PEPTIDES

FIELD OF THE INVENTION

The present invention relates to peptides, at least part of which is derived from Thyroid Stimulating Hormone Receptor (TSHR). These peptides may be useful in the prevention and/or treatment of Graves Disease (GD).

BACKGROUND TO THE INVENTION

Graves' Disease is characterised by an overactive thyroid gland, which results in the production of an excessive amount of thyroid hormone and enlargement of the thyroid gland (goitre). The resulting state of hyperthyroidism may cause a wide range of neuropsychological and physical symptoms. GD is the most common cause of hyperthyroidism (60-90% of all cases) and usually presents itself during midlife, but also appears in children, adolescents, and the elderly. It affects up to 2% of the female population, and is between five and ten times as common in females as in males. Pediatric GD affects about 6,000 children in the US and 6,000 in the EU. GD is also the most common cause of severe hyperthyroidism, which is accompanied by more clinical signs and symptoms and laboratory abnormalities as compared with milder forms of hyperthyroidism.

There is a strong hereditary component linked to GD. There are no recent population studies on GD, however, a few quasi population studies on hyperthyroidism do exist and all estimates for incidence and prevalence of GD are thus approximate. The incidence of hyperthyroidism varies from 26:100,000 to 93:100,000 and the overall prevalence is estimated to be at 1.3%, with 42% of cases being overt and 62% subclinical.

About 30-50% of people with GD will also suffer from Graves' opthalmopathy (GO), a protrusion of one or both of the eyes. Many cases of GO are mild and self-limiting, however 20% of cases have significant/moderate to severe disease, with at least half of these require steroids and 3-5% of GO patients have painful, sight-threatening disease with dysthyroid optic neuropathy (DON). The budging of the eyes may cause severe dryness of the cornea as the eye lids are unable to close at night. Increased pressure in the optic nerve can lead to visual field defects and vision loss. GO may also be associated with pretibial myxedemia.

The symptoms and signs of GD virtually all result from the direct and indirect effects of hyperthyroidism, with main exceptions being GO, goitre, and pretibial myxedema. Symptoms of hyperthyroidism may include insomnia, hand tremor, hyperactivity, hair loss, excessive sweating, heat intolerance and weight loss despite increased appetite. Further signs are most commonly a diffusely enlarged (usually symmetric) non-tender thyroid, lid lag, excessive lacrimation due to Graves' opthalmopathy, arrhythmias of the heart and hypertension. Thyrotoxic patients may experience behavioural and personality changes, such as psychosis, agitation, and depression. In milder hyperthyroidism, patients may experience less overt manifestations, for example anxiety, restlessness, irritability and emotional lability.

There is currently no cure available for GD and present treatments are therefore directed towards targeting the presenting symptoms. There are three treatment modalities for GD, oral antithyroid drugs (ATDs), radioactive iodine (RAI) and thyroidectomy. The latter two approaches result in lifetime supplementation of thyroid hormones. Therapy with radioiodine is the most common treatment in the United States, whilst ATDs are the first line treatment in Europe, Japan and most of the rest of the world.

ATD therapy is associated with some rare side-effects and has a remission rate of 50-60%. There is growing recognition the RAI can precipitate or worsen active GO and the number of patients treated with ATDs is the United States is increasing.

Due to the varying success of each treatment option, patients are often subjected to more than one approach if the first attempted treatment does not prove entirely successful. The risk of relapse or subsequent hypothyroidism is substantial and the general efficacy of available treatments for GD is less than desired. There is thus a need for alternative therapies for GD that are effective at treating GD and at alleviating or reducing the symptoms of the disease.

DESCRIPTION OF THE FIGURES

Figure 1: Immunogenicity of RNB-5 in DR3 mice. Mice (N=2 male; N=2 female) were primed with RNB-5 and after 10 days, LN cells (pooled per gender) and splenocytes were cultured with different concentrations of peptide and cell proliferation was measured. Stimulation indexes (SI) represent the ratio of thymidine incorporation of peptide-stimulated culture to that of non-stimulated culture. F, female; M, male; LN, lymph nodes.

Figure 2: Identification of apitopes within RNB-5. DR3 mice were immunized with RNB-5/CFA and hybridomas were generated. $5x10^4$ TSHR-specific hybridoma cells were cultured

with $5x10^4$ fresh (black bars) or fixed (white bars) VAVY cells and 25 µg/mL antigen (RNB-5 or RNB-5 nested peptide). Representative clones are shown. After 48h, antigen-induced IL-2 production was measured. The graph represents the mean of a duplicate measurement and results are representative of 2 independent experiments. APC, antigen presenting cell.

Figure 3: Identification of apitopes within RNB-5. DR4 mice were immunized with TSHR/CFA and hybridomas were generated. $5x10^4$ TSHR-specific hybridoma cells were cultured with $5x10^4$ fresh (black bars) or fixed (white bars) BM14 cells and 25 µg/mL antigen (TSHR, RNB-5 or RNB-5 nested peptide). Representative clones are shown. After 48h, antigen-induced IL-2 production was measured. The graph represents the mean of a duplicate measurement. APC, antigen presenting cell.

Figure 4A: Identification of apitopes within RNB-4. DR4 mice were immunized with TSHR-CFA and hybridomas were generated. $5x10^4$ TSHR-specific hybridoma cells were cultured with $5x10^4$ fresh (black bars) or fixed (white bars) BM14 cells and 25 µg/mL antigen (TSHR, RNB-4 or RNB-4 nested peptide). A representative clone is shown. After 48h, antigen-induced IL-2 production was measured and shown as OD values. The graph represents the mean of a duplicate measurement and results are representative of 3 independent measurements. APC, antigen presenting cell.

Figure 4B: Identification of apitopes within RNB-4. DR4 mice were immunized with TSHR/CFA and hybridomas were generated. $5x10^4$ TSHR-specific hybridoma cells were cultured with $5x10^4$ fresh (black bars) or fixed (white bars) BM14 cells and antigen (25 µg/mL TSHR of RNB-4; 100 µg/mL RNB-4 nested peptides). After 48h, antigen-induced IL-2 production was measured and shown as OD values.

Figure 5: *Ex vivo* tolerisation protocol. A, Mice are injected subcutaneously at the back of the neck with 100 µg of peptide on days -8, -6 and -4 (high dose schedule). On day 0, mice are injected subcutaneously at the base of the tail with RNB-5/CFA. B, Mice are injected subcutaneously at the back of the neck with 0.1 µg, 1 µg and 10 µg peptide on days -15, -13 and -11, followed by 3 injections of 100 µg peptide on days -8, -6 and -4 (dose escalation schedule). On day 0, mice are injected subcutaneously at the base of the tail with TSHR/CFA or peptide/CFA. For both schedules, mice are sacrificed 10 days after immunization to measure the proliferation of LN cells and splenocytes upon TSHR restimulation.

Figure 6: *Ex vivo* tolerance induction by RNB-5 apitopes. Mice are pretreated with RNB-5 apitopes according to the high dose schedule (A-B) or the dose escalation schedule (C-F).

Data represent mean ± SEM of SI values for the PBS-treated mice (black lines) and peptide-treated mice (red lines). Graphs A, B, C, E and F represent experiments performed in DR3 mice, graph D represent an experiment performed in DR4 mice. 2-way ANOVA was used to measure overall treatment effects on T cell proliferation and p-values are written in the graphs. Bonferroni post-hoc testing was used and significant differences are indicated in the graphs (* $p<0.05$; ** $p<0.01$; *** $p<0.001$). SI, stimulation index; LN, lymph nodes.

Figure 7: *Ex vivo* tolerance induction by RNB-9 peptides. DR3 mice are pretreated according the dose escalation schedule with RNB-9B (A, C) or RNB-9C (B,D). Data represent mean ± SEM of SI values for the PBS-treated mice (black lines) and peptide-treated mice (red lines). 2-way ANOVA was used to measure overall treatment effects on T cell proliferation and p-values are written in the graphs. Bonferroni post-hoc testing was used and significant differences are indicated in the graphs (* $p<0.05$; ** $p<0.01$; *** $p<0.001$). SI, stimulation index; LN, lymph nodes.

Figure 8: TSHR antibody levels (total IgG) measured by ELISA. Mice were immunized once (group A+B) or twice (group C) with 50 µg TSHR in adjuvant. OD values are shown per group as mean ± SEM.

Figure 9: Serum T4 levels in LacZ-Ad and Ad-TSHR-Ad immunized mice. Data shown are individual values for mice from different groups before (A), 4 weeks after (B) and 10 weeks after (C) the first immunization. The number of hyperthyroid versus total number for each group is indicated. Mice were considered hyperthyroid when their T4 levels exceeded the mean + 2SD for serum T4 values in LacZ-Ad immunized mice. Mean T4 levels was not significantly different between TSHR-Ad and LacZ-Ad injected mice at 4 or 10 weeks. One-way ANOVA, Bonferroni post-hoc testing, $p<0.05$ was considered significantly different.

Figure 10: Anti-TSHR antibody levels (total IgG, ELISA) in LacZ-Ad and TSHR-Ad immunized mice. Data shown are individual values for mice from different groups before (A), 4 weeks after (B) and 10 weeks after (C) the first immunization. Statistical analysis was performed with one-way ANOVA and Bonferroni post-hoc testing. Significant differences are indicated in the graphs (* $p<0.05$; ** $p<0.01$).

Figure 11: Response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. Hybridoma clones (represented in different colours) were cultured with fresh APCs and 25 µg/mL antigen for 48 hours prior to determination of IL-2 production. Replacement of amino

acids in the central region of the RNB-5D-GKK or RNB-5D-KKK hampers recognition by hybridoma clones, indicating that those amino acids are important in the epitope region.

Figure 12: Response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. Hybridoma clones (represented in different colours) were cultured with fresh (full bars) or fixed (empty bars) APCs and 25 µg/mL antigen for 48 hours prior to determination of IL-2 production.

Figure 13: Response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. Hybridoma clones (represented in different colours) were cultured with fresh APCs and 25 µg/mL antigen for 48 hours prior to determination of IL-2 production.

Figure 14: Response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. Hybridoma clones (represented in different colours) were cultured with fixed APCs and 25 µg/mL antigen for 48 hours prior to determination of IL-2 production.

Figure 15: Response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. Hybridoma clones (represented in different colours) were cultured with fresh and fixed APCs and 25 µg/mL antigen for 48 hours prior to determination of IL-2 production.

Figure 16: Ex vivo tolerance induction by RNB 4K-GKK in DR4 mice according to the dose escalation schedule. 2-way ANOVA was used to measure overall treatment effects on T cell proliferation and p-values are written in the graphs. Bonferroni post-hoc testing was used and significant differences are indicated in the graphs (* $p<0.05$; ** $p<0.01$; *** $p<0.001$) Data represents mean ± SEM for the PBS-treated (black lines) and peptide treated mice (red lines). SI stimulation index; LN lymph nodes

Figure 17: Identification of the RNB12 region by reactivity of a T cell line generated from Graves' disease patients. A T cell line was generated by stimulating isolated PBMCs from a Graves' disease patient with RNB12 for 12 days. After an additional re-stimulation cycle of 12 days, the RNB12 specific T cells was tested for recognition of individual nested peptides in the RNB12 region. SI, stimulation index

Figure 18: Identification of apitopes within the RNB12 region using a RNB12 specific TCL generated from a healthy donor. The RNB12 specific T cells were cultured with BM14, a human cell line expressing human MHC class II molecules in presence of peptide. Black bars represent the stimulation in presence of fresh, but irradiated BM14 cells and white bars presence of fixed APCs. (See materials and methods). Before adding 3H-thymidine to the cultures, culture supernatant was collected and frozen. The supernatant was analysed for IFN gamma (A) to confirm the proliferative T cell response (B). TCL, T cell line; APC, antigen presenting cell; MHC class II, major histocompatibility complex class II; SI, stimulation index; OD, optical density.

Figure 19: Examples of Ex vivo tolerance induction by modified RNB5D modified peptides in DR3 mice according to the dose escalation schedule. 2-way ANOVA was used to measure overall treatment effects on T cell proliferation and p-values are written in the graphs. (* $p<0.05$; ** $p<0.01$; *** $p<0.001$; **** $p<0.0001$) Data represents mean ± SEM for the PBS-treated (black lines) and peptide treated mice (red lines). SI stimulation index. A: RNB5D-K1; B: RNB5D-K3; C: RNB5D-K16

Figure 20: Graph illustrating the apitope status of RNB5D modified peptides . An example of the response of a TSHR- and RNB-5-specific hybridoma clone, isolated from HLA-DR3 and HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides. The hybridoma clone was cultured with fresh (black bars) and fixed (white bars) APCs and 25 μg/ml antigen for 48 hours prior to determination of IL-2 production.

SUMMARY OF ASPECTS OF THE INVENTION

The present inventors have identified a number of peptides derived from TSHR which are useful in the prevention and/or treatment of GD.

Disclosed is a peptide which is capable of binding to an MHC molecule *in vitro* and being presented to a T cell without antigen processing, and which comprises all or a portion of the following Thyroid Stimulating Hormone Receptor (TSHR) peptides:

RNB_5: ISRIYVSIDVTLQQLESHSFYNLSKVTHI	(SEQ ID No 1)
RNB_4: LRTIPSHAFSNLPNISRIYVSIDVTLQQL	(SEQ ID No 2)
RNB_9: TGLKMFPDLTKVYSTDIFFILEITDNPYM	(SEQ ID No 3)
RNB_12: LTLKLYNNGFTSVQGYAFNGTKLDAVYL	(SEQ ID No 64)

In a first aspect, the present invention provides a peptide which is capable of binding to an MHC class II molecule in vitro and being presented to a T cell without antigen processing, which is selected from the following:

RNB_4K: NLPNISRIYVSIDVT	(SEQ ID No. 62)
RNB_4K-GKK: KKGNLPNISRIYVSIDVTGKK	(SEQ ID No. 63)
RNB_9B: GLKMFPDLTKVYSTD	(SEQ ID No 18)

The peptide may be selected from the following TSHR peptides and derivatives thereof:

RNB_5D-GKK: KKGIYVSIDVTLQQLESHGKK	(SEQ ID No 12)
RNB_5D-KKK: KKKIYVSIDVTLQQLESHKKK	(SEQ ID No. 21)
RNB_5E-GKK: KKGYVSIDVTLQQLESHSGKK	(SEQ ID No 13)
RNB_5A: ISRIYVSIDVTLQQL	(SEQ ID No 6)
RNB_5B: SRIYVSIDVTLQQLE	(SEQ ID No 7)
RNB_5C: RIYVSIDVTLQQLES	(SEQ ID No 8)
RNB_5D: IYVSIDVTLQQLESH	(SEQ ID No 9)
RNB_5E: YVSIDVTLQQLESHS	(SEQ ID No 10)
RNB_5F: VSIDVTLQQLESHSF	(SEQ ID No 11)
RNB_5F-GKK: KKGVSIDVTLQQLESHSFGKK	(SEQ ID No 14)
RNB_4J-GKK: KKGSNLPNISRIYVSIDVGKK	(SEQ ID No 16)
RNB_4J: SNLPNISRIYVSIDV	(SEQ ID No 15)
RNB_4K: NLPNISRIYVSIDVT	(SEQ ID No. 62)
RNB_4K-GKK: KKGNLPNISRIYVSIDVTGKK	(SEQ ID No. 63)
RNB_9A: TGLKMFPDLTKVYST	(SEQ ID No 17)
RNB_9B: GLKMFPDLTKVYSTD	(SEQ ID No 18)
RNB_9C: LKMFPDLTKVYSTDI	(SEQ ID No 19)
RNB_9D: KMFPDLTKVYSTDIF	(SEQ ID No 20)
RNB_12A: LTLKLYNNGFTSVQG	(SEQ ID No. 65)
RNB_12B: TLKLYNNGFTSVQGY	(SEQ ID No. 66)
RNB_12B-KKK: KKK TLKLYNNGFTSVQGYKKK	(SEQ ID No. 67)

The peptide may comprise the RNB 5A, 5B, 5C, 5D, 5E, 5F, 4J, 4K, 9A, 9B, 9C, 9D, 12A or 12B sequence, or a variant thereof in which one or more amino acids has been replaced by another amino acid, such as K, which has been modified at one or both ends, for example by the introduction of "GKK" or "KKK" sequences.

The peptide may comprise the RNB-5D sequence, or a variant thereof in which one or more amino acids has been replaced by another amino acid, such as K, which has been modified at one or both ends, for example by the introduction of "GKK" or "KKK" sequences.

The present disclosure also provides a peptide which comprises the sequence:

KK-(G/K)-aa1-(RNB-5D peptide)-aa2-aa3-Z-(G/K)-KK

wherein aa1 is no amino acid, I, K or T;

RNB-5D peptide is YVSIDVTLQQLE, or a variant thereof in which one or more amino acids has been replaced by K,
aa2 is no amino acid, S or K;
aa3 is no amino acid, H or K
which is capable of binding to an MHC molecule *in vitro* and being presented to a T cell without antigen processing.

In this example, the RNB-5D peptide may be YVSIDVTLQQLE, or a variant thereof in which one, two or three amino acids is/are replaced by K.

The peptide may be selected from the following group, which are all identified as being apitopes (Table 1) : KKGIYVSIDVTLQQLESHGKK (SEQ ID No 12), KKGKYVSIDVTLQQLESHGKK (SEQ ID No 22), KKGIKVSIDVTLQQLESHGKK (SEQ ID No 23), KKGIYKSIDVTLQQLESHGKK (SEQ ID No 24), KKGIYVSIDVKLQQLESHGKK (SEQ ID No 25), KKGIYVSIDVTLQKLESHGKK(SEQ ID No 26), KKGIYVSIDVTLQQKESHGKK (SEQ ID No 27), KKGIYVSIDVTLQQLKSHGKK (SEQ ID No 28), KKGIYVSIDVTLQQLEKHGKK (SEQ ID No 29), KKGIYVSIDVTLQQLESKGKK (SEQ ID No 30), KKGYVSIDVTLQQLEGKK (SEQ ID No 31), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No 33), KKGYVSIDVTLQQKEGKK (SEQ ID No 34), KKGYVSIDVKLQKKEGKK (SEQ ID No 35), KKGIYVSIDVTLQQLEGKK (SEQ ID No 36), KKGIYVSIDVKLQQLEGKK (SEQ ID No 37), KKGIYVSIDVTLQKLEGKK (SEQ ID No 38), KKGIYVSIDVTLQQKEGKK (SEQ ID No 39), KKGIYVSIDVKLQKKEGKK (SEQ ID No 40), KKGTYVSIDVTLQQLEGKK (SEQ ID No 41), KKGTYVSIDVKLQQLEGKK (SEQ ID No 42), KKGTYVSIDVTLQKLEGKK (SEQ ID No 43), KKGTYVSIDVTLQQKEGKK (SEQ ID No 44), KKGTYVSIDVKLQKKEGKK (SEQ ID No 45), KKKIYVSIDVTLQQLESHKKK (SEQ ID No 21), KKKKYVSIDVTLQQLESHKKK (SEQ ID No 46), KKKIKVSIDVTLQQLESHKKK (SEQ ID No 47), KKKIYKSIDVTLQQLESHKKK (SEQ ID No 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No 49), KKKIYVSIDVKLQQLESHKKK (SEQ ID No 50), KKKIYVSIDVTLKQLESHKKK (SEQ ID No 51), KKKIYVSIDVTLQKLESHKKK (SEQ ID No 52), KKKIYVSIDVTLQQKESHKKK (SEQ ID No 53), KKKIYVSIDVTLQQLKSHKKK (SEQ ID No 54), KKKIYVSIDVTLQQLEKHKKK (SEQ ID No 55), KKKIYVSIDVTLQQLESKKKK (SEQ

ID No 56), KKKYVSIDVTLQQLEKKK (SEQ ID No 57), KKKYVSIDVKLQQLEKKK (SEQ ID No 58), KKKYVSIDVTLQKLEKKK (SEQ ID No 59), KKKYVSIDVTLQQKEKKK (SEQ ID No 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

The peptide may be selected from the following group, which are all identified as apitopes and have improved solubility:
KKGKYVSIDVTLQQLESHGKK (SEQ ID No. 22), KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVTLQQLEGKK (SEQ ID No. 31), KKGYVSIDVKLQQLEGKK (SEQ ID No. 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGIYVSIDVKLQKKEGKK (SEQ ID No. 40), KKGTYVSIDVKLQQLEGKK (SEQ ID No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No. 49), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVKLQQLEKKK (SEQ ID No. 58), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

The peptide may be selected from the following group, which are all identified as apitopes and have the best solubility: KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGTYVSIDVKLQQLEGKK (SEQ Id No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

The following peptides are of particular interest: KKGYVSIDVTLQKLEGKK (SEQ ID No. 32), KKGYVSIDVKLQKKEGKK (SEQ ID No. 34), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

In a second aspect, the present invention provides a composition comprising a plurality of peptides, including one or more peptide(s) according to the first aspect of the invention.

In a third aspect, the present invention provides a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, for use in supressing or preventing the production of TSHR autoantibodies *in vivo*.

In a fourth aspect, the present invention provides a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, for use in treating and/or preventing Graves' Disease in a subject.

The present disclosure provides the use of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, in the manufacture of a medicament to suppress or prevent the production of TSHR autoantibodies *in vivo.*

In a fifth aspect, the present invention provides the use of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, in the manufacture of a medicament to suppress or prevent the production of TSHR autoantibodies in vivo, wherein said peptide or composition is to be administered to the subject.

The present disclosure provides use of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, in the manufacture of a medicament to treat and/or prevent Graves' Disease.

In a sixth aspect, the present invention provides the use of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, in the manufacture of a medicament to treat and/or prevent Graves' Disease in a subject, wherein said peptide or composition is to be administered to the subject.

The present disclosure also provides a method for suppressing or preventing the production of TSHR autoantibodies in a subject, which comprises the step of administration of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, to the subject.

The present disclosure also provides a method for treating Graves' Disease in a subject which comprises the step of administration of a peptide according to the first aspect of the invention, or a composition according to the second aspect of the invention, to the subject.

The subject may be HLA-DR3 or HLA-DR4.

DETAILED DESCRIPTION

PEPTIDES

In a first aspect, the present invention relates to a peptide.

The term “peptide” is used in the normal sense to mean a series of residues, typically L-amino acids, connected one to the other, typically by peptide bonds between the α-amino and carboxyl groups of adjacent amino acids. The term includes modified peptides and synthetic peptide analogues.

The peptide of the present invention may be made using chemical methods (Peptide Chemistry, A practical Textbook. Mikos Bodansky, Springer-Verlag, Berlin.). For example, peptides can be synthesized by solid phase techniques (Roberge JY *et al* (1995) Science 269: 202-204), cleaved from the resin, and purified by preparative high performance liquid chromatography (e.g., Creighton (1983) Proteins Structures And Molecular Principles, WH Freeman and Co, New York NY). Automated synthesis may be achieved, for example, using the ABI 43 1 A Peptide Synthesizer (Perkin Elmer) in accordance with the instructions provided by the manufacturer.

The peptide may alternatively be made by recombinant means, or by cleavage from a longer polypeptide. For example, the peptide may be obtained by cleavage from the thyrotropin receptor protein, which may be followed by modification of one or both ends. The composition of a peptide may be confirmed by amino acid analysis or sequencing (e.g., the Edman degradation procedure).

For practical purposes, there are various other characteristics which the peptide may show. For example, it is important that the peptide is sufficiently stable *in vivo* to be therapeutically useful. The half-life of the peptide *in vivo* may be at least 10 minutes, 30 minutes, 4 hours, or 24 hours.

The peptide may also demonstrate good bioavailability *in vivo*. The peptide may maintain a conformation *in vivo* which enables it to bind to an MHC molecule at the cell surface without due hindrance.

APITOPES

In an adaptive immune response, T lymphocytes are capable of recognising internal epitopes of a protein antigen. Antigen presenting cells (APC) take up protein antigens and degrade them into short peptide fragments. A peptide may bind to a major histocompatibility complex (MHC) class I or II molecule inside the cell and be carried to the cell surface. When presented at the cell surface in conjunction with an MHC molecule, the peptide may be recognised by a T cell (via the T cell receptor (TCR)), in which case the peptide is a T cell epitope.

An epitope is thus a peptide derivable from an antigen which is capable of binding to the peptide-binding groove of an MHC class I or II molecule and being recognised by a T cell.

The minimal epitope is the shortest fragment derivable from an epitope, which is capable of binding to the peptide-binding grove of an MHC class I or II molecule and being recognised by a T cell. For a given immunogenic region, it is typically possible to generate a "nested set" of overlapping peptides which act as epitopes, all of which contain the minimal epitope but differ in their flanking regions.

By the same token, it is possible to identify the minimal epitope for a particular MHC molecule:T cell combination by measuring the response to truncated peptides. For example, if a response is obtained to the peptide comprising residues 1-15 in the overlapping library, sets which are truncated at both ends (ie. 1-14, 1-13, 1-12 etc. and 2-15, 3-15, 4-15 etc.) can be used to identify the minimal epitope.

The present inventors have previously determined that there is a link between the capacity of a peptide to bind to an MHC class I or II molecule and be presented to a T cell without further processing, and the peptide's capacity to induce tolerance *in vivo* (WO 02/16410). If a peptide is too long to bind the peptide binding groove of an MHC molecule without further processing (e.g. trimming), or binds in an inappropriate conformation then it will not be tolerogenic *in vivo*. If, on the other hand, the peptide is of an appropriate size and conformation to bind directly to the MHC peptide binding groove and be presented to a T cell, then this peptide can be predicted to be useful for tolerance induction.

It is thus possible to investigate the tolerogenic capacity of a peptide by investigating whether it can bind to an MHC class I or II molecule and be presented to a T cell without further antigen processing *in vitro*.

The peptides of the present invention are apitopes (Antigen Processing-Independent epiTOPES) in that they are capable of binding to an MHC molecule and stimulating a response from TSHR specific T cells without further antigen processing. Such apitopes can be predicted to cause tolerance to TSHR, following the rule-based method described in WO 02/16410.

A peptide of the present invention may be any length that is capable of binding to an MHC class I or II molecule without any further processing. Typically, the peptide of the present invention is capable of binding MHC class II.

Peptides that bind to MHC class I molecules are typically 7 to 13, more usually 8 to 10 amino acids in length. The binding of the peptide is stabilised at its two ends by contacts between

atoms in the main chain of the peptide and invariant sites in the peptide-binding groove of all MHC class I molecules. There are invariant sites at both ends of the groove which bind the amino and carboxy termini of the peptide. Variations in peptide length are accommodated by a kinking in the peptide backbone, often at proline or glycine residues that allow flexibility.

Peptides which bind to MHC class II molecules are typically between 8 and 20 amino acids in length, more usually between 10 and 17 amino acids in length, and can be longer (for example up to 40 amino acids). These peptides lie in an extended conformation along the MHC II peptide-binding groove which (unlike the MHC class I peptide-binding groove) is open at both ends. The peptide is held in place mainly by main-chain atom contacts with conserved residues that line the peptide-binding groove.

The peptide of the present invention may comprise between 8 and 30 amino acids, for example 8 to 25 amino acids, 8 to 20 amino acids, 8 to 15 amino acids or 8 to 12 amino acids.

PORTION

The peptide of the present invention may comprise all or a portion of the TSHR-derived peptides shown as SEQ ID NOs 1-3.

The term "portion" refers to a peptide that is derived from SEQ ID NOs 1-3 and contains at least a minimal epitope of the peptide.

Such a peptide may comprise one or more mutations, typically amino acid substitutions within the TSHR-derived sequence. The amino acid may be substituted for an amino acid such as glycine, lysine or glutamic acid. The peptide may comprise up to three, up to two or one amino acid substitution from the TSHR-derived sequence.

Such a peptide may comprise amino acids at one or both ends which are not derivable from the TSHR sequence. For example, the peptide may have one or more glycine and/or lysine and/or glutamic acid residues at one or both ends. For example, the additional amino acids may comprise a glycine or lysine spacer, followed by the amino acid pairs KK, KE, EK or EE at one or both ends.

For example, the peptide may have the following formula:

KKG-*TSHR-derived portion*-GKK.

The peptide, including the non-TSHR derived amino acids, must be an apitope, i.e. capable of binding to an MHC molecule *in vitro* and presented to a T cell without antigen processing.

THYROID STIMULATING HORMONE RECEPTOR (TSHR)

GD is an autoimmune disease caused by auto-reactive T and B lymphocytes targeting the primary auto-antigen, the Thyroid Stimulating Hormone Receptor (TSHR).

TSHR is a G-protein coupled receptor on thyroid follicular cells in the thyroid gland that stimulates the production of thyroxine (T4) and triiodothyronine (T3) via a cAMP signal cascade upon binding of its ligand, the thyroid-stimulating hormone (TSH). Upon internalization, degradation and presentation of the TSHR by APCs, T cells become activated and interact with auto-reactive B cells, which in turn produce stimulating agonistic auto-antibodies directed against TSHR. The thyroid-stimulating immunoglobulins bind to the same receptor pocket as the TSH, activating the TSHR mediated signal transduction and leading to the production of excess thyroid hormone from the thyroid gland and thyroid growth.

TSHR, also known as thyrotropin receptor, is primarily expressed on thyroid epithelial cells.

The TSHR holoreceptor has 764 residues and comprises an N-terminal extracellular domain, to which TSH binds, a serpentine (or transmembrane domain) and a C-terminal intracellular domain.

TSHR comprises a large extracellular domain (418 amino acids) with highly conserved Cys residues, which facilitate the formation of an extracellular domain tertiary structure that may be important in both ligand binding and inactive receptor conformation. The extracellular domain comprises over half the total protein length and is sufficient for high-affinity ligand binding. After being transported to the cell surface the receptor molecule is subjected to intra-molecular cleavage, leading to the removal of a 50 amino acid sequence between residues 316 and 366. As a result the receptor comprises two subunits, the α subunit comprising the extracellular ligand-binding domain and the β subunit comprising the transmembrane domain and the short C-terminal sequence, bound together with disulphide bonds. In subsequent steps, the α subunit is shed, leading to an excess of ligand-binding domain deprived β subunits on the cell membrane.

Following the binding of circulating TSH to TSHR, a G-protein signaling cascade activates adenylyl cyclase and intercellular levels of cAMP rise. cAMP activates all functional aspects of the thyroid cell, including iodine pumping, thyroglobulin synthesis, iodination, endocytosis and proteolysis, thyroid peroxidase activity and hormone release.

The amino acid sequence of mature TSHR is given below (SEQ ID No. 21).

```
  1 mrpadllqlv llldlprdlg gmgcssppce chqeedfrvt ckdiqripsl ppstqtlkli
 61 ethlrtipsh afsnlpnisr iyvsidvtlq qleshsfynl skvthieirn trnltyidpd
121 alkelpllkf lgifntglkm fpdltkvyst diffileitd npymtsipvn afqglcnetl
181 tlklynngft svqgyafngt kldavylnkn kyltvidkda fggvysgpsl ldvsqtsvta
241 lpskglehlk eliarntwtl kklplslsfl hltradlsyp shccafknqk kirgileslm
301 cnessmqslr qrksvnalns plhqeyeenl gdsivgykek skfqdthnna hyyvffeeqe
361 deiigfgqel knpqeetlqa fdshydytic gdsedmvctp ksdefnpced imgykflriv
421 vwfvsllall gnvfvllill tshyklnvpr flmcnlafad fcmgmyllli asvdlythse
481 yynhaidwqt gpgcntagff tvfaselsvy tltvitlerw yaitfamrld rkirlrhaca
541 imvggwvccf llallplvgi ssyakvsicl pmdtetplal ayivfvltln ivafvivccc
601 yvkiyitvrn pqynpgdkdt kiakrmavli ftdficmapi sfyalsailn kplitvsnsk
661 illvlfypln scanpflyai ftkafqrdvf illskfgick rqaqayrgqr vppknstdiq
721 vqkvthdmrq glhnmedvye lienshltpk kqgqiseeym qtvl
```

The peptide of the invention is at least partially derivable from TSHR. The peptide or portion thereof may be derivable from a region of 64-92, 78-106, 107-135, 136-164 or 201-229 of TSHR. The peptide or portion thereof may be derivable from a fragment of the antigen which arises by natural processing of the antigen by an antigen presenting cell.

Region 64-92 of TSHR (RNB_4) has the following sequence:

LRTIPSHAFSNLPNISRIYVSIDVTLQQL (SEQ ID No 2)

The peptide may comprise the minimal epitope from the following peptide:

TSHR 73-87 (RNB_4J): SNLPNISRIYVSIDV (SEQ ID No 15)

TSHR 73-87 (RNB_4J-GKK): KKGSNLPNISRIYVSIDVGKK (SEQ ID No 16)

The peptide may comprise the minimal epitope from the following peptide:

TSHR 74-88 (RNB_4K): NLPNISRIYVSIDVT (SEQ ID No. 62)

TSHR 74-88 (RNB_4K-GKK): KKGNLPNISRIYVSIDVTGKK (SEQ ID No. 63)

Region 78-106 of TSHR (RNB_5) has the following sequence:

ISRIYVSIDVTLQQLESHSFYNLSKVTHI (SEQ ID No 1)

The peptide may comprise the minimal epitope from the following peptides: TSHR 78-92 (RNB_5A), 79-93 (RNB_5B), 80-94 (RNB_5C), 81-95 (RNB_5D), 82-96 (RNB_5E) and 83-97 (RNB_5F).

The sequences of TSHR 78-92, 79-93, 80-94, 81-95, 82-96 and 83-97 are:

TSHR 78-92 (RNB_5A): ISRIYVSIDVTLQQL (SEQ ID No 6)
TSHR 79-93 (RNB_5B): SRIYVSIDVTLQQLE (SEQ ID No 7)
TSHR 80-94 (RNB_5C): RIYVSIDVTLQQLES (SEQ ID No 8)
TSHR 81-95 (RNB_5D): IYVSIDVTLQQLESH (SEQ ID No 9)
TSHR 82-96 (RNB_5E): YVSIDVTLQQLESHS (SEQ ID No 10)
TSHR 83-97 (RNB_5F): VSIDVTLQQLESHSF (SEQ ID No 11)
TSHR 81-95 (RNB_5D-GKK): KKGIYVSIDVTLQQLESHGKK (SEQ ID No 12)
TSHR 81-95 (RNB_5D-KKK):KKKIYVSIDVTLQQLESHKKK(SEQ ID No. 21)

TSHR 82-96 (RNB_5E-GKK): KKGYVSIDVTLQQLESHSGKK (SEQ ID No 13)
TSHR 83-97 (RNB_5F-GKK): KKGVSIDVTLQQLESHSFGKK (SEQ ID No 14)

Region 136-164 (RNB_9) of TSHR has the following sequence:

TGLKMFPDLTKVYSTDIFFILEITDNPYM (SEQ ID No 3)

The peptide may comprise the minimal epitope from the following peptides: TSHR 136-150 (RNB_9A), 137-151 (RNB_9B), 138-152 (RNB_9C) and 139-153 (RNB_9D).

The sequences of TSHR 136-150, 137-151, 138-152 and 139-153 are:

TSHR 136-150 (RNB_9A): TGLKMFPDLTKVYST (SEQ ID No 17)
TSHR 137-151 (RNB_9B): GLKMFPDLTKVYSTD (SEQ ID No 18)
TSHR 138-152 (RNB_9C): LKMFPDLTKVYSTDI (SEQ ID No 19)
TSHR 139-153 (RNB_9D): KMFPDLTKVYSTDIF (SEQ ID No 20)

Region 180-207 of TSHR (RNB_12) has the following sequence:

LTLKLYNNGFTSVQGYAFNGTKLDAVYL (SEQ ID No 64)

The peptide may comprise the minimal epitope from one the peptides shown in the following table:

RNB-12	A	LTLKLYNNGFTSVQG	SEQ ID No. 65

B	TLKLYNNGFTSVQGY	66
C	LKLYNNGFTSVQGYA	68
D	KLYNNGFTSVQGYAF	69
E	LYNNGFTSVQGYAFN	70
F	YNNGFTSVQGYAFNG	71
G	NNGFTSVQGYAFNGT	72
H	NGFTSVQGYAFNGTK	73
I	GFTSVQGYAFNGTKL	74
J	FTSVQGYAFNGTKLD	75
K	TSVQGYAFNGTKLDA	76
L	SVQGYAFNGTKLDAV	77
M	VQGYAFNGTKLDAVY	78

The peptide may comprise the minimal epitope from one the following peptides:

TSHR 180-194 (RNB_12A): LTLKLYNNGFTSVQG (SEQ ID No. 65)

TSHR 180-194 (RNB_12B): TLKLYNNGFTSVQGY (SEQ ID No. 66)

TSHR 180-194 (RNB_12B-KKK): KKKTLKLYNNGFTSVQGYKKK (SEQ ID No. 67).

The present invention also provides a peptide which comprises the sequence:

KK-(G/K)-aa1-(RNB-5D peptide)-aa2-aa3-Z-(G/K)-KK

wherein aa1 is no amino acid, I, K or T;

RNB-5D peptide is YVSIDVTLQQLE, or a variant thereof in which one or more amino acids has been replaced by K,

aa2 is no amino acid, S or K;

aa3 is no amino acid, H or K

which is capable of binding to an MHC molecule *in vitro* and being presented to a T cell without antigen processing.

In this embodiment, the RNB-5D peptide may be YVSIDVTLQQLE, or a variant thereof in which one, two or three amino acids is/are replaced by K.

The peptide may be selected from the following group, which are all identified as being apitopes (Table 1) : KKGIYVSIDVTLQQLESHGKK (SEQ ID No 12), KKGKYVSIDVTLQQLESHGKK (SEQ ID No 22), KKGIKVSIDVTLQQLESHGKK (SEQ ID No 23), KKGIYKSIDVTLQQLESHGKK (SEQ ID No 24), KKGIYVSIDVKLQQLESHGKK (SEQ ID No 25), KKGIYVSIDVTLQKLESHGKK(SEQ ID No 26), KKGIYVSIDVTLQQKESHGKK (SEQ ID No 27), KKGIYVSIDVTLQQLKSHGKK (SEQ ID No 28), KKGIYVSIDVTLQQLEKHGKK (SEQ ID No 29), KKGIYVSIDVTLQQLESKGKK (SEQ ID No 30), KKGYVSIDVTLQQLEGKK (SEQ ID No 31), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No 33), KKGYVSIDVTLQQKEGKK (SEQ ID No 34), KKGYVSIDVKLQKKEGKK (SEQ ID No 35), KKGIYVSIDVTLQQLEGKK (SEQ ID No 36), KKGIYVSIDVKLQQLEGKK (SEQ ID No 37), KKGIYVSIDVTLQKLEGKK (SEQ ID No 38), KKGIYVSIDVTLQQKEGKK (SEQ ID No 39), KKGIYVSIDVKLQKKEGKK (SEQ ID No 40), KKGTYVSIDVTLQQLEGKK (SEQ ID No 41), KKGTYVSIDVKLQQLEGKK (SEQ ID No 42), KKGTYVSIDVTLQKLEGKK (SEQ ID No 43), KKGTYVSIDVTLQQKEGKK (SEQ ID No 44), KKGTYVSIDVKLQKKEGKK (SEQ ID No 45), KKKIYVSIDVTLQQLESHKKK (SEQ ID No 21), KKKKYVSIDVTLQQLESHKKK (SEQ ID No 46), KKKIKVSIDVTLQQLESHKKK (SEQ ID No 47), KKKIYKSIDVTLQQLESHKKK (SEQ ID No 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No 49), KKKIYVSIDVKLQQLESHKKK (SEQ ID No 50), KKKIYVSIDVTLKQLESHKKK (SEQ ID No 51), KKKIYVSIDVTLQKLESHKKK (SEQ ID No 52), KKKIYVSIDVTLQQKESHKKK (SEQ ID No 53), KKKIYVSIDVTLQQLKSHKKK (SEQ ID No 54), KKKIYVSIDVTLQQLEKHKKK (SEQ ID No 55), KKKIYVSIDVTLQQLESKKKK (SEQ ID No 56), KKKYVSIDVTLQQLEKKK (SEQ ID No 57), KKKYVSIDVKLQQLEKKK (SEQ ID No 58), KKKYVSIDVTLQKLEKKK (SEQ ID No 59), KKKYVSIDVTLQQKEKKK (SEQ ID No 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

The peptide may be selected from the following group, which are all identified as apitopes and have improved solubility:
KKGKYVSIDVTLQQLESHGKK (SEQ ID No. 22), KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVTLQQLEGKK (SEQ ID No. 31), KKGYVSIDVKLQQLEGKK (SEQ ID No. 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGIYVSIDVKLQKKEGKK (SEQ ID No. 40), KKGTYVSIDVKLQQLEGKK (SEQ ID No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45),

KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No. 49), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVKLQQLEKKK (SEQ ID No. 58), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

The peptide may be selected from the following group, which are all identified as apitopes and have the best solubility: KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGTYVSIDVKLQQLEGKK (SEQ Id No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

The following peptides are of particular interest: KKGYVSIDVTLQKLEGKK (SEQ ID No. 32), KKGYVSIDVKLQKKEGKK (SEQ ID No. 34), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

TOLERANCE

T cell epitopes play a central role in the adaptive immune response to any antigen, whether self or foreign. The central role played by T cell epitopes in hypersensitivity diseases (which include allergy, autoimmune diseases and transplant rejection) has been demonstrated through the use of experimental models. It is possible to induce inflammatory or allergic diseases by injection of synthetic peptides (based on the structure of T cell epitopes) in combination with adjuvant.

By contrast, it has been shown to be possible to induce immunogenic tolerance towards particular antigens by administration of peptide epitopes in soluble form. Administration of soluble peptide antigens has been demonstrated as an effective means of inhibiting disease in experimental autoimmune encephalomyelitis (EAE – a model for multiple sclerosis (MS)) (Metzler and Wraith (1993) Int. Immunol. **5**:1159-1165; Liu and Wraith (1995) Int. Immunol. 7:1255-1263; Anderton and Wraith (1998) Eur. J. Immunol. 28:1251-1261); and experimental models of arthritis, diabetes, and uveoretinitis (reviewed in Anderton and Wraith (1998) as

above). This has also been demonstrated as a means of treating an ongoing disease in EAE (Anderton and Wraith (1998) as above).

Tolerance is the failure to respond to an antigen. Tolerance to self antigens is an essential feature of the immune system, when this is lost, autoimmune disease can result. The adaptive immune system must maintain the capacity to respond to an enormous variety of infectious agents while avoiding autoimmune attack of the self antigens contained within its own tissues. This is controlled to a large extent by the sensitivity of immature T lymphocytes to apoptotic cell death in the thymus (central tolerance). However, not all self antigens are detected in the thymus, so death of self-reactive thymocytes remains incomplete. There are thus also mechanisms by which tolerance may be acquired by mature self-reactive T lymphocytes in the peripheral tissues (peripheral tolerance). A review of the mechanisms of central and peripheral tolerance is given in Anderton *et al* (1999) (*Immunological Reviews* **169**:123-137).

GD is currently believed to be caused by TSHR stimulating autoantibodies that bind to and activate the TSHR, thereby stimulating thyroid hormone synthesis and secretion, and thyroid growth. The peptides of the present invention are capable of inducing tolerance to TSHR, such that when administered to a subject, they may reinstate tolerance to the TSHR self-protein and curtail the pathogenic immune response.

Tolerance may result from or be characterised by the induction of anergy in at least a portion of CD4+ T cells. In order to activate a T cell, a peptide must associate with a "professional" APC capable of delivering two signals to T cells. The first signal (signal 1) is delivered by the MHC-peptide complex on the cell surface of the APC and is received by the T cell via the TCR. The second signal (signal 2) is delivered by costimulatory molecules on the surface of the APC, such as CD80 and CD86, and received by CD28 on the surface of the T cell. It is thought that when a T cell receives signal 1 in the absence of signal 2, it is not activated and, in fact, becomes anergic. Anergic T cells are refractory to subsequent antigenic challenge, and may be capable of suppressing other immune responses. Anergic T cells are thought to be involved in mediating T cell tolerance.

Peptides which require processing before they can be presented in conjunction with MHC molecules do not induce tolerance because they have to be handled by mature antigen presenting cells. Mature antigen presenting cells (such as macrophages, B cells and dendritic cells) are capable of antigen processing, but also of delivering both signals 1 and 2 to a T cell, leading to T cell activation. Apitopes, on the other hand, will be able to bind class II MHC on

immature APC. Thus they will be presented to T cells without co-stimulation, leading to T cell anergy and tolerance.

Of course, apitopes are also capable of binding to MHC molecules at the cell surface of mature APC. However, the immune system contains a greater abundance of immature than mature APC (it has been suggested that less than 10% of dendritic cells are activated, Summers et al. (2001) Am. J. Pathol. **159**: 285-295). The default position to an apitope will therefore be anergy/tolerance, rather than activation.

It has been shown that, when tolerance is induced by peptide inhalation, the capacity of antigen-specific CD4+ T cells to proliferate is reduced. Also, the production of IL-2, IFN-γ and IL-4 production by these cells is down-regulated, but production of IL-10 is increased. Neutralisation of IL-10 in mice in a state of peptide-induced tolerance has been shown to restore completely susceptibility to disease. It has been proposed that a population of regulatory cells persist in the tolerant state which produce IL-10 and mediate immune regulation (Burkhart *et al* (1999) Int. Immunol. **11**:1625-1634).

The induction of tolerance to TSHR can be monitored *in vivo* by looking for a reduction in the level of:

i) TSHR autoantibodies;

ii) CD4+ T cells specific for TSHR; and/or

iii) B cells capable of secreting TSHR autoantibodies

by techniques known in the art.

The induction of tolerance can therefore also be monitored by various techniques including:

(a) the induction of anergy in CD4+ T cells (which can be detected by subsequent challenge with antigen *in vitro*);

(b) changes in the CD4+ T cell population, including

(i) reduction in proliferation;

(ii) down-regulation in the production of IL-2, IFN-γ and IL-4; and

(iii) increase in the production of IL-10.

As used herein, the term "tolerogenic" means capable of inducing tolerance.

COMPOSITION

The present invention also relates to a composition, such as a pharmaceutical composition comprising one or more peptide(s) according to the first or second aspect of the invention.

The peptide may comprise a plurality of peptides, for example two, three, four, five or six peptides.

The composition of the present invention may be for prophylactic or therapeutic use.

When administered for prophylactic use, the composition may reduce or prevent the generation of an immune response to TSHR. The level of immune response is less than would be obtained if the patient had not been treated the composition. The term "reduce" indicates that a partial reduction in immune response is observed, such as a 50%, 70%, 80% or 90% reduction in the response that would have been observed if the patient had not been treated with the composition (or in the response observed in an untreated patient over the same time-period). The term "prevent" indicates that no appreciable immune response to TSHR is observed.

When administered for therapeutic use, the composition may suppress an already on-going immune response to TSHR. The term "suppress" indicates a reduction in the level of an on-going immune response, compared to the level before peptide treatment, or the levels which would have been observed at the same time point had the treatment not been given.

Treatment with the composition of the present invention may cause a reduction in level of any or all of the following:

i) TSHR autoantibodies
ii) CD4+ T cells specific for TSHR
iii) B cells secreting TSHR autoantibodies.

Detection of all of the factors can be carried out by techniques known in the art, such as ELISA, flow cytometry etc.

Treatment with the composition of the present invention may also or alternatively cause anergy in CD4+ T cells specific for TSHR. Anergy can be detected by, for example, subsequent challenge with TSHR *in vitro*.

Where there are two or more apitopes, the pharmaceutical composition may be in the form of a kit, in which some or each of the apitopes are provided separately for simultaneous, separate or sequential administration.

Alternatively (or in addition) if the pharmaceutical composition (or any part thereof) is to be administered in multiple doses, each dose may be packaged separately.

Also, in the pharmaceutical compositions of the present invention, the or each apitope may be admixed with any suitable binder(s), lubricant(s), suspending agent(s), coating agent(s), or solubilising agent(s).

FORMULATION

The composition may by prepared as an injectable, either as liquid solution or suspension; solid form suitable for solution in, or suspension in, liquid prior to injection may also be prepared. The preparation may also be emulsified, or the peptides encapsulated in liposomes. The active ingredients may be mixed with excipients which are pharmaceutically acceptable and compatible with the active ingredient. Suitable excipients are, for example, water, saline (for example, phosphate-buffered saline), dextrose, glycerol, ethanol, or the like and combinations thereof.

In addition, if desired, the composition may contain minor amounts of auxiliary substances such as wetting or emulsifying agents and/or pH buffering agents. Buffering salts include phosphate, citrate, acetate, hydrochloric acid and/or sodium hydroxide may be used for pH adjustment. For stabilisation, disaccharides may be used such as sucrose or trehalose.

If the composition comprises a plurality of peptides, the relative ratio of the peptides may be approximately equal. Alternatively the relative ratios of each peptide may be altered, for example, to focus the tolerogenic response on a particular sub-set of autoreactive T-cells or if it is found that one peptide works better than the others in particular HLA types.

After formulation, the composition may be incorporated into a sterile container which is then sealed and stored at a low temperature, for example 4°C, or it may be freeze-dried.

Conveniently the composition is prepared as a lyophilized (freeze dried) powder. Lyophilisation permits long-term storage in a stabilised form. Lyophilisation procedures are well known in the art, see for example

http://www.devicelink.com/ivdt/archive/97/01/006.html. Bulking agents are commonly used prior to freeze-drying, such as mannitol, dextran or glycine.

The composition may be administered in a convenient manner such as by the oral, intravenous (where water soluble), intramuscular, subcutaneous, sublingual, intranasal, intradermal or suppository routes or implanting (e.g. using slow release molecules).

The composition may advantageously be administered via intranasal, subcutaneous or intradermal routes.

The peptide and composition of the invention may be used to treat a human subject. The subject may have GD. The subject may have TSHR autoantibodies.

The subject may be an HLA-haplotype which is associated with a predisposition to develop inhibitory THSR autoantibodies. The subject may express HLA-DR3 or HLA-DR4. Methods for determining the HLA haplotype of an individual are known in the art.

Typically, a physician will determine the actual dosage which will be most suitable for an individual subject and it will vary with the age, weight and response of the particular patient.

In a preferred embodiment a "dose escalation" protocol may be followed, where a plurality of doses is given to the patient in ascending concentrations. Such an approach has been used, for example, for phospholipase A2 peptides in immunotherapeutic applications against bee venom allergy (Müller *et al* (1998) J. Allergy Clin Immunol. 101:747-754 and Akdis et al (1998) J. Clin. Invest. 102:98-106).

KITS

Conveniently, if the composition comprises a plurality of peptides, they may be administered together, in the form of a mixed composition or cocktail. However, there may be circumstances in which it is preferable to provide the peptides separately in the form of a kit, for simultaneous, separate, sequential or combined administration.

The kit may also comprise mixing and/or administration means (for example a vapouriser for intranasal administration; or a syringe and needle for subcutaneous/intradermal dosing). The kit may also comprise instructions for use.

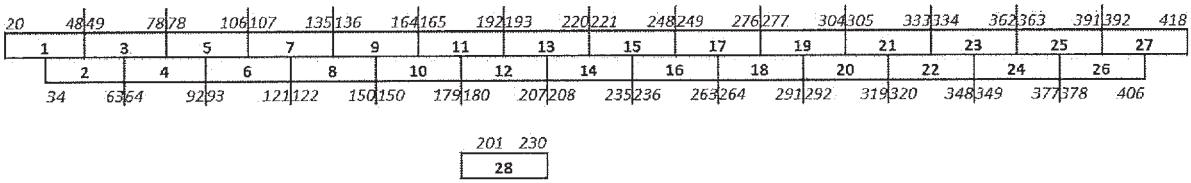
The pharmaceutical composition or kit of the invention may be used to treat and/or prevent a disease.

In particular, the composition/kit may be used to treat and/or prevent GD.

EXAMPLES

Example 1 - Selection of HLA-DR3 TSHR peptides

To identify important epitope regions in the TSHR, the ECD of the TSHR (AA20-418) was divided in 28 overlapping peptides of 28-30 amino acids (28-30-mers) overlapping by 15 amino acids, as shown below.



Name	Length (AA)	Sequence
RNB-1	29	GGMGCSSPPCECHQEEDFRVTCKDIQRIP
RNB-2	30	EEDFRVTCKDIQRIPSLPPSTQTLKLIETH
RNB-3	30	SLPPSTQTLKLIETHLRTIPSHAFSNLPNI
RNB-4	29	LRTIPSHAFSNLPNISRIYVSIDVTLQQL
RNB-5	29	ISRIYVSIDVTLQQLESHSFYNLSKVTHI
RNB-6	29	ESHSFYNLSKVTHIEIRNTRNLTYIDPDA
RNB-7	29	EIRNTRNLTYIDPDALKELPLLKFLGIFN
RNB-8	29	LKELPLLKFLGIFNTGLKMFPDLTKVYST
RNB-9	29	TGLKMFPDLTKVYSTDIFFILEITDNPYM
RNB-10	30	TDIFFILEITDNPYMTSIPVNAFQGLCNET
RNB-11	28	TSIPVNAFQGLCNETLTLKLYNNGFTSV
RNB-12	28	LTLKLYNNGFTSVQGYAFNGTKLDAVYL
RNB-13	28	QGYAFNGTKLDAVYLNKNKYLTVIDKDA
RNB-14	28	NKNKYLTVIDKDAFGGVYSGPSLLDVSQ
RNB-15	28	FGGVYSGPSLLDVSQTSVTALPSKGLEH
RNB-16	28	TSVTALPSKGLEHLKELIARNTWTLKKL
RNB-17	28	LKELIARNTWTLKKLPLSLSFLHLTRAD

RNB-18	28	PLSLSFLHLTRADLSYPSHCCAFKNQKK
RNB-19	28	LSYPSHCCAFKNQKKIRGILESLMCNES
RNB-20	28	IRGILESLMCNESSMQSLRQRKSVNALN
RNB-21	29	SMQSLRQRKSVNALNSPLHQEYEENLGDS
RNB-22	29	SPLHQEYEENLGDSIVGYKEKSKFQDTHN
RNB-23	29	IVGYKEKSKFQDTHNNAHYYVFFEEQEDE
RNB-24	29	NAHYYVFFEEQEDEIIGFGQELKNPQEET
RNB-25	29	IIGFGQELKNPQEETLQAFDSHYDYTICG
RNB-26	29	LQAFDSHYDYTICGDSEDMVCTPKSDEFN
RNB-27	27	DSEDMVCTPKSDEFNPCEDIMGYKFLR
RNB-28	29	KLDAVYLNKNKYLTVIDKDAFGGVYSGPS

The immunogenicity of all peptides was then evaluated by immunizing HLA-DRB1*0301 transgenic mice (DR3 mice) with 200 µg of a pool of 3 peptides emulsified in CFA. After 10 days, LN cells and splenocytes were isolated and stimulated *in vitro* with 10-25 µg/mL of the corresponding individual peptides. Based on the stimulation indexes (SI; 3H-thymidine incorporation (counts per minute) of peptide-stimulated cells divided by that of non-stimulated cells), peptides RNB-5 and RNB-9 were found to be highly immunogenic (SI>10).

Figure 1 shows that LN and splenocytes, isolated from RNB-5 immunized mice, strongly respond to RNB-5 stimulation *in vitro*.

All examples described here will focus on peptide RNB-5.

Example 2 – Identification of apitopes within RNB-5

To determine the exact epitope position within RNB-5, a panel of 15-mer overlapping peptides spanning RNB-5 was synthesized using standard F-moc chemistry. Each peptide was displaced by 1 amino acid, as shown below:

Name	**Sequence**
RNB_5A	ISRIYVSIDVTLQQL
RNB_5B	SRIYVSIDVTLQQLE
RNB_5C	RIYVSIDVTLQQLES
RNB_5D	IYVSIDVTLQQLESH
RNB_5E	YVSIDVTLQQLESHS
RNB_5F	VSIDVTLQQLESHSF

RNB_5G	SIDVTLQQLESHSFY
RNB_5H	IDVTLQQLESHSFYN
RNB_5I	DVTLQQLESHSFYNL
RNB_5J	VTLQQLESHSFYNLS
RNB_5K	TLQQLESHSFYNLSK
RNB_5L	LQQLESHSFYNLSKV
RNB_5M	QQLESHSFYNLSKVT
RNB_5N	QLESHSFYNLSKVTH
RNB_5O	LESHSFYNLSKVTHI

Name	**Modified sequence**
RNB_5D-GKK = RNB_5D_G0	KKGIYVSIDVTLQQLESHGKK
RNB_5E-GKK	KKGYVSIDVTLQQLESHSGKK
RNB_5F-GKK	KKGVSIDVTLQQLESHSFGKK
RNB_5D_KKK = RNB_5D_K0	KKKIYVSIDVTLQQLESHKKK
RNB_5D_G1	KKGKYVSIDVTLQQLESHGKK
RNB_5D_G2	KKGIKVSIDVTLQQLESHGKK
RNB_5D_G3	KKGIYKSIDVTLQQLESHGKK
RNB_5D_G4	KKGIYVKIDVTLQQLESHGKK
RNB_5D_G5	KKGIYVSKDVTLQQLESHGKK
RNB_5D_G6	KKGIYVSIKVTLQQLESHGKK
RNB_5D_G7	KKGIYVSIDKTLQQLESHGKK
RNB_5D_G8	KKGIYVSIDVKLQQLESHGKK
RNB_5D_G9	KKGIYVSIDVTKQQLESHGKK
RNB_5D_G10	KKGIYVSIDVTLKQLESHGKK
RNB_5D_G11	KKGIYVSIDVTLQKLESHGKK
RNB_5D_G12	KKGIYVSIDVTLQQKESHGKK
RNB_5D_G13	KKGIYVSIDVTLQQLKSHGKK
RNB_5D_G14	KKGIYVSIDVTLQQLEKHGKK
RNB_5D_G15	KKGIYVSIDVTLQQLESKGKK
RNB_5D_G16	KKGYVSIDVTLQQLEGKK
RNB_5D_G17	KKGYVSIDVKLQQLEGKK
RNB_5D_G18	KKGYVSIDVTLQKLEGKK
RNB_5D_G19	KKGYVSIDVTLQQKEGKK
RNB_5D_G20	KKGYVSIDVKLQKKEGKK

RNB_5D_G21	KKGIYVSIDVTLQQLEGKK
RNB_5D_G22	KKGIYVSIDVKLQQLEGKK
RNB_5D_G23	KKGIYVSIDVTLQKLEGKK
RNB_5D_G24	KKGIYVSIDVTLQQKEGKK
RNB_5D_G25	KKGIYVSIDVKLQKKEGKK
RNB_5D_G26	KKGTYVSIDVTLQQLEGKK
RNB_5D_G27	KKGTYVSIDVKLQQLEGKK
RNB_5D_G28	KKGTYVSIDVTLQKLEGKK
RNB_5D_G29	KKGTYVSIDVTLQQKEGKK
RNB_5D_G30	KKGTYVSIDVKLQKKEGKK
RNB_5D_K1	KKKKYVSIDVTLQQLESHKKK
RNB_5D_K2	KKKIKVSIDVTLQQLESHKKK
RNB_5D_K3	KKKIYKSIDVTLQQLESHKKK
RNB_5D_K4	KKKIYVKIDVTLQQLESHKKK
RNB_5D_K5	KKKIYVSKDVTLQQLESHKKK
RNB_5D_K6	KKKIYVSIKVTLQQLESHKKK
RNB_5D_K7	KKKIYVSIDKTLQQLESHKKK
RNB_5D_K8	KKKIYVSIDVKLQQLESHKKK
RNB_5D_K9	KKKIYVSIDVTKQQLESHKKK
RNB_5D_K10	KKKIYVSIDVTLKQLESHKKK
RNB_5D_K11	KKKIYVSIDVTLQKLESHKKK
RNB_5D_K12	KKKIYVSIDVTLQQKESHKKK
RNB_5D_K13	KKKIYVSIDVTLQQLKSHKKK
RNB_5D_K14	KKKIYVSIDVTLQQLEKHKKK
RNB_5D_K15	KKKIYVSIDVTLQQLESKKKK
RNB_5D_K16	KKKYVSIDVTLQQLEKKK
RNB_5D_K17	KKKYVSIDVKLQQLEKKK
RNB_5D_K18	KKKYVSIDVTLQKLEKKK
RNB_5D_K19	KKKYVSIDVTLQQKEKKK
RNB_5D_K20	KKKYVSIDVKLQKKEKKK

First, the peptides were analysed using hybridomas generated from DR3 mice. Hybridomas specific for TSHR and RNB-5 were shown to react to RNB-5 A-F presented by both fresh and fixed VAVY cells. Antigen-induced IL-2 production of representative clones is shown in Figure 2.

To determine the ability of these 15-mer peptides to bind to HLA-DR molecule, 2 software tools were used: NetMHCII (http://www.cbs.dtu.dk/services/NetMHCII) and Immune Epitope DataBase (http://tools.immuneepitope.org/analyze/html/mhc_II_binding.html). Using both methods, nested peptides RNB-5A up to RNB-5F were identified as strong binders to both HLA-DRB1*0301 and HLA-DRB1*0401 molecules.

Although GD in humans is strongly associated with the HLA-DRB1*0301 haplotype, the HLA-DRB1*0401 haplotype often occurs in GD patients as well. Since RNB-5A to 5F peptides were predicted to bind to HLA-DRB1*0401 molecules, RNB-5 was tested for its ability to generate an immune response in DR4 mice *in vivo*. LN cells and splenocytes isolated from RNB-5/CFA-immunized DR4 mice showed strong immune responses when stimulated with RNB-5 nested peptides. In addition, the RNB-5 specific hybridomas, generated in DR3 mice, respond to the RNB-5 nested peptides when presented by BM14-cells (HLA-DRB1*0401). Therefore, new hybridomas were generated by immunizing DR4 mice with TSHR/CFA. Hybridomas specific for both TSHR protein and RNB-5 peptide were selected to identify apitopes within RNB-5. Peptides RNB-5A to 5F were identified as apitopes again (Figure 3). The RNB-5 DEF nested peptides were modified by adding amino acids 'GKK' on both the C- and N-terminus. TSHR- and RNB-5 specific hybridomas also react to these modified peptides when presented by both fresh and fixed APCs. Taken together, these data emphasize that this region is interesting for GD patients with either HLA-DRB1*0301 or HLA-DRB1*0401 haplotype.

Part of the TSHR-specific hybridomas generated by immunizing DR4 mice with TSHR/CFA were shown to bind to RNB-4 instead of RNB-5, indicating the presence of other immunogenic regions within the TSHR. RNB-4 specific hybridomas were selected to identify apitopes within RNB-4. Peptide RNB-4J was identified as an apitope (Figure 4). The RNB-4 nested peptide sequences are shown in the table below.

Name	Sequence
RNB_4A	LRTIPSHAFSNLPNI
RNB_4B	RTIPSHAFSNLPNIS
RNB_4C	TIPSHAFSNLPNISR
RNB_4D	IPSHAFSNLPNISRI
RNB_4E	PSHAFSNLPNISRIY
RNB_4F	SHAFSNLPNISRIYV
RNB_4G	HAFSNLPNISRIYVS
RNB_4H	AFSNLPNISRIYVSI
RNB_4I	FSNLPNISRIYVSID
RNB_4J	SNLPNISRIYVSIDV
RNB_4K	NLPNISRIYVSIDVT
RNB_4L	LPNISRIYVSIDVTL
RNB_4M	PNISRIYVSIDVTLQ
RNB_4N	NISRIYVSIDVTLQQ

Name	Modified sequence
RNB_4J-GKK	KKGSNLPNISRIYVSIDVGKK
RNB_4K-GKK	KKGNLPNISRIYVSIDVTGKK

The apitope status of RNB-5D modified peptides was also investigated (Figure 20).

In addition to the RNB-4 and RNB-5 apitopes, the *in silico* prediction software tools also identified peptides RNB-9A to 9D as strong binders to HLA-DRB1*0301 molecules. The peptide sequences are shown in the table below.

Name	Sequence
RNB_9A	TGLKMFPDLTKVYST
RNB_9B	GLKMFPDLTKVYSTD
RNB_9C	LKMFPDLTKVYSTDI
RNB_9D	KMFPDLTKVYSTDIF

The response of TSHR- and RNB-5-specific hybridoma clones, isolated from HLA-DR3 or HLA-DR4 mice immunized with TSHR/CFA, to RNB-5D modified peptides was tested. The results are shown in Figures 11 to 15.

Example 3 – *Ex vivo* tolerance assay

To assess the ability of the RNB-5 apitopes to induce tolerance, the ability of these apitopes to inhibit the immune response was first investigated in healthy HLA-DRB1*0301 or HLA-DRB1*0401 mice *ex vivo*. Mice were pretreated with different RNB-5 apitopes according to the high-dose or the dose-escalation schedule, as described in the method section. The studies showed that pre-treatment with RNB-5 apitopes significantly reduce TSHR-induced T cell proliferation, both in DR3 and DR4 mice (Figure 6A-D). RNB-5 DEF nested peptides were modified by adding amino acids 'GKK' on both the C- and N-terminus. Pre-treatment with these modified apitopes also significantly reduced TSHR-induced T cell proliferation (Figure 6E-F).

Peptides RNB-9A to 9D were predicted to bind strongly to HLA-DRB1*0301 molecules and their ability to induce specific immune tolerance was also investigated. DR3 mice were pretreated with RNB-9A to 9D according to the dose-escalation schedule. RNB-9B and 9C pre-treatment caused a significant reduction in TSHR-induced T cell proliferation in both LN and splenocyte cells (Figure 7).

Peptide RNB 4K-GKK was also shown to significantly reduce TSHR-induced T cell proliferation in DR4 mice (Figure 16).

The RNB-5D modified peptides also significantly reduced TSHR-induced T cell proliferation. Representative experiments with RNB5D-K1, RNB5D-K3 and RNB5D-K16 are shown in Figure 19.

Example 4 – Animal model for GD

To investigate the ability of RNB-5 apitopes to reduce GD-like symptoms in mice, two different animal models for GD were developed.

First, C57/Bl6 mice were immunized with TSHR/CFA to induce anti-TSHR antibody production. To investigate whether a boost immunization would further increase the anti-TSHR antibody levels, one group of mice received a second immunization 4 weeks later with TSHR/IFA. Anti-TSHR antibody levels in sera of mice immunized once reach a plateau level 2 weeks after immunization. A second immunization causes a strong increase in anti-TSHR antibody levels (Figure 8).

Second, Balb/c mice were injected with LacZ-Ad or TSHR-Ad viral particles to induce hyperthyroidism, cause by the action of anti-TSHR antibodies on the thyroid. T4 hormone levels and total IgG anti-TSHR antibody titers were measured in the sera of all mice before, 4 weeks after and 10 weeks after the first injection with adenoviral vectors (Figure 9). Immunizing mice with 10^{10} TSHR-Ad viral particles induced hyperthyroidism in 3/7 mice and 1/7 mice when measured 4 weeks and 10 weeks after the first immunization, respectively. This indicates that T4 levels in 2 mice were normalized during the experiment. Immunizing mice with 10^{11} TSHR-Ad viral particles induced hyperthyroidism in 1/6 mice, both at 4 weeks and 10 weeks after the first immunization. Here, one mouse being hyperthyroid at 4 weeks had normal T4 levels at 10 weeks, while T4 levels of another mouse strongly increased between 4 and 10 weeks. Anti-TSHR antibody levels were measured as total IgG values, without determining their stimulating or blocking effect on the TSHR (Figure 10). Immunizing mice with TSHR-Ad viral particles clearly induced anti-TSHR antibody production. Mice immunized with 10^{10} or 10^{11} TSHR-Ad viral particles produced significantly more antibodies than LacZ-Ad immunized mice. Anti-TSHR antibody levels did not differ between the 10^{10}-TSHR-Ad and 10^{11}-TSHR-Ad immunized mice. No correlation was found between total IgG anti-TSHR antibody levels and T4 levels.

These animal models are used to investigate whether RNB-5 apitopes can reduce the GD-like symptoms *in vivo*.

Example 5 – Identification of apitopes in the RNB12 region

The RNB12 as well as the nested peptides are not immunogenic in mice. Therefore the region was identified by the reactivity of a T cell line generated from Graves' disease patients. Figure 17 shows the results obtained from such a T cell line.

RNB12 and the modified peptide RNB12-KKK were confirmed to be apitopes (Figure 18).

Materials and methods

Mice

HLA-DRB1*0301 transgenic mice (DR3 mice) were bred and maintained in the Immunogenetics mouse colony of Mayo Clinic. HLA DR3-tg founder mice were obtained from Gunter Hammerling (German Cancer Research Center, Heidelberg, Germany). Briefly, a

6-kb *Nde*I fragment of a HLA DRA genomic clone in pUC and a 24-kb *Cla*I*Sal*I fragment of cos 4.1 containing the *B* gene were coinjected into fertilized eggs from (C57BL/6xDBA/2)-F1 donors mated with C57BL/6 males. The transgenic mice were bred on to I-Ab knockout mice. DR3 mice were bred on to C57BL/10 background for 10 generations. These DR3 mice express the HLA-DRB1*0301 molecule but not the mouse MHC-II molecule.

The DR4 mouse strain was originally created by Lars Fugger et al (PNAS 1994; volume 91:6151-6155) in that a HLA-DRA*0101/ HLA-DRB1*0101 and mCD3-huCD4c/g constructs were co-microinjected into embryos from (DBA/1xA.CA)F1 matings and viable embryos were transferred into pseudopregnant female (Balb/c x 129)F1 for development to term. The offspring has later been bred into the IA-b knockout C57BL/6 genetic background (AB0 mice) lacking mouse MHC class II molecule expression. The only MHC class II molecule expressed in these DR4 mice is therefore the human HLA DR4 molecule.

Animal studies were approved by the 'Ethical Committee for Animal experiments' (ECD) at Hasselt University and performed with the highest standards of care in a pathogen-free facility.

Peptides

Peptides were synthesised by GL Biochem Ltd (Shangai, China) and stored in dimethyl sulfoxide (DMSO; Sigma-Aldrich, Bornem, Belgium) at -80°C.

Investigation of peptides binding to HLA-DRB1*0301

NetMHCII 2.2 Server

NetMHCII 2.2 server predicts binding of peptides to HLA-DRB1*0301 using artificial neuron networks. The prediction values are given in nM IC50 values. Strong and weak binding peptides are indicated in the output. High affinity binding peptides have an IC50 value below 50 nM, and weak binding peptides an IC50 values below 500 nM. The result is presented as prediction score which is calculated as follows: 1-log50000(aff). Website address: http://www.cbs.dtu.dk/services/NetMHCII.

Immune Epitope DataBase (IEDB): consensus method

For each peptide, a percentile rank for each of the four methods (ARB, combinatorial library, SMM_align and Sturniolo) was generated by comparing the peptide's score against the scores of five million random 15-mers selected from SWISSPROT database. A small numbered percentile rank indicates high affinity. The median percentile rank of the four methods was then used to generate the rank for consensus method. Website address:

http://tools.immuneepitope.org/analyze/html/mhc_II_binding.html.

Determination of immunogenicity of the long peptides

Priming

DR3 mice were injected subcutaneously at the base of the tail with 100 µg of antigen in PBS (Lonza, Verviers, Belgium) emulsified with Complete Freund Adjuvant ((CFA; BD Benelux, Erembodegem, Belgium) containing 4 mg/ml Mycobacterium tuberculosis (MTb, BD Benelux)) (100µl/injection). Depending on the experiment, RNB peptides or full-length TSHR-289 protein were used as antigen. Control animals were injected at the same time with PBS/CFA alone.

Cell culture

Ten days after immunization, draining lymph nodes (LN) and spleen were harvested. LN cells and splenocytes were isolated and cultured in X-vivo 15 medium (supplemented with glutamine, penicillin and streptomycin; Lonza) in 96-well flat bottom plates. To investigate antigen-induced cell proliferation, $0.5x10^6$ cells/well were cultured (200 µl/well) for 72 hours with different antigen concentrations (0-25 µg/ml) or with 12.5 µg/ml purified protein derivative (PPD; priming control; Statens serum institut, Copenhagen, Denmark).

Proliferation assay and cytokine analysis

After 72 hours, 60 µL of cell supernatant was harvested and frozen. 20 µL/well of tritiated thymidine (PerkinElmer, Zaventem, Belgium) were then added to the cells to obtain a final concentration of 1 µCi/well. The cells were incubated at 37°C, and after 16h, plates were frozen. Thawed plates were harvested and read with β-counter (Wallac 1450 Microbeta Trilux Liquid Scintillation Counter) to assess the cell proliferation. The thawed supernatant was analysed with the mouse Th1/Th2 10plex FlowCytomix Multiplex (Bender MedSystems, Vienna, Austria) to measure the antigen-induced cytokine production.

Generation of RNB-5 specific hybridomas

Priming and T cell line establishment

On day 0, mice were injected subcutaneously at the base of the tail with 100 µg antigen/CFA (RNB-5 for DR3 mice; TSHR for DR4 mice). Control mice were immunized with PBS/CFA. On day 10, the draining LNs and spleens were removed and single-cell suspensions were generated. Some of the cells were used to measure antigen-induced cell proliferation, as described above. The remaining splenocytes and LN cells were mixed and $CD4^+$ T-cells were isolated using a negative purification kit (untouched $CD4^+$ T-cells; Miltenyi, Leiden, The Netherlands). $CD4^+$ T-cells were then cultured together with antigen (25µg/ml RNB-5 or 0.5

µg/ml TSHR-289 protein) and irradiated splenocytes (3000 rad) from DR3 mice (APC:$CD4^+$ T-cell ratio 1:1; $5x10^6$cells/ml). Cells were cultured in X-vivo 15 medium to avoid foetal calf serum (FCS)-induced cell activation. On day 4, 20 U/ml of recombinant human IL-2 (R&D, Abingdon, United Kingdom) was added to the cells. On day 7, living cells were harvested by eliminating dead cells using Ficoll density gradient separation (Histopaque 1083, Sigma-Aldrich). Cells were then restimulated as described above, changing the APC: $CD4^+$ T-cell ratio to 2:1. On day 9, living cells were harvested and some of them were used for fusion. The remaining $CD4^+$ T-cells were left in culture and IL-2 was added on day 10. On day 14, living cells were harvested, restimulated with antigen in the presence of APC (ratio of APC:$CD4^+$ T-cells at 3:1), and used for a second fusion on day 16.

Fusion

$1x10^7$ BW5147 cells (Health Protection Agency Culture Collections, Salisbury, UK) and $5x10^6$ $CD4^+$ T-cells were mixed in a 50 ml tube and washed in 37°C serum free medium. After centrifugation, the cell pellet was gently resuspended. 1 ml of 37°C polyethylene glycol (PEG; 40-50% solution, Sigma-Aldrich) was added over 45 sec, keeping the cells in a small 37°C water bath. The cells were incubated at 37°C for 45 sec. Then, 1 ml of 37°C serum free medium was added over 30 sec while swirling, followed by 2, 3, 4, 10 and 30 ml consecutively. The tube was inverted very slowly and incubated at 37°C for 4 min. Cells were centrifuged for 5 min at 1300 rpm at room temperature (RT) without brake. The supernatant was removed and 50 ml of RT serum free medium was slowly added to avoid dislodging the cell pellet. The washing step was repeated with complete medium. Finally, cells were resuspended in RT complete medium with 10%-FCS and plated at different cell concentrations in 96-well flat bottom plates (100 µl/well). After 48h, cells were cultured in 1x hypoxanthine-aminopterin-thymidine (HAT, Sigma-Aldrich) medium and hybridoma cell growth was detected after approximately 6 days. Clones were maintained in HAT medium until they were stable, then weaned via Hypoxanthine-thymidine (HT, Sigma-Aldrich) medium to complete RPMI medium. At a regular base, clones were frozen in freezing medium (90% FCS+10%DMSO).

Assessment of antigen-specificity of clones

Hybridoma cells were cultured with $5x10^4$ VAVY or BM14 cells (human cell line expressing HLA-DRB1*0301 or HLA-DRB1*0401, respectively; International Histocompatibility Working group, Seattle, USA) and antigen (10-25 µg/ml). After 48h, antigen-induced IL-2 production was measured by enzyme-linked immunosorbent assay (ELISA).

IL-2 ELISA

96-well plates (Immunosorb 96 well, Fisher Scientific, Erembodegem, Belgium) were coated overnight at 4°C with 50µl/well purified rat anti-mouse IL-2 capture Ab (BD Biosciences, Oxford, UK), diluted 1:250 in carbonate buffer. After 2 washes with PBS-0.05% Tween, wells were blocked with 10% FCS/PBS for 1 hour at RT. Then, wells were incubated with 50 µl of cell culture supernatant or IL-2 standard (BD Biosciences, Belgium, Erembodegem) for 2h at RT. Wells were incubated with 50µl/well of biotin rat anti-mouse IL-2 (BD Biosciences) diluted 1:1000 in 10% FCS/PBS for 1 h at RT, followed by incubation with 50µl/well extravidin peroxidase (Sigma-Aldrich) diluted 1:1000 in PBS for 30 min at RT. To detect antibody-binding, 50µl/well of TMB substrate solution (Perbio Science, Erembodegem, Belgium) was added. After 11 min, the color reaction was stopped using 50µl/well 2M H_2SO_4. Optical density (OD) was measured at 450 nm (630 nm ref) (Tecan Benelux, Mechelen, Belgium).

Antigen processing independent presentation system

Antigen-specific clones were tested for their reactivity to the 15-mer peptides (RNB-5A to 5O), presented by fixed or not fixed VAVY or BM14 cells (=APCs). $5x10^4$ cells from the individual clones were cultured with 25 µg/ml peptide and $5x10^4$ fixed or fresh APCs. To fixate APCs, cells were incubated with 0.5% paraformaldehyde (Merck, Darmstadt, Germany) (pH7) for 5 min at RT. The fixation reaction was stopped by adding 0.4M glycine (Sigma-Aldrich) and washing the cells in RPMI-10%FCS. Additionally, reactivity towards human TSHR-289 protein (Chesapeake-PERL, Savage, Maryland, USA) was measured to identify cryptic epitopes. After 48h, antigen-induced IL-2 production was measured by ELISA.

Assessment of RNB-5 apitope solubility

Solubility of the peptides was analysed by Anabiotec (Zwijnaarde, Belgium). In short, peptide samples were dissolved at two different target concentrations (1mg/ml and 4 mg/ml) by adding PBS pH 7.0 ± 0.1. The peptide solutions were incubated at RT for at least 16 hours. Turbidity was measured at 320 and 360 nm, before and after centrifugation. Peptide concentration was determined by using absorbance at 280 and 205 nm and by HPLC-UV.

Peptides were dissolved at stock concentration of 20 mg/mL in DMSO. Dilution series of target concentrations 4, 2 and 1 mg/mL were prepared in PBS. The peptide solutions were incubated at RT for 16-17 hours to allow any precipitate to form. Turbidity was scored by visual observation and adsorbance was measured at 205 nm, 280 nm and 320 nm using a Nanodrop device. Peptide solutions were centrifugated at 14800 rpm for 10 minutes and visual observation and adsorbance measurements were repeated. Peptide concentration was calculated using the following formula:

$$Concentration\ \left(\frac{mg}{mL}\right) = \frac{A_{280}\ (no\ units) x\ Molecular\ Weight\ (Da)}{Extinction\ Coefficient\ (\varepsilon_{280})(M_{-1}cm_{-1})\ x\ l\ (cm)}$$

Tolerance induction with RNB-5 apitope treatment

DR3 mice were injected subcutaneously in the back of the neck with RNB-5 15-mer peptides (100µg/injection) or PBS at day -8, -6, -4 (high dose schedule) (Figure 5). Alternatively, mice were injected with 0.1µg, 1µg and 10 µg peptides on days -15, -13 and -11 respectively, followed by 3 injections of 100µg peptide on days -8, -6 and -4 (dose escalation schedule). On day 0, the mice were injected subcutaneously in the base of the tail with 100 µg antigen/CFA (RNB-5 peptide or TSHR-289 protein). Ten days after immunization, the draining LNs and spleens were harvested. Proliferation assay and cytokine measurement were performed as described above.

Animal models for GD

Immunization of mice with TSHR A-subunit adenovirus

Adenovirus expressing the human TSHR A-subunit (amino acid residues 1-289, A-subunit Ad) and control adenovirus (LacZ-Ad) expressing β-galactosidase were purchased from Viraquest (North Liberty, IA, USA). Six-week old female Balb/cJOlaHsd mice (Harlan Laboratories, Venray, The Netherlands) were injected intramuscularly in the thigh muscle with TSHR-Ad (10^{10} or 10^{11} particles) or LacZ-Ad (10^{10} particles). All mice were immunized simultaneously using the same batch of adenovirus. Mice were injected on three occasions at three weekly intervals (day 0, 21 and 42) and blood was drawn before the first immunization and one week after the second immunization. All mice were euthanized 4 weeks after the third injection (week 10) to obtain blood and thyroid glands.

Immunization of mice with TSHR/CFA

Female six-week old C57/Bl6JOlaHsd mice (Harlan Laboratories) (8 mice per group) were subcutaneously challenged at the base of the tail with 50 µg TSHR-289 protein emulsified in CFA with 4 mg/ml MTb (50µl). Mice were tail bled on days 0 (preimmune), 7, 21, 35, 49, 63 (Group A), days 0, 14, 28, 42, 56 (Group B) or days 0, 21, 28, 42, 56 (Group C). Mice of group C received a boost immunization at week 4 with 50 µg TSHR-289 protein emulsified in incomplete Freunds'adjuvant (IFA). Ten weeks after the first immunization, all mice were euthanized and blood was collected by cardiac puncture.

TSHR antibodies

Anti-TSHR antibodies (IgG class) against purified TSHR-289 protein (Chesapeake-Perl) were measured using ELISA. 96-wells plates (half area 96-well, Fisher Scientific) were coated overnight at RT with 50 µl/well of TSHR-289 protein in PBS (0.5µg/ml). After washing with PBS-0.05% Tween, wells were blocked with 1% BSA (w/v) in PBS for 1h at RT and incubated with test sera (duplicate aliquots, 1:50 dilution). Mouse anti-TSHR antibody (A9, Abcam, Cambridge, UK) was used as a positive control. Antibody binding was then detected with horseradish peroxidase-conjugated goat anti-mouse IgG (Abcam) and the signal was developed with TMB. Optical density (OD) was measured in a plate reader at 450 nm (Tecan Benelux).

Serum thyroxine and thyroid histology

Total thyroxine (T4) was measured in undiluted mouse serum (10µl) using the CBI mouse/rat thyroxine ELISA kit (Calbiotech, Spring Valley, CA, USA) according to the manufacturer's instructions. T4 values were computed from standards in the kit and expressed as µg/dl. Thyroid glands were fixed in 10% neutral buffered formalin (pH 7.5), processed to sections and stained with hematoxylin and eosin. Sections were observed for pathological changes (hypertrophy, hypercellularity of epithelial cells and infiltration of lymphocytes) and scored (KWS Biotest, Bristol, UK).

Table 1

	Peptide	Sequence	Solubility	Induce response of hybridomas	Apitope
RNB-5D-GKK	G0	KKGIYVSIDVTLQQLESHGKK	+	+++	+
	G1	KKGKYVSIDVTLQQLESHGKK	++	++	+
	G2	KKGIKVSIDVTLQQLESHGKK	+	+	+
	G3	KKGIYKSIDVTLQQLESHGKK	++++	+	+
	G4	KKGIYVKIDVTLQQLESHGKK	+	-	-
	G5	KKGIYVSKDVTLQQLESHGKK	ND	-	-
	G6	KKGIYVSIKVTLQQLESHGKK	ND	-	-
	G7	KKGIYVSIDKTLQQLESHGKK	ND	-	-
	G8	KKGIYVSIDVKLQQLESHGKK	+	+++	+
	G9	KKGIYVSIDVTKQQLESHGKK	ND	-	-
	G10	KKGIYVSIDVTLKQLESHGKK	ND	-+	-
	G11	KKGIYVSIDVTLQKLESHGKK	+	+++	+
	G12	KKGIYVSIDVTLQQKESHGKK	+	+++	+
	G13	KKGIYVSIDVTLQQLKSHGKK	+	+++	+
	G14	KKGIYVSIDVTLQQLEKHGKK	+	+++	+
	G15	KKGIYVSIDVTLQQLESKGKK	+	+++	+
	G16	KKGYVSIDVTLQQLEGKK	++	++	+

	G17	KKGYVSIDVKLQQLEGKK	++++	++	+
	G18	KKGYVSIDVTLQKLEGKK	++++	+++	+
	G19	KKGYVSIDVTLQQKEGKK	++++	++	+
	G20	KKGYVSIDVKLQKKEGKK	++++	+	+
	G21	KKGIYVSIDVTLQQLEGKK	+	+++	+
	G22	KKGIYVSIDVKLQQLEGKK	+	+++	+
	G23	KKGIYVSIDVTLQKLEGKK	+	+++	+
	G24	KKGIYVSIDVTLQQKEGKK	+	+++	+
	G25	KKGIYVSIDVKLQKKEGKK	+++	++	+
	G26	KKGTYVSIDVTLQQLEGKK	+	+++	+
	G27	KKGTYVSIDVKLQQLEGKK	++++	++	+
	G28	KKGTYVSIDVTLQKLEGKK	+	+++	+
	G29	KKGTYVSIDVTLQQKEGKK	+	++	+
	G30	KKGTYVSIDVKLQKKEGKK	++++	++	+
	M1	KKGIYLSIDATLQRLEPHGKK	+	-	-

RNB-5D-KKK	K0	KKKIYVSIDVTLQQLESHKKK	+	+++	+
	K1	KKKKYVSIDVTLQQLESHKKK	++++	++	+
	K2	KKKIKVSIDVTLQQLESHKKK	+	-+	+
	K3	KKKIYKSIDVTLQQLESHKKK	++++	+	+
	K4	KKKIYVKIDVTLQQLESHKKK	+++	-+	+
	K5	KKKIYVSKDVTLQQLESHKKK	ND	-	-
	K6	KKKIYVSIKVTLQQLESHKKK	ND	-	-
	K7	KKKIYVSIDKTLQQLESHKKK	ND	-	-
	K8	KKKIYVSIDVKLQQLESIIKKK	+	+++	+
	K9	KKKIYVSIDVTKQQLESHKKK	ND	-	-
	K10	KKKIYVSIDVTLKQLESHKKK	ND	+	+
	K11	KKKIYVSIDVTLQKLESHKKK	+	+++	+
	K12	KKKIYVSIDVTLQQKESHKKK	+	+++	+
	K13	KKKIYVSIDVTLQQLKSHKKK	+	+++	+
	K14	KKKIYVSIDVTLQQLEKHKKK	+	+++	+
	K15	KKKIYVSIDVTLQQLESKKKK	+	+++	+
	K16	KKKYVSIDVTLQQLEKKK	++++	++	+
	K17	KKKYVSIDVKLQQLEKKK	++	++	+
	K18	KKKYVSIDVTLQKLEKKK	+	++	+
	K19	KKKYVSIDVTLQQKEKKK	++++	++	+
	K20	KKKYVSIDVKLQKKEKKK	+++	+	+

T cell lines from human PBMCs (Example 5)

Peripheral blood monocytes (PBMC) from healthy donors or Graves' disease patients were isolated (Histopaque-1077, Sigma-Aldrich), and frozen in aliquots. At day 0, cells were thawed and 106 PBMCs/ml cultured with 20ug/ml peptide in supplemented (10mM HEPES, 50U/ml Penicillin/Streptomycin and 4mM L-Glutamine (Lonza)) RPMI 1640 (Lonza) with 5% AB serum (Sigma Aldrich) added in a 6 well plate (Greiner Bio-one) and incubated in 37C

and 5% CO2. After 7 days rhIL-2 (R&D Systems) is added to a final concentration of 20U/ml. At day 12, the cells are harvested, washed and put back into culture at a concentration of 106 + 2x106 newly thawed irradiated autologous PBMCs/ml in a 6 well plate stimulated with 5-10ug/ml peptide and 20U/ml of rhIL-2. At days 15, 18 and 21 additional rhIL-2 was added to a final concentration of 20u/ml.

At day 24 the cells were harvested, washed and 2x104 cultured in a 96 well round-bottom plate (Cellstar, Greiner Bio One) with 105 irradiated autologous PBMCs and VAVY/BM14/MGAR human cell lines expressing human MHC cl II molecules (International Histocompatibility Working group, Seattle, US) in supplemented RPMI + 5% AB serum in presence of different antigens (peptides, protein) in concentration from 5- 50ug/ml. The cultures were incubated for 48h with 0.5 uCI/well 3H-thymidine (Perkin Elmer) added the final 18h. After the plates been frozen the cells were harvested and read with β counter (Wallac 1450 Microbeta Trilux) to assess proliferation. Before adding 3H-thymidine, 60ul/well cell culture supernatant was removed for cytokine analysis.

IFN gamma ELISA

The supernatants from TCL cultures were assessed for IFN gamma content by use of the Human IFN-gamma Duoset kit, R&D Systems following the manufacturer's instruction. Optical density was measured at 450nm (Tecan Benelux)

All publications mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described methods and system of the invention will be apparent to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in molecular biology, immunology or related fields are intended to be within the scope of the following claims.

CLAIMS

1. A peptide which is capable of binding to an MHC class II molecule in vitro and being presented to a T cell without antigen processing, which is selected from the following:

RNB_4K: NLPNISRIYVSIDVT (SEQ ID No. 62)

RNB_4K-GKK: KKGNLPNISRIYVSIDVTGKK (SEQ ID No. 63)

RNB_9B: GLKMFPDLTKVYSTD (SEQ ID No 18)

2. A peptide which is capable of binding to an MHC class II molecule in vitro and being presented to a T cell without antigen processing, wherein the peptide is selected from the following group: KKGIYVSIDVTLQQLESHGKK (SEQ ID No 12), KKGKYVSIDVTLQQLESHGKK (SEQ ID No 22), KKGIKVSIDVTLQQLESHGKK (SEQ ID No 23), KKGIYKSIDVTLQQLESHGKK (SEQ ID No 24), KKGIYVSIDVKLQQLESHGKK (SEQ ID No 25), KKGIYVSIDVTLQKLESHGKK(SEQ ID No 26), KKGIYVSIDVTLQQKESHGKK (SEQ ID No 27), KKGIYVSIDVTLQQLKSHGKK (SEQ ID No 28), KKGIYVSIDVTLQQLEKHGKK (SEQ ID No 29), KKGIYVSIDVTLQQLESKGKK (SEQ ID No 30), KKGYVSIDVTLQQLEGKK (SEQ ID No 31), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No 33), KKGYVSIDVTLQQKEGKK (SEQ ID No 34), KKGYVSIDVKLQKKEGKK (SEQ ID No 35), KKGIYVSIDVTLQQLEGKK (SEQ ID No 36), KKGIYVSIDVKLQQLEGKK (SEQ ID No 37), KKGIYVSIDVTLQKLEGKK (SEQ ID No 38), KKGIYVSIDVTLQQKEGKK (SEQ ID No 39), KKGIYVSIDVKLQKKEGKK (SEQ ID No 40), KKGTYVSIDVTLQQLEGKK (SEQ ID No 41), KKGTYVSIDVKLQQLEGKK (SEQ ID No 42), KKGTYVSIDVTLQKLEGKK (SEQ ID No 43), KKGTYVSIDVTLQQKEGKK (SEQ ID No 44), KKGTYVSIDVKLQKKEGKK (SEQ ID No 45), KKKIYVSIDVTLQQLESHKKK (SEQ ID No 21), KKKKYVSIDVTLQQLESHKKK (SEQ ID No 46), KKKIKVSIDVTLQQLESHKKK (SEQ ID No 47), KKKIYKSIDVTLQQLESHKKK (SEQ ID No 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No 49), KKKIYVSIDVKLQQLESHKKK (SEQ ID No 50), KKKIYVSIDVTLKQLESHKKK (SEQ ID No 51), KKKIYVSIDVTLQKLESHKKK (SEQ ID No 52), KKKIYVSIDVTLQQKESHKKK (SEQ ID No 53), KKKIYVSIDVTLQQLKSHKKK (SEQ ID No 54), KKKIYVSIDVTLQQLEKHKKK (SEQ ID No 55), KKKIYVSIDVTLQQLESKKKK (SEQ ID No 56), KKKYVSIDVTLQQLEKKK (SEQ ID No 57), KKKYVSIDVKLQQLEKKK (SEQ ID No 58), KKKYVSIDVTLQKLEKKK (SEQ ID No 59), KKKYVSIDVTLQQKEKKK (SEQ ID No 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

3. A peptide according to claim 2, wherein the peptide is selected from the group consisting of:
KKGKYVSIDVTLQQLESHGKK (SEQ ID No. 22), KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVTLQQLEGKK (SEQ ID No. 31), KKGYVSIDVKLQQLEGKK (SEQ ID No. 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGIYVSIDVKLQKKEGKK (SEQ ID No. 40), KKGTYVSIDVKLQQLEGKK (SEQ ID No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKIYVKIDVTLQQLESHKKK (SEQ ID No. 49), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVKLQQLEKKK (SEQ ID No. 58), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60), KKKYVSIDVKLQKKEKKK (SEQ ID No. 61).

4. A peptide according to claim 3, wherein the peptide is selected from the group consisting of: KKGIYKSIDVTLQQLESHGKK (SEQ ID No. 24), KKGYVSIDVKLQQLEGKK (SEQ ID No 32), KKGYVSIDVTLQKLEGKK (SEQ ID No. 33), KKGYVSIDVTLQQKEGKK (SEQ ID No. 34), KKGYVSIDVKLQKKEGKK (SEQ ID No. 35), KKGTYVSIDVKLQQLEGKK (SEQ Id No. 42), KKGTYVSIDVKLQKKEGKK (SEQ ID No. 45), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

5. A peptide according to claim 3, wherein the peptide is selected from the group consisting of: KKGYVSIDVTLQKLEGKK (SEQ ID No. 32), KKGYVSIDVKLQKKEGKK (SEQ ID No. 34), KKKKYVSIDVTLQQLESHKKK (SEQ ID No. 46), KKKIYKSIDVTLQQLESHKKK (SEQ ID No. 48), KKKYVSIDVTLQQLEKKK (SEQ ID No. 57), KKKYVSIDVTLQQKEKKK (SEQ ID No. 60).

6. A composition comprising a plurality of peptides, including one or more peptide(s) according to any preceding claim.

7. A peptide according to any of claims 1 to 5, or a composition according to claim 6, for use in supressing or preventing the production of TSHR autoantibodies *in vivo*.

8. A peptide according to any of claims 1 to 5, or a composition according to claim 6, for use in treating and/or preventing Graves' Disease in a subject.

9. The use of a peptide according to any of claims 1 to 5, or a composition according to claim 6, in the manufacture of a medicament to suppress or prevent the production of TSHR autoantibodies *in vivo*, wherein said peptide or composition is to be administered to the subject.

10. The use of a peptide according to any of claims 1 to 5, or a composition according to claim 6, in the manufacture of a medicament to treat and/or prevent Graves' Disease in a subject, wherein said peptide or composition is to be administered to the subject.

11. The use according to claim 9 or 10, wherein the subject is HLA-DR3.

12. The use according to claim 9 or 10, wherein the subject in HLA-DR4.