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SUMMARY

The present disclosure is directed to individual peptide immunogen constructs targeting portions of the Interleukin-31 (IL-31) protein for the treatment and/or prevention of a pruritic
15 condition and/or an allergic condition, such as atopic dermatitis. The present disclosure is also directed to compositions containing the peptide immunogen constructs, methods of making and using the peptide immunogen constructs, and antibodies produced by the peptide immunogen constructs.

In one aspect, the present disclosure refers to an IL-31 peptide immunogen construct can
20 be represented by the formulae: (Th) m -(A) n -(IL-31 fragment)-X or (IL-31 fragment)-(A) n -(Th) m -X wherein Th is a heterologous T helper epitope; A is a heterologous spacer; (IL-31 fragment) is a B cell epitope having 15 to 75 amino acid residues from SEQ ID NO: 1 or SEQ ID NO: 2, wherein the IL-31 fragment is selected from the group consisting of SEQ ID NOs: 3-13 and 93-98; X is an α -COOH or α -CONH₂ of an amino acid; m is from 1 to 4; and n is from 0
25 to 10.

In another aspect, the present disclosure refers to an IL-31 peptide immunogen construct comprising: a B cell epitope comprising 15 to 75 amino acid residues from the full-length IL-31 protein sequence of SEQ ID NO: 1 or SEQ ID NO: 2, wherein the B cell epitope is selected from the group consisting of SEQ ID NOs: 3-13 and 93-98; a T helper epitope comprising an
30 amino acid sequence selected from the group consisting of SEQ ID NOs: 14-42; and an optional heterologous spacer selected from the group consisting of an amino acid, Lys-, Gly-, Lys-Lys-Lys-, (α , ϵ -N)Lys, and ϵ -N-Lys-Lys-Lys-Lys (SEQ ID NO: 91), wherein the B cell epitope is covalently linked to the T helper epitope directly or through the optional heterologous spacer.

In yet another aspect, the present disclosure refers to a composition comprising a peptide
35 immunogen construction as disclosed herein.

In yet another aspect, the present disclosure refers to a pharmaceutical composition comprising: a. a peptide immunogen construct as disclosed herein; and b. and a pharmaceutically acceptable delivery vehicle and/or adjuvant.

5 The disclosed peptide immunogen constructs contain about 25 or more amino acids. The peptide immunogen constructs contain a B cell epitope from portions of the canine IL-31 protein (GenBank: BAH97742.1). The full-length amino acid sequence of the canine and human IL-31 protein is shown as SEQ ID NO: 1 and SEQ ID NO: 2, respectively, in **Table 1**. The B cell epitope can be linked to a heterologous T helper cell (Th) epitope derived from pathogen
10 proteins through an optional heterologous spacer. The disclosed peptide immunogen constructs stimulate the generation of highly specific antibodies directed against IL-31. The disclosed peptide immunogen constructs can be used as an immunotherapy for animals suffering from a pruritic condition and/or an allergic condition, such as atopic dermatitis.

 The B cell epitope portion of the peptide immunogen constructs have amino acid
15 sequences from the full-length canine IL-31 protein (SEQ ID NO: 1) or the full-length human IL-31 protein (SEQ ID NO: 2). In some examples, the B cell epitope has a sequence containing any of SEQ ID NOs: 1 to 13 and 93 to 98, as shown in **Table 1**.

 The peptide immunogen constructs of the present disclosure can contain a heterologous Th epitope amino acid sequence derived from a pathogenic protein (e.g., SEQ ID NOs: 14 to 42)
20 as shown in **Table 2**. In certain examples, the heterologous Th epitope is derived from natural pathogens, such as Diphtheria Toxin (SEQ ID NO: 18), Plasmodium Falciparum (SEQ ID NO: 19), Cholera Toxin (SEQ ID NO: 21). In other examples, the heterologous Th epitope is an idealized artificial Th epitope derived from Measles Virus Fusion protein (MVF 1 to 5) or Hepatitis B Surface Antigen (HBsAg 1 to 3) in the form of either single sequence or
25 combinatorial sequences (e.g., SEQ ID NOs: 25, 24, and 26).

CLAIMS

1. An IL-31 peptide immunogen construct can be represented by the formulae:

$(Th)_m-(A)_n-(IL-31 \text{ fragment})-X$

or

$(IL-31 \text{ fragment})-(A)_n-(Th)_m-X$

wherein

Th is a heterologous T helper epitope;

A is a heterologous spacer;

(IL-31 fragment) is a B cell epitope having 15 to 75 amino acid residues from SEQ ID NO: 1 or SEQ ID NO: 2, wherein the IL-31 fragment is selected from the group consisting of SEQ ID NOs: 3-13 and 93-98;

X is an α -COOH or α -CONH₂ of an amino acid;

m is from 1 to 4; and

n is from 0 to 10.

2. The IL-31 peptide immunogen construct according to claim 1, wherein the Th epitope is selected from the group consisting of SEQ ID NOs: 14-42.

3. The IL-31 peptide immunogen construct according to claim 1, wherein the peptide immunogen construct is selected from the group consisting of SEQ ID NOs: 43-90 and 99-105.

4. An IL-31 peptide immunogen construct comprising:

a B cell epitope comprising 15 to 75 amino acid residues from the full-length IL-31 protein sequence of SEQ ID NO: 1 or SEQ ID NO: 2, wherein the B cell epitope is selected from the group consisting of SEQ ID NOs: 3-13 and 93-98;

a T helper epitope comprising an amino acid sequence selected from the group consisting of SEQ ID NOs: 14-42; and

an optional heterologous spacer selected from the group consisting of an amino acid, Lys-, Gly-, Lys-Lys-Lys-, (α , ϵ -N)Lys, and ϵ -N-Lys-Lys-Lys-Lys (SEQ ID NO: 91),

wherein the B cell epitope is covalently linked to the T helper epitope directly or

through the optional heterologous spacer.

5. The IL-31 peptide immunogen construct of claim 4, wherein the T helper epitope is selected from the group consisting of SEQ ID NOs: 14-42.

6. The IL-31 peptide immunogen construct of claim 4, wherein the optional heterologous spacer is (α , ϵ -N)Lys or ϵ -N-Lys-Lys-Lys-Lys (SEQ ID NO: 91).

7. The IL-31 peptide immunogen construct of claim 4, wherein the T helper epitope is covalently linked to the amino terminus of the B cell epitope.

8. The IL-31 peptide immunogen construct of claim 4, wherein the T helper epitope is covalently linked to the amino terminus of the B cell epitope through the optional heterologous spacer.

9. A composition comprising a peptide immunogen construction according to any of claims 1 to 3.

10. A pharmaceutical composition comprising:

- a. a peptide immunogen construct according to any of claims 1 to 3; and
- b. and a pharmaceutically acceptable delivery vehicle and/or adjuvant.

11. The pharmaceutical composition of claim 10, wherein

- a. the IL-31 peptide immunogen construct is selected from the group consisting of SEQ ID NOs: 43-90 and 99-105 ; and
- b. the IL-31 peptide immunogen construct is mixed with an CpG oligodeoxynucleotide (ODN) to form a stabilized immunostimulatory complex.