consolidated Ara h 1 T cell epitopes on a given HLA-type, thus demonstrating that each of the identified Ara h 1 T cell epitopes was also presented by 2 or more different HLA-molecules.

Predicting HLA-binding motifs: Ara h 1 20-mer peptides

Table 13 provides a results summary for an HLA-DR prediction algorithm for binding motifs within dominant Ara h 1 20-mers.

[illegible]

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Predicting HLA-binding motifs: Ara h 2 20-mer peptides

Table 14 provides a results summary for 2 HLA-DR prediction algorithms for binding motifs within 3 dominant Ara h 2 20-mers (NB dominant '20-mer 5' not shown as predicted and actual epitopes fall in overlap with '20-mer 4').

Table 14

20-mer name	Sequence	Residues
Ara h 2 pep 4	RRCQSQLERANLRPCEQHLM (SEQ ID NO:122)	28-47
Ara h 2 pep 11	ELNEFENNQRCEALQQIM (SEQ ID NO:123)	91-110
Ara h 2 pep 15	KRELRLNPQQCGLRAPQRCD (SEQ ID NO:124)	127-146

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Table 15

Shading indicates particularly frequent alleles in Caucasian populations.

HLA-DRB alleles	Freq in US caucasians	multi-pred: Hidden Markov Method; >7			Propred prediction: Sturniolo; top 3%		
		Ara h 2 pep 4	Ara h 2 pep 11	Ara h 2 pep 15	Ara h 2 pep 4	Ara h 2 pep 11	Ara h 2 pep 15
DRB1_0101:	9.1	LERANLRPC	FENNQRQCMC	LRNLPQQCG			LRNLPQQCG
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA	LRPCEQHLM		LRNLPQQCG
DRB1_0102:	1.4						
DRB1_0301:	13.1	LERANLRPC	FENNQRQCMC	LRNLPQQCG			
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_0305:						FENNQRQCMC	
DRB1_0306:							
DRB1_0307:							
DRB1_0308:							
DRB1_0309:							
DRB1_0311:							
DRB1_0401:	5.4	(SEQ ID NO:125) LERANLRPC	(SEQ ID NO:127) FENNQRQCMC	(SEQ ID NO:129) LRNLPQQCG			
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_0402:	1	(SEQ ID NO:126) LERANLRPC	(SEQ ID NO:128) FENNQRQCMC	(SEQ ID NO:130) LRNLPQQCG			
DRB1_0404:	3.9						
DRB1_0405:	0.3						
DRB1_0408:							
DRB1_0410:							
DRB1_0421:							
DRB1_0423:							
DRB1_0426:							
DRB1_0701:	14.8	LERANLRPC	FENNQRQCMC	LRNLPQQCG			
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_0703:							
DRB1_0801:	2.2	LERANLRPC	FENNQRQCMC	LRNLPQQCG			
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_0802:						FENNQRQCMC	
DRB1_0804:							
DRB1_0806:							
DRB1_0813:							
DRB1_0817:							
DRB1_1101:	5.6	LERANLRPC	FENNQRQCMC	LRNLPQQCG		FENNQRQCMC	
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA	LERANLRPC		
DRB1_1102:					LRPCEQHLM		
DRB1_1104:	2.7						
DRB1_1106:							
DRB1_1107:							
DRB1_1114:						FENNQRQCMC	
DRB1_1120:					LRPCEQHLM		
DRB1_1121:					LERANLRPC		
					LRPCEQHLM		
DRB1_1128:							
DRB1_1301:	9.6	LERANLRPC	FENNQRQCMC	LRNLPQQCG	LRPCEQHLM		LRNLPQQCG
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_1302:	0.7				LRPCEQHLM		
DRB1_1304:					LRPCEQHLM		LRNLPQQCG
DRB1_1305:							
DRB1_1307:						FENNQRQCMC	
DRB1_1311:							
DRB1_1321:							
DRB1_1322:					LERANLRPC		
					LRPCEQHLM		
DRB1_1323:						FENNQRQCMC	
DRB1_1327:					LRPCEQHLM		LRNLPQQCG
DRB1_1328:					LRPCEQHLM		LRNLPQQCG
DRB1_1501:	14.2	LERANLRPC	FENNQRQCMC	LRNLPQQCG			
		LRPCEQHLM	LNEFENNQRQ	LPOQCGLRA			
DRB1_1502:	0.7						
DRB1_1506:							
DRB5_0101:							
DRB5_0105:							

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Refining peptides for therapeutic delivery

Potentially problematic cysteine residues were replaced with structurally conserved, but less chemically reactive serine residues. Retained T cell reactivity was confirmed (Figures 10 and 11). Serine-containing T cell epitope peptides showed comparable T cell responses to native cysteine-containing peptides.

*Combining overlapping Ara h 1 T cell epitopes into single peptides 20 aa long***Table 16**

20-mer peptide	Minimum sequence required for T-cell recognition		Consolidated epitope (common core underlined)		Confirmed Responder	
# Residues	Residues	Sequence	Residues/aa	Sequence	Sub-TCL	jects
23 (199-218)	(206-213)	FQNLQNHRR	10 aa	<u>FQNLQNHRR</u> IV	6	3
	(206-215)	FQNLQNHRRIV				
24 (208-227)	(213-222)	RIVQIEAKPN	13 aa	<u>RIVQIEAKPN</u> TLV	6	3
	(213-225)	RIVQIEAKPNTLV				
	(214-219)	IVQIEA				
Overlapping epitopes combined			(206-225) 20 aa	FQNLQNHRRIVQIEAKPNTLV*	12	6
40 (352-371)	(353-371)	WSTRSSENNEGIVVKVSKE	(353-371) 19 aa	WSTRSSEN <u>NEGIVVKVSKE</u> *	3	3
	(359-371)	ENNEGIVVKVSKE				
	(361-370)	NEGIVVKVSK				
46 (406-425)	(409-418)	NNTGKLFEVK	(409-425) 17 aa	<u>NNEGKLFEVK</u> PDKKNPQ	3	2
	(409-425)	NNTGKLFEVKPDKKNPQ				
	(411-418)	FGKLFEVK				
47 (415-434)	(416-427)	EVKPDKKNPQLQ	(416-427) 12 aa	<u>EVKPDKKNPQLQ</u>	2	1
Overlapping epitopes combined			(409-427) 19 aa	NNTGKLFEVKPDKKNPQLQ*	3	2
49 (433-452)	(436-445)	VEIKEGALML	(436-452) 17 aa	<u>VEIKEGALML</u> PHFNSKA*	5	2
	(436-449)	VEIKEGALMLPHFN				
	(440-452)	EGALMLPHFNSKA				
50 (442-461)	(442-458)	ALMLPHFNSKAMVIVVV	(442-458) 17 aa	<u>ALMLPHFNSKAMVIVVV</u> *	6	3
	(443-457)	LMLPHFNSKAMVIVV				
	(446-456)	PHFNSKAMVIV				
	(451-459)	KAMVIVVVN	(451-461) 11 aa	<u>KAMVIVVVN</u> KG	3	2
	(452-461)	AMVIVVVNKG				
	(453-461)	IVVVNKG				
51 (451-470)	(452-467)	AMVIVVVNKG TGNLEL	(452-470) 19 aa	<u>AMVIVVVNKG TGNLEL</u> VAV	7	4
	(452-468)	AMVIVVVNKG TGNLELV				
	(457-469)	VVNKG TGNLELVA				
	(457-470)	VVNKG TGNLELVAV				
Overlapping epitopes combined			(451-470) 20 aa	KAMVIVVVNKG TGNLELVAV*	10	6
57 (505-524)	(507-524)	GDVFIMPAAHPVAINASS	(507-524) 18 aa	GDVFIMPAAHPVAINASS*	12	4
	(509-524)	VFIMPAAHPVAINASS				
	(510-521)	FIMPAAHPVAIN				
	(511-517)	IMPAAHP				
	(511-521)	IMPAAHPVAIN				

Grey shading indicates overlapping consolidated T cell epitope pairs combined into single peptides for further analyses as outlined in the text. * Asterisks and boxes indicate the seven Ara h 1 candidate peptides proposed for a therapeutic.

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Combining overlapping Ara h 2 T cell epitopes into single peptides 20 aa long

Table 17

Dominant 20-mers		Core Epitopes		Candidate Peptides	
Residues	Sequence	Residues	Sequence	Residues	Sequence
28-47	RRCQSQLERANLRPCEQHLM	32-44	SQLERANLRPCEQ (SEQ ID NO:94)	32-47 C42S	SQLERANLRPSEQHLM (SEQ ID NO:141)
		37-47	ANLRPCEQHLM		
82-101	SQHQRCCNELNEFENNQR	91-102	ELNEFENNQR	91-107	ELNEFENNQRSMSEALQ (SEQ ID NO:142)
91-110	ELNEFENNQRSMCEALQQIM	95-107	EFENNQRSMCEALQ (SEQ ID NO:143)	C[101+103]S	
127-146	KRELRLNPQQCGLRAPQRCD	128-141	RELRLNPQQCGLRA		
				128-141 C137S	RELRLNPQQSGLRA

Ara h 1 and Ara h 2 candidate peptides summarised

There are 10 candidate peptides: 7 from Ara h 1 and 3 from Ara h 2 (Table 18)

Table 18

Peptide info	Sequence	Residues	length	HLA-restriction
Ara h 1 dominant T cell epitopes				
23+24 core	FQNLQNHRIVQIEAKPNTLV	206-225	20 aa	HLA-DR
40 core	WSTRSSENNEGVIVKVSKE	353-371	19 aa	HLA-DQ
46+47 core	NNFGKLFVVKPDKKNPQLQ	409-427	19 aa	HLA-DR
core 49	VEIKEGALMLPHFNSKA	436-452	17 aa	HLA-DQ
50 core	ALMLPHFNSKAMVIVVV	442-458	17 aa	HLA-DR
51 'core'	KAMVIVVVNKGTTGNLELVAV	451-470	20 aa	HLA-DR
57 core	GDVFIMPAAHPVAINASS	507-525	19 aa	HLA-DR or HLA-DQ
Ara h 2 dominant T cell epitopes				
4+4/5 core	SQLERANLRPSEQHLM	32-47 C42S	16 aa	HLA-DP, -DQ or DP
10+10/11 core	ELNEFENNQRSMSEALQ	91-107 C[101+103]S	17 aa	HLA-DR or -DQ
15 core	RELRLNPQQSGLRA	128-141	14 aa	HLA-DR

Also designed are 13 additional shorter peptide variants (based on single T cell epitopes) for comparison. Some sequences have been lengthened or shortened (in line with native sequences and critical residues for T cell recognition) to improve peptide properties for production and solubility. This resulted in a panel of 23 candidate peptides for comparison. Peptide details are summarised in Table 19.

All of the peptides in Table 18 were produced at 95-99.9% purity and solutions determined for solubility. T cell responses were then compared to each of these peptides at 2 doses in PBMC from 25 peanut-allergic subjects in order to select a final therapeutic combination.

Table 19

Peptide # / Info	Sequence	Residues	length	Buffer (mg/ml)	Peptide # / Info	Sequence	Residues	length	Buffer (mg/ml)
10 main candidate peptides					13 shorter variant peptides				
Ara h 1 Peptides									
1 core 23-24	FGNIQNHRIQIEAKPNTV	206-225	20 aa	2% acetic acid/H ₂ O	11 23 core	FGNIQNHRIV	206-215	10 aa	PBS
2 core 40	STRSSRNREGVIVYSKE	354-371	18 aa	PBS	12 24 core	RIVQIEAKPNTIV	213-225	13 aa	PBS
3 core 46-47	NMFGLFIVPRDKRPQIQ	409-427	19 aa	PBS	13 40 short core	ENREGVIVYSKE	359-371	13 aa	PBS
					14 46 core	NMFGLFIVPRDKRPQ	409-425	17 aa	PBS
					15 47 core	ENPRDKRPQIQ	416-427	12 aa	PBS
4 core 49	VERFGALMLPHTNSKA	436-452	17 aa	PBS					
5 cores n 50	ALMLPHTNSKAMVIVY	442-458	17 aa	1% acetic acid/PBS	16 50/51 core	KAMVIVVIVNIG (SEQ ID NO 13)	451-461	11 aa	10% acetic acid
6 cores n 51	KAMVIVVIVNIGTGNLEIVAV	451-470	20 aa	30% acetic acid/H ₂ O	17 51 core d	AMVIVVIVNIGTGNLEIV	452-468	17 aa	10% acetic acid
					18 51 core b	VVAVGIGNLEIVAVIR (SEQ ID NO 10)	457-470	14 aa	PBS
7 core 52 (extra E)	GDVFGAPPAAPVAINASSF	502-525	19 aa	0.1M NH ₄ HCO ₃	19 52 short core	VIVMPAAHIVZAINASS	509-524	16 aa	1% acetic acid/PBS
Ara h 2 Peptides									
8 24B	SGLEBANLRPSEQLIM	32-47 C125	16 aa	PBS	20 A (SEQ ID NO 13)SGLEBANLRPSEL	32-46 C125	13 aa	PBS	
					21 B (SEQ ID NO 14)AMRPSEQLIM	37-47 C125	11 aa	PBS	
9 C1D	ELINEHNQGRSMELALQ	91-107 C101+103S	17 aa	0.1M NH ₄ HCO ₃	22 C (SEQ ID NO 15)ELINEHNQGRSM	91-102 C101S	12 aa	0.1M NH ₄ HCO ₃	
					23 D (SEQ ID NO 16)ELINEHNQGRSMELALQ	94-107 C101+103S	14 aa	0.1M NH ₄ HCO ₃	
10 E	PEIRNPGQSGIIR	128-141 C125	14 aa	PBS					

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- NB Buffers: all peptides tried in PBS first; then 0.1M NH_4HCO_3 if sequence suggested preference for high pH, or 1% acetic acid for low pH; if not soluble in 1% acetic acid, increased to 2, 5, 10% etc.
- N-terminal 'W' omitted from 'peptide 2 to improve stability and ease of synthesis
- C-terminal 'E' added to 'peptide 7 to improve solubility (otherwise peptide insoluble except in toxic buffers)

Considerations for selecting final peptides

Aims:

Maximise population coverage and/or T cell reactivity whilst minimising sequence number and/or length.

Broad considerations for peptide selection:

- Comparison of T cell responses in 23-peptide screen
- Prior T cell reactivity data (for individual T cell epitopes/peptides)
- Sequence (ease of production/solubility)
- HLA-restriction (most degenerate and HLA-DQ-restricted T cell epitopes)

Considerations for selection based on data from 23-peptide screen:

- Main assessment criteria based on SI values for CD25+CFSE-low cells
- Donor responder frequency per peptide at one or both concentrations
- Compare responses to long versus short variants
- Strength/consistency of responses (i.e. those subjects who respond to both concentrations vs those who respond to just one concentration)
- Patterns of responses

Table 20 shows the analysis of PBMC T cell responses to the full set of 23 candidate peptides in 34 peanut-allergic subjects. These data show SI values for % CD25+CFSElow CD4+ T cells with peptide/unstimulated.

Data are grouped into a long and short version of each T cell epitope-containing region (see column borders; e.g. 1st 'group' = peptides 1, 23 and 24 [Pep 1 combines overlapping peps 23 and 24 which each contain a separate T cell epitope]). The summary at the bottom of each group comments on the optimal peptide selected from that group. (Data show SI values for % CD25+CFSElow CD4+ T cells with peptide/unstimulated).

Data are sorted by descending value for 50 μg sample of long version for each peptide 'group' (or 10 μg sample where responses are better to this dose). Each row within in a peptide group shows data for a single subject, but the order of subjects varies in each peptide group.

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[illegible]

Table 20 (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
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code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
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code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
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code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42	code 43-44	code 45-46	code 47-48	code 49-50	code 51-52	code 53-54	code 55-56	code 57-58	code 59-60	code 61-62	code 63-64	code 65-66	code 67-68	code 69-70	code 71-72	code 73-74	code 75-76	code 77-78	code 79-80	code 81-82	code 83-84	code 85-86	code 87-88	code 89-90	code 91-92	code 93-94	code 95-96	code 97-98	code 99-100	
code 23-24	code 25-26	code 27-28	code 29-30	code 31-32	code 33-34	code 35-36	code 37-38	code 39-40	code 41-42																														

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Summary of responses to 23-peptide panel in cohort of 34

The data indicate that the selected 7 peptides are the best combination, but boxes indicate groups containing other viable peptides as substitutions (or additions) to the current pool:

For example:

- 1) Peptide 3 could replace peptide 15
- 2) Peptide 8 could replace peptide 21
- 3) Peptide 9 could replace peptide 23

Peptides Recognised	New pool 7b																		Control																					
	Avg h1 peptides									Avg h2 peptides									Avg h1 peptides									Avg h2 peptides												
	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
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2	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
3	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
4	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
5	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
6	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
7	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
8	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
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25	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
26	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
27	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
28	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
29	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
30	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
31	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
32	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
33	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
34	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
35	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
36	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
37	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
38	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
39	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
40	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
41	100	95	93	87	82	75	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	82	87	93	95	100	100	95	93	87	82	75	70	60	50	40	30	20	10	0
42	100	95	93	87																																				

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Summary of responses to each peptide of 7-peptide mix in cohort of 39

- All recognised 1 or more peptides
- 13/39 (33%) recognise 100% of peptides
- 21/39 (54%) recognise >85% (6 or more) peptides
- 31/39 (79%) recognise >70% (5 or more) peptides
- Each peptide recognised by at least 25/39 subjects (64%)

Of the 74 subjects tested, all reacted to at least 1 peptide of the 7 selected peptides.

*Responses to different peptide pools***Table 23**

Peptide #	Core	Pool 1	Pool 2	Pool 3	Pool 4	Pool 5	Pool 7a	Pool 7b	Diluent
1	23-24	x		x			x	x	2% acid
2	40	x		x			x	x	PBS
3	46+47	x		x	x				PBS
4	49	x		x	x		x	x	PBS
5	50	x		x	x				1% acid
6	51	x		x					10% acid
7	57	x		x					0.1M
8	A+B		x	x					PBS
9	C+D		x	x					0.1M
10	E		x	x		x	x		PBS
11	23				x				PBS
12	24				x				PBS
13	40 short				x				PBS
14	46								PBS
15	47						x	x	PBS
16	50/51								10% acid
17	51a								10% acid
18	51b				x				PBS
19	57 short				x		x	x	1% acid
20	A					x			PBS
21	B					x	x	x	PBS
22	C					x			0.1M
23	D					x	x	x	0.1M

NB: Table 19 provides the sequences for each of peptides 1-23.

Pool 1 = 7 x original Ara h 1 'candidates'

Pool 2 = 3 x original Ara h 2 'candidates'

Pool 3 = 10 x mix of above 2 pools (Ara h 1 & 2)

Pool 4 = 3 x Ara h 1 'candidates' + 5 x shorter variants (*equivalent Ara h 1 sequence coverage to pool 1*)

Pool 5 = 5 x shorter (single epitope) variants of Ara h 2 candidates (*equivalent Ara h 2 sequence coverage to pool 2*)

Table 24: Refined peptide pool

Peptide Vax						
Original name	#	HLA	Sequence	Residues	aa	Notes
Cores 23+24	1	DR	FQNLQNHRIVQIEAKPNTLV	Ara h 1 [206-225]	20	Contains 2 major Ara h 1 epitopes Present in Ara h 1 T cell patent
Core 40	2	DQ	STRSSENNEGVIVKVSKE	Ara h 1 [354-371]	18	*key sequence flagged in Ara h 1 patent, but one residue shorter to facilitate stability; contains one major Ara h 1 T cell epitope
Core 47	15	DR	EVKPKDKNPQLQ	Ara h 1 [416-427]	12	Shortened version of a candidate peptide in Ara h 1 patent; contains 1 Ara h 1 T cell epitope Induced equivalent T cell responses to longer version containing an additional T cell epitope in screen of 25 new subjects
Core 49	4	DR/DQ	VEIKEGALMLPHENSKA	Ara h 1 [436-452]	17	*key sequence flagged in Ara h 1 patent
Core 57 (short)	19	DR/DQ	VFIMPAAHPVAINASS	Ara h 1 [509-524]	16	*shortened version of key sequence flagged in Ara h 1 patent; Easier to produce and more soluble Induced equivalent T cell responses to longer version containing an additional epitope in screen of 25 new subjects
B	21	DR/DQ	ANLRPSEQHLM	Ara h 2 [37-47] C42S	11	Induced equivalent T cell responses to longer version containing an additional T cell epitope in screen of 25 new subjects

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D	23	DQ	EFENNQRSMSEALQ	Ara h 2 [94-107] C[101+103]S	14	Induced equivalent T cell responses to longer version containing an additional T cell epitope in screen of 25 new subjects; One residue longer than core T cell epitope reported in Ara h 2 paper.
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Pool 7a = 5 x Ara h 1 + 3 x Ara h 2 for 'refined' pool (same as final pool but with additional Ara h 2 T cell epitope)

Pool 7b = 5 x Ara h 1 + 3 x Ara h 2 for 'refined' pool of 7

Basophil responses to 7-peptide pool (Pool 7b)

Basophil reactivity data was collected from 14 peanut-allergic subjects following incubation with peanut (CPE) or the 7-peptide pool (pool 7b) over a 3-4 log concentration range (g/ml)(Figure 2). In these subjects, basophil activation and histamine release was induced by whole peanut and positive controls, but not by the 7-peptide mixture.

Prior to selection of pools 7a and 7b. Pools 7a and 7b were subsequently designed and tested.

PBMC T cell responses were compared to whole peanut and peptide pools 1-5 of Table 23. (Figures 12 and 13). In relation to pools 1-5, none of the pools were able to induce a positive T cell response in all subjects tested. Nearly all responses were considerably lower to the peptide pool than to whole peanut (at the concentrations tested) and only one subject of each of pools 2, 3 and 4 showed a greater or equal response to the peptides as to whole peanut. In relation to pools 7a and 7b, 100% response was described to pools 7a and 7b (SI > 1.5). Pools 7a and 7b induced comparable or greater responses to whole peanut in many subjects 6/30 = 100 CPE response, 6/30 = 50-80% of CPE response.

When comparing PBMC T cell responses to the 7-peptide pool (Figure 14), there was no significant difference between pools 7a and 7b (comparing paired data; n = 15 per group; no advantage adding 3rd Ara h 2 peptide). There was still no significant difference when comparing full data set for pool 7b (n=30) with cohort for pool 7a using non-paired Mann Whitney test for non-parametric data; p = 0.9).

In summary, pools 7a and 7b were both significantly better than the other 5 pools tested. There was no significant difference in pool 7a over pool 7b. Pool 7b was recognised by 100% of subjects tested and induced comparable or greater PBMC T cell responses than peanut in over 33% of subjects. Pools 1-5 were not recognised by 100% of subjects and very rarely induced responses equal to whole peanut.

TABLE 25: More detailed summary of steps and data

Approach	Results
1) Identification of dominant T cell epitopes of major peanut allergens Ara h 1 and Ara h 2	
Isolated CD4+ T cells specific for Ara h 1 or Ara h 2 from PBMC of peanut-allergic subjects	145 Ara h 1-specific T cell lines (TCL) (18 subjects) 69 Ara h 2-specific TCL (16 subjects) Total = 214 TCL from 20 subjects
Determined specificity to overlapping 20-mer peptides spanning whole Ara h 1 or 2 sequence & selected dominant 20-mers	9 (of 69) dominant Ara h 1 20-mers 4 (of 17) dominant Ara h 2 20-mers
Confirmed dominant 20-mers could target PBMC T cells in peanut-allergic subjects (CFSE screens)	1 Ara h 1 20-mer detected in 17/19 1 Ara h 2 20-mer detected in 6/6
Assessed total frequency of responders (combined data from TCL data and CFSE screens)	1 dominant Ara h 1 20-mer recognised by 43/45. 1 dominant Ara h 2 20-mer recognised by 16/16
Mapped core T cell epitope sequences within dominant 20-mers	10 dominant Ara h 1 core T cell epitopes 5 dominant Ara h 2 core T cell epitopes
2) Determining HLA-restriction of core T cell epitopes	
Blocked T cell epitope presentation to specific TCL using anti-HLA antibodies HLA-genotyped subjects used for TCL generation	Ara h 1 T cell epitopes HLA-DR &/or -DQ restricted Ara h 2 T cell epitopes HLA-DR, -DQ &/or -DP restricted. All T cell epitopes presented by 1 HLA-molecule
Assessed HLA-binding degeneracy with algorithms	Strong & degenerate binding motifs in all T cell epitopes
3) Design of therapeutic candidate peptides	
Replaced cysteine residues with serine residues	All serine variants still T cell reactive

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Combined overlapping T cell epitopes into peptides 20 aa long Designed shorter variants with single T cell epitopes	7 candidate Ara h 1 peptides (Prickett et al 2013) 3 candidate Ara h 2 peptides (Prickett et al 2011) 13 shorter variants of above candidate peptides
Synthesised all 23 peptides to GLP-grade purity. Determined suitable solutions for solubility.	All peptides obtained at 95-99.9% purity 22/23 peptides soluble in PBS, 0.1M NH ₄ HCO ₃ , or 1-2% acetic acid (1 insoluble peptide redesigned and new version now soluble; peptide 7 in Table 18)
4) Selection and testing of final therapeutic mixture	
Compared PBMC T cell reactivity to all 23 peptides (2 doses) in new peanut-allergic cohort	34 subjects screened with all 23 peptides Optimal peptide combinations determined
Peptides selected for final therapeutic (considered T cell responses, peptide properties, responder frequency, HLA-restriction, patents)	7 peptides selected (5xAra h 1 and 2xAra h 2) Presented on HLA-DR (5/7) and/or HLA-DQ (5/7) 1-7 of peptides recognised by 56/56 donors
Assessed PBMC T cell response to 7-peptide mix at 2 therapeutic doses in peanut-allergic cohort	T cell response seen in 24/25 subjects (often comparable or greater than response to peanut)

EXAMPLE 3*Ara h 2 peptide-induced T cell anergy in an Ara h 2 epitope specific TCC (Figure 15)*

T cells (1×10^6 /ml) of an Ara h 2 peptide specific human T cell clone were cultured for 16 hours in the presence of Ara h 2 peptide (ANLRPSEQHLM (SEQ ID NO:31; hatched) at 100 µg/ml in the absence of accessory cells or in complete medium* alone (No Ag). The T cells were then washed thoroughly and rechallenged (10^4 /well) with complete medium alone, IL-2 50U/ml or an immunogenic concentration of the Ara h 2 peptide (10 µg/ml) in the presence of irradiated autologous PBMC (10^5 /well) as accessory cells. Proliferation as correlated with tritiated thymidine incorporation was determined at 72 hours. Results are expressed as mean cpm +SD for triplicate cultures. *Complete medium: RPMI + 5% AB serum + Pen/Strep/L-glutamine + 10U/mL of IL-2.

Ara h 1 peptide-induced anergy in an Ara h 1 epitope-specific TCC (Figure 16)

T cells (1×10^6 /ml) of an Ara h 1 peptide specific human T cell clone were cultured for 16 hours in the presence of Ara h 1 peptide (STRSSENNEGIVKVSKE (SEQ ID NO:12; hatched) or an irrelevant Bahia grass Pas n 1 peptide (stippled) at 100 µg/ml in the absence of accessory cells

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or in complete medium* alone (No Ag). The T cells were then washed thoroughly and rechallenged (10^4 /well) with complete medium alone, IL-2 50U/ml or an immunogenic concentration of the Ara h I peptide (10 μ g/ml) in the presence of irradiated autologous PBMC (10^5 /well) as accessory cells. Proliferation as correlated with tritiated thymidine incorporation was determined at 72 hours. Results are expressed as mean cpm for triplicate cultures. *Complete medium: RPMI + 5% AB serum + Pen/Strep/L-glutamine + 10U/mL of IL-2.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations of any two or more of said steps or features.

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CLAIMS:

1. An immunomodulatory composition comprising peptides, which peptides comprise at least five of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) NEGVIVKVXK (SEQ ID NO:3)
- (iv) EVKPDKKNPQLQ (SEQ ID NO:4)
- (v) EGALML (SEQ ID NO:5)
- (vi) IMPAAHP (SEQ ID NO:6)
- (vii) LRPXEQHLM (SEQ ID NO:7); and
- (viii) ENNQRXMXEA (SEQ ID NO:8)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine and said composition comprises at least one epitopic region selected from SEQ ID NOS:1-6 and at least one epitopic region selected from SEQ ID NOS:7-8,

wherein the composition does not contain the combination of an amino acid sequence ALMLPHFNSKAMVIVVV (SEQ ID NO:34) and an amino acid sequence KAMVIVVVNKG TG NLELVAV (SEQ ID NO:42).

2. The composition according to claim 1, wherein the composition contains a peptide having the amino acid sequence ALMLPHFNSKAMVIVVV (SEQ ID NO:34) and does not contain a peptide having the amino acid sequence KAMVIVVVNKG TG NLELVAV (SEQ ID NO:42).

3. The composition according to claim 1, wherein the composition contains a peptide having the amino acid sequence KAMVIVVVNKG TG NLELVAV (SEQ ID NO:42) and does not contain a peptide having the amino acid sequence ALMLPHFNSKAMVIVVV (SEQ ID NO:34).

4. The composition according to any one of claims 1 to 3, wherein the epitopic region LRPXEQHLM is LRPSEQHLM (SEQ ID NO: 137).

5. The composition according to any one of claims 1 to 4, wherein the epitopic region ENNQRXMXEA is ENNQ RSMSEA (SEQ ID NO: 138).

6. The composition according to any one of claims 1 to 5, wherein said composition comprises at least 6 of said epitopic regions.

7. The composition according to any one of claims 1 to 5, wherein said composition comprises at least 7 epitopic regions.

8. The composition according to any one of claims 1 to 5, wherein said composition comprises each of said 8 epitopic regions.

9. The composition according to any one of claims 1 to 8, wherein said composition comprises one or more peptides, each of which peptides is up to 60 contiguous amino acids in length and which peptides include one or more of the Ara h 1 and Ara h 2 T cell epitopic regions defined by SEQ ID NOS:1-8.

10. The composition according to any one of claims 1 to 9, wherein said composition comprises Ara h 1 and Ara h 2 T cell peptides selected from the list consisting of:

- (i) FQNLQNHHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGIVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPXEQHLM (SEQ ID NO:15)
- (vii) EFENNQRXMXEALQ (SEQ ID NO:16)
- (viii) NNFGKLFVVKPDKKNPQLQ (SEQ ID NO:17)
- (ix) GDVFIMPAAHPVAINASSE (SEQ ID NO:18)
- (x) SQLERANLRPXEQHLM (SEQ ID NO:19)
- (xi) ELNEFENNQRXMXEALQ (SEQ ID NO:20)
- (xii) FQNLQNHHRIV (SEQ ID NO:21)
- (xiii) RIVQIEAKPNTLV (SEQ ID NO:22)
- (xiv) ENNEGIVIVKVSKE (SEQ ID NO:23)
- (xv) EVKPDKKNPQLQD (SEQ ID NO:24)
- (xvi) EFENNQRXMXEALQQI (SEQ ID NO:25)
- (xvii) NNFGKLFVVKPDKKNPQLQD (SEQ ID NO:26)
- (xviii) ELNEFENNQRXMXEALQQI (SEQ ID NO:27)
- (xx) WSTRSSENNEGIVIVKVSKE (SEQ ID NO:28); and
- (xxi) GDVFIMPAAHPVAINASS (SEQ ID NO:29)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

11. The composition according to claim 10, wherein said residue X is serine.

12. The composition according to claim 10, wherein said composition comprises Ara h 1 and Ara h 2 T cell peptides selected from the list consisting of:

- (i) FQNLQNHHRIVQIEAKPNTLV (SEQ ID NO:11)
- (ii) STRSSENNEGIVIVKVSKE (SEQ ID NO:12)
- (iii) EVKPDKKNPQLQ (SEQ ID NO:4)
- (iv) VEIKEGALMLPHFNSKA (SEQ ID NO:13)
- (v) VFIMPAAHPVAINASS (SEQ ID NO:14)
- (vi) ANLRPSEQHLM (SEQ ID NO:31)
- (vii) EFENNQRSMSEALQ (SEQ ID NO:32)
- (viii) EVKPDKKNPQLQD (SEQ ID NO:24); and
- (ix) EFENNQRSMSEALQQI (SEQ ID NO:33)

or functional derivative or homologue thereof.

13. The composition according to claim 12, wherein said composition comprises each of the

Ara h 1 and Ara h 2 T cell peptides selected from the list consisting of:

- (i) FQNLQNHRIVQIEAKPNTLV (SEQ ID NO:11);
- (ii) EVKPKDKKNPQLQ (SEQ ID NO:4);
- (iii) VEIKEGALMLPHFNSKA (SEQ ID NO:13);
- (iv) VFIMPAAHPVAINASS (SEQ ID NO:14);
- (v) ANLRPSEQHLM (SEQ ID NO:31);
- (vi) EFENNQRSMSEALQ (SEQ ID NO:32); and
- (vii) RELRNLPQQXGLRA (SEQ ID NO:43)

or functional derivatives or homologues thereof, wherein residue X is cysteine or serine.

14. The composition according to any one of claims 1 to 13, wherein said peptides are capable of reducing Ara h 1 and/or Ara h 2 hypersensitivity or hypersensitivity to a composition comprising Ara h 1 and/or Ara h 2 when administered to a subject having a condition characterised by said hypersensitivity.

15. The composition according to any one of claims 1 to 14, said composition additionally including one or more peptides selected from the list consisting of:

- (i) NNFGKLFEVKPKDKKNPQ (SEQ ID NO:35)
- (ii) SQLERANLRPXEQ (SEQ ID NO:36)
- (iii) ELNEFENNQRXM (SEQ ID NO:37)
- (iv) NNFGKLFEVKPKDKKNPQLQD (SEQ ID NO:38)
- (v) NNFGKLFEVKPKDKKNPQL (SEQ ID NO:40); and
- (vi) SQLERANLRPXEQH (SEQ ID NO:41)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine.

16. A composition comprising one or more nucleic acid molecules encoding, or complementary to a sequence encoding the at least five Ara h 1 and Ara h 2 T cell epitopic regions or peptides comprising the at least five Ara h 1 and Ara h 2 T cell epitopic regions according to any one of claims 1 to 13 or 15, wherein the one or more nucleic acid molecules comprises a sequence encoding an epitopic region selected from LRPSEQHLM (SEQ ID NO: 137) or ENNQRSMSEA (SEQ ID NO:138).

17. A vector comprising one or more nucleic acid molecules encoding, or complementary to a sequence encoding the at least five Ara h 1 and Ara h 2 T cell epitopic regions or peptides comprising the at least five Ara h 1 and Ara h 2 T cell epitopic regions according to any one of claims 1 to 13 or 16.

18. A method for the treatment and/or prophylaxis of a condition in a subject, which condition is characterised by the aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2 or an allergen in a composition comprising Ara h 1 and/or Ara h 2, said method comprising administering to said subject an effective amount of an immunomodulatory composition according to any one of claims 1 to 16, or the vector according to claim 17, for a time

and under conditions sufficient to remove or reduce the presence or function in said subject of T cells directed to said Ara h 1 and/or Ara h 2 or other allergen.

19. Use of an immunomodulatory composition according to any one of claims 1 to 16, or the vector according to claim 17, in the manufacture of a medicament for the treatment of a condition in a subject, which condition is characterised by an aberrant, unwanted or otherwise inappropriate immune response to Ara h 1 and/or Ara h 2.

20. The method or use according to claim 18 or 19, wherein condition is hypersensitivity to peanuts or tree nuts which contain Ara h 1 and Ara h 2 or Ara h 1-like or Ara h 2-like molecules.

21. The method or use according to claim 20, wherein said nuts are hazelnuts, almonds or brazil nuts.

22. The method or use according to any one of claims 18 to 21, wherein said method or use desensitises or induces immunological tolerance to Ara h 1 and/or Ara h 2 or other allergen of said composition.

23. The method or use according to claim 22, wherein said desensitization or tolerance is achieved by inducing T cell anergy or apoptosis.

24. The method or use according to claim 22, wherein said desensitisation or tolerance is achieved by inducing Ara h 1 or Ara h 2-specific Treg cells.

25. The method according to any one of claims 18 or 20 to 24, wherein said composition is administered intradermally or transdermally.

26. The method or use according to any one of claims 18 to 25, wherein said subject is a human.

27. An immunomodulatory composition comprising peptides, which peptides consist of at least five of the Ara h 1 and Ara h 2 T cell epitopic regions from the list consisting of:

- (i) FQNLQNHR (SEQ ID NO:1)
- (ii) IVQIEA (SEQ ID NO:2)
- (iii) EVKPKDKKNPQLQ (SEQ ID NO:4)
- (iv) EGALML (SEQ ID NO:5)
- (v) IMPAAHP (SEQ ID NO:6)
- (vi) LRPXEQHLM (SEQ ID NO:7);
- (vii) ENNQRXMXEA (SEQ ID NO:8);
- (viii) RELRNLPQQXGLRA (SEQ ID NO:43)

or functional derivatives or homologues thereof wherein residue X is cysteine or serine and which peptides consist of at least one epitopic region selected from SEQ ID NOS:1-6 and at least one epitopic region selected from SEQ ID NOS:7-8,

wherein the composition does not contain the combination of an amino acid sequence

ALMLPHFNSKAMVIVVV (SEQ ID NO:34) and an amino acid sequence

KAMVIVVVNKG TGNLELVAV (SEQ ID NO:42),

wherein the peptides comprising the epitopic region of FQNLQNHR (SEQ ID NO:1) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 1, 11, 21 and 47;
 wherein the peptides comprising the epitopic region of IVQIEA (SEQ ID NO:2) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 2, 11, 22 and 48;
 wherein the peptides comprising the epitopic region of EVKPDKKNPQLQ (SEQ ID NO:4) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 4, 17, 24, 26, 34, 38 and 51;

wherein the peptides comprising the epitopic region of EGALML (SEQ ID NO:5) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 5, 13 and 52;
 wherein the peptides comprising the epitopic region of IMPAAHP (SEQ ID NO:6) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 6, 14, 18, 29 and 55;

wherein the peptides comprising the epitopic region of LRPXEQHLM (SEQ ID NO:7) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 7, 15, 19, 31, 56, 57, 122 and 137;

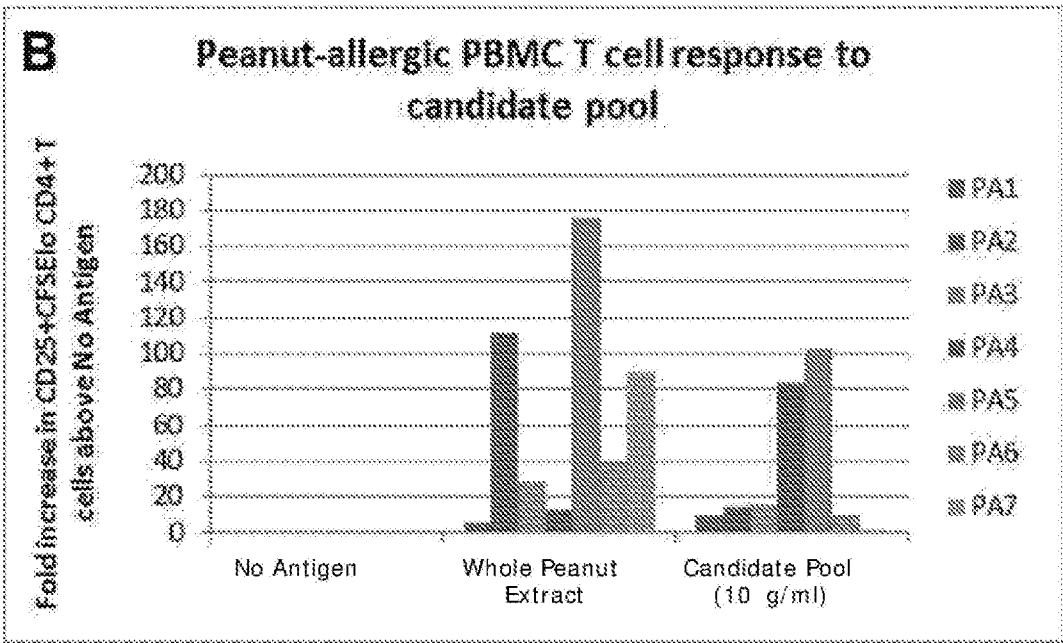
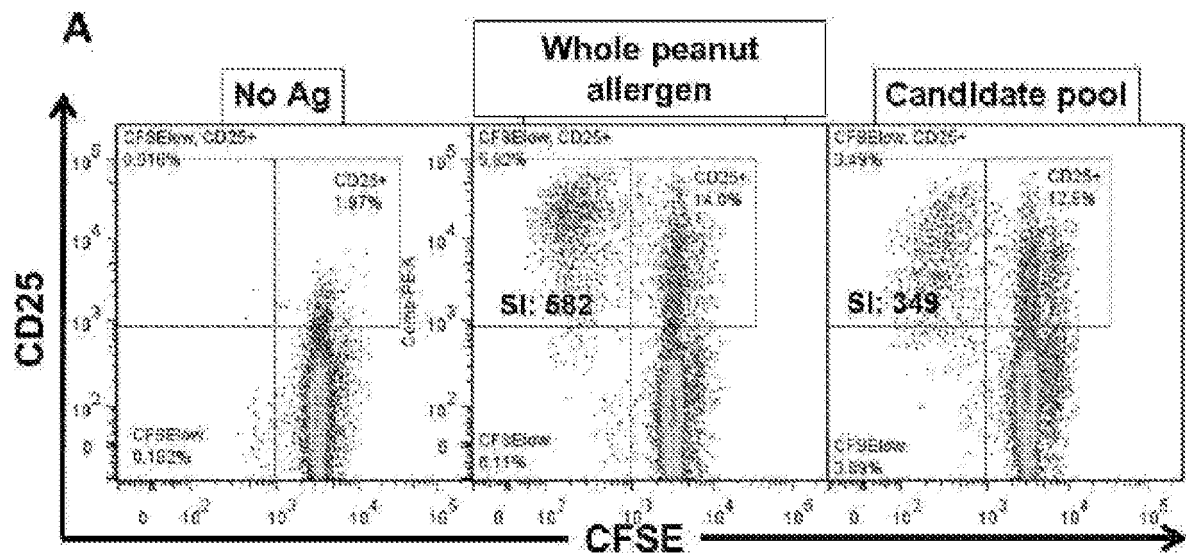
wherein the peptides comprising the epitopic region of ENNQRXMXEA (SEQ ID NO:8) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 8, 16, 20, 25, 27, 32, 33, 58, 123 and 138; and

wherein the peptides comprising the epitopic region of RELRNLPQQXGLRA (SEQ ID NO:43) comprise an amino acid sequence selected from the group consisting of SEQ ID NO: 59 or 124.

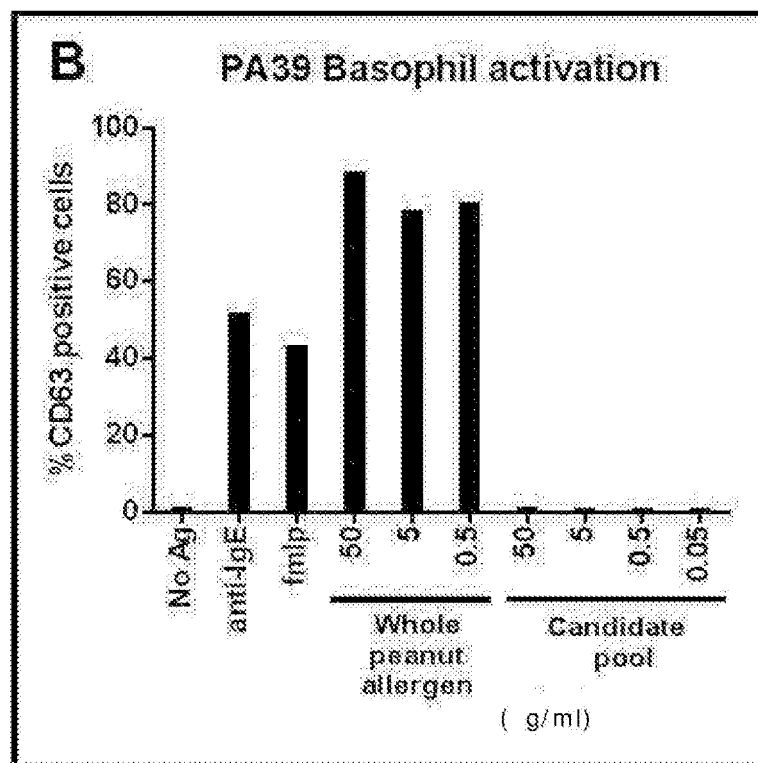
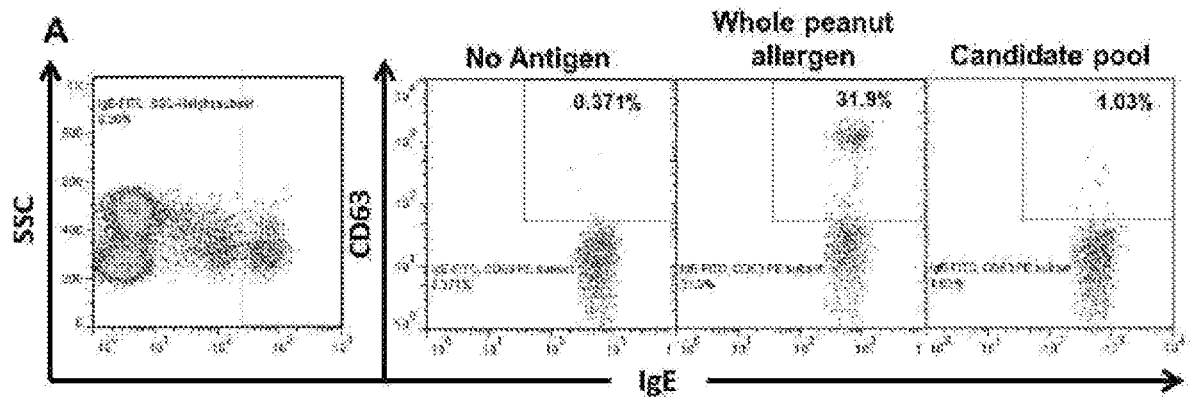
28. The composition according to claim 27, wherein the composition contains a peptide having the amino acid sequence ALMLPHFNSKAMVIVVV (SEQ ID NO:34) and does not contain a peptide having the amino acid sequence KAMVIVVVNKG TGNLELVAV (SEQ ID NO:42).

29. The composition according to claim 27, wherein the composition contains a peptide having the amino acid sequence KAMVIVVVNKG TGNLELVAV (SEQ ID NO:42) and does not contain a peptide having the amino acid sequence ALMLPHFNSKAMVIVVV (SEQ ID NO:34).

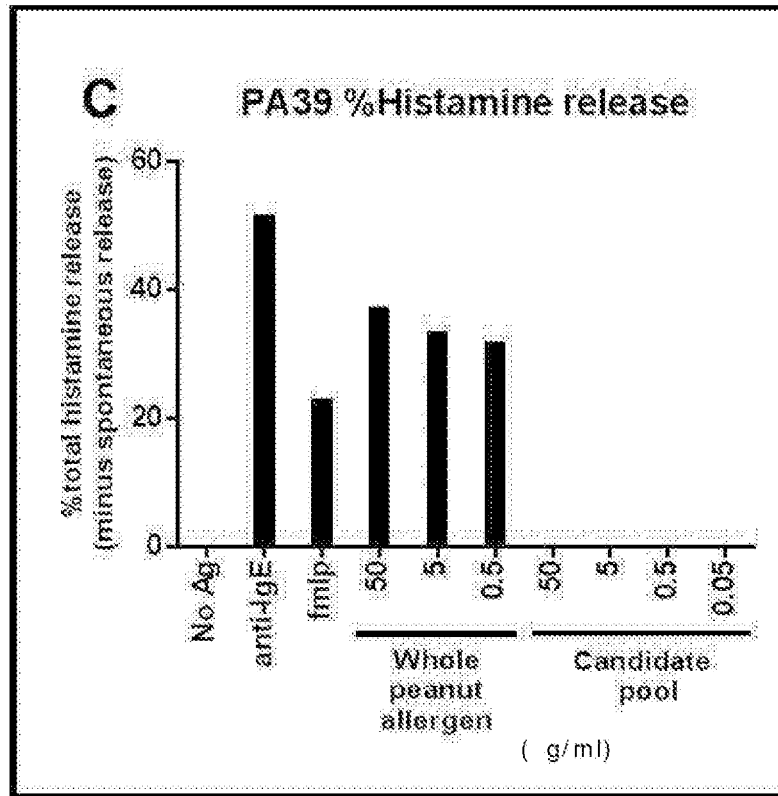
FIGURE 1



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FIGURE 2

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**FIGURE 2 (continued)**

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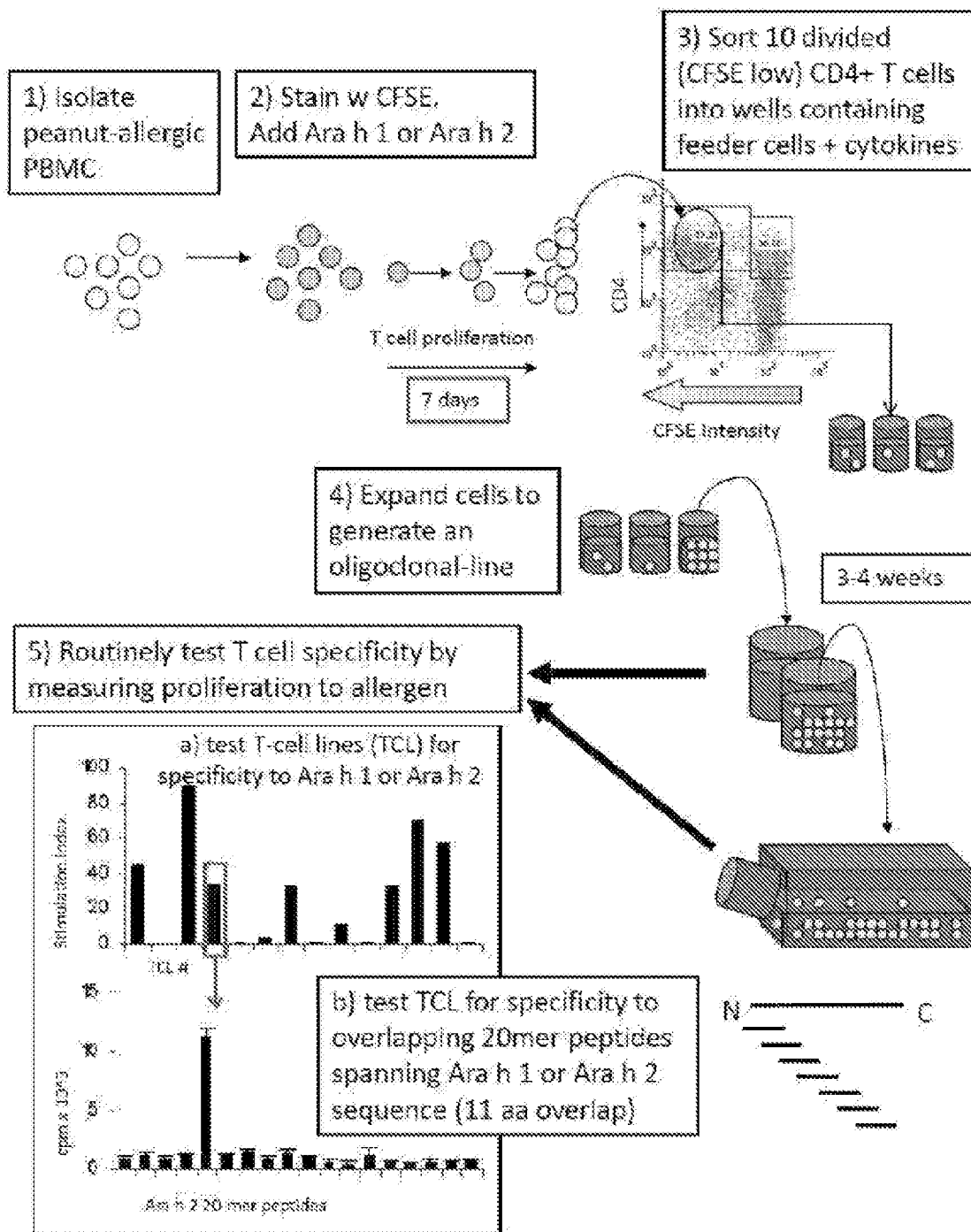
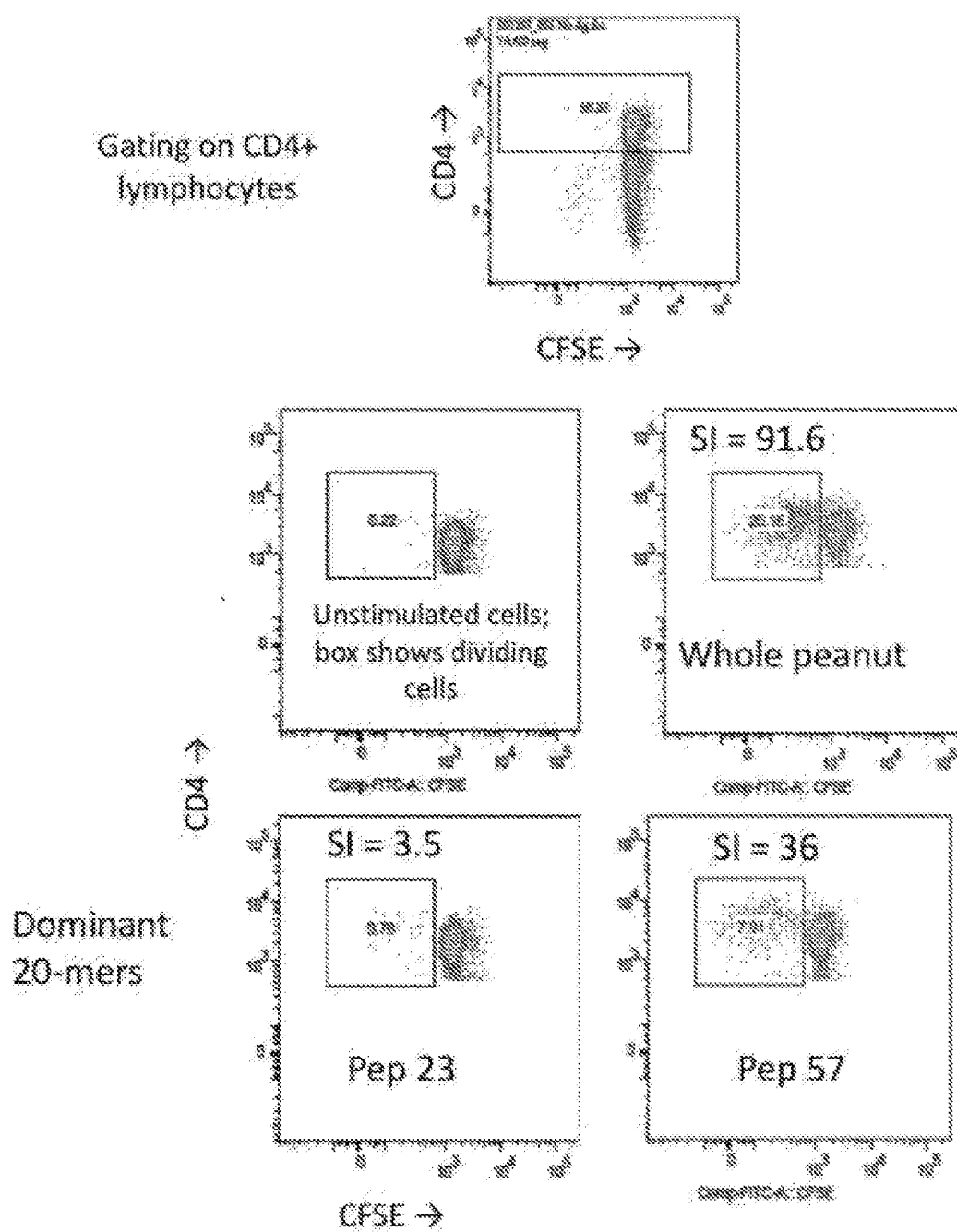
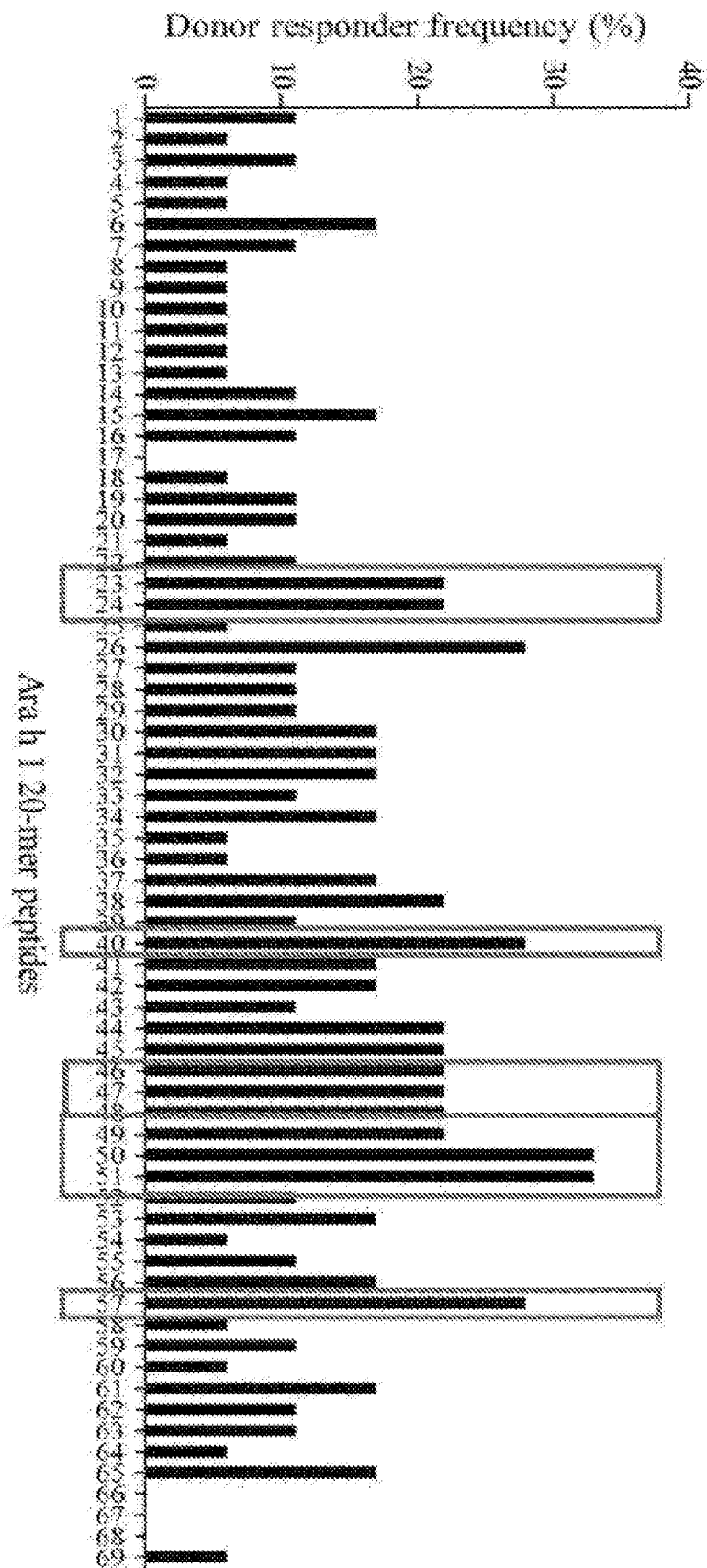
FIGURE 3

FIGURE 4



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FIGURE 5

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FIGURE 6

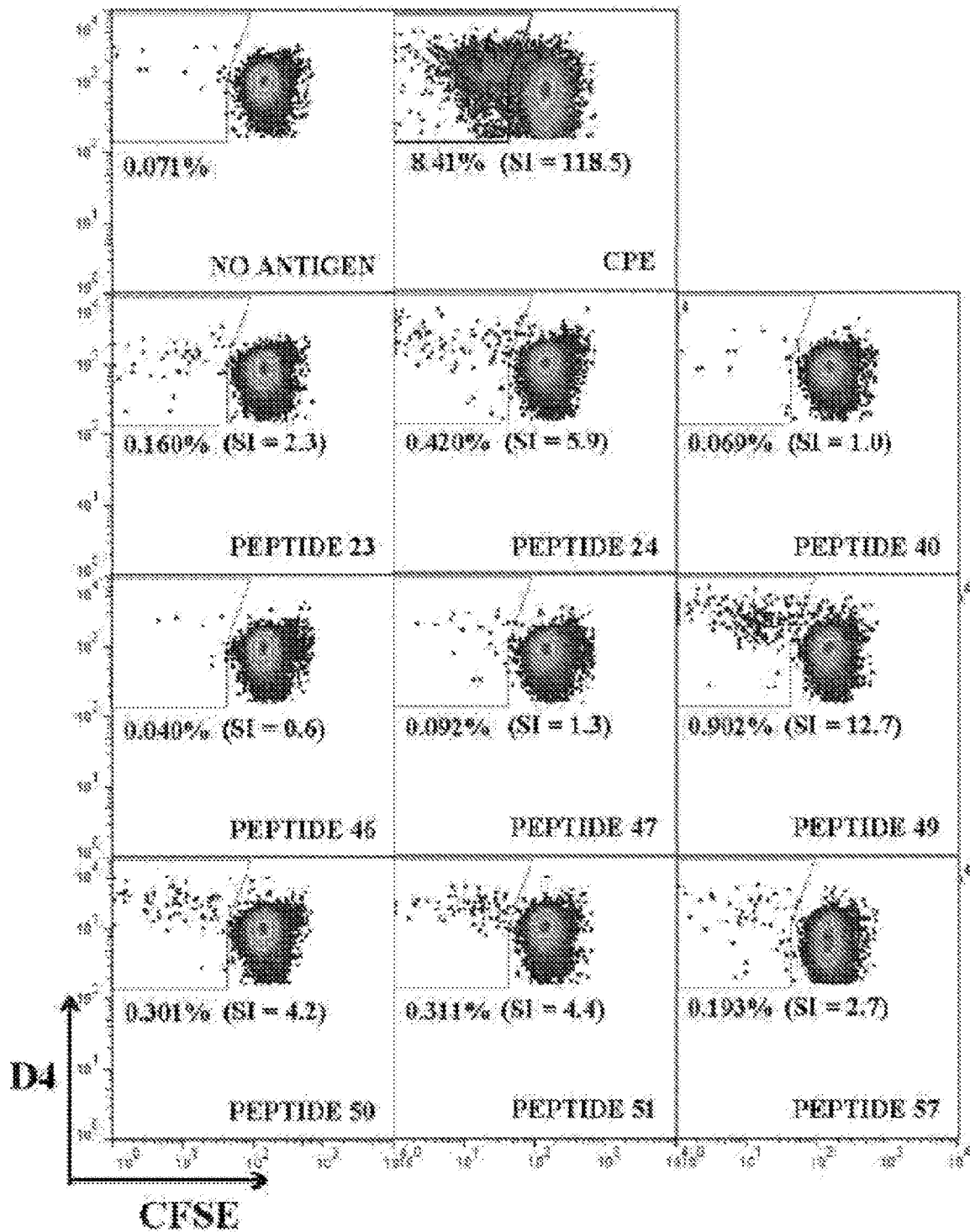
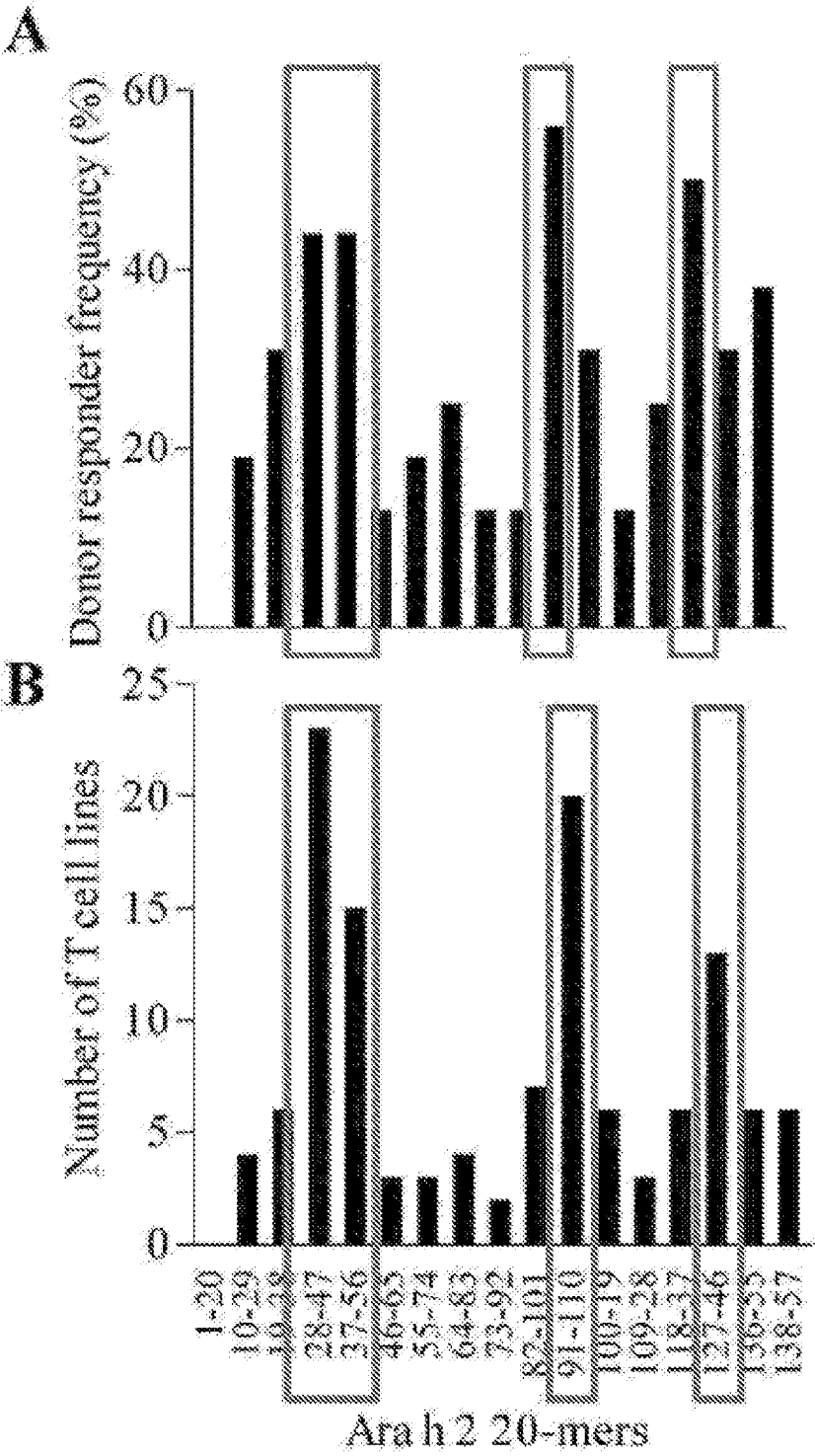
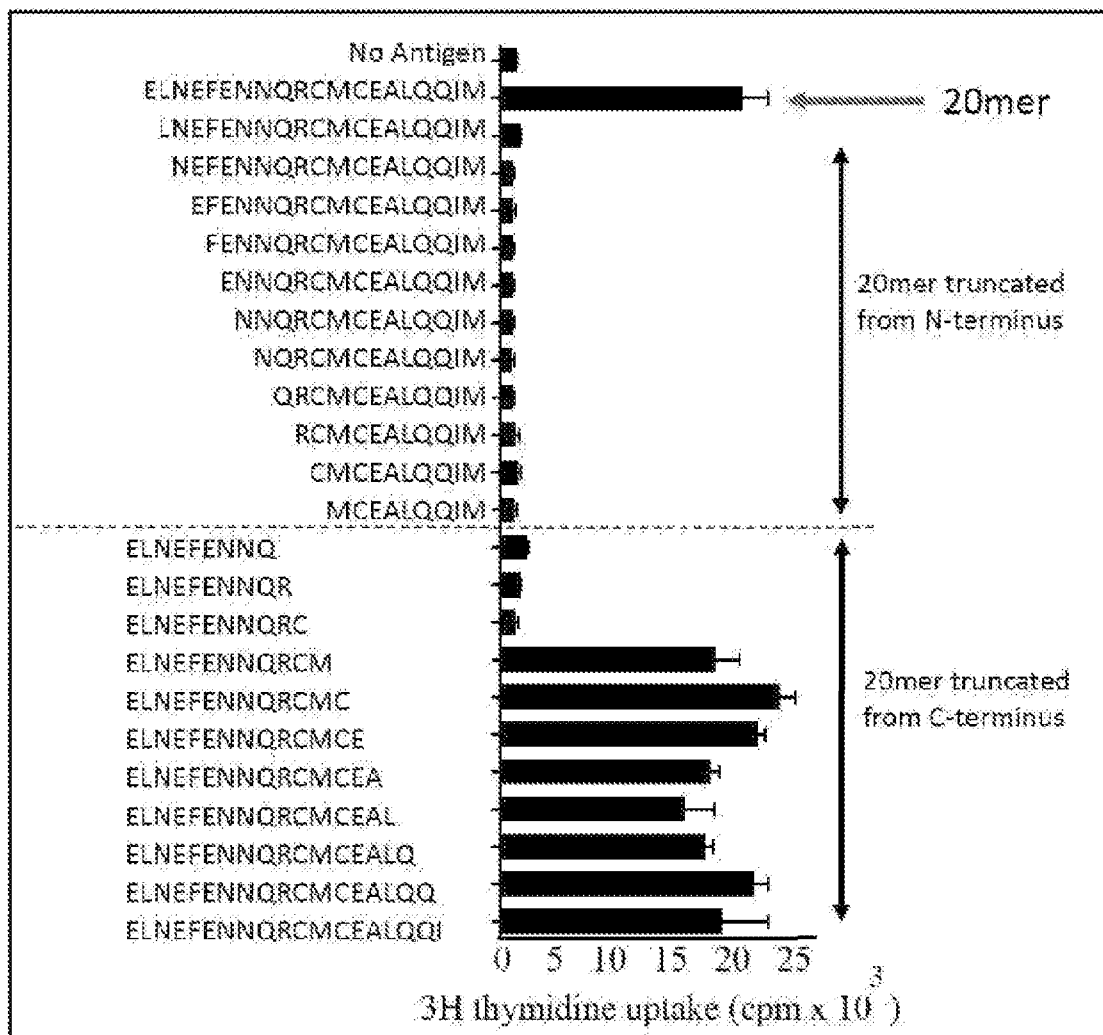


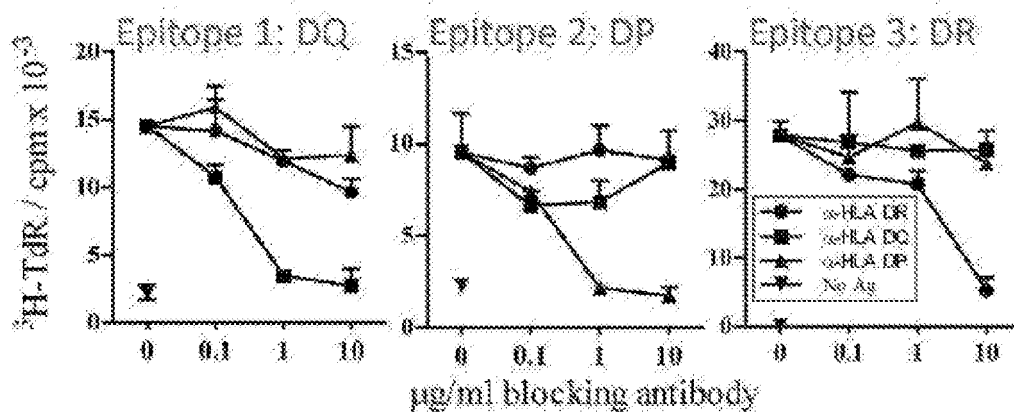
FIGURE 7



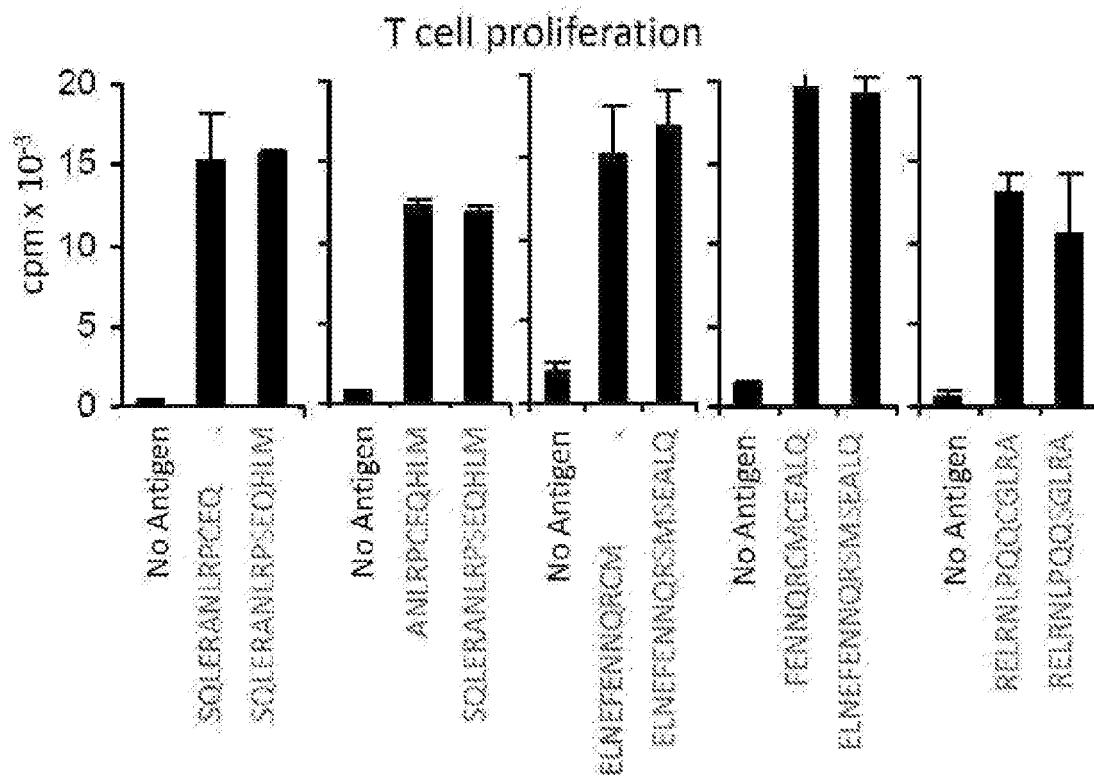
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FIGURE 8

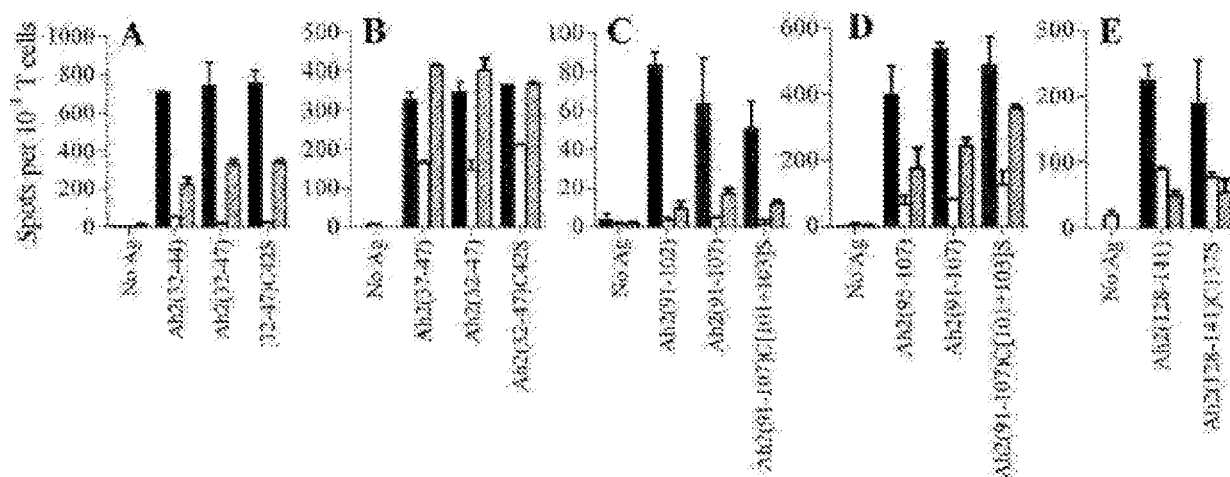
Core Epitope:

ELNEFENNQRCMCEALQQIM**FIGURE 9**

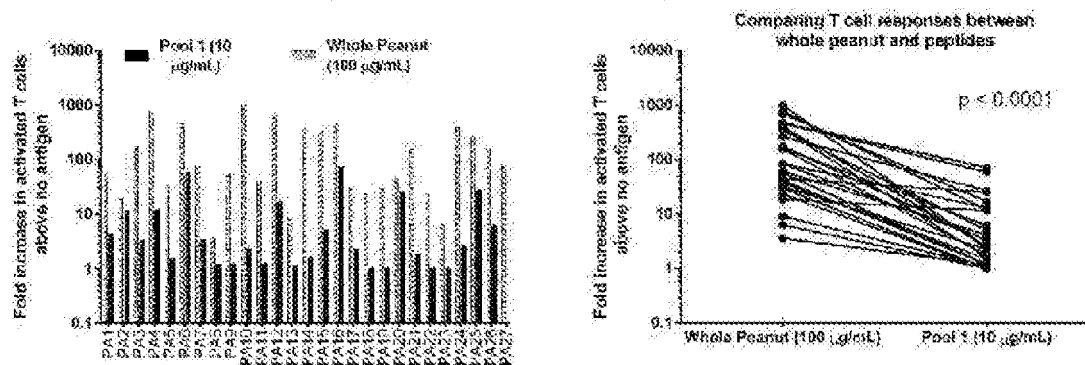
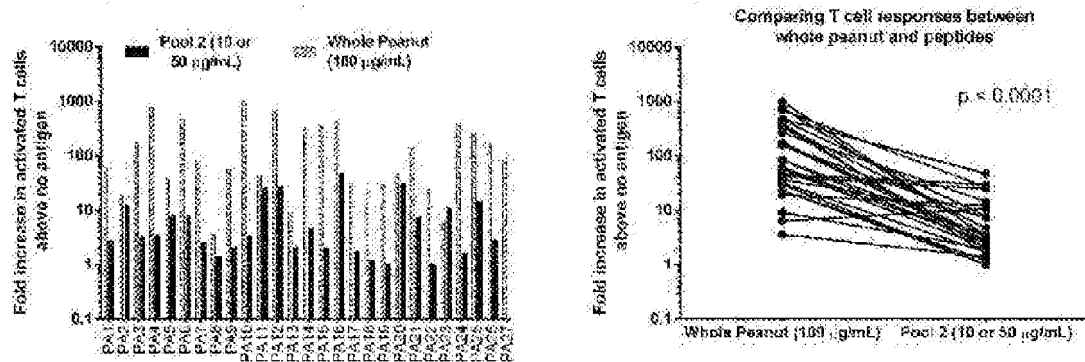
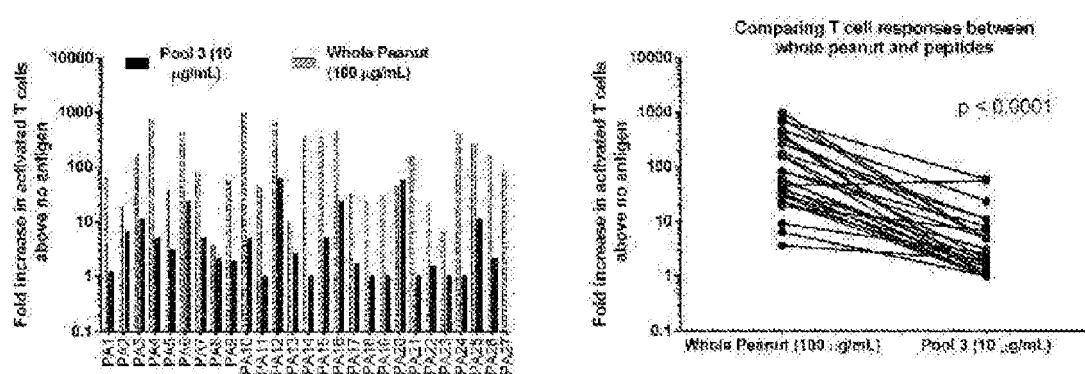
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FIGURE 10**FIGURE 11**

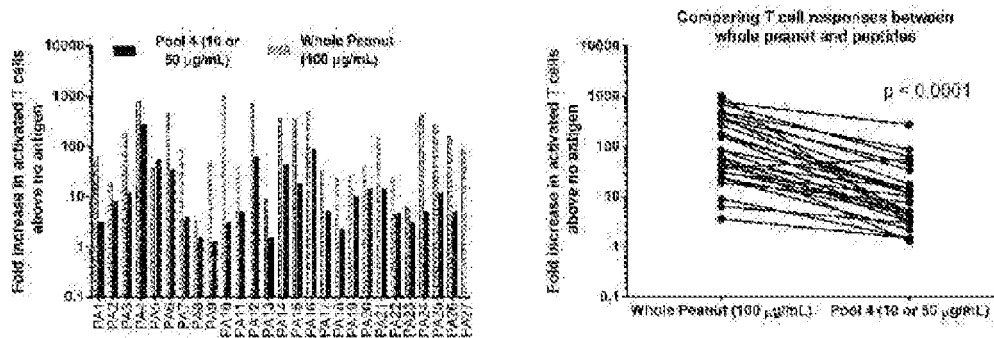
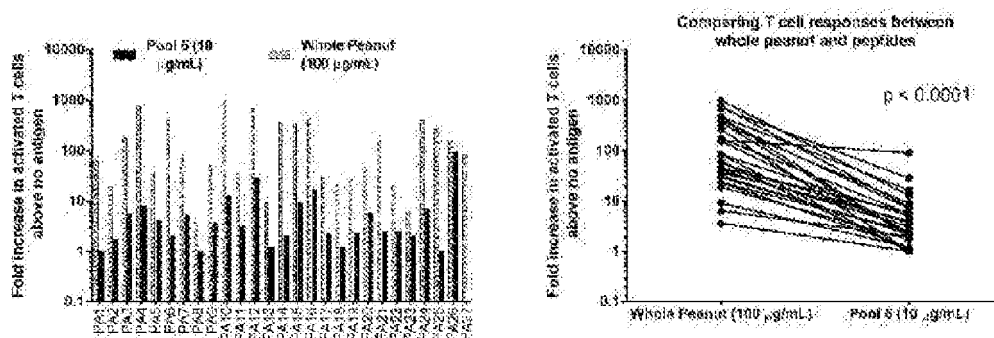
T cell cytokine production



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FIGURE 12**1) Pool 1 (7 x Ara h 1 'long' candidates; all Ara h 1 epitopes)****2) Pool 2 (3 x Ara h 2 'long' candidates; all Ara h 2 epitopes)****3) Pool 3 (7 x Ara h 1 'long' + 3 x Ara h 2 candidates; all Ara h 1 & 2 epitopes)**

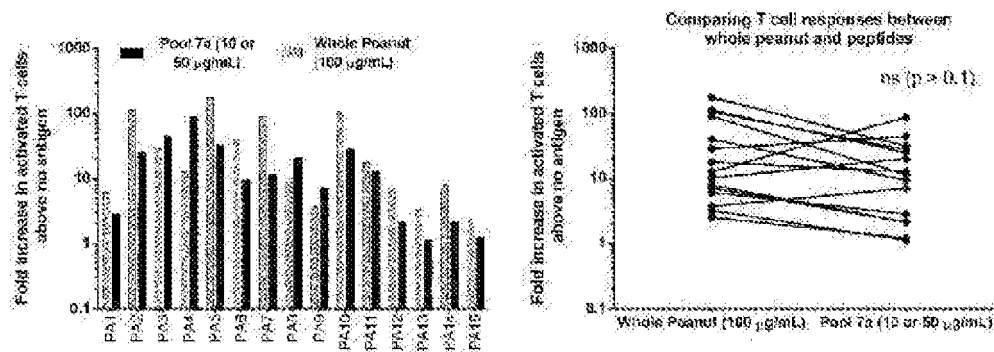
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FIGURE 12 (continued)**4) Pool 4 (3 x Ara h 1 'long' candidates + 5 x short Ara h 1 single epitopes; all Ara h 1 epitopes)****5) Pool 5 (5 x Ara h 2 short (single epitopes); all Ara h 2 epitopes)**

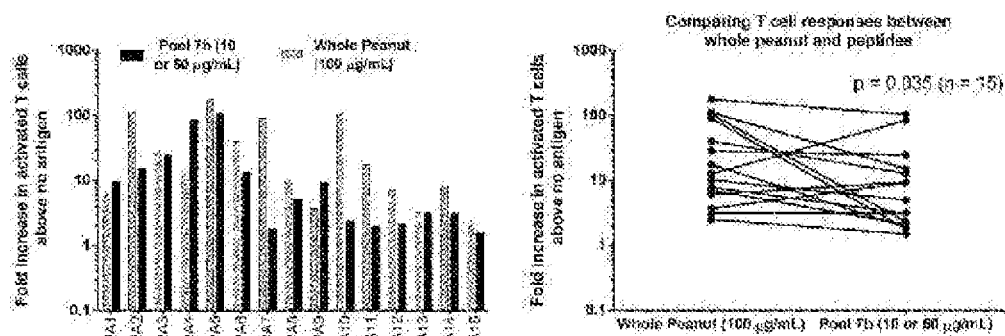
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FIGURE 13

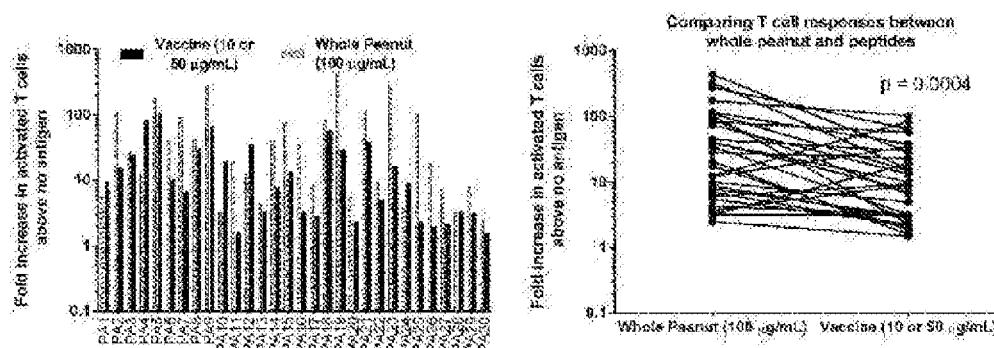
6) Pool 7a (refined 8-peptide pool from 23-peptide screen; 5 x Ara h 1 & 3 x Ara h 2 peptides)



7) Pool 7b (final 7-peptide pool from 23-peptide screen; 5 x Ara h 1 & 2 x Ara h 2 peptides)



8) Pools 7b for larger cohort (n = 30)

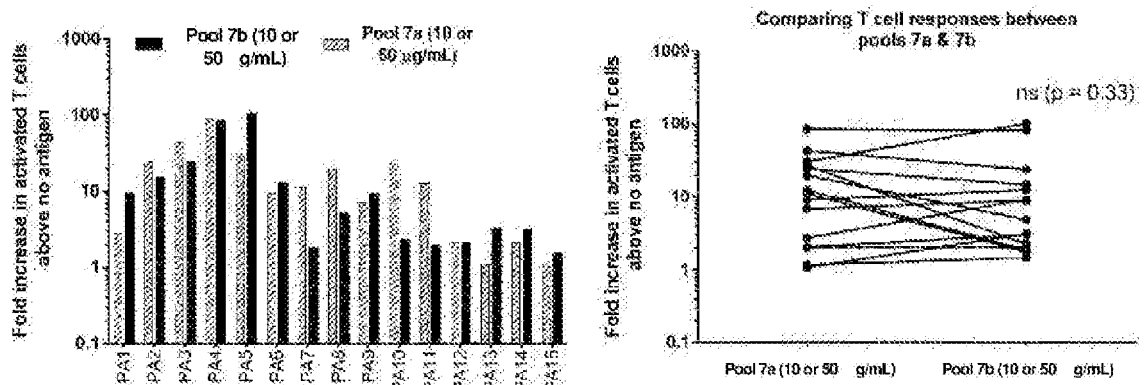


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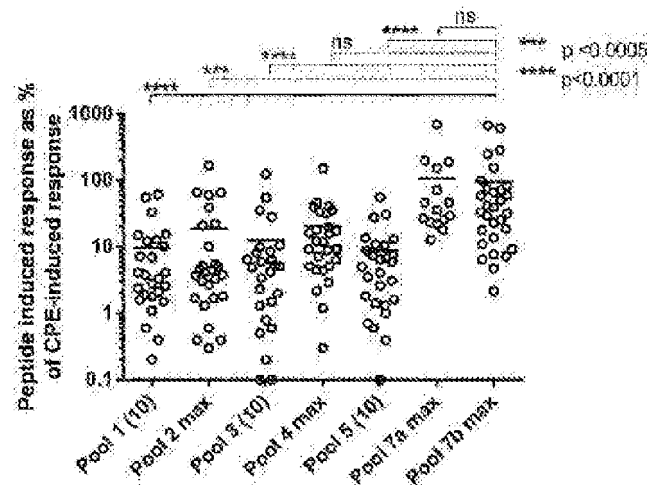
FIGURE 14

8) No significant difference between pools 7a and 7b

(comparing paired data; n = 15 per group; No advantage adding 3rd Ara h 2 peptide)



9) Pool 7b (and 7a) significantly better than most other pools tested



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FIGURE 15

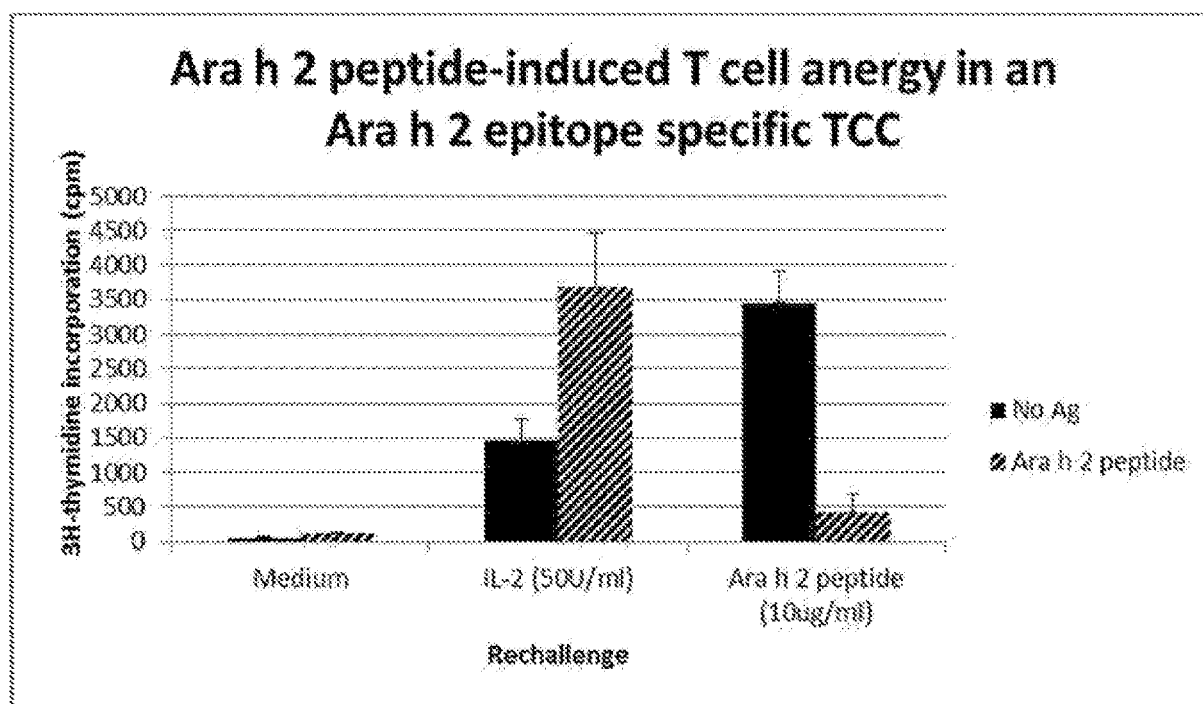
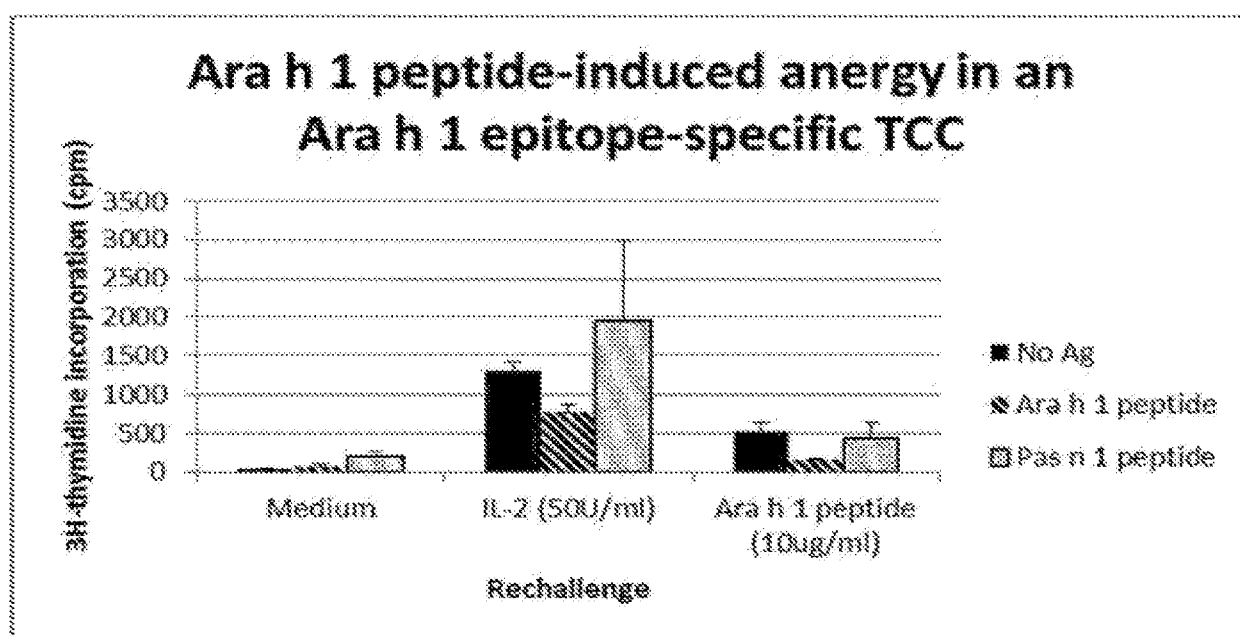


FIGURE 16



PCTAU2014050249-seq1-000001-EN-20141003
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ALFRED HEALTH

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<130> P38407PCAU

<150> AU 2013903686

<151> 2013-09-25

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 35 40 45
 Glu Pro Asp Asp Leu Lys Gln Lys Ala Cys Glu Ser Arg Cys Thr Lys
 50 55 60
 Leu Glu Tyr Asp Pro Arg Cys Val Tyr Asp Pro Arg Gly His Thr Gly
 65 70 75 80
 Thr Thr Asn Gln Arg Ser Pro Pro Gly Glu Arg Thr Arg Gly Arg Gln
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 Gly Arg Trp Gly Pro Ala Gly Pro Arg Glu Arg Glu Arg Glu Glu Asp
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1 5 10 15

Lys Glu

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<213> Ara h 2

<400> 31

Ala Asn Leu Arg Pro Ser Glu Gln His Leu Met
1 5 10

<210> 32
<211> 14
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<400> 32

Glu Phe Glu Asn Asn Gln Arg Ser Met Ser Glu Ala Leu Gln
1 5 10

<210> 33
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<213> Ara h 2

<400> 33

Glu Phe Glu Asn Asn Gln Arg Ser Met Ser Glu Ala Leu Gln Gln Ile
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<210> 34

<211> 17

<212> PRT

<213> Ara h 1

<400> 34

Ala Leu Met Leu Pro His Phe Asn Ser Lys Ala Met Val Ile Val Val
 1 5 10 15

Val

<210> 35

<211> 17

<212> PRT

<213> Ara h 1

<400> 35

Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys Lys Asn Pro
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Gln

<210> 36

<211> 13

<212> PRT

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<220>

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<222> (11)..(11)

<223> X is cysteine or serine

<400> 36

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<210> 37

<211> 12

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<222> (11)..(11)

<223> X is cysteine or serine

<400> 37

Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Xaa Met
1 5 10

<210> 38
<211> 20
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<400> 38

Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys Lys Asn Pro
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Gln Leu Gln Asp
20

<210> 39
<211> 19
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<400> 39

Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Ser Met Ser Glu Ala Leu
1 5 10 15

Gln Gln Ile

<210> 40
<211> 18
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<400> 40

Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys Lys Asn Pro
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Gln Leu

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1 5 10

<210> 42
<211> 21

<212> PRT
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<400> 42

Lys Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu
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Leu Val Ala Val Asp
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Lys Ala Met Val Ile Val Val Val Asn Lys Gly
1 5 10

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<400> 45

Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu
1 5 10 15

Val

<210> 46
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<400> 46

Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu Val Ala Val Arg Lys
1 5 10 15

<210> 47

<211> 20
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<213> Ara h 1

<400> 47

Phe Asp Gln Arg Ser Arg Gln Phe Gln Asn Leu Gln Asn His Arg Ile
1 5 10 15

Val Gln Ile Glu
20

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<213> Ara h 1

<400> 48

Asn Leu Gln Asn His Arg Ile Val Gln Ile Glu Ala Lys Pro Asn Thr
1 5 10 15

Leu Val Leu Pro
20

<210> 49
<211> 20
<212> PRT
<213> Ara h 1

<400> 49

Arg Trp Ser Thr Arg Ser Ser Glu Asn Asn Glu Gly Val Ile Val Lys
1 5 10 15

Val Ser Lys Glu
20

<210> 50
<211> 20
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<400> 50

Asp Leu Ser Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys
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Lys Asn Pro Gln
20

<210> 51
<211> 20
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<400> 51

Phe Glu Val Lys Pro Asp Lys Lys Asn Pro Gln Leu Gln Asp Leu Asp
1 5 10 15

Met Met Leu Thr
20

<210> 52
<211> 20
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<213> Ara h 1

<400> 52

Leu Thr Cys Val Glu Ile Lys Glu Gly Ala Leu Met Leu Pro His Phe
1 5 10 15

Asn Ser Lys Ala
20

<210> 53
<211> 20
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<213> Ara h 1

<400> 53

Ala Leu Met Leu Pro His Phe Asn Ser Lys Ala Met Val Ile Val Val
1 5 10 15

Val Asn Lys Gly
20

<210> 54
<211> 21
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<213> Ara h 1

<400> 54

Lys Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu
1 5 10 15

Leu Val Ala Val Ala
20

<210> 55
<211> 20
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<400> 55

Lys Glu Gly Asp Val Phe Ile Met Pro Ala Ala His Pro Val Ala Ile
1 5 10 15

Asn Ala Ser Ser
20

<210> 56
<211> 20

<212> PRT
<213> Ara h 2

<400> 56

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1 5 10 15

Gln His Leu Met
20

<210> 57
<211> 20
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<213> Ara h 2

<400> 57

Ala Asn Leu Arg Pro Cys Glu Gln His Leu Met Gln Lys Ile Gln Arg
1 5 10 15

Asp Glu Asp Ser
20

<210> 58
<211> 20
<212> PRT
<213> Ara h 2

<400> 58

Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Cys Met Cys Glu Ala Leu
1 5 10 15

Gln Gln Ile Met
20

<210> 59
<211> 20
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<400> 59

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1 5 10 15

Gln Arg Cys Asp
20

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<400> 60

Phe Gln Asn Leu Gln Asn His Arg
1 5

<210> 61
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 <212> PRT
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Phe Gln Asn Leu Gln Asn His Arg Ile Val
 1 5 10

<210> 62
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 <212> PRT
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<400> 62

Arg Ile Val Gln Ile Glu Ala Lys Pro Asn
 1 5 10

<210> 63
 <211> 13
 <212> PRT
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<400> 63

Arg Ile Val Gln Ile Glu Ala Lys Pro Asn Thr Leu Val
 1 5 10

<210> 64
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<400> 64

Ile Val Gln Ile Glu Ala
 1 5

<210> 65
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<400> 65

Trp Ser Thr Arg Ser Ser Glu Asn Asn Glu Gly Val Ile Val Lys Val
 1 5 10 15

Ser Lys Glu

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 <211> 14
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<400> 66

Glu Asn Asn Glu Gly Val Ile Val Lys Val Ser Lys Glu Ala

1

5

10

<210> 67
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Asn Glu Gly Val Ile Val Lys Val Ser Lys
 1 5 10

<210> 68
 <211> 10
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<400> 68

Asn Asn Phe Gly Lys Leu Phe Glu Val Lys
 1 5 10

<210> 69
 <211> 17
 <212> PRT
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<400> 69

Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys Lys Asn Pro
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Gln

<210> 70
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Phe Gly Lys Leu Phe Glu Val Lys
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<210> 71
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<400> 71

Glu Val Lys Pro Asp Lys Lys Asn Pro Gln Leu Gln
 1 5 10

<210> 72
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<400> 72

Val Glu Ile Lys Glu Gly Ala Leu Met Leu
1 5 10

<210> 73
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<400> 73

Val Glu Ile Lys Glu Gly Ala Leu Met Leu Pro His Phe Asn
1 5 10

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<211> 13
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Glu Gly Ala Leu Met Leu Pro His Phe Asn Ser Lys Ala
1 5 10

<210> 75
<211> 17
<212> PRT
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<400> 75

Ala Leu Met Leu Pro His Phe Asn Ser Lys Ala Met Val Ile Val Val
1 5 10 15

Val

<210> 76
<211> 15
<212> PRT
<213> Ara h 1

<400> 76

Leu Met Leu Pro His Phe Asn Ser Lys Ala Met Val Ile Val Val
1 5 10 15

<210> 77
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<400> 77

Pro His Phe Asn Ser Lys Ala Met Val Ile Val
1 5 10

<210> 78
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<400> 78

Lys Ala Met Val Ile Val Val Val Asn
1 5

<210> 79

<211> 10

<212> PRT

<213> Ara h 1

<400> 79

Ala Met Val Ile Val Val Val Asn Lys Gly
1 5 10

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<212> PRT

<213> Ara h 1

<400> 80

Ile Val Val Val Asn Lys Gly
1 5

<210> 81

<211> 16

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Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu
1 5 10 15

<210> 82

<211> 17

<212> PRT

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<400> 82

Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu
1 5 10 15

Val

<210> 83

<211> 13

<212> PRT

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<400> 83

Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu Val Ala
1 5 10

<210> 84

<211> 14

<212> PRT
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<400> 84

Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu Val Ala Val
1 5 10

<210> 85
<211> 17
<212> PRT
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<400> 85

Val Glu Ile Lys Glu Gly Ala Leu Met Leu Pro His Phe Asn Ser Lys
1 5 10 15

Ala

<210> 86
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<212> PRT
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<400> 86

Lys Ala Met Val Ile Val Val Val Asn Lys Gly
1 5 10

<210> 87
<211> 19
<212> PRT
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<400> 87

Ala Met Val Ile Val Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu
1 5 10 15

Val Ala Val

<210> 88
<211> 18
<212> PRT
<213> Ara h 1

<400> 88

Gly Asp Val Phe Ile Met Pro Ala Ala His Pro Val Ala Ile Asn Ala
1 5 10 15

Ser Ser

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<213> Ara h 1

<400> 89

Val Phe Ile Met Pro Ala Ala His Pro Val Ala Ile Asn Ala Ser Ser
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<210> 90

<211> 12

<212> PRT

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<400> 90

Phe Ile Met Pro Ala Ala His Pro Val Ala Ile Asn
1 5 10

<210> 91

<211> 7

<212> PRT

<213> Ara h 1

<400> 91

Ile Met Pro Ala Ala His Pro
1 5

<210> 92

<211> 11

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<213> Ara h 1

<400> 92

Ile Met Pro Ala Ala His Pro Val Ala Ile Asn
1 5 10

<210> 93

<211> 20

<212> PRT

<213> Ara h 2

<400> 93

Arg Arg Cys Gln Ser Gln Leu Glu Arg Ala Asn Leu Arg Pro Cys Glu
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Gln His Leu Met
20

<210> 94

<211> 13

<212> PRT

<213> Ara h 2

<400> 94

Ser Gln Leu Glu Arg Ala Asn Leu Arg Pro Cys Glu Gln
1 5 10

<210> 95

<211> 11
 <212> PRT
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<400> 95

Ser Gln Leu Glu Arg Ala Asn Leu Arg Pro Cys
 1 5 10

<210> 96
 <211> 9
 <212> PRT
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<400> 96

Leu Glu Arg Ala Asn Leu Arg Pro Cys
 1 5

<210> 97
 <211> 11
 <212> PRT
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<400> 97

Leu Glu Arg Ala Asn Leu Arg Pro Cys Glu Gln
 1 5 10

<210> 98
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<400> 98

Glu Arg Ala Asn Leu Arg Pro Cys Glu Gln
 1 5 10

<210> 99
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<400> 99

Ala Asn Leu Arg Pro Cys Glu Gln His Leu Met
 1 5 10

<210> 100
 <211> 9
 <212> PRT
 <213> Ara h 2

<400> 100

Leu Arg Pro Cys Glu Gln His Leu Met
 1 5

<210> 101
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<400> 101

Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Cys Met Cys Glu Ala Leu
 1 5 10 15

Gln Gln Ile Met
 20

<210> 102

<211> 12

<212> PRT

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<400> 102

Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Cys Met
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Leu Asn Glu Phe Glu Asn Asn Gln Arg Cys Met
 1 5 10

<210> 104

<211> 14

<212> PRT

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Glu Phe Glu Asn Asn Gln Arg Cys Met Cys Glu Ala Leu Gln
 1 5 10

<210> 105

<211> 10

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Glu Asn Asn Gln Arg Cys Met Cys Glu Ala
 1 5 10

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<211> 11

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Asn Asn Gln Arg Cys Met Cys Glu Ala Leu Gln
 1 5 10

<210> 107

<211> 20
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Lys Arg Glu Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu Arg Ala Pro
1 5 10 15

Gln Arg Cys Asp
20

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<400> 108

Arg Glu Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu
1 5 10

<210> 109
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<212> PRT
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Glu Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu Arg
1 5 10

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Glu Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu
1 5 10

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Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu
1 5 10

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Leu Arg Asn Leu Pro Gln Gln Cys Gly
1 5

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Arg Glu Leu Arg Asn Leu Pro Gln Gln Cys Gly Leu Arg Ala
 1 5 10

<210> 114
 <211> 20
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Phe Asp Gln Arg Ser Arg Gln Phe Gln Asn Leu Gln Asn His Arg Ile
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Val Gln Ile Glu
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<210> 115
 <211> 20
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<400> 115

Asn Leu Gln Asn His Arg Ile Val Gln Ile Glu Ala Lys Pro Asn Thr
 1 5 10 15

Leu Val Leu Pro
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<210> 116
 <211> 20
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 <213> Ara h 1

<400> 116

Asp Leu Ser Asn Asn Phe Gly Lys Leu Phe Glu Val Lys Pro Asp Lys
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Lys Asn Pro Gln
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<210> 117
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<400> 117

Phe Glu Val Lys Pro Asp Lys Lys Asn Pro Gln Leu Gln Asp Leu Asp
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Met Met Leu Thr
20

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Leu Thr Cys Val Glu Ile Lys Glu Gly Ala Leu Met Leu Pro His Phe
1 5 10 15

Asn Ser Lys Ala
20

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Ala Leu Met Leu Pro His Phe Asn Ser Lys Ala Met Val Ile Val Val
1 5 10 15

Val Asn Lys Gly
20

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Leu Val Ala Val
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Asn Ala Ser Ser
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Gln His Leu Met
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Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Cys Met Cys Glu Ala Leu
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Gln Gln Ile Met
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Gln Arg Cys Asp
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Leu Glu Arg Ala Asn Leu Arg Pro Cys
1 5

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Leu Arg Pro Cys Glu Gln His Leu Met
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Leu Arg Asn Leu Pro Gln Gln Cys Gly
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Leu Pro Gln Gln Cys Gly Leu Arg Ala
1 5

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Val Val Asn Lys Gly Thr Gly Asn Leu Glu Leu Val Ala Val Arg Lys
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Ser Gln Leu Glu Arg Ala Asn Leu Arg Pro Ser Glu Gln
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Ala Asn Leu Arg Pro Ser Glu Gln His Leu Met
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Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Ser Met
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Glu Phe Glu Asn Asn Gln Arg Ser Met Ser Glu Ala Leu Gln
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1 5 10 15

Asn Gln Arg Cys
20

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Ser Gln Leu Glu Arg Ala Asn Leu Arg Pro Ser Glu Gln His Leu Met
1 5 10 15

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Glu Leu Asn Glu Phe Glu Asn Asn Gln Arg Ser Met Ser Glu Ala Leu
1 5 10 15

Gln

<210> 143
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<400> 143

Glu Asn Asn Glu Gly Val Ile Val Lys Val Ser Lys Glu
1 5 10