

NON-LIPIDATED VARIANTS OF *NEISSERIA MENINGITIDIS*
ORF2086 ANTIGENS

This application asserts priority to U.S. Provisional Application Serial No.
5 61/381,837, filed on September 10, 2010, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to non-lipidated variants of *Neisseria meningitidis* ORF2086 antigens in immunogenic compositions as described herein. The present
10 invention also relates to methods of preserving the conformation of non-lipidated variants of *Neisseria meningitidis* ORF2086 antigens. The present invention further includes compositions and methods relating to improved expression of non-lipidated *N. meningitidis* ORF2086 antigens, as compared to the corresponding wild-type antigen.

Background of the Invention

15 rLP2086 is a recombinant 28-kDa lipoprotein that induces cross-reactive bacterial antibodies against a number of *Neisseria meningitidis* strains, including *Neisseria meningitidis* serotype B (MnB) strains, or more precisely, serogroup B (MnB) strains. Based on deduced amino acid sequence homology, two different subfamilies of rLP2086 were identified, A and B. These two subfamilies were used in the formulation
20 of the MnB-rLP2086 vaccine samples containing 20, 60, 120, and 200 µg/mL each in 10 mM Histidine (pH 6.0), 150 mM NaCl, and 0.5 mg/mL aluminum with varying levels of Polysorbate 80 (PS-80). Native LP2086 is a lipoprotein. Fletcher et al. *Infection & Immunity*, vol. 72(4):2088-2100 (2004) demonstrated that rLP2086 with an amino
25 terminal lipid was more immunogenic than non-lipidated versions of the same protein in mice. Additional preclinical and clinical studies have demonstrated that the combination of these two lipidated proteins can provide broad coverage across the fHBP family. Meningococcal meningitis is a devastating disease that can kill children and young adults within hours despite the availability of antibiotics. There remains a need for suitable serogroup B meningococcal immunogenic compositions.

Summary of the Invention

To meet these and other needs for a meningococcal vaccine, additional compositions have been evaluated to provide coverage for using non-lipidated variants of *N. meningitidis* ORF2086 polypeptides. A first aspect of the present invention

5 provides an immunogenic composition comprising a non-lipidated ORF2086 protein, wherein the ORF2086 protein is a B44, a B02, a B03, a B22, a B24, a B09, an A05, an A04, an A12, or an A22 variant. In some embodiments, the ORF2086 protein is a B44, a B22, a B09, an A05, an A12, or an A22 variant.

Another aspect of the present invention provides an immunogenic composition
10 comprising a non-lipidated ORF2086 protein Subfamily B variant (P2086 Subfamily B polypeptide). In some embodiments, the P2086 Subfamily B polypeptide is a B44, a B02, a B03, a B22, a B24, or a B09 variant. In some embodiments, the immunogenic composition further comprises a non-lipidated ORF2086 protein Subfamily A variant (P2086 Subfamily A polypeptide). In some embodiments, the P2086 Subfamily A
15 polypeptide is an A05, an A04, an A12, or an A22 variant.

In some embodiments, the immunogenic composition further comprises an adjuvant. In some embodiments, the adjuvant is an aluminum adjuvant, a saponin, a CpG nucleotide sequence or any combination thereof. In some embodiments, the aluminum adjuvant is AlPO_4 , $\text{Al}(\text{OH})_3$, $\text{Al}_2(\text{SO}_4)_3$, or alum. In some embodiments the
20 concentration of aluminum in the immunogenic composition is between 0.125 $\mu\text{g/ml}$ and 0.5 $\mu\text{g/ml}$. In some embodiments the concentration of aluminum in the immunogenic composition is 0.25 $\mu\text{g/ml}$. In a preferred embodiment, the concentration of aluminum in the immunogenic composition is between 0.125 mg/ml and 0.5 mg/ml. In some preferred embodiments the concentration of aluminum in the immunogenic composition
25 is 0.25 mg/ml.

In some embodiments, the saponin concentration in the immunogenic composition is between 1 $\mu\text{g/ml}$ and 250 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic composition is between 10 $\mu\text{g/ml}$ and 100 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic composition is 10
30 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic composition is 100 $\mu\text{g/ml}$. In some embodiments, the saponin is QS-21 Stimulon® (Agenus, Lexington, MA) or ISCOMATRIX® (CSL Limited, Parkville, Australia).

In some embodiments, the immunogenic composition confers the ability to raise an immunogenic response to *Neisseria meningitidis* after administration of multiple doses of the immunogenic composition to a subject. In some embodiments, the immunogenic response is conferred after administration of two doses to the subject. In
5 some embodiments, the immunogenic response is conferred after administration of three doses to the subject.

Another aspect of the invention provides a composition conferring increased immunogenicity of a non-lipidated P2086 antigen, wherein the composition comprises a saponin and at least one non-lipidated P2086 antigen. In some embodiments, the
10 saponin concentration in the immunogenic composition is between 1 µg/ml and 250 µg/ml. In some embodiments, the saponin concentration in the immunogenic composition is between 10 µg/ml and 100 µg/ml. In some embodiments, the saponin concentration in the immunogenic composition is 10 µg/ml. In some embodiments, the saponin concentration in the immunogenic composition is 100 µg/ml. In some
15 embodiments, the saponin is QS-21 or ISCOMATRIX.

In some embodiments, the composition further comprises aluminum. In some embodiments, the aluminum is present as AlPO_4 , $\text{Al}(\text{OH})_3$, $\text{Al}_2(\text{SO}_4)_3$, or alum. In some embodiments the concentration of aluminum in the composition is between 0.125 µg/ml and 0.5 µg/ml. In some embodiments the concentration of aluminum in the composition
20 is 0.25 µg/ml. In a preferred embodiment, the concentration of aluminum in the composition is between 0.125 mg/ml and 0.5 mg/ml. In some preferred embodiments the concentration of aluminum in the composition is 0.25 mg/ml.

In some embodiments, the immunogenic composition confers the ability to raise an immunogenic response to *Neisseria meningitidis* after administration of multiple
25 doses of the immunogenic composition to a subject. In some embodiments, the immunogenic response is conferred after administration of two doses to the subject. In some embodiments, the immunogenic response is conferred after administration of three doses to the subject.

In some embodiments, the non-lipidated P2086 antigen is a P2086 Subfamily B polypeptide. In some embodiments, the P2086 Subfamily B polypeptide is a B44, a
30 B02, a B03, a B22, a B24 or a B09 variant. In some embodiments, the non-lipidated P2086 antigen is a P2086 Subfamily A polypeptide. In some embodiment, the P2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.

In some embodiments, the composition comprises at least two non-lipidated P2086 antigens, wherein the two non-lipidated P2086 antigens are at least one non-lipidated P2086 Subfamily A polypeptide and at least one non-lipidated P2086 Subfamily B polypeptide. In some embodiments, the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B44 variant. In some embodiments, the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B22 variant. In some embodiments, the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B09 variant.

Another aspect of the invention provides a method for conferring immunity to a subject against a *Neisseria meningitidis* bacteria, wherein the method comprises the step of administering to the subject an immunogenic composition comprising a non-lipidated P2086 Subfamily B polypeptide. In some embodiments, the P2086 Subfamily B polypeptide is a B44, a B02, a B03, a B22, a B24 or a B09 variant. In some embodiments, the immunogenic composition further comprises a P2086 Subfamily A polypeptide. In some embodiments, the P2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.

In some embodiments, the immunogenic composition further comprises an adjuvant. In some embodiments, the adjuvant is an aluminum adjuvant, a saponin, a CpG nucleotide sequence or any combination thereof. In some embodiments, the aluminum adjuvant is AlPO_4 , $\text{Al}(\text{OH})_3$, $\text{Al}_2(\text{SO}_4)_3$, or alum. In some embodiments, the concentration of aluminum in the immunogenic composition is between 0.125 $\mu\text{g/ml}$ and 0.5 $\mu\text{g/ml}$. In some embodiments, the concentration of aluminum in the immunogenic composition is 0.25 $\mu\text{g/ml}$. In a preferred embodiment, the concentration of aluminum in the immunogenic composition is between 0.125 mg/ml and 0.5 mg/ml. In some embodiments, the concentration of aluminum in the immunogenic composition is 0.25 mg/ml.

In some embodiments, the saponin concentration in the immunogenic composition is between 1 $\mu\text{g/ml}$ and 250 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic composition is between 10 $\mu\text{g/ml}$ and 100 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic composition is 10 $\mu\text{g/ml}$. In some embodiments, the saponin concentration in the immunogenic

composition is 100 µg/ml. In some embodiments, the saponin is QS-21 or ISCOMATRIX.

In some embodiments, the immunogenic composition is administered to the subject in multiple doses over a dosing schedule. In some embodiments, the immunogenic composition is administered to the subject in two doses over a dosing schedule. In some embodiments, the immunogenic composition is administered to the subject in three doses over a dosing schedule.

Another aspect of the invention provides a method of producing a non-lipidated P2086 variant comprising the steps of (a) cloning an ORF2086 variant nucleic acid into an expression vector to generate an ORF2086 expression vector; (b) transforming bacteria with the ORF2086 expression vector; (c) inducing expression of the P2086 variant from the ORF2086 expression vector; and (d) isolating the expressed P2086 variant protein; wherein the ORF2086 expression vector does not comprise a lipidation control sequence. In some embodiments, the bacteria is *E. coli*. In some embodiments, expression is induced by addition of IPTG.

In some embodiments, the codon encoding the N-terminal Cys of the P2086 variant is deleted. In some embodiments, the codon encoding the N-terminal Cys of the P2086 variant is mutated to generate an Ala, Gly or Val codon. In some embodiments, the P2086 variant is an A05, B01, or B44 variant. In some embodiments, the P2086 variant is a B09 variant.

In some embodiments, the N-terminal tail is mutated to add Ser and Gly residues to extend the Gly/Ser stalk immediately downstream of the N-terminal Cys. In some embodiments, the total number of Gly and Ser residues in the Gly/Ser stalk is at least 7, at least 8, at least 9, at least 10, at least 11, or at least 12.

In some embodiments, the codons of the N-terminal tail of the P2086 variant are optimized by point mutagenesis. In some embodiments, the codons of the N-terminal tail of the ORF2086 variant are optimized by point mutagenesis such that the codon encoding the fifth amino acid of the ORF2086 variant is 100% identical to nucleotides 13-15 of SEQ ID NO: 8 and the codon encoding the thirteenth amino acid of the ORF2086 variant is 100% identical to nucleotides 37-39 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is optimized such that the 5' 45 nucleic acids are 100% identical to nucleic acids 1-45 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is

optimized such that the 5' 42 nucleic acids are 100% identical to nucleic acids 4-45 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is optimized such that the 5' 39 nucleic acids are 100% identical to nucleic acids 4-42 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated
5 P2086 variant comprises at least one amino acid substitution compared to amino acids 1-15 of SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises two amino acid substitutions compared to amino acids 1-15 of SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises at least one amino acid substitution compared to amino acids 2-15 of
10 SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises two amino acid substitutions compared to amino acids 2-15 of SEQ ID NO: 18. In some embodiments, the amino acid substitutions are conservative amino acid substitutions.

In one embodiment, the present invention relates to stable formulations of
15 *Neisseria meningitis* ORF2086 Subfamily B Antigens in immunogenic compositions. The present invention also relates to methods of preserving the conformation of *Neisseria meningitis* ORF2086 Antigens and methods for determining the potency of *Neisseria meningitis* rLP2086 antigens.

In one aspect, the invention relates to a composition that includes an isolated
20 non-pyruvylated non-lipidated ORF2086 polypeptide. In one embodiment, the composition is immunogenic. In another embodiment, the polypeptide includes a deletion of an N-terminal Cys compared to the corresponding wild-type non-lipidated ORF2086 polypeptide. In one embodiment, the polypeptide includes the amino acid sequence selected from the group consisting of SEQ ID NO:12, SEQ ID NO:13, SEQ ID
25 NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO: 20, and SEQ ID NO: 21, wherein the cysteine at position 1 is deleted. In another embodiment, the polypeptide includes the amino acid sequence selected from the group consisting of SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO: 50, and SEQ ID NO: 55.

30 In yet another embodiment, the polypeptide is encoded by a nucleotide sequence that is operatively linked to an expression system, wherein said expression system is capable of being expressed in a bacterial cell. In one embodiment, the expression system is a plasmid expression system. In one embodiment, the bacterial cell is an *E.*

coli cell. In another embodiment, the nucleotide sequence is linked to a regulatory sequence that controls expression of said nucleotide sequence.

In another aspect, the invention relates to a composition that includes a non-pyruvylated non-lipidated ORF2086 polypeptide obtainable by a process. The process includes expressing a nucleotide sequence encoding a polypeptide having the amino acid sequence selected from the group consisting of SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO: 20, and SEQ ID NO: 21, wherein the cysteine at position 1 is deleted, wherein the nucleotide sequence is operatively linked to an expression system that is capable of being expressed in a bacterial cell. In one embodiment, the bacterial cell is *E. coli*.

In one aspect, the invention relates to a composition that includes an isolated polypeptide, which includes the amino acid sequence set forth in SEQ ID NO: 49, and an isolated polypeptide, which includes the amino acid sequence set forth in SEQ ID NO: 44. In one embodiment, the compositions described herein are immunogenic. In another embodiment, the compositions described herein further include an ORF2086 subfamily A polypeptide from serogroup B *N. meningitidis*. In another embodiment, compositions described herein elicit a bactericidal immune response in a mammal against an ORF2086 subfamily B polypeptide from serogroup B *N. meningitidis*.

In one aspect, the invention relates to an isolated polypeptide that includes the amino acid sequence set forth in SEQ ID NO: 49. In another aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 46. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 47. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 48. In one aspect, the invention relates to an isolated polypeptide that includes the amino acid sequence set forth in SEQ ID NO: 50. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 45. In one aspect, the invention relates to an isolated polypeptide that includes the amino acid sequence set forth in SEQ ID NO: 44.

In one aspect, the invention relates to a plasmid that includes a nucleotide sequence selected from the group consisting of SEQ ID NO: 46, SEQ ID NO: 47, SEQ ID NO: 48, and SEQ ID NO: 45, wherein the plasmid is capable of being expressed in a bacterial cell. In one embodiment, the bacterial cell is *E. coli*.

In one aspect, the invention relates to a method of eliciting bactericidal antibodies specific to an ORF2086 subfamily B serogroup B *N. meningitidis* in a mammal. The method includes administering to the mammal an effective amount of an isolated polypeptide that includes the amino acid sequence selected from the group consisting of SEQ ID NO: 44 and SEQ ID NO: 49, or a combination thereof.

In one aspect, the invention relates to a method for producing a polypeptide. The method includes expressing in a bacterial cell a polypeptide, which includes a sequence having greater than 90% identity to SEQ ID NO:21, said sequence including at least one domain selected from the group consisting of amino acids 13-18 of SEQ ID NO: 21, amino acids 21-34 of SEQ ID NO: 21, and amino acids 70-80 of SEQ ID NO: 21, or a combination thereof, wherein the sequence lacks an N-terminal cysteine. The method further includes purifying the polypeptide. In one embodiment, the sequence further includes at least one domain selected from the group consisting of amino acids 96-116 of SEQ ID NO: 21, amino acids 158-170 of SEQ ID NO: 21, amino acids 172-185 of SEQ ID NO: 21, amino acids 187-199 of SEQ ID NO: 21, amino acids 213-224 of SEQ ID NO: 21, amino acids 226-237 of SEQ ID NO: 21, amino acids 239-248 of SEQ ID NO: 21, or a combination thereof. In one embodiment, the bacterial cell is *E. coli*.

In one aspect, the invention relates to an isolated polypeptide produced by a process that includes the method described herein. In another aspect, the invention relates to an immunogenic composition produced by a process that includes the method described herein.

In one aspect, the invention relates to an immunogenic composition that includes an ORF2086 subfamily B polypeptide from serogroup B *N. meningitidis*, wherein the polypeptide is a non-pyruvylated non-lipidated B44. In one embodiment, the composition further includes a second ORF2086 subfamily B polypeptide from serogroup B *N. meningitidis*, wherein the second polypeptide is a non-pyruvylated non-lipidated B09. In one embodiment, the composition includes no more than 3 ORF2086 subfamily B polypeptides. In another embodiment, the composition includes no more than 2 ORF2086 subfamily B polypeptides. In one embodiment, the composition further includes a ORF2086 subfamily A polypeptide. In another embodiment, the composition includes an A05 subfamily A polypeptide.

Brief Description of the Drawings

Figure 1: P2086 Variant Nucleic Acid Sequences.

Figure 2: P2086 Variant Amino Acid Sequences. The Gly/Ser stalk in the N-terminal tail of each variant is underlined.

5 Figure 3: Structure of the ORF2086 Protein

Figure 4: Removal of N-terminal Cys Results in Loss of Expression in *E. coli*.

Figure 5: Effect of Gly/Ser Stalk Length on Non-lipidated ORF2086 Variant Expression.

The sequence associated with the protein variant labeled B01 is set forth in SEQ ID NO:

35. The sequence associated with the protein variant labeled B44 is set forth in SEQ ID

10 NO: 36. The sequence associated with the protein variant labeled A05 is set forth in

SEQ ID NO: 37. The sequence associated with the protein variant labeled A22 is set

forth in SEQ ID NO: 38. The sequence associated with the protein variant labeled B22

is set forth in SEQ ID NO: 39. The sequence associated with the protein variant labeled

A19 is set forth in SEQ ID NO: 40.

15 Figure 6: High Levels of Non-lipidated B09 Expression Despite A Short Gly/Ser Stalk.

The left two lanes demonstrated expression of the N-terminal Cys-deleted B09 variant

before and after induction. The third and fourth lanes demonstrate expression of the

N-terminal Cys positive B09 variant before and after induction. The right most lane is a

molecular weight standard. The amino acid sequence shown under the image is set

20 forth in SEQ ID NO: 41. The nucleotide sequence representative of the N-terminal Cys-

deleted A22 variant, referred to as "A22_001" in the figure, is set forth in SEQ ID NO:

42, which is shown under SEQ ID NO: 41 in the figure. The nucleotide sequence

representative of the N-terminal Cys-deleted B22 variant, referred to as "B22_001" in

the figure, is set forth in SEQ ID NO: 52. The nucleotide sequence representative of the

25 N-terminal Cys-deleted B09 variant, referred to as "B09_004" in the figure, is set forth in

SEQ ID NO: 53.

Figure 7: Codon Optimization Increases Expression of Non-lipidated B22 and A22

Variants. The left panel demonstrates expression of the N-terminal Cys-deleted B22

variant before (lanes 1 and 3) and after (lanes 2 and 4) IPTG induction. The right panel

30 demonstrates expression of the N-terminal Cys-deleted A22 variant before (lane 7) and

after (lane 8) IPTG induction. Lanes 5 and 6 are molecular weight standards.

Figure 8: P2086 Variant Nucleic and Amino Acid Sequences

Sequence Identifiers

SEQ ID NO: 1 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A04 gene, which includes a codon encoding an N-terminal Cys.

5 SEQ ID NO: 2 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A05 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 3 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A12 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 4 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A12-2 gene, which includes a codon encoding an N-terminal Cys.

10 SEQ ID NO: 5 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A22 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 6 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B02 gene, which includes a codon encoding an N-terminal Cys.

15 SEQ ID NO: 7 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B03 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 8 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B09 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 9 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B22 gene, which includes a codon encoding an N-terminal Cys.

20 SEQ ID NO: 10 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B24 gene, which includes a codon encoding an N-terminal Cys.

SEQ ID NO: 11 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B44 gene, which includes a codon encoding an N-terminal Cys.

25 SEQ ID NO: 12 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant A04, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 13 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant A05, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 14 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant A12, which includes an N-terminal Cys at amino acid position 1.

- 5 SEQ ID NO: 15 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant A22, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 16 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B02, which includes an N-terminal Cys at amino acid position 1.

- 10 SEQ ID NO: 17 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B03, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 18 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B09, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 19 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B22, which includes an N-terminal Cys at amino acid position 1.

- 15 SEQ ID NO: 20 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B24, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 21 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B44, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 22 sets forth a DNA sequence for a forward primer, shown in Example 2.

- 20 SEQ ID NO: 23 sets forth a DNA sequence for a reverse primer, shown in Example 2.

SEQ ID NO: 24 sets forth a DNA sequence for a forward primer, shown in Example 2, Table 1.

SEQ ID NO: 25 sets forth a DNA sequence for a reverse primer, shown in Example 2, Table 1.

SEQ ID NO: 26 sets forth a DNA sequence for a forward primer, shown in Example 2, Table 1.

SEQ ID NO: 27 sets forth a DNA sequence for a reverse primer, shown in Example 2, Table 1.

5 SEQ ID NO: 28 sets forth a DNA sequence for a Gly/Ser stalk, shown in Example 4.

SEQ ID NO: 29 sets forth the amino acid sequence for a Gly/Ser stalk, shown in Example 4, which is encoded by, for example SEQ ID NO: 28.

SEQ ID NO: 30 sets forth a DNA sequence for a Gly/Ser stalk, shown in Example 4.

10 SEQ ID NO: 31 sets forth the amino acid sequence a Gly/Ser stalk, shown in Example 4, which is encoded by, for example SEQ ID NO: 30.

SEQ ID NO: 32 sets forth a DNA sequence for a Gly/Ser stalk, shown in Example 4.

SEQ ID NO: 33 sets forth the amino acid sequence for a Gly/Ser stalk, which is encoded by, for example, SEQ ID NO: 32 and SEQ ID NO: 34.

SEQ ID NO: 34 sets forth a DNA sequence for a Gly/Ser stalk, shown in Example 4.

15 SEQ ID NO: 35 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant B01, shown in Figure 5.

SEQ ID NO: 36 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant B44, shown in Figure 5.

20 SEQ ID NO: 37 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant A05, shown in Figure 5.

SEQ ID NO: 38 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant A22, shown in Figure 5.

SEQ ID NO: 39 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant B22, shown in Figure 5.

SEQ ID NO: 40 sets forth the amino acid sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant A19, shown in Figure 5.

SEQ ID NO: 41 sets forth the amino acid sequence for the N-terminus of a *N. meningitidis*, serogroup B, 2086 variant, shown in Figure 6.

- 5 SEQ ID NO: 42 sets forth a DNA sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant A22, shown in Figure 6.

- SEQ ID NO: 43 sets forth a codon-optimized DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B44 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 11. Plasmid pDK087 includes SEQ ID
10 NO: 43.

SEQ ID NO: 44 sets forth the amino acid sequence for a non-lipidated *N. meningitidis*, serogroup B, 2086 variant B44. SEQ ID NO: 44 is identical to SEQ ID NO: 21 wherein the N-terminal cysteine at position 1 of SEQ ID NO: 21 is deleted. SEQ ID 44 is encoded by, for example, SEQ ID NO: 43.

- 15 SEQ ID NO: 45 sets forth a codon-optimized DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B09 gene, wherein the codon encoding an N-terminal cysteine is deleted, and wherein the sequence includes codons encoding an additional Gly/Ser region, as compared to SEQ ID NO: 8. Plasmid pEB063 includes SEQ ID NO: 45.

- 20 SEQ ID NO: 46 sets forth a codon-optimized DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B09 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 8. Plasmid pEB064 includes SEQ ID NO: 46.

- SEQ ID NO: 47 sets forth a codon-optimized DNA sequence for the *N. meningitidis*,
25 serogroup B, 2086 variant B09 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 8. Plasmid pEB 065 includes SEQ ID NO: 47.

SEQ ID NO: 48 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B09 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 8. Plasmid pLA134 includes SEQ ID NO: 48.

5 SEQ ID NO: 49 sets forth the amino acid sequence for a non-lipidated *N. meningitidis*, serogroup B, 2086 variant B09. SEQ ID NO: 49 is identical to SEQ ID NO: 18 wherein the N-terminal cysteine at position 1 of SEQ ID NO: 18 is deleted. SEQ ID 49 is encoded by, for example, a DNA sequence selected from the group consisting of SEQ ID NO: 46, SEQ ID NO: 47, and SEQ ID NO: 48.

10 SEQ ID NO: 50 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B09, wherein the codon encoding an N-terminal cysteine is deleted and wherein the sequence includes codons encoding an additional Gly/Ser region, as compared to SEQ ID NO: 18. SEQ ID NO: 50 is encoded by, for example, SEQ ID NO: 45.

15 SEQ ID NO: 51 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B44 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 11. Plasmid pLN056 includes SEQ ID NO: 51.

SEQ ID NO: 52 sets forth a DNA sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant B22, shown in Figure 6.

20 SEQ ID NO: 53 sets forth a DNA sequence for the N-terminus of *N. meningitidis*, serogroup B, 2086 variant B09, shown in Figure 6.

SEQ ID NO: 54 sets forth a DNA sequence for a *N. meningitidis*, serogroup B, 2086 variant A05 gene, wherein the codon encoding an N-terminal cysteine is deleted, as compared to SEQ ID NO: 2.

25 SEQ ID NO: 55 sets forth the amino acid sequence for a non-lipidated *N. meningitidis*, serogroup B, 2086 variant A05. SEQ ID NO: 55 is identical to SEQ ID NO: 13 wherein the N-terminal cysteine at position 1 of SEQ ID NO: 13 is deleted. SEQ ID NO: 55 is encoded by, for example, SEQ ID NO: 54.

SEQ ID NO: 56 sets forth the amino acid sequence of a serine-glycine repeat sequence, shown in Example 7.

5 SEQ ID NO: 57 sets forth the amino acid sequence for a non-lipidated *N. meningitidis*, serogroup B, 2086 variant B01. SEQ ID NO: 57 is identical to SEQ ID NO: 58 wherein the N-terminal cysteine at position 1 of SEQ ID NO: 58 is deleted.

SEQ ID NO: 58 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B01, which includes an N-terminal Cys at amino acid position 1.

10 SEQ ID NO: 59 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B15, which includes an N-terminal Cys at amino acid position 1.

SEQ ID NO: 60 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B16, which includes an N-terminal Cys at amino acid position 1.

15 SEQ ID NO: 61 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant B22, in which the codon for the N-terminal Cys at amino acid position 1 of SEQ ID NO: 19 is replaced with a codon for a Glycine.

20 SEQ ID NO: 62 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant B22, in which the N-terminal Cys at amino acid position 1 of SEQ ID NO: 19 is replaced with a Glycine.

25 SEQ ID NO: 63 sets forth a DNA sequence for the *N. meningitidis*, serogroup B, 2086 variant A22, in which the codon for the N-terminal Cys at amino acid position 1 of SEQ ID NO: 15 is replaced with a codon for a Glycine.

30 SEQ ID NO: 64 sets forth the amino acid sequence for the *N. meningitidis*, serogroup B, 2086 variant A22, in which the N-terminal Cys at amino acid position 1 of SEQ ID NO: 15 is replaced with a Glycine.

Detailed Description of the Invention

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as those commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, 5 suitable methods and materials are described below. The materials, methods and examples are illustrative only, and are not intended to be limiting. All publications, patents and other documents mentioned herein are incorporated by reference in their entirety.

10 It is noted that in this disclosure, terms such as "comprises", "comprised", "comprising", "contains", "containing" and the like can have the meaning attributed to them in U.S. patent law; *e.g.*, they can mean "includes", "included", "including" and the like. Such terms refer to the inclusion of a particular ingredients or set of ingredients without excluding any other ingredients. Terms such as "consisting essentially of" and 15 "consists essentially of" have the meaning attributed to them in U.S. patent law, *e.g.*, they allow for the inclusion of additional ingredients or steps that do not detract from the novel or basic characteristics of the invention, *i.e.*, they exclude additional unrecited ingredients or steps that detract from novel or basic characteristics of the invention, and they exclude ingredients or steps of the prior art, such as documents in the art that are 20 cited herein or are incorporated by reference herein, especially as it is a goal of this document to define embodiments that are patentable, *e.g.*, novel, non-obvious, inventive, over the prior art, *e.g.*, over documents cited herein or incorporated by reference herein. And, the terms "consists of" and "consisting of" have the meaning ascribed to them in U.S. patent law; namely, that these terms are close-ended. 25 Accordingly, these terms refer to the inclusion of a particular ingredient or set of ingredients and the exclusion of all other ingredients.

Definitions

As used herein, the singular forms "a," "an," and "the" include plural references unless the context clearly dictates otherwise. Thus, *e.g.*, references to "the method" 30 includes one or more methods, and/or steps of the type described herein and/or which will become apparent to one of ordinary skill in the art upon reading this disclosure and so forth.

As used herein, the plural forms include singular references unless the context clearly dictates otherwise. Thus, *e.g.*, references to "the methods" includes one or more methods, and/or steps of the type described herein and/or which will become apparent to one of ordinary skill in the art upon reading this disclosure and so forth.

5 As used herein, "about" means within a statistically meaningful range of a value such as a stated concentration range, time frame, molecular weight, temperature or pH. Such a range can be within an order of magnitude, typically within 20%, more typically still within 10%, and even more typically within 5% of a given value or range. The allowable variation encompassed by the term "about" will depend upon the particular
10 system under study, and can be readily appreciated by one of ordinary skill in the art. Whenever a range is recited within this application, every whole number integer within the range is also contemplated as an embodiment of the invention.

The term "adjuvant" refers to a compound or mixture that enhances the immune response to an antigen as further described and exemplified herein. Non-limiting
15 examples of adjuvants that can be used in the vaccine of the present invention include the RIBI adjuvant system (Ribi Inc., Hamilton, Mont.), alum, mineral gels such as aluminum hydroxide gel, oil-in-water emulsions, water-in-oil emulsions such as, *e.g.*, Freund's complete and incomplete adjuvants, Block copolymer (CytRx, Atlanta Ga.), QS-21 (Cambridge Biotech Inc., Cambridge Mass.), SAF-M (Chiron, Emeryville Calif.),
20 AMPHIGEN® adjuvant, saponin, Quil A or other saponin fraction, monophosphoryl lipid A, and Avridine lipid-amine adjuvant.

An "antibody" is an immunoglobulin molecule capable of specific binding to a target, such as a carbohydrate, polynucleotide, lipid, polypeptide, etc., through at least one antigen recognition site, located in the variable region of the immunoglobulin
25 molecule. As used herein, unless otherwise indicated by context, the term is intended to encompass not only intact polyclonal or monoclonal antibodies, but also engineered antibodies (*e.g.*, chimeric, humanized and/or derivatized to alter effector functions, stability and other biological activities) and fragments thereof (such as Fab, Fab', F(ab')₂, Fv), single chain (ScFv) and domain antibodies, including shark and camelid
30 antibodies), and fusion proteins comprising an antibody portion, multivalent antibodies, multispecific antibodies (*e.g.*, bispecific antibodies so long as they exhibit the desired biological activity) and antibody fragments as described herein, and any other modified configuration of the immunoglobulin molecule that comprises an antigen recognition

site. An antibody includes an antibody of any class, such as IgG, IgA, or IgM (or sub-class thereof), and the antibody need not be of any particular class. Depending on the antibody amino acid sequence of the constant domain of its heavy chains, immunoglobulins can be assigned to different classes. There are five major classes of immunoglobulins: IgA, IgD, IgE, IgG, and IgM, and several of these may be further divided into subclasses (isotypes), e.g., IgG1, IgG2, IgG3, IgG4, IgA1 and IgA2 in humans. The heavy-chain constant domains that correspond to the different classes of immunoglobulins are called alpha, delta, epsilon, gamma, and mu, respectively. The subunit structures and three-dimensional configurations of different classes of immunoglobulins are well known.

"Antibody fragments" comprise only a portion of an intact antibody, wherein the portion preferably retains at least one, preferably most or all, of the functions normally associated with that portion when present in an intact antibody.

The term "antigen" generally refers to a biological molecule, usually a protein, peptide, polysaccharide, lipid or conjugate which contains at least one epitope to which a cognate antibody can selectively bind; or in some instances to an immunogenic substance that can stimulate the production of antibodies or T-cell responses, or both, in an animal, including compositions that are injected or absorbed into an animal. The immune response may be generated to the whole molecule, or to one or more various portions of the molecule (e.g., an epitope or hapten). The term may be used to refer to an individual molecule or to a homogeneous or heterogeneous population of antigenic molecules. An antigen is recognized by antibodies, T-cell receptors or other elements of specific humoral and/or cellular immunity. The term "antigen" includes all related antigenic epitopes. Epitopes of a given antigen can be identified using any number of epitope mapping techniques, well known in the art. See, e.g., *Epitope Mapping Protocols in Methods in Molecular Biology*, Vol. 66 (Glenn E. Morris, Ed., 1996) Humana Press, Totowa, N. J. For example, linear epitopes may be determined by e.g., concurrently synthesizing large numbers of peptides on solid supports, the peptides corresponding to portions of the protein molecule, and reacting the peptides with antibodies while the peptides are still attached to the supports. Such techniques are known in the art and described in, e.g., U.S. Pat. No. 4,708,871; Geysen et al. (1984) *Proc. Natl. Acad. Sci. USA* 81:3998-4002; Geysen et al. (1986) *Molec. Immunol.* 23:709-715, all incorporated herein by reference in their entireties. Similarly,

conformational epitopes may be identified by determining spatial conformation of amino acids such as by, e.g., x-ray crystallography and 2-dimensional nuclear magnetic resonance. See, e.g., Epitope Mapping Protocols, *supra*. Furthermore, for purposes of the present invention, an "antigen" may also be used to refer to a protein that includes
5 modifications, such as deletions, additions and substitutions (generally conservative in nature, but they may be non-conservative), to the native sequence, so long as the protein maintains the ability to elicit an immunological response. These modifications may be deliberate, as through site-directed mutagenesis, or through particular synthetic procedures, or through a genetic engineering approach, or may be accidental, such as
10 through mutations of hosts, which produce the antigens. Furthermore, the antigen can be derived, obtained, or isolated from a microbe, e.g. a bacterium, or can be a whole organism. Similarly, an oligonucleotide or polynucleotide, which expresses an antigen, such as in nucleic acid immunization applications, is also included in the definition. Synthetic antigens are also included, for example, polyepitopes, flanking epitopes, and
15 other recombinant or synthetically derived antigens (Bergmann et al. (1993) *Eur. J. Immunol.* 23:2777 2781; Bergmann et al. (1996) *J. Immunol.* 157:3242 3249; Suhrbier, A. (1997) *Immunol. and Cell Biol.* 75:402 408; Gardner et al. (1998) 12th World AIDS Conference, Geneva, Switzerland, Jun. 28 - Jul. 3, 1998).

The term "conservative" amino acid substitutions may be made on the basis of
20 similarity in polarity, charge, solubility hydrophobicity, hydrophilicity, and/or the amphipathic nature of the residues involved. For example, non-polar (hydrophobic) amino acids include alanine, leucine, isoleucine, valine, proline, tryptophan, and methionine; polar/neutral amino acids include glycine, serine, threonine, cysteine, tyrosine, asparagine, and glutamine; positively charged (basic) amino acids include
25 arginine, lysine, and histidine; and negatively charged (acidic) amino acids include aspartic acid and glutamic acid. In some embodiments, the conservative amino acid changes alter the primary sequence of the ORF2086 polypeptides, but do not alter the function of the molecule. When generating these mutants, the hydropathic index of amino acids can be considered. The importance of the hydropathic amino acid index in
30 conferring interactive biologic function on a polypeptide is generally understood in the art (Kyte & Doolittle, 1982, *J. Mol. Biol.*, 157(1):105-32). It is known that certain amino acids can be substituted for other amino acids having a similar hydropathic index or score and still result in a polypeptide with similar biological activity. Each amino acid

has been assigned a hydropathic index on the basis of its hydrophobicity and charge characteristics. Those indices are: isoleucine (+4.5); valine (+4.2); leucine (+3.8); phenylalanine (+2.8); cysteine/cystine (+2.5); methionine (+1.9); alanine (+1.8); glycine (-0.4); threonine (-0.7); serine (-0.8); tryptophan (-0.9); tyrosine (-1.3); proline (-1.6);
5 histidine (-3.2); glutamate (-3.5); glutamine (-3.5); aspartate (-3.5); asparagine (-3.5); lysine (-3.9); and arginine (-4.5).

It is believed that the relative hydropathic character of the amino acid residue determines the secondary and tertiary structure of the resultant polypeptide, which in turn defines the interaction of the polypeptide with other molecules, such as enzymes,
10 substrates, receptors, antibodies, antigens, and the like. It is known in the art that an amino acid can be substituted by another amino acid having a similar hydropathic index and still obtain a functionally equivalent polypeptide. In such changes, the substitution of amino acids whose hydropathic indices are within ± 2 is preferred, those within ± 1 are particularly preferred, and those within ± 0.5 are even more particularly preferred.

15 Conservative amino acids substitutions or insertions can also be made on the basis of hydrophilicity. As described in U.S. Pat. No. 4,554,101, which is hereby incorporated by reference the greatest local average hydrophilicity of a polypeptide, as governed by the hydrophilicity of its adjacent amino acids, correlates with its immunogenicity and antigenicity, *i.e.*, with a biological property of the polypeptide. U.S.
20 Pat. No. 4,554,101 recites that the following hydrophilicity values have been assigned to amino acid residues: arginine (+3.0); lysine (+3.0); aspartate (+3.0 $\pm$ 1); glutamate (+3.0 $\pm$ 1); serine (+0.3); asparagine (+0.2); glutamine (+0.2); glycine (0); proline (-0.5 $\pm$ 1); threonine (-0.4); alanine (-0.5); histidine (-0.5); cysteine (-1.0); methionine (-1.3); valine (-1.5); leucine (-1.8); isoleucine (-1.8); tyrosine (-2.3); phenylalanine (-2.5); tryptophan
25 (-3.4). It is understood that an amino acid can be substituted for another having a similar hydrophilicity value and still obtain a biologically equivalent, and in particular, an immunologically equivalent polypeptide. In such changes, the substitution of amino acids whose hydrophilicity values are within ± 2 is preferred; those within ± 1 are particularly preferred; and those within ± 0.5 are even more particularly preferred.
30 Exemplary substitutions which take various of the foregoing characteristics into consideration are well known to those of skill in the art and include, without limitation: arginine and lysine; glutamate and aspartate; serine and threonine; glutamine and asparagine; and valine, leucine and isoleucine.

The term "effective immunogenic amount" as used herein refers to an amount of a polypeptide or composition comprising a polypeptide which is effective in eliciting an immune response in a vertebrate host. For example, an effective immunogenic amount of a rLP2086 protein of this invention is an amount that is effective in eliciting an
5 immune response in a vertebrate host. The particular "effective immunogenic dosage or amount" will depend upon the age, weight and medical condition of the host, as well as on the method of administration. Suitable doses are readily determined by persons skilled in the art.

The term "Gly/Ser stalk" as used herein refers to the series of Gly and Ser
10 residues immediately downstream of the N-terminal Cys residue of a protein encoded by ORF2086. There can be between 5 and 12 Gly and Ser residues in the Gly/Ser stalk. Accordingly, the Gly/Ser stalk consists of amino acids 2 to between 7 and 13 of the protein encoded by ORF2086. Preferably, the Gly/Ser stalk consists of amino acids 2 and up to between 7 and 13 of the protein encoded by ORF2086. The Gly/Ser stalks
15 of the P2086 variants of the present invention are represented by the underlined sequences in Figure 2 (SEQ ID NO: 12-21). As shown herein, the length of the Gly/Ser stalk can affect the stability or expression level of a non-lipidated P2086 variant. In an exemplary embodiment, effects from affecting the length of the Gly/Ser stalk are compared to those from the corresponding wild-type variant.

20 The term "immunogenic" refers to the ability of an antigen or a vaccine to elicit an immune response, either humoral or cell-mediated, or both.

An "immunogenic amount", or an "immunologically effective amount" or "dose", each of which is used interchangeably herein, generally refers to the amount of antigen or immunogenic composition sufficient to elicit an immune response, either a cellular (T
25 cell) or humoral (B cell or antibody) response, or both, as measured by standard assays known to one skilled in the art.

The term "immunogenic composition" relates to any pharmaceutical composition containing an antigen, e.g. a microorganism, or a component thereof, which composition can be used to elicit an immune response in a subject. The immunogenic
30 compositions of the present invention can be used to treat a human susceptible to *N. meningidis* infection, by means of administering the immunogenic compositions via a systemic transdermal or mucosal route. These administrations can include injection via the intramuscular (i.m.), intraperitoneal (i.p.), intradermal (i.d.) or subcutaneous routes;

application by a patch or other transdermal delivery device; or via mucosal administration to the oral/alimentary, respiratory or genitourinary tracts. In one embodiment, the immunogenic composition may be used in the manufacture of a vaccine or in the elicitation of a polyclonal or monoclonal antibodies that could be used to passively protect or treat a subject.

Optimal amounts of components for a particular immunogenic composition can be ascertained by standard studies involving observation of appropriate immune responses in subjects. Following an initial vaccination, subjects can receive one or several booster immunizations adequately spaced.

The term "isolated" means that the material is removed from its original environment (e.g., the natural environment if it is naturally occurring or from its host organism if it is a recombinant entity, or taken from one environment to a different environment). For example, an "isolated" protein or peptide is substantially free of cellular material or other contaminating proteins from the cell or tissue source from which the protein is derived, or substantially free of chemical precursors or other chemicals when chemically synthesized, or otherwise present in a mixture as part of a chemical reaction. In the present invention, the proteins may be isolated from the bacterial cell or from cellular debris, so that they are provided in a form useful in the manufacture of an immunogenic composition. The term "isolated" or "isolating" may include purifying, or purification, including for example, the methods of purification of the proteins, as described herein. The language "substantially free of cellular material" includes preparations of a polypeptide or protein in which the polypeptide or protein is separated from cellular components of the cells from which it is isolated or recombinantly produced. Thus, a protein or peptide that is substantially free of cellular material includes preparations of the capsule polysaccharide, protein or peptide having less than about 30%, 20%, 10%, 5%, 2.5%, or 1%, (by dry weight) of contaminating protein or polysaccharide or other cellular material. When the polypeptide/protein is recombinantly produced, it is also preferably substantially free of culture medium, i.e., culture medium represents less than about 20%, 10%, or 5% of the volume of the protein preparation. When polypeptide or protein is produced by chemical synthesis, it is preferably substantially free of chemical precursors or other chemicals, i.e., it is separated from chemical precursors or other chemicals which are involved in the synthesis of the protein or polysaccharide. Accordingly, such preparations of the

polypeptide or protein have less than about 30%, 20%, 10%, 5% (by dry weight) of chemical precursors or compounds other than polypeptide/protein or polysaccharide fragment of interest.

The term "N-terminal tail" as used herein refers to the N-terminal portion of a protein encoded by ORF2086, which attaches the protein to the cell membrane. An N-terminal tail is shown at the bottom of the side view structure in Figure 3. An N-terminal tail typically comprises the N-terminal 16 amino acids of the protein encoded by ORF2086. In some embodiments, the N-terminal tail is amino acids 1-16 of any one of SEQ ID NOs: 12-21. The term "ORF2086" as used herein refers to Open Reading Frame 2086 from a *Neisseria* species bacteria. *Neisseria* ORF2086, the proteins encoded therefrom, fragments of those proteins, and immunogenic compositions comprising those proteins are known in the art and are described, e.g., in WO2003/063766, and in U.S. Patent Application Publication Nos. US 20060257413 and US 20090202593, each of which is hereby incorporated by reference in its entirety.

The term "P2086" generally refers to the protein encoded by ORF2086. The "P" before "2086" is an abbreviation for "protein." The P2086 proteins of the invention may be lipidated or non-lipidated. "LP2086" and "P2086" typically refer to lipidated and non-lipidated forms of a 2086 protein, respectively. The P2086 protein of the invention may be recombinant. "rLP2086" and "rP2086" typically refer to lipidated and non-lipidated forms of a recombinant 2086 protein, respectively. "2086" is also known as factor H-binding protein (fHBP) due to its ability to bind to factor H.

The term "pharmaceutically acceptable carrier" as used herein is intended to include any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like, compatible with administration to humans or other vertebrate hosts. Typically, a pharmaceutically acceptable carrier is a carrier approved by a regulatory agency of a Federal, a state government, or other regulatory agency, or listed in the U.S. Pharmacopeia or other generally recognized pharmacopeia for use in animals, including humans as well as non-human mammals. The term "carrier" refers to a diluent, adjuvant, excipient, or vehicle with which the pharmaceutical composition is administered. Such pharmaceutical carriers can be sterile liquids, such as water and oils, including those of petroleum, animal, vegetable or synthetic origin. Water, saline solutions and aqueous dextrose and glycerol solutions can be employed as liquid carriers, particularly for

injectable solutions. Suitable pharmaceutical excipients include starch, glucose, lactose, sucrose, gelatin, malt, rice, flour, chalk, silica gel, sodium stearate, glycerol monostearate, talc, sodium chloride, dried skim milk, glycerol, propylene, glycol, water, ethanol and the like. The composition, if desired, can also contain minor amounts of wetting, bulking, emulsifying agents, or pH buffering agents. These compositions can take the form of solutions, suspensions, emulsion, sustained release formulations and the like. Examples of suitable pharmaceutical carriers are described in "Remington's Pharmaceutical Sciences" by E. W. Martin. The formulation should suit the mode of administration. The appropriate carrier will be evident to those skilled in the art and will depend in large part upon the route of administration.

A "protective" immune response refers to the ability of an immunogenic composition to elicit an immune response, either humoral or cell mediated, which serves to protect the subject from an infection. The protection provided need not be absolute, i.e., the infection need not be totally prevented or eradicated, if there is a statistically significant improvement compared with a control population of subjects, e.g. infected animals not administered the vaccine or immunogenic composition. Protection may be limited to mitigating the severity or rapidity of onset of symptoms of the infection. In general, a "protective immune response" would include the induction of an increase in antibody levels specific for a particular antigen in at least 50% of subjects, including some level of measurable functional antibody responses to each antigen. In particular situations, a "protective immune response" could include the induction of a two fold increase in antibody levels or a four fold increase in antibody levels specific for a particular antigen in at least 50% of subjects, including some level of measurable functional antibody responses to each antigen. In certain embodiments, opsonising antibodies correlate with a protective immune response. Thus, protective immune response may be assayed by measuring the percent decrease in the bacterial count in a serum bactericidal activity (SBA) assay or an opsonophagocytosis assay, for instance those described below. Such assays are also known in the art. For meningococcal vaccines, for example, the SBA assay is an established surrogate for protection. In some embodiments, there is a decrease in bacterial count of at least 10%, 25%, 50%, 65%, 75%, 80%, 85%, 90%, 95% or more, as compared to the bacterial count in the absence of the immunogenic composition.

The terms "protein", "polypeptide" and "peptide" refer to a polymer of amino acid residues and are not limited to a minimum length of the product. Thus, peptides, oligopeptides, dimers, multimers, and the like, are included within the definition. Both full-length proteins and fragments thereof are encompassed by the definition. The terms also include modifications, such as deletions, additions and substitutions (generally conservative in nature, but which may be non-conservative), to a native sequence, preferably such that the protein maintains the ability to elicit an immunological response within an animal to which the protein is administered. Also included are post-expression modifications, *e.g.* glycosylation, acetylation, lipidation, phosphorylation and the like.

The term "recombinant" as used herein refers to any protein, polypeptide, or cell expressing a gene of interest that is produced by genetic engineering methods. The term "recombinant" as used with respect to a protein or polypeptide, means a polypeptide produced by expression of a recombinant polynucleotide. The proteins of the present invention may be isolated from a natural source or produced by genetic engineering methods. "Recombinant," as used herein, further describes a nucleic acid molecule, which, by virtue of its origin or manipulation, is not associated with all or a portion of the polynucleotide with which it is associated in nature. The term "recombinant" as used with respect to a host cell means a host cell which includes a recombinant polynucleotide.

The terms "stabilizer" refers to a compound that binds to an antigen and maintains the epitopes or immunoreactivity of the antigen over a period of time. Stabilizers are known in the art. Examples of stabilizers include multivalent cations, for example, calcium or aluminum.

The term "subject" refers to a mammal, bird, fish, reptile, or any other animal. The term "subject" also includes humans. The term "subject" also includes household pets. Non-limiting examples of household pets include: dogs, cats, pigs, rabbits, rats, mice, gerbils, hamsters, guinea pigs, ferrets, birds, snakes, lizards, fish, turtles, and frogs. The term "subject" also includes livestock animals. Non-limiting examples of livestock animals include: alpaca, bison, camel, cattle, deer, pigs, horses, llamas, mules, donkeys, sheep, goats, rabbits, reindeer, yak, chickens, geese, and turkeys.

The term "mammals" as used herein refers to any mammal, such as, for example, humans, mice, rabbits, non-human primates. In a preferred embodiment, the mammal is a human.

The terms "vaccine" or "vaccine composition", which are used interchangeably, refer to pharmaceutical compositions comprising at least one immunogenic composition that induces an immune response in a subject.

General Description

The present invention arises out of the novel discovery that particular formulations and dosing schedules of non-lipidated variants of P2086 elicit higher bactericidal antibody titers than previous formulations of P2086, as described, for example, in Fletcher et al., *Infection & Immunity*. Vol. 72(4):2088-2100 (2004). Alternatively, the present invention arises out of the novel discovery that particular formulations and dosing schedules of non-lipidated variants of P2086 elicit higher bactericidal antibody titers than commercially available formulations of lipidated LP2086 variants. It is noted, however, that commercial formulations of lipidated LP2086 may not be presently available. Higher response rates (as defined by a four fold increase or greater in SBA titers over baseline) were observed for the vaccine containing the non-lipidated rP2086 variant compared to the lipidated rLP2086 vaccine. The formulation of the non-lipidated P2086 variant elicited bactericidal antibodies against a broader spectrum of strains, including strains with both similar (>92% ID) and diverse (<92% ID) LP2086 sequences.

The present invention also identifies previously unidentified difficulties expressing non-lipidated P2086 variants and provides methods for overcoming these difficulties and novel compositions there from. While plasmid constructs encoding non-lipidated P2086 variants provided strong expression of the non-lipidated variants, these variants were pyruvylated on the N-terminal Cys. Pyruvylation prevents or reduces the likelihood of manufacturing consistency or uniformity of the polypeptides. The inventors further found that deletion of the N-terminal Cys from the non-lipidated P2086 variant sequences avoided pyruvylation of non-lipidated P2086 variants. Attempts to overcome the pyruvylation by deletion of the codon for the N-terminal Cys either abrogated expression or resulted in the expression of insoluble variants. Alternatively, removal of the N-terminal Cys from the non-lipidated P2086 variants decreased expression in

some variants. Surprisingly, however, the inventors discovered that at least non-pyruvylated non-lipidated A05, B01, B09, and B44 variants can be expressed despite deletion of the N-terminal Cys residue. Generally, these polypeptides could be expressed without additional modifications other than the Cys deletion, as compared to the corresponding wild-type non-lipidated sequence. See, for example, Examples 2 and 4. Furthermore, the inventors discovered that the non-pyruvylated non-lipidated variants were surprisingly immunogenic and they unexpectedly elicited bactericidal antibodies.

Accordingly, the present invention provides two methods for overcoming or reducing the likelihood of these difficulties in expressing non-lipidated variants. However, additional methods are contemplated by the present invention. The first method was to vary the length of the Gly/Ser stalk in the N-terminal tail, immediately downstream of the N-terminal Cys. The second method was codon optimization within the N-terminal tail. However, optimization of additional codons is contemplated by the present invention. These methods provide enhanced expression of soluble non-lipidated P2086 variants. For example, in one embodiment, enhanced expression of soluble non-lipidated P2086 variants is compared to expression of the corresponding wild-type non-lipidated variants.

Isolated polypeptides

The inventors surprisingly discovered isolated non-pyruvylated, non-lipidated ORF2086 polypeptides. The inventors further discovered that the polypeptides are unexpectedly immunogenic and are capable of eliciting a bactericidal immune response.

As used herein, the term "non-pyruvylated" refers to a polypeptide having no pyruvate content. Non-lipidated ORF2086 polypeptides having a pyruvate content typically exhibited a mass shift of +70, as compared to the corresponding wild-type polypeptide. In one embodiment, the inventive polypeptide does not exhibit a mass shift of +70 as compared to the corresponding wild-type non-lipidated polypeptide when measured by mass spectrometry. See, for example, Example 10.

In another embodiment, the isolated non-pyruvylated, non-lipidated ORF2086 polypeptide includes a deletion of an N-terminal cysteine residue compared to the corresponding wild-type non-lipidated ORF2086 polypeptide. The term "N-terminal cysteine" refers to a cysteine (Cys) at the N-terminal or N-terminal tail of a polypeptide.

More specifically, the "N-terminal cysteine" as used herein refers to the N-terminal cysteine at which LP2086 lipoproteins are lipidated with a tripalmitoyl lipid tail, as is known in the art. For example, when referring to any one of SEQ ID NOs: 12-21 as a reference sequence, the N-terminal cysteine is located at position 1.

5 The term "wild-type non-lipidated ORF2086 polypeptide" or "wild-type non-lipidated 2086 polypeptide" or "wild-type non-lipidated polypeptide" as used herein refers to an ORF2086 polypeptide having an amino acid sequence that is identical to the amino acid sequence of the corresponding mature lipidated ORF2086 polypeptide found in nature. The only difference between the non-lipidated and lipidated molecules
10 is that the wild-type non-lipidated ORF2086 polypeptide is not lipidated with a tripalmitoyl lipid tail at the N-terminal cysteine.

As is known in the art, the non-lipidated 2086 form is produced by a protein lacking the original leader sequence or by a leader sequence which is replaced with a portion of sequence that does not specify a site for fatty acid acylation in a host cell.
15 See, for example, WO2003/063766, which is incorporated herein by reference in its entirety.

Examples of a non-lipidated ORF2086 include not only a wild-type non-lipidated ORF2086 polypeptide just described but also polypeptides having an amino acid sequence according to any one of SEQ ID NOs: 12-21 wherein the N-terminal Cys is
20 deleted and polypeptides having an amino acid sequence according to any one of SEQ ID NOs: 12-21 wherein the N-terminal Cys is substituted. Further examples of a non-lipidated ORF2086 polypeptide include amino acid sequences selected from SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO: 55, SEQ ID NO: 57, SEQ ID NO: 62, and SEQ ID NO: 64.

25 Examples of a wild-type non-lipidated ORF2086 polypeptide include polypeptides having an amino acid sequence according to any one of SEQ ID NOs: 12-21, shown in Figure 2, SEQ ID NO: 58, SEQ ID NO: 59, and SEQ ID NO: 60. These exemplary wild-type non-lipidated ORF2086 polypeptides include an N-terminal Cys.

As used herein, for example, a "non-lipidated" B44 polypeptide includes a
30 polypeptide having the amino acid sequence selected from SEQ ID NO: 21, SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted, and SEQ ID NO: 44. A "wild-type non-lipidated" B44 polypeptide includes a polypeptide having the amino acid sequence SEQ ID NO: 21. A "non-pyruvylated non-lipidated" B44 polypeptide includes

a polypeptide having the amino acid sequence selected from SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted and SEQ ID NO: 44.

As another example, as used herein, a "non-lipidated" B09 polypeptide includes a polypeptide having the amino acid sequence selected from SEQ ID NO: 18, SEQ ID NO: 18 wherein the N-terminal Cys at position 1 is deleted, SEQ ID NO: 49, and SEQ ID NO: 50. A "wild-type non-lipidated" B09 polypeptide includes a polypeptide having the amino acid sequence SEQ ID NO: 18. A "non-pyruvylated non-lipidated" B09 includes a polypeptide having the amino acid sequence selected from SEQ ID NO: 18 wherein the N-terminal Cys at position 1 is deleted, SEQ ID NO: 49, and SEQ ID NO: 50.

As yet a further example, as used herein, a "non-lipidated" A05 polypeptide includes a polypeptide having the amino acid sequence selected from SEQ ID NO: 13, SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is deleted, and SEQ ID NO: 55. A "wild-type non-lipidated" A05 includes a polypeptide having the amino acid sequence SEQ ID NO: 13. A "non-pyruvylated non-lipidated" A05 includes a polypeptide having the amino acid sequence selected from SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is deleted and SEQ ID NO: 55.

The term "deletion" of the N-terminal Cys as used herein includes a mutation that deletes the N-terminal Cys, as compared to a wild-type non-lipidated polypeptide sequence. For example, a "deletion" of the N-terminal Cys refers to a removal of the amino acid Cys from a reference sequence, e.g., from the corresponding wild-type sequence, thereby resulting in a decrease of an amino acid residue as compared to the reference sequence.

In another embodiment, the N-terminal Cys is substituted with an amino acid that is not a Cys residue. For example, in an exemplary embodiment, the N-terminal Cys at position 1 of SEQ ID NOs: 12-21 includes a C→G substitution at position 1. See, for example, SEQ ID NO: 62 as compared to SEQ ID NO: 19 (B22 wild-type), and SEQ ID NO: 64 as compared to SEQ ID NO: 15 (A22 wild-type). Exemplary amino acids to replace the N-terminal Cys include any non-Cys amino acid, preferably a polar uncharged amino acid such as, for example, glycine. In a preferred embodiment, the substitution is made with a non-conservative residue to Cys.

The inventors surprisingly discovered that expressing non-lipidated ORF2086 polypeptides having a deletion of an N-terminal Cys residue resulted in no detectable

pyruvylation when measured by mass spectrometry, as compared to the corresponding wild-type non-lipidated ORF2086 polypeptide. Examples of non-pyruvylated non-lipidated ORF2086 polypeptides include those having an amino acid sequence selected from the group consisting of SEQ ID NO:12 (A04), SEQ ID NO:13 (A05), SEQ ID NO:14 (A12), SEQ ID NO:15 (A22), SEQ ID NO:16 (B02), SEQ ID NO:17 (B03), SEQ ID NO:18 (B09), SEQ ID NO:19 (B22), SEQ ID NO: 20 (B24), and SEQ ID NO: 21 (B44), wherein the cysteine at position 1 is deleted. Additional examples of isolated non-pyruvylated, non-lipidated ORF2086 polypeptides include polypeptides having an amino acid sequence selected from the group consisting of SEQ ID NO: 44 , SEQ ID NO: 49, SEQ ID NO: 50 , and SEQ ID NO: 55. Preferably, the non-pyruvylated non-lipidated ORF2086 polypeptide includes at least about 250, 255, or 260 consecutive amino acids, and at most about 270, 269, 268, 267, 266, 265, 264, 263, 260, 259, 258, 257, 256, or 255 consecutive amino acids. Any minimum value may be combined with any maximum value to define a range. More preferably, the polypeptide has at least 254 or 262 consecutive amino acids.

In one embodiment, the isolated non-pyruvylated, non-lipidated ORF2086 polypeptide is encoded by a nucleotide sequence that is operatively linked to an expression system, wherein the expression system is capable of being expressed in a bacterial cell. In an exemplary embodiment, the nucleotide sequence is linked to a regulatory sequence that controls expression of the nucleotide sequence.

Suitable expression systems, regulatory sequences, and bacterial cells are known in the art. For example, any plasmid expression vector, e.g., PET[™] (Novogen, Madison Wis.) or PMAL[™] (New England Biolabs, Beverly, Mass.) can be used as long as the polypeptide is able to be expressed in a bacterial cell. Preferably, the PET[™] vector is used for cloning and expression of recombinant proteins in *E. coli*. In the PET[™] system, the cloned gene may be expressed under the control of a phage T7 promoter. Exemplary bacterial cells include *Pseudomonas fluorescens*, and preferably, *E. coli*.

In one aspect, the invention relates to a non-pyruvylated non-lipidated ORF2086 polypeptide obtainable by the process. The polypeptide is preferably isolated. The invention further relates to compositions that include a non-pyruvylated non-lipidated ORF2086 polypeptide obtainable by a process. The composition is preferably an immunogenic composition. The process includes expressing a nucleotide sequence

encoding a polypeptide having the amino acid sequence selected from the group consisting of SEQ ID NO:12, SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO: 20, and SEQ ID NO: 21, wherein the cysteine at position 1 is deleted. The nucleotide sequence is
5 operatively linked to an expression system that is capable of being expressed in a bacterial cell. In one embodiment, the process includes expressing a nucleotide sequence encoding a polypeptide having the amino acid sequence selected from the group consisting of SEQ ID NO: 44, SEQ ID NO: 49 , SEQ ID NO: 50, and SEQ ID NO: 55. In another embodiment, the nucleotide sequence is selected from the group
10 consisting of SEQ ID NO: 43, SEQ ID NO: 51, SEQ ID NO: 46, SEQ ID NO: 47, SEQ ID NO: 48, SEQ ID NO: 45, SEQ ID NO: 54. Preferably the bacterial cell is *E. coli*.

In one aspect, the invention relates to a composition that includes a first isolated polypeptide, which includes the amino acid sequence set forth in SEQ ID NO: 49, and a second isolated polypeptide, which includes the amino acid sequence set forth in SEQ
15 ID NO: 44. In a preferred embodiment, the polypeptides are immunogenic. In another preferred embodiment, the composition further includes an ORF2086 subfamily A polypeptide from serogroup B *N. meningitidis*. Preferably, the ORF2086 subfamily A polypeptide is a non-pyruvylated non-lipidated ORF2086 subfamily A polypeptide. In an exemplary embodiment, the ORF2086 subfamily A polypeptide is A05, examples of
20 which include, for example, SEQ ID NO: 13, wherein the N-terminal cysteine at position 1 is deleted, and SEQ ID NO: 55.

In another aspect, the invention relates to a method for producing an isolated polypeptide. The method includes expressing in a bacterial cell a polypeptide, which includes a sequence having greater than 90% identity to SEQ ID NO:21, said sequence
25 includes at least one domain selected from the group consisting of amino acids 13-18 of SEQ ID NO: 21, amino acids 21-34 of SEQ ID NO: 21, and amino acids 70-80 of SEQ ID NO: 21, or a combination thereof, wherein the polypeptide lacks an N-terminal cysteine. The method further includes purifying the polypeptide. The polypeptide produced therein includes a non-pyruvylated non-lipidated ORF2086 polypeptide.
30 Preferably, the polypeptide is immunogenic. In a preferred embodiment, the bacterial cell is *E. coli*.

Examples of polypeptides that include at least one domain selected from the group consisting of amino acids 13-18 of SEQ ID NO: 21, amino acids 21-34 of SEQ ID

NO: 21, and amino acids 70-80 of SEQ ID NO: 21, or a combination thereof, include
SEQ ID NO: 12 (A04), SEQ ID NO: 13 (A05), SEQ ID NO: 14 (A12), SEQ ID NO: 15
(A22), SEQ ID NO: 16 (B02), SEQ ID NO: 17 (B03), SEQ ID NO: 18 (B09), SEQ ID NO:
19 (B22), SEQ ID NO: 20 (B24), and SEQ ID NO: 21 (B44). Preferably the cysteine at
5 position 1 of these polypeptides is deleted. Further exemplary polypeptides include
SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO: 50, SEQ ID NO: 55, SEQ ID NO: 62, and
SEQ ID NO: 64.

In one exemplary embodiment, the isolated polypeptide sequence further
includes at least one domain selected from the group consisting of amino acids 96-116
10 of SEQ ID NO: 21, amino acids 158-170 of SEQ ID NO: 21, amino acids 172-185 of
SEQ ID NO: 21, amino acids 187-199 of SEQ ID NO: 21, amino acids 213-224 of SEQ
ID NO: 21, amino acids 226-237 of SEQ ID NO: 21, amino acids 239-248 of SEQ ID
NO: 21, or a combination thereof. Examples of polypeptides that include at least one
domain selected from the group consisting of amino acids 13-18 of SEQ ID NO: 21,
15 amino acids 21-34 of SEQ ID NO: 21, and amino acids 70-80 of SEQ ID NO: 21, or a
combination thereof, and further including at least one domain selected from the group
consisting of amino acids 96-116 of SEQ ID NO: 21, amino acids 158-170 of SEQ ID
NO: 21, amino acids 172-185 of SEQ ID NO: 21, amino acids 187-199 of SEQ ID NO:
21, amino acids 213-224 of SEQ ID NO: 21, amino acids 226-237 of SEQ ID NO: 21,
20 amino acids 239-248 of SEQ ID NO: 21, or a combination thereof, include SEQ ID NO:
16 (B02), SEQ ID NO: 17 (B03), SEQ ID NO: 18 (B09), SEQ ID NO: 19 (B22), SEQ ID
NO: 20 (B24), and SEQ ID NO: 21 (B44). Preferably the cysteine at position 1 of these
polypeptides is deleted. Further exemplary polypeptides include a polypeptide having
the amino acid sequence selected from SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO:
25 50, and SEQ ID NO: 55, and SEQ ID NO: 62.

In one aspect, the invention relates to an isolated polypeptide produced by a
process described herein. In one embodiment, the isolated polypeptide is a non-
pyruvylated non-lipidated polypeptide. In another aspect, the invention relates to an
immunogenic composition produced by a process described herein.

30 In one aspect, the invention relates to an isolated polypeptide that includes the
amino acid sequence set forth in SEQ ID NO: 18 wherein the N-terminal Cys at position
1 is deleted or SEQ ID NO: 49. Exemplary nucleotide sequences that encode SEQ ID
NO: 49 include sequences selected from SEQ ID NO: 46, SEQ ID NO: 47, and SEQ ID

NO: 48. Preferably, the nucleotide sequence is SEQ ID NO: 46. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 46. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 47. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 48.

In one aspect, the invention relates to a plasmid including a nucleotide sequence selected from SEQ ID NO: 46, SEQ ID NO: 47, SEQ ID NO: 48, and SEQ ID NO: 45, wherein the plasmid is capable of being expressed in a bacterial cell. Suitable expression systems, regulatory sequences, and bacterial cells are known in the art, as described above. Preferably, the bacterial cell is *E. coli*.

In another aspect, the invention relates to an isolated polypeptide that includes the amino acid sequence set forth in SEQ ID NO: 50. In an exemplary embodiment, SEQ ID NO: 50 is encoded by SEQ ID NO: 45.

In yet another aspect, the invention relates to an isolated polypeptide that includes the amino acid sequence set forth in SEQ ID NO: 21 wherein the N-terminal Cys is deleted or SEQ ID NO: 44. Exemplary nucleotide sequences that encode SEQ ID NO: 44 include sequences selected from SEQ ID NO: 43 and SEQ ID NO: 51. Preferably, the nucleotide sequence is SEQ ID NO: 43. In one aspect, the invention relates to an isolated nucleotide sequence that includes SEQ ID NO: 43.

Immunogenic Compositions

In a preferred embodiment, the compositions described herein including an isolated non-pyruvylated non-lipidated ORF2086 polypeptide are immunogenic. Immunogenic compositions that include a protein encoded by a nucleotide sequence from *Neisseria meningitidis* ORF2086 are known in the art. Exemplary immunogenic compositions include those described in WO2003/063766, and US patent application publication numbers US 20060257413 and US 20090202593, which are incorporated herein by reference in their entirety. Such immunogenic compositions described therein include a protein exhibiting bactericidal activity identified as ORF2086 protein, immunogenic portions thereof, and/or biological equivalents thereof. The ORF2086 protein refers to a protein encoded by open reading frame 2086 of *Neisseria* species.

The protein may be a recombinant protein or an isolated protein from native *Neisseria* species. For example, *Neisseria* ORF2086 proteins may be isolated from

bacterial strains, such as those of *Neisseria* species, including strains of *Neisseria meningitidis* (serogroups A, B, C, D, W-135, X, Y, Z, and 29E), *Neisseria gonorrhoeae*, and *Neisseria lactamica*, as well as immunogenic portions and/or biological equivalents of said proteins.

5 The ORF2086 proteins include 2086 Subfamily A proteins and Subfamily B proteins, immunogenic portions thereof, and/or biological equivalents thereof. 2086 subfamily A proteins and 2086 subfamily B proteins are known in the art, see, for example Fletcher et al., 2004 cited above and Murphy et al., *J Infect Dis.* 2009 Aug 1;200(3):379-89. See also WO2003/063766, which discloses SEQ ID NOs: 260 to 278
10 therein as representing amino acid sequences associated with proteins of 2086 Subfamily A. In addition, disclosed in WO2003/063766 are SEQ ID NOS: 279 to 299 therein as representing amino acid sequences associated with proteins of 2086 Subfamily B. WO2003/063766 is incorporated herein by reference in its entirety. The ORF2086 proteins or equivalents thereof, etc. may be lipidated or non lipidated.
15 Preferably, the *Neisseria* ORF2086 protein is non lipidated. Alternatively, the immunogenic compositions may be combinations of lipidated and non lipidated ORF2086 proteins.

 In (an) one embodiment, the immunogenic composition includes an isolated protein having at least 95% amino acid sequence identity to a protein encoded by a
20 nucleotide sequence from *Neisseria* ORF2086.

 In one embodiment, the immunogenic composition includes an isolated protein having at least 95% amino acid sequence identity to a Subfamily A protein encoded by a nucleotide sequence from *Neisseria* ORF2086. Preferably, the immunogenic composition includes an isolated Subfamily A protein encoded by a nucleotide
25 sequence from *Neisseria* ORF2086. In some embodiments, the ORF2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.
 In some embodiments, the ORF2086 Subfamily A polypeptide is an A05, an A12, or an A22 variant.

 In another embodiment, the immunogenic composition includes an isolated
30 protein having at least 95% amino acid sequence identity to a Subfamily B protein encoded by a nucleotide sequence from *Neisseria* ORF2086. Preferably, the immunogenic composition includes an isolated Subfamily B protein encoded by a nucleotide sequence from *Neisseria* ORF2086. In some embodiments, the ORF2086

Subfamily B protein is a B44, a B02, a B03, a B22, a B24 or a B09 variant. In some embodiments, the ORF2086 Subfamily B protein is a B44, a B22, or a B09 variant.

In a preferred embodiment, the immunogenic composition includes an isolated non-pyruvylated non-lipidated polypeptide having at least 95% amino acid sequence identity to a Subfamily B protein encoded by a nucleotide sequence from *Neisseria* ORF2086. For example, in some embodiments, the ORF2086 Subfamily B protein is sequences selected from a B44 having an amino acid sequence as shown in SEQ ID NO: 21; a B02 having an amino acid sequence as shown in SEQ ID NO: 16; a B03 having an amino acid sequence as shown in SEQ ID NO: 17; a B22 having an amino acid sequence as shown in SEQ ID NO:19; a B24 having an amino acid sequence as shown in SEQ ID NO: 20; or a B09 variant having an amino acid sequence as shown in SEQ ID NO:18, wherein the N-terminal Cys is deleted, or a combination thereof.

More preferably, the immunogenic composition includes a non-pyruvylated non-lipidated B09 polypeptide, a non-pyruvylated non-lipidated B44 polypeptide, or combinations thereof. In one embodiment, the composition includes a non-pyruvylated non-lipidated B09 variant having the amino acid sequence as shown in SEQ ID NO:18, wherein the N-terminal Cys is deleted, a non-pyruvylated non-lipidated B44 having the amino acid sequence as shown in SEQ ID NO: 21, wherein the N-terminal Cys is deleted, or a combination thereof. In another embodiment, the immunogenic composition includes a non-pyruvylated non-lipidated B09 having SEQ ID NO: 49, a non-pyruvylated non-lipidated B44 having SEQ ID NO: 44, or a combination thereof.

In one aspect, the invention relates to an immunogenic composition that includes an ORF2086 subfamily B polypeptide from serogroup B *N. meningitidis*, wherein the polypeptide is a non-pyruvylated non-lipidated B44. The B44 may include the amino acid sequence as shown in SEQ ID NO: 21, wherein the N-terminal Cys is deleted or SEQ ID NO: 44. In one embodiment, the composition further includes a second ORF2086 subfamily B polypeptide from serogroup B *N. meningitidis*, wherein the second polypeptide is a non-pyruvylated non-lipidated B09. The B09 may include the amino acid sequence as shown in SEQ ID NO: 18, wherein the N-terminal Cys is deleted, or SEQ ID NO: 49. In one embodiment, the immunogenic composition is a vaccine.

In another embodiment, the composition includes no more than 3 ORF2086 subfamily B polypeptides. In a further embodiment, the composition includes no more than 2 ORF2086 subfamily B polypeptides.

In one embodiment, the composition further includes one or more ORF2086 subfamily A polypeptides. In a preferred embodiment, the composition includes an A05 subfamily A polypeptide.

In yet another embodiment, the immunogenic composition includes an isolated protein having at least 95% amino acid sequence identity to a Subfamily A protein encoded by a nucleotide sequence from *Neisseria* ORF2086, and an isolated protein having at least 95% amino acid sequence identity to a Subfamily B protein encoded by a nucleotide sequence from *Neisseria* ORF2086.

Preferably, the immunogenic composition includes an isolated Subfamily A protein encoded by a nucleotide sequence from *Neisseria* ORF2086 and an isolated Subfamily B protein encoded by a nucleotide sequence from *Neisseria* ORF2086. More preferably, the immunogenic composition includes an isolated non-pyruvylated non-lipidated Subfamily A ORF2086 polypeptide and an isolated non-pyruvylated non-lipidated Subfamily B ORF2086 polypeptide. In some embodiments, the ORF2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant. In a preferred embodiment, the ORF2086 Subfamily A polypeptide is an A05 having an amino acid sequence as shown in SEQ ID NO: 13; an A04 having an amino acid sequence as shown in SEQ ID NO: 12; an A12 having an amino acid sequence as shown in SEQ ID NO: 14; or an A22 variant having an amino acid sequence as shown in SEQ ID NO: 15, wherein the N-terminal Cys is deleted, or any combination thereof. In some embodiments, the ORF2086 Subfamily B protein is a B44, a B02, a B03, a B22, a B24 or a B09 variant. In a preferred embodiment, the ORF2086 Subfamily B protein is a B44 having the amino acid sequence as shown in SEQ ID NO: 21; a B02 having an amino acid sequence as shown in SEQ ID NO: 16; a B03 having an amino acid sequence as shown in SEQ ID NO: 17; a B22 having an amino acid sequence as shown in SEQ ID NO: 19; a B24 having an amino acid sequence as shown in SEQ ID NO: 20; or a B09 variant having an amino acid sequence as shown in SEQ ID NO: 18, wherein the N-terminal Cys is deleted, or a combination thereof.

In one embodiment, the immunogenic composition includes a 1:1 ratio of a Subfamily A protein to a Subfamily B protein.

In another aspect, the isolated polypeptides and compositions described herein elicit a bactericidal immune response in a mammal against an ORF2086 polypeptide from serogroup B *N. meningitidis*. The compositions have the ability to induce bactericidal anti-meningococcal antibodies after administration to a mammal, and in preferred embodiments can induce antibodies that are bactericidal against strains with the respective subfamilies. Further information on bactericidal responses is given below. See, for example, Examples 6, 11, 12, and 13. Bactericidal antibodies are an indicator of protection in humans and preclinical studies serve as a surrogate, and any new immunogenic composition candidate should elicit these functional antibodies.

In an exemplary embodiment, the isolated non-pyruvylated non-lipidated B09 polypeptide having SEQ ID NO: 18 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 49, and immunogenic compositions thereof, elicits bactericidal antibodies against (e.g., that can bind to) an ORF2086 polypeptide from serogroup B *N. meningitidis*, subfamily A or preferably subfamily B. Preferably, the non-pyruvylated non-lipidated B09 polypeptide and immunogenic compositions thereof, elicits bactericidal antibodies against the A05 variant (SEQ ID NO: 13); B44 variant (SEQ ID NO: 21); B16 variant (SEQ ID NO: 60); B24 variant (SEQ ID NO: 20); B09 variant (SEQ ID NO: 18), or a combination thereof. In an exemplary embodiment, the non-pyruvylated non-lipidated B09 polypeptide and immunogenic compositions thereof, elicits bactericidal antibodies against B44 variant (SEQ ID NO: 21); B16 variant (SEQ ID NO: 60); B24 variant (SEQ ID NO: 20); B09 variant (SEQ ID NO: 18), or a combination thereof. See, for example, Example 11, Example 12, and Example 13.

In another exemplary embodiment, the isolated non-pyruvylated non-lipidated B44 polypeptide having SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 44, and immunogenic compositions thereof, elicits bactericidal antibodies against (e.g., that can bind to) an ORF2086 polypeptide from serogroup B *N. meningitidis*, subfamily B. Preferably, the non-pyruvylated non-lipidated B44 polypeptide and immunogenic compositions thereof, elicits bactericidal antibodies against the B44 variant (SEQ ID NO: 21); B16 variant (SEQ ID NO: 60); B24 variant (SEQ ID NO: 20); B09 variant (SEQ ID NO: 18), or a combination thereof. See, for example, Example 11. Additionally, the non-pyruvylated non-lipidated B44 polypeptide and immunogenic compositions thereof may also elicit bactericidal antibodies that bind to the B02 variant (SEQ ID NO: 16). See, for example, Example 12 and Example 13.

Moreover, the non-pyruvylated non-lipidated B44 polypeptide and immunogenic compositions thereof may also elicit bactericidal antibodies that bind to B03 variant (SEQ ID NO: 17) and B15 variant (SEQ ID NO: 59). See, for example, Example 6.

In a further exemplary embodiment, the isolated non-pyruvylated non-lipidated B22 polypeptide having SEQ ID NO: 19 wherein the N-terminal Cys at position 1 is deleted, and immunogenic compositions thereof, elicits bactericidal antibodies against (e.g., that can bind to) an ORF2086 polypeptide from serogroup B *N. meningitidis*, subfamily B. Preferably, the non-pyruvylated non-lipidated B22 polypeptide elicits bactericidal antibodies against the B44 variant (SEQ ID NO: 21); B16 variant (SEQ ID NO: 60); B24 variant (SEQ ID NO: 20); B09 variant (SEQ ID NO: 18), or a combination thereof. See, for example, Example 13.

In one embodiment, the isolated non-pyruvylated non-lipidated A05 polypeptide having SEQ ID NO: 13 wherein the N-terminal Cys is deleted or SEQ ID NO: 55, and immunogenic compositions thereof, elicits bactericidal antibodies against (e.g., that can bind to) an ORF2086 polypeptide from serogroup B *N. meningitidis*, subfamily A. Preferably, the non-pyruvylated non-lipidated A05 and immunogenic compositions thereof, elicits bactericidal antibodies against the A05 variant (SEQ ID NO: 13), A22 variant (SEQ ID NO: 15), A12 variant (SEQ ID NO: 14), or a combination thereof. See, for example, Example 6 and 13.

In one aspect, the invention relates to a method of eliciting bactericidal antibodies specific to serogroup B *N. meningitidis* in a mammal. In an exemplary embodiment, the method includes eliciting bactericidal antibodies specific to an ORF2086 subfamily B serogroup B *N. meningitidis*, an ORF2086 subfamily A serogroup B *N. meningitidis*, or a combination thereof. The method includes administering to the mammal an effective amount of an isolated non-pyruvylated non-lipidated 2086 polypeptide or immunogenic composition thereof, as described above.

In a preferred embodiment, the method includes eliciting bactericidal antibodies specific to an ORF2086 subfamily B serogroup B *N. meningitidis*. The isolated polypeptide or immunogenic composition includes a non-pyruvylated non-lipidated B44 polypeptide. In another preferred embodiment, the composition further includes a non-pyruvylated non-lipidated B09 polypeptide. In an exemplary embodiment, the isolated polypeptide or immunogenic composition includes SEQ ID NO: 49, SEQ ID NO: 44, or a combination thereof. In another exemplary embodiment, the isolated polypeptide or

immunogenic composition includes SEQ ID NO: 18, wherein the N-terminal Cys at position 1 is deleted, SEQ ID NO: 21, wherein the N-terminal Cys at position 1 is deleted, or a combination thereof. In yet another exemplary embodiment, the isolated polypeptide or immunogenic composition includes SEQ ID NO: 19, wherein the N-terminal Cys at position 1 is deleted,

In a preferred embodiment, the method includes eliciting bactericidal antibodies specific to an ORF2086 subfamily A serogroup B *N. meningitidis*. The isolated polypeptide or immunogenic composition includes a non-pyruvylated non-lipidated A05 polypeptide. In a preferred embodiment, the isolated polypeptide or immunogenic composition includes SEQ ID NO: 13, wherein the N-terminal Cys at position 1 is deleted. In another preferred embodiment, the composition further includes a non-pyruvylated non-lipidated B44 polypeptide. See, for example, Example 6 and 13. In an exemplary embodiment, the isolated polypeptide or immunogenic composition includes SEQ ID NO: 55, SEQ ID NO: 44, or a combination thereof. In a preferred embodiment, the isolated polypeptide or immunogenic composition includes SEQ ID NO: 13, wherein the N-terminal Cys at position 1 is deleted, SEQ ID NO: 21, wherein the N-terminal Cys at position 1 is deleted, or a combination thereof.

The immunogenic composition may include a protein encoded by a nucleotide sequence from *Neisseria* ORF2086, polynucleotides, or equivalents thereof as the sole active immunogen in the immunogenic composition. Alternatively, the immunogenic composition may further include active immunogens, including other *Neisseria* sp. immunogenic polypeptides, or immunologically-active proteins of one or more other microbial pathogens (e.g. virus, prion, bacterium, or fungus, without limitation) or capsular polysaccharide. The compositions may comprise one or more desired proteins, fragments or pharmaceutical compounds as desired for a chosen indication.

Any multi-antigen or multi-valent immunogenic composition is contemplated by the present invention. For example, the immunogenic composition may include combinations of two or more ORF2086 proteins, a combination of ORF2086 protein with one or more Por A proteins, a combination of ORF2086 protein with *meningococcus* serogroup A, C, Y and W135 polysaccharides and/or polysaccharide conjugates, a combination of ORF2086 protein with *meningococcus* and *pneumococcus* combinations, or a combination of any of the foregoing in a form suitable for a desired

administration, e.g., for mucosal delivery. Persons of skill in the art would be readily able to formulate such multi-antigen or multi-valent immunologic compositions.

The present invention also contemplates multi-immunization regimens wherein any composition useful against a pathogen may be combined therein or therewith the compositions of the present invention. For example, without limitation, a patient may be administered the immunogenic composition of the present invention and another immunological composition for immunizing against human papillomavirus virus (HPV), such as the HPV vaccine GARDASIL®, as part of a multi-immunization regimen. Persons of skill in the art would be readily able to select immunogenic compositions for use in conjunction with the immunogenic compositions of the present invention for the purposes of developing and implementing multi-immunization regimens.

The ORF2086 polypeptides, fragments and equivalents can be used as part of a conjugate immunogenic composition; wherein one or more proteins or polypeptides are conjugated to a carrier in order to generate a composition that has immunogenic properties against several serotypes, or serotypes of *N. meningitidis*, specifically meningococcus serogroups specifically serogroup B, and/or against several diseases. Alternatively, one of the ORF2086 polypeptides can be used as a carrier protein for other immunogenic polypeptides. Formulation of such immunogenic compositions is well known to persons skilled in this field.

Immunogenic compositions of the invention preferably include a pharmaceutically acceptable carrier. Suitable pharmaceutically acceptable carriers and/or diluents include any and all conventional solvents, dispersion media, fillers, solid carriers, aqueous solutions, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like. Suitable pharmaceutically acceptable carriers include, for example, one or more of water, saline, phosphate buffered saline, dextrose, glycerol, ethanol and the like, as well as combinations thereof.

Pharmaceutically acceptable carriers may further include minor amounts of auxiliary substances such as wetting or emulsifying agents, preservatives or buffers, which enhance the shelf life or effectiveness of the antibody. The preparation and use of pharmaceutically acceptable carriers is well known in the art. Except insofar as any conventional media or agent is incompatible with the active ingredient, use thereof in the immunogenic compositions of the present invention is contemplated.

Immunogenic compositions can be administered parenterally, e.g., by injection, either subcutaneously or intramuscularly, as well as orally or intranasally. Methods for intramuscular immunization are described by Wolff et al. Biotechniques;11(4):474-85, (1991). and by Sedegah et al. PNAS Vol. 91, pp. 9866-9870, (1994). Other modes of administration employ oral formulations, pulmonary formulations, suppositories, and transdermal applications, for example, without limitation. Oral formulations, for example, include such normally employed excipients as, for example, pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, and the like, without limitation. Preferably, the immunogenic composition is administered intramuscularly.

The immunogenic compositions of the present invention can further comprise one or more additional "immunomodulators", which are agents that perturb or alter the immune system, such that either up-regulation or down-regulation of humoral and/or cell-mediated immunity is observed. In one particular embodiment, up-regulation of the humoral and/or cell-mediated arms of the immune system is preferred. Examples of certain immunomodulators include, for example, an adjuvant or cytokine, or ISCOMATRIX (CSL Limited, Parkville, Australia), described in U.S. Patent No. 5,254,339 among others.

Non-limiting examples of adjuvants that can be used in the vaccine of the present invention include the RIBI adjuvant system (Ribi Inc., Hamilton, Mont.), alum, mineral gels such as aluminum hydroxide gel, oil-in-water emulsions, water-in-oil emulsions such as, e.g., Freund's complete and incomplete adjuvants, Block copolymer (CytRx, Atlanta Ga.), QS-21 (Cambridge Biotech Inc., Cambridge Mass.), SAF-M (Chiron, Emeryville Calif.), AMPHIGEN® adjuvant, saponin, Quil A or other saponin fraction, monophosphoryl lipid A, and Avridine lipid-amine adjuvant. Non-limiting examples of oil-in-water emulsions useful in the vaccine of the invention include modified SEAM62 and SEAM 1/2 formulations. Modified SEAM62 is an oil-in-water emulsion containing 5% (v/v) squalene (Sigma), 1% (v/v) SPAN® 85 detergent (ICI Surfactants), 0.7% (v/v) polysorbate ® 80 detergent (ICI Surfactants), 2.5% (v/v) ethanol, 200 µg/ml Quil A, 100 µg/ml cholesterol, and 0.5% (v/v) lecithin. Modified SEAM 1/2 is an oil-in-water emulsion comprising 5% (v/v) squalene, 1% (v/v) SPAN® 85 detergent, 0.7% (v/v) polysorbate 80 detergent, 2.5% (v/v) ethanol, 100 µg/ml Quil A, and 50 µg/ml cholesterol.

Other "immunomodulators" that can be included in the vaccine include, e.g., one or more interleukins, interferons, or other known cytokines or chemokines. In one embodiment, the adjuvant may be a cyclodextrin derivative or a polyanionic polymer, such as those described in U.S. patent numbers 6,165,995 and 6,610,310, respectively.

5 It is to be understood that the immunomodulator and/or adjuvant to be used will depend on the subject to which the vaccine or immunogenic composition will be administered, the route of injection and the number of injections to be given.

In some embodiments, the adjuvant is saponin. In some embodiments, the saponin concentration is between 1 µg/ml and 250 µg/ml; between 5 µg/ml and 150
10 µg/ml; or between 10 µg/ml and 100 µg/ml. In some embodiments, the saponin concentration is about 1 µg/ml; about 5 µg/ml; about 10 µg/ml; about 20 µg/ml; about 30 µg/ml; about 40 µg/ml; about 50 µg/ml; about 60 µg/ml; about 70 µg/ml; about 80 µg/ml; about 90 µg/ml; about 100 µg/ml; about 110 µg/ml; about 120 µg/ml; about 130 µg/ml; about 140 µg/ml; about 150 µg/ml; about 160 µg/ml; about 170 µg/ml; about 180
15 µg/ml; about 190 µg/ml; about 200 µg/ml; about 210 µg/ml; about 220 µg/ml; about 230 µg/ml; about 240 µg/ml; or about 250 µg/ml.

In certain preferred embodiments, the proteins of this invention are used in an immunogenic composition for oral administration which includes a mucosal adjuvant and used for the treatment or prevention of *N. meningitidis* infection in a human host.
20 The mucosal adjuvant can be a cholera toxin; however, preferably, mucosal adjuvants other than cholera toxin which may be used in accordance with the present invention include non-toxic derivatives of a cholera holotoxin, wherein the A subunit is mutagenized, chemically modified cholera toxin, or related proteins produced by modification of the cholera toxin amino acid sequence. For a specific cholera toxin
25 which may be particularly useful in preparing immunogenic compositions of this invention, see the mutant cholera holotoxin E29H, as disclosed in Published International Application WO 00/18434, which is hereby incorporated herein by reference in its entirety. These may be added to, or conjugated with, the polypeptides of this invention. The same techniques can be applied to other molecules with mucosal
30 adjuvant or delivery properties such as *Escherichia coli* heat labile toxin (LT).

Other compounds with mucosal adjuvant or delivery activity may be used such as bile; polycations such as DEAE-dextran and polyornithine; detergents such as sodium dodecyl benzene sulphate; lipid-conjugated materials; antibiotics such as

streptomycin; vitamin A; and other compounds that alter the structural or functional integrity of mucosal surfaces. Other mucosally active compounds include derivatives of microbial structures such as MDP; acridine and cimetidine. STIMULON™ QS-21, MPL, and IL-12, as described above, may also be used.

5 The immunogenic compositions of this invention may be delivered in the form of ISCOMS (immune stimulating complexes), ISCOMS containing CTB, liposomes or encapsulated in compounds such as acrylates or poly(DL-lactide-co- glycoside) to form microspheres of a size suited to adsorption. The proteins of this invention may also be incorporated into oily emulsions.

10 An amount (i.e., dose) of immunogenic composition that is administered to the patient can be determined in accordance with standard techniques known to those of ordinary skill in the art, taking into consideration such factors as the particular antigen, the adjuvant (if present), the age, sex, weight, species, condition of the particular patient, and the route of administration.

15 For example, a dosage for an adolescent human patient may include at least 0.1 µg, 1 µg, 10 µg, or 50 µg of a *Neisseria* ORF2086 protein, and at most 80 µg, 100 µg, 150 µg, or 200 µg of a *Neisseria* ORF2086 protein. Any minimum value and any maximum value may be combined to define a suitable range.

Adjuvants

20 Immunogenic compositions as described herein also comprise, in certain embodiments, one or more adjuvants. An adjuvant is a substance that enhances the immune response when administered together with an immunogen or antigen. A number of cytokines or lymphokines have been shown to have immune modulating activity, and thus are useful as adjuvants, including, but not limited to, the interleukins
25 1-α, 1-β, 2, 4, 5, 6, 7, 8, 10, 12 (see, e.g., U.S. Patent No. 5,723,127), 13, 14, 15, 16, 17 and 18 (and its mutant forms); the interferons-α, β and γ; granulocyte-macrophage colony stimulating factor (GM-CSF) (see, e.g., U.S. Patent No. 5,078,996 and ATCC Accession Number 39900); macrophage colony stimulating factor (M-CSF); granulocyte colony stimulating factor (G-CSF); and the tumor necrosis factors α and β.

30 Still other adjuvants that are useful with the immunogenic compositions described herein include chemokines, including without limitation, MCP-1, MIP-1α, MIP-1β, and RANTES; adhesion molecules, such as a selectin, e.g., L-selectin,

P-selectin and E-selectin; mucin-like molecules, e.g., CD34, GlyCAM-1 and MadCAM-1; a member of the integrin family such as LFA-1, VLA-1, Mac-1 and p150.95; a member of the immunoglobulin superfamily such as PECAM, ICAMs, e.g., ICAM-1, ICAM-2 and ICAM-3, CD2 and LFA-3; co-stimulatory molecules such as B7-1, B7-2, CD40 and
 5 CD40L; growth factors including vascular growth factor, nerve growth factor, fibroblast growth factor, epidermal growth factor, PDGF, BL-1, and vascular endothelial growth factor; receptor molecules including Fas, TNF receptor, Flt, Apo-1, p55, WSL-1, DR3, TRAMP, Apo-3, AIR, LARD, NGRF, DR4, DR5, KILLER, TRAIL-R2, TRICK2, and DR6; and Caspase (ICE).

10 Other exemplary adjuvants include, but are not limited to aluminum hydroxide; aluminum phosphate; STIMULON™ QS-21 (Aquila Biopharmaceuticals, Inc., Framingham, Mass.); MPL™ (3-O-deacylated monophosphoryl lipid A; Corixa, Hamilton, Mont.), 529 (an amino alkyl glucosamine phosphate compound, Corixa, Hamilton, Mont.), IL-12 (Genetics Institute, Cambridge, Mass.); GM-CSF (Immunex
 15 Corp., Seattle, Wash.); N-acetyl-muramyl-L-theronyl-D-isoglutamine (thr-MDP); N-acetyl-nor-muramyl-L-alanyl-D-isoglutamine (CGP 11637, referred to as nor-MDP); N-acetylmuramyl-L-alanyl-D-isoglutaminyl-L-alanine-2-(1'-2'-dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy-ethylamine) (CGP 19835A, referred to as MTP-PE); and cholera toxin. In certain preferred embodiments, the adjuvant is
 20 QS-21.

Additional exemplary adjuvants include non-toxic derivatives of cholera toxin, including its A subunit, and/or conjugates or genetically engineered fusions of the *N. meningitidis* polypeptide with cholera toxin or its B subunit ("CTB"), procholeraenoid, fungal polysaccharides, including schizophyllan, muramyl dipeptide, muramyl dipeptide
 25 ("MDP") derivatives, phorbol esters, the heat labile toxin of *E. coli*, block polymers or saponins.

Aluminum phosphate has been used as the adjuvant in a phase 1 clinical trial to a concentration 0.125 mg/dose, much lower than the limit of 0.85 mg/ dose specified by the US Code of Federal Regulations [610.15(a)]. Aluminum-containing adjuvants are
 30 widely used in humans to potentiate the immune response of antigens when administered intramuscularly or subcutaneously. In some embodiments, the concentration of aluminum in the immunogenic composition is between 0.125 µg/ml and 0.5 µg/ml; between 0.20 µg/ml and 0.40 µg/ml; or between 0.20 µg/ml and 0.30 µg/ml.

In some embodiments, the concentration of aluminum in the immunogenic composition is about 0.125 µg/ml; about 0.15 µg/ml; about 0.175 µg/ml; about 0.20 µg/ml; about 0.225 µg/ml; about 0.25 µg/ml; about 0.275 µg/ml; about 0.30 µg/ml; about 0.325 µg/ml; about 0.35 µg/ml; about 0.375 µg/ml; about 0.40 µg/ml; about 0.425 µg/ml; about 0.45 µg/ml; about 0.475 µg/ml; or about 0.50 µg/ml.

In a preferred embodiment, the concentration of aluminum in the immunogenic composition is between 0.125 mg/ml and 0.5 mg/ml; between 0.20 mg/ml and 0.40 mg/ml; or between 0.20 mg/ml and 0.30 mg/ml. In some embodiments, the concentration of aluminum in the immunogenic composition is about 0.125 mg/ml; about 0.15 mg/ml; about 0.175 mg/ml; about 0.20 mg/ml; about 0.225 mg/ml; about 0.25 mg/ml; about 0.275 mg/ml; about 0.30 mg/ml; about 0.325 mg/ml; about 0.35 mg/ml; about 0.375 mg/ml; about 0.40 mg/ml; about 0.425 mg/ml; about 0.45 mg/ml; about 0.475 mg/ml; or about 0.50 mg/ml.

Suitable adjuvants used to enhance an immune response further include, without limitation, MPL™ (3-O-deacylated monophosphoryl lipid A, Corixa, Hamilton, MT), which is described in U.S. Patent No. 4,912,094. Also suitable for use as adjuvants are synthetic lipid A analogs or aminoalkyl glucosamine phosphate compounds (AGP), or derivatives or analogs thereof, which are available from Corixa (Hamilton, MT), and which are described in United States Patent No. 6,113,918. One such AGP is 2-[(R)-3-Tetradecanoyloxytetradecanoylamino] ethyl 2-Deoxy-4-O-phosphono-3-O-[(R)-3-tetradecanoyloxytetradecanoyl]-2-[(R)-3-tetradecanoyloxytetradecanoyl-amino]-β-D-glucopyranoside, which is also known as 529 (formerly known as RC529). This 529 adjuvant is formulated as an aqueous form (AF) or as a stable emulsion (SE).

Still other adjuvants include muramyl peptides, such as N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-normuramyl-L-alanine-2-(1'-2' dipalmitoyl-sn-glycero-3-hydroxyphosphoryl-oxy)-ethylamine (MTP-PE); oil-in-water emulsions, such as MF59 (U.S. Patent No. 6,299,884) (containing 5% Squalene, 0.5% polysorbate 80, and 0.5% Span 85 (optionally containing various amounts of MTP-PE) formulated into submicron particles using a microfluidizer such as Model 110Y microfluidizer (Microfluidics, Newton, MA)), and SAF (containing 10% Squalene, 0.4% polysorbate 80, 5% pluronic-blocked polymer L121, and thr-MDP, either microfluidized into a submicron emulsion or vortexed to

generate a larger particle size emulsion); incomplete Freund's adjuvant (IFA); aluminum salts (alum), such as aluminum hydroxide, aluminum phosphate, aluminum sulfate; Amphigen; Avridine; L121/squalene; D-lactide-poly(lactide)/glycoside; pluronic polyols; killed *Bordetella*; saponins, such as Stimulon™ QS-21 (Antigenics, Framingham, MA.),
5 described in U.S. Patent No. 5,057,540, ISCOMATRIX (CSL Limited, Parkville, Australia), described in U.S. Patent No. 5,254,339, and immunostimulating complexes (ISCOMATRIX); *Mycobacterium tuberculosis*; bacterial lipopolysaccharides; synthetic polynucleotides such as oligonucleotides containing a CpG motif (e.g., U.S. Patent No. 6,207,646); IC-31 (Intercell AG, Vienna, Austria), described in European Patent Nos.
10 1,296,713 and 1,326,634; a pertussis toxin (PT) or mutant thereof, a cholera toxin or mutant thereof (e.g., U.S. Patent Nos. 7,285,281, 7,332,174, 7,361,355 and 7,384,640); or an *E. coli* heat-labile toxin (LT) or mutant thereof, particularly LT-K63, LT-R72 (e.g., U.S. Patent Nos. 6,149,919, 7,115,730 and 7,291,588).

Methods of Producing Non-Lipidated P2086 Antigens

15 In one aspect, the invention relates to a method of producing a non-pyruvylated non-lipidated ORF2086 polypeptide. The method includes expressing a nucleotide sequence encoding a ORF2086 polypeptide wherein the N-terminal cysteine is deleted as compared to the corresponding wild-type sequence, and wherein the nucleotide sequence is operatively linked to an expression system that is capable of being
20 expressed in a bacterial cell. Exemplary polypeptides produced by the method include any polypeptide described herein. For example, preferably, the polypeptide has the amino acid sequence set forth in SEQ ID NO: 12; SEQ ID NO: 13; SEQ ID NO: 14; SEQ ID NO: 15; SEQ ID NO: 16; SEQ ID NO: 17; SEQ ID NO: 18; SEQ ID NO: 19; SEQ ID NO: 20; SEQ ID NO: 21, wherein the cysteine at position 1 is deleted, as compared to
25 the corresponding wild-type sequence. Additional exemplary polypeptides include a polypeptide having the amino acid sequences selected from SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO: 50, SEQ ID NO: 55, SEQ ID NO: 57, SEQ ID NO: 62, and SEQ ID NO: 64. The method further includes purifying the polypeptide.

In some embodiments, the invention provides a method for producing soluble
30 non-lipidated P2086 antigens comprising the steps of cloning the ORF2086 variant nucleic acid sequence into an *E. coli* expression vector without a lipidation control sequence, transforming *E. coli* bacteria with the ORF2086 expression vector, inducing

expression and isolating the expressed P2086 protein. In some embodiments, expression is induced with IPTG.

In some embodiments, the codon for the N-terminal Cys of the ORF2086 variant is deleted. Examples of such codons include TGC. In some embodiments, the codon
5 for the N-terminal Cys of the ORF2086 variant is mutated by point mutagenesis to generate an Ala, Gly, or Val codon. In some embodiments, Ser and Gly codons are added to the N-terminal tail of the ORF2086 variant to extend the Gly/Ser stalk immediately downstream of the N-terminal Cys. In some embodiments, the total number of Gly and Ser residues within the Gly/Ser stalk is at least 7, 8, 9, 10, 11, or 12.
10 In some embodiments, the codon for the N-terminal Cys is deleted. In some embodiments, the N-terminal 7, 8, 9, 10, 11, or 12 residues are either Gly or Ser.

In some embodiments, the codons of the N-terminal tail of the non-lipidated ORF2086 variant are optimized by point mutagenesis. In some embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is optimized to match the
15 N-terminal tail of the B09 variant. In some embodiments, the codons of the N-terminal tail of the ORF2086 variant are optimized by point mutagenesis such that the codon encoding the fifth amino acid of the ORF2086 variant is 100% identical to nucleotides 13-15 of SEQ ID NO: 8 and the codon encoding the thirteenth amino acid of the ORF2086 variant is 100% identical to nucleotides 37-39 of SEQ ID NO: 8. In some
20 embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is optimized such that the 5' 45 nucleic acids are 100% identical to nucleic acids 1-45 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated ORF2086 variant is optimized such that the 5' 42 nucleic acids are 100% identical to nucleic acids 4-45 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated ORF2086
25 variant is optimized such that the 5' 39 nucleic acids are 100% identical to nucleic acids 4-42 of SEQ ID NO: 8. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises at least one amino acid substitution compared to amino acids 1-15 of SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises two amino acid substitutions compared to amino acids 1-15 of
30 SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises at least one amino acid substitution compared to amino acids 2-15 of SEQ ID NO: 18. In some embodiments, the N-terminal tail of the non-lipidated P2086 variant comprises two amino acid substitutions compared to amino acids 2-15 of SEQ

ID NO: 18. In some embodiments, the amino acid substitutions are conservative amino acid substitutions.

In some embodiments, the codons of the non-lipidated variant have been optimized for increased expression. Codon optimization is known in the art. See, e.g.,
5 Sastalla et al, *Applied and Environmental Microbiology*, vol. 75(7): 2099-2110 (2009)
and Coleman et al, *Science*, vol. 320: 1784 (2008). In some embodiments, codon optimization includes matching the codon utilization of an amino acid sequence with the codon frequency of the host organism chosen while including and/or excluding specific DNA sequences. In some embodiments, codon optimization further includes minimizing
10 the corresponding secondary mRNA structure to reduce translational impediments. In some embodiments, the N-terminal tail has been codon optimized to comprise any one of SEQ ID NO: 28, 30, 32, and 34. In some embodiments, the Gly/Ser stalk has been codon optimized to comprise any one of SEQ ID NO: 28, 30, 32, and 34.

In order that this invention may be better understood, the following examples are
15 set forth. The examples are for the purpose of illustration only and are not to be construed as limiting the scope of the invention.

Immunogenic Composition Formulations

In certain embodiments, the immunogenic compositions of the invention further comprise at least one of an adjuvant, a buffer, a cryoprotectant, a salt, a divalent cation,
20 a non-ionic detergent, an inhibitor of free radical oxidation, a diluent or a carrier.

The immunogenic compositions of the invention may further comprise one or more preservatives in addition to a plurality of meningococcal protein antigens and capsular polysaccharide-protein conjugates. The FDA requires that biological products in multiple-dose (multi-dose) vials contain a preservative, with only a few exceptions.
25 Vaccine products containing preservatives include vaccines containing benzethonium chloride (anthrax), 2-phenoxyethanol (DTaP, HepA, Lyme, Polio (parenteral)), phenol (Pneumo, Typhoid (parenteral), Vaccinia) and thimerosal (DTaP, DT, Td, HepB, Hib, Influenza, JE, Mening, Pneumo, Rabies). Preservatives approved for use in injectable drugs include, e.g., chlorobutanol, m-cresol, methylparaben, propylparaben,
30 2-phenoxyethanol, benzethonium chloride, benzalkonium chloride, benzoic acid, benzyl alcohol, phenol, thimerosal and phenylmercuric nitrate.

Formulations of the invention may further comprise one or more of a buffer, a salt, a divalent cation, a non-ionic detergent, a cryoprotectant such as a sugar, and an anti-oxidant such as a free radical scavenger or chelating agent, or any multiple combination thereof. The choice of any one component, e.g., a chelator, may
5 determine whether or not another component (e.g., a scavenger) is desirable. The final composition formulated for administration should be sterile and/or pyrogen free. The skilled artisan may empirically determine which combinations of these and other components will be optimal for inclusion in the preservative containing immunogenic compositions of the invention depending on a variety of factors such as the particular
10 storage and administration conditions required.

In certain embodiments, a formulation of the invention which is compatible with parenteral administration comprises one or more physiologically acceptable buffers selected from, but not limited to, Tris (trimethamine), phosphate, acetate, borate, citrate, glycine, histidine and succinate. In certain embodiments, the formulation is buffered to
15 within a pH range of about 6.0 to about 9.0, preferably from about 6.4 to about 7.4.

In certain embodiments, it may be desirable to adjust the pH of the immunogenic composition or formulation of the invention. The pH of a formulation of the invention may be adjusted using standard techniques in the art. The pH of the formulation may be adjusted to be between 3.0 and 8.0. In certain embodiments, the pH of the
20 formulation may be, or may adjusted to be, between 3.0 and 6.0, 4.0 and 6.0, or 5.0 and 8.0. In other embodiments, the pH of the formulation may be, or may adjusted to be, about 3.0, about 3.5, about 4.0, about 4.5, about 5.0, about 5.5, about 5.8, about 6.0, about 6.5, about 7.0, about 7.5, or about 8.0. In certain embodiments, the pH may be, or may adjusted to be, in a range from 4.5 to 7.5, or from 4.5 to 6.5, from 5.0 to 5.4,
25 from 5.4 to 5.5, from 5.5 to 5.6, from 5.6 to 5.7, from 5.7 to 5.8, from 5.8 to 5.9, from 5.9 to 6.0, from 6.0 to 6.1, from 6.1 to 6.2, from 6.2 to 6.3, from 6.3 to 6.5, from 6.5 to 7.0, from 7.0 to 7.5 or from 7.5 to 8.0. In a specific embodiment, the pH of the formulation is about 5.8.

In certain embodiments, a formulation of the invention which is compatible with
30 parenteral administration comprises one or more divalent cations, including but not limited to $MgCl_2$, $CaCl_2$ and $MnCl_2$, at a concentration ranging from about 0.1 mM to about 10 mM, with up to about 5 mM being preferred.

In certain embodiments, a formulation of the invention which is compatible with parenteral administration comprises one or more salts, including but not limited to sodium chloride, potassium chloride, sodium sulfate, and potassium sulfate, present at an ionic strength which is physiologically acceptable to the subject upon parenteral administration and included at a final concentration to produce a selected ionic strength or osmolality in the final formulation. The final ionic strength or osmolality of the formulation will be determined by multiple components (e.g., ions from buffering compound(s) and other non-buffering salts. A preferred salt, NaCl, is present from a range of up to about 250 mM, with salt concentrations being selected to complement other components (e.g., sugars) so that the final total osmolality of the formulation is compatible with parenteral administration (e.g., intramuscular or subcutaneous injection) and will promote long term stability of the immunogenic components of the immunogenic composition formulation over various temperature ranges. Salt-free formulations will tolerate increased ranges of the one or more selected cryoprotectants to maintain desired final osmolality levels.

In certain embodiments, a formulation of the invention which is compatible with parenteral administration comprises one or more cryoprotectants selected from but not limited to disaccharides (e.g., lactose, maltose, sucrose or trehalose) and polyhydroxy hydrocarbons (e.g., dulcitol, glycerol, mannitol and sorbitol).

In certain embodiments, the osmolality of the formulation is in a range of from about 200 mOs/L to about 800 mOs/L, with a preferred range of from about 250 mOs/L to about 500 mOs/L, or about 300 mOs/L - about 400 mOs/L. A salt-free formulation may contain, for example, from about 5% to about 25% sucrose, and preferably from about 7% to about 15%, or about 10% to about 12% sucrose. Alternatively, a salt-free formulation may contain, for example, from about 3% to about 12% sorbitol, and preferably from about 4% to 7%, or about 5% to about 6% sorbitol. If salt such as sodium chloride is added, then the effective range of sucrose or sorbitol is relatively decreased. These and other such osmolality and osmolality considerations are well within the skill of the art.

In certain embodiments, a formulation of the invention which is compatible with parenteral administration comprises one or more free radical oxidation inhibitors and/or chelating agents. A variety of free radical scavengers and chelators are known in the art and apply to the formulations and methods of use described herein. Examples

include but are not limited to ethanol, EDTA, a EDTA/ethanol combination, triethanolamine, mannitol, histidine, glycerol, sodium citrate, inositol hexaphosphate, tripolyphosphate, ascorbic acid/ascorbate, succinic acid/succinate, malic acid/maleate, desferal, EDDHA and DTPA, and various combinations of two or more of the above. In
5 certain embodiments, at least one non-reducing free radical scavenger may be added at a concentration that effectively enhances long term stability of the formulation. One or more free radical oxidation inhibitors/chelators may also be added in various combinations, such as a scavenger and a divalent cation. The choice of chelator will determine whether or not the addition of a scavenger is needed.

10 In certain embodiments, a formulation of the invention which is compatible with parenteral administration comprises one or more non-ionic surfactants, including but not limited to polyoxyethylene sorbitan fatty acid esters, Polysorbate-80 (Tween 80), Polysorbate-60 (Tween 60), Polysorbate-40 (Tween 40) and Polysorbate-20 (Tween
15 20), polyoxyethylene alkyl ethers, including but not limited to Brij 58, Brij 35, as well as others such as Triton X-100; Triton X-114, NP40, Span 85 and the Pluronic series of non-ionic surfactants (e.g., Pluronic 121), with preferred components Polysorbate-80 at a concentration from about 0.001% to about 2% (with up to about 0.25% being preferred) or Polysorbate-40 at a concentration from about 0.001% to 1% (with up to about 0.5% being preferred).

20 In certain embodiments, a formulation of the invention comprises one or more additional stabilizing agents suitable for parenteral administration, e.g., a reducing agent comprising at least one thiol (-SH) group (e.g., cysteine, N-acetyl cysteine, reduced glutathione, sodium thioglycolate, thiosulfate, monothioglycerol, or mixtures thereof). Alternatively or optionally, preservative-containing immunogenic composition
25 formulations of the invention may be further stabilized by removing oxygen from storage containers, protecting the formulation from light (e.g., by using amber glass containers).

Preservative-containing immunogenic composition formulations of the invention may comprise one or more pharmaceutically acceptable carriers or excipients, which includes any excipient that does not itself induce an immune response. Suitable
30 excipients include but are not limited to macromolecules such as proteins, saccharides, polylactic acids, polyglycolic acids, polymeric amino acids, amino acid copolymers, sucrose (Paoletti et al, 2001, *Vaccine*, 19:2118), trehalose, lactose and lipid aggregates (such as oil droplets or liposomes). Such carriers are well known to the skilled artisan.

Pharmaceutically acceptable excipients are discussed, e.g., in Gennaro, 2000, Remington: The Science and Practice of Pharmacy, 20th edition, ISBN:0683306472.

Compositions of the invention may be lyophilized or in aqueous form, i.e. solutions or suspensions. Liquid formulations may advantageously be administered
5 directly from their packaged form and are thus ideal for injection without the need for reconstitution in aqueous medium as otherwise required for lyophilized compositions of the invention.

Direct delivery of immunogenic compositions of the present invention to a subject may be accomplished by parenteral administration (intramuscularly, intraperitoneally,
10 intradermally, subcutaneously, intravenously, or to the interstitial space of a tissue); or by rectal, oral, vaginal, topical, transdermal, intranasal, ocular, aural, pulmonary or other mucosal administration. In a preferred embodiment, parenteral administration is by intramuscular injection, e.g., to the thigh or upper arm of the subject. Injection may be via a needle (e.g., a hypodermic needle), but needle free injection may alternatively be
15 used. A typical intramuscular dose is 0.5mL. Compositions of the invention may be prepared in various forms, e.g., for injection either as liquid solutions or suspensions. In certain embodiments, the composition may be prepared as a powder or spray for pulmonary administration, e.g., in an inhaler. In other embodiments, the composition may be prepared as a suppository or pessary, or for nasal, aural or ocular
20 administration, e.g., as a spray, drops, gel or powder.

Optimal amounts of components for a particular immunogenic composition may be ascertained by standard studies involving observation of appropriate immune responses in subjects. Following an initial vaccination, subjects can receive one or several booster immunizations adequately spaced.

25 *Packaging and Dosage Forms*

Immunogenic compositions of the invention may be packaged in unit dose or multi-dose form (e.g. 2 doses, 4 doses, or more). For multi-dose forms, vials are typically but not necessarily preferred over pre-filled syringes. Suitable multi-dose formats include but are not limited to: 2 to 10 doses per container at 0.1 to 2 mL per
30 dose. In certain embodiments, the dose is a 0.5 mL dose. See, e.g., International Patent Application WO2007/127668, which is incorporated by reference herein.

Compositions may be presented in vials or other suitable storage containers, or may be presented in pre-filled delivery devices, e.g., single or multiple component syringes, which may be supplied with or without needles. A syringe typically but need not necessarily contains a single dose of the preservative-containing immunogenic composition of the invention, although multi-dose, pre-filled syringes are also envisioned. Likewise, a vial may include a single dose but may alternatively include multiple doses.

Effective dosage volumes can be routinely established, but a typical dose of the composition for injection has a volume of 0.5 mL. In certain embodiments, the dose is formulated for administration to a human subject. In certain embodiments, the dose is formulated for administration to an adult, teen, adolescent, toddler or infant (i.e., no more than one year old) human subject and may in preferred embodiments be administered by injection.

Liquid immunogenic compositions of the invention are also suitable for reconstituting other immunogenic compositions which are presented in lyophilized form. Where an immunogenic composition is to be used for such extemporaneous reconstitution, the invention provides a kit with two or more vials, two or more ready-filled syringes, or one or more of each, with the contents of the syringe being used to reconstitute the contents of the vial prior to injection, or vice versa.

Alternatively, immunogenic compositions of the present invention may be lyophilized and reconstituted, e.g., using one of a multitude of methods for freeze drying well known in the art to form dry, regular shaped (e.g., spherical) particles, such as micropellets or microspheres, having particle characteristics such as mean diameter sizes that may be selected and controlled by varying the exact methods used to prepare them. The immunogenic compositions may further comprise an adjuvant which may optionally be prepared with or contained in separate dry, regular shaped (e.g., spherical) particles such as micropellets or microspheres. In such embodiments, the present invention further provides an immunogenic composition kit comprising a first component that includes a stabilized, dry immunogenic composition, optionally further comprising one or more preservatives of the invention, and a second component comprising a sterile, aqueous solution for reconstitution of the first component. In certain embodiments, the aqueous solution comprises one or more preservatives, and

may optionally comprise at least one adjuvant (see, e.g., WO2009/109550 (incorporated herein by reference)).

In yet another embodiment, a container of the multi-dose format is selected from one or more of the group consisting of, but not limited to, general laboratory glassware, 5 flasks, beakers, graduated cylinders, fermentors, bioreactors, tubings, pipes, bags, jars, vials, vial closures (e.g., a rubber stopper, a screw on cap), ampoules, syringes, dual or multi-chamber syringes, syringe stoppers, syringe plungers, rubber closures, plastic closures, glass closures, cartridges and disposable pens and the like. The container of the present invention is not limited by material of manufacture, and includes materials 10 such as glass, metals (e.g., steel, stainless steel, aluminum, etc.) and polymers (e.g., thermoplastics, elastomers, thermoplastic-elastomers). In a particular embodiment, the container of the format is a 5 mL Schott Type 1 glass vial with a butyl stopper. The skilled artisan will appreciate that the format set forth above is by no means an exhaustive list, but merely serve as guidance to the artisan with respect to the variety of 15 formats available for the present invention. Additional formats contemplated for use in the present invention may be found in published catalogues from laboratory equipment vendors and manufacturers such as United States Plastic Corp. (Lima, OH), VWR.

EXAMPLES

Example 1: Experimental Procedures

Serum bactericidal assay

Cynomolgus macaques (n = 5/group) were immunized intramuscularly with
5 rLP2086 or rP2086 (A + B) proteins adsorbed to AlPO₄. Cynomolgus macaques are an
example of non-human primates. Animals were vaccinated at weeks 0, 4 and 24, and
ORF2086-specific IgG and functional antibody titers were determined at weeks 0, 4, 6
and 26. Serum ORF2086-specific IgG titers were determined against rLP2086A and B.

Functional antibody titers were examined by serum bactericidal assay (SBA)
10 against *Neisseria meningitidis* strains expressing either LP2086 with sequences
homologous or heterologous to those contained in the vaccine.

Serum bactericidal antibodies in macaques or rabbits immunized with ORF2086
vaccine were determined using SBAs with human complement. Rabbit immune sera or
macaques immune sera were heat-inactivated to remove intrinsic complement activity
15 and subsequently serially diluted 1:2 in Dulbecco's PBS with Ca²⁺ and Mg²⁺ (D-PBS)
in a 96-well microtiter plate to test for serum bactericidal activity against *N. meningitidis*
strains. Bacteria used in the assay were grown in GC media supplemented with
Kellogg's supplement (GCK) and monitored by optical density at 650 nm. Bacteria were
harvested for use in the assay at a final OD₆₅₀ of 0.50-0.55, diluted in D-PBS and 1000–
20 3000 CFU were added to the assay mixture with 20% human complement.

Human serum with no detectable bactericidal activity was used as the exogenous
complement source. Complement sources were tested for suitability against each
individual test strain. A complement source was used only if the number of bacteria
surviving in controls without added immune sera was >75%. Ten unique complement
25 sources were required to perform the SBAs described in this study.

After a 30 min incubation at 37°C with 5% CO₂, D-PBS was added to the reaction
mixture and aliquots transferred to microfilter plates filled with 50% GCK media. The
microfilter plates were filtered, incubated overnight at 37°C with 5% CO₂ and
microcolonies were stained and quantified. The serum bactericidal titers were defined
30 as the interpolated reciprocal serum dilution that yielded a 50% reduction in CFU
compared to the CFU in control wells without immune sera. The SBA titer is defined as
the reciprocal of the interpolated dilution of test serum that causes a 50% reduction in

bacterial counts after a 30min incubation at 37°C. Susceptibility to killing with ORF2086 immune sera was established if there was a 4-fold or greater rise in SBA titer for ORF2086 immune sera compared to the corresponding pre-immune sera. Sera that were negative against the assay strain at the starting dilution were assigned a titer of one half the limit of detection for the assay (i.e. 4).

Example 2: Cloning and Expression of Non-Lipidated ORF2086 Variants

The mature P2086 amino acid sequence corresponding to residues 27-286 from *N. meningitidis* strain M98250771 (A05) was originally derived from PCR amplification from genomic DNA. The forward primer, with a sequence of

10 TGCCATATGAGCAGCGGAAGCGGAAG (SEQ ID NO: 22), annealed to the 5' sequence and contained an NdeI site for cloning. The reverse primer, with a sequence of CGGATCCCTACTGTTTGCCGGCGATGC (SEQ ID NO: 23), annealed to the 3' end of the gene and contained a termination codon TAG followed by restriction site BamHI. The 799 bp amplified fragment was first cloned into an intermediate vector PCR2.1

15 (Invitrogen, Carlsbad, CA) This plasmid was cleaved with NdeI and BamHI, and was ligated into expression vector pET9a (Novagen, Madison, WI) which had been cleaved with NdeI and BamHI. The resulting vector pLA100 (which includes SEQ ID NO: 54), expressed the mature Subfamily A05 P2086 from strain M98250771 without the N-terminal cysteine (see SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is

20 deleted or SEQ ID NO: 55) that would be present in the lipidated protein. BLR(DE3) *E. coli* host strain [F- ompT hsdSB(rB-mB-) gal dcm Δ(srl-recA)306::Tn10 (TetR) (DE3)] (Novagen) was used to obtain expression of fHBP.

The same cloning steps were used to prepare the B02, B03, B09, B22, B24, B44, A04, A12, and A22 N-terminal Cys-deleted variants. The N-terminal Cys-containing

25 variants were also prepared by this same method using forward primers which also included the Cys codon (e.g. the first codon of SEQ ID NOs: 1-11). Based on the sequences provided herein, the skilled worker would be able to design forward and reverse primers for each of these variants. For example, the following primers were used to amplify the B44 non-lipidated variant followed by cloning into pET9a using NdeI

30 and BlnI.

Table 1

N-terminal Cys	Primer Sequence	SEQ ID NO
Included—Fwd	5' TTTCTTcccgggAAGGAGatatacatatg TGCAGCAGCGGAGGCGGCGG 3'	24
Included—Rev	5' TTTCTTgctcagcaTTATTGC TTGGCGGCAAGACCGAT 3'	25
Deleted—Fwd	5' TTTCTTcccgggAAGGAGatatacatatg AGCAGCGGAGGCGGCGG 3'	26
Deleted—Rev	5' TTTCTTgctcagcaTTATTGC TTGGCGGCAAGACCGAT 3'	27

Results

Non-lipidated plasmid constructs were strongly expressed, but the non-lipidated protein variants were pyruvylated at the N-terminal Cys residue. See Examples 8 and 9, which describes, for example, a method for expressing the constructs. To overcome this pyruvylation, the N-terminal Cys codon was deleted. See, for example, Example 10. Deletion of the N-terminal Cys, however, abrogated expression of the A22 and B22 variants. See e.g., Figure 4. The A05, B01, and B44 variants, however, were still expressed despite deletion of the N-terminal Cys residue. See, for example, SEQ ID NO: 13 (A05), wherein the N-terminal Cys at position 1 is deleted, SEQ ID NO: 35 (B01 N-terminus), and SEQ ID NO: 21(B44), wherein the N-terminal Cys at position 1 is deleted. See e.g., Figure 5. In addition, expression of the non-lipidated B09 variant was not affected by deletion of the N-terminal Cys residue. See, for example, Example 4.

Example 3: Effect of Gly/Ser Stalk on Non-Lipidated Variant Expression

To determine why the A05, B01, and B44 variants were expressed in the absence of the N-terminal Cys and the A22 and B22 variants were not, the sequences of these variants were aligned. The A05, B01, and B44 variants all possess an
5 extended series of 10 or 11 Gly and Ser residues immediately following the N-terminal Cys (i.e. Gly/Ser stalk). The A22 and B22 variants, however, only had a Gly/Ser stalk consisting of 6 Gly and Ser residues. Accordingly, the Gly/Ser stalk of the A22 and B22 variants was expanded by insertion of additional Gly and Ser residues.

Long Gly/Ser stalk variants were prepared by the methods described in Example
10 2 using forward primers that encode a Gly/Ser stalk with either 10 or 11 Gly and Ser residues.

The N-terminal Cys-deleted, long Gly/Ser stalk (10-11 Gly/Ser residues) A22 and B22 variants showed increased expression over the N-terminal Cys-deleted A22 and B22 short Gly/Ser stalk (6 Gly/Ser residues) variants. These expression levels,
15 however, were still reduced compared to the A05, B01, and B44 variant expression levels.

Example 4: Codon Optimization

Expression of the non-lipidated B09 variant was not affected by deletion of the N-terminal Cys residue (see SEQ ID NO: 18, wherein the cysteine at position 1 is
20 deleted, or SEQ ID NO: 49). See, e.g., Figure 6. Sequence evaluation of the B09 variant demonstrated that the B09 variant has a Gly/Ser stalk consisting of 6 Gly and Ser residues, similar to the Gly/Ser stalk of the A22 and B22 variants. Indeed, the N-terminal tails of the B09 and A22 variants are identical at the amino acid level. The N-terminal tails of the B09 and A22 variants (SEQ ID NO: 53 and 42, respectively),
25 however, vary at the nucleic acid level by 2 nucleic acids: nucleic acids 15 and 39 of SEQ ID NO: 8. See e.g., Figure 6. The first 14 amino acids of the N-terminal tail of the B22 variant are identical to the B09 and A22 variants, and the N-terminal tail of the B22 variant only differs at the 15th amino acid. Nucleic acids 1-42 of the B22 variant are identical to nucleic acids 1-42 of the A22 variant. Nucleic acids 1-42 of the B22 variant
30 (see SEQ ID NO: 52) are identical to nucleic acids 1-42 of B09 (see SEQ ID NO: 53) but for differences at nucleic acids 15 and 39, when optimally aligned. Accordingly, the B22 variant differs from the B09 variant at amino acids 15 and 39 of SEQ ID NO: 8. This last

sentence contains a typographical error and should state that the B22 variant differs from the B09 variant at nucleic acids 15 and 39 of SEQ ID NO: 8.

To determine if the nucleic acid differences affected the expression level of the B09 variant compared to the A22 and B22 variants, the A22 and B22 variants were
 5 mutated by point mutation to incorporate nucleic acids 15 and 39 into the corresponding codons for Gly5 and Gly13. Incorporation of these silent nucleic acid mutations significantly increased expression of the A22 and B22 N-terminal Cys-deleted variants to levels similar to the N-terminal Cys-deleted B09 variant. *See e.g.*, Figure 7. Accordingly, codon optimization to match the B09 variant can increase expression of
 10 N-terminal Cys-deleted non-lipidated P2086 variants.

Further analysis of the non-lipidated variant sequences suggested additional codon optimizations in the Gly/Ser stalk to improve expression. Accordingly, additional non-lipidated variants were constructed by the method of Example 2 using forward primers comprising such codon optimized sequences. The forward primers used to
 15 generate optimized Gly/Ser stalks include any of the following sequences:

ATGAGCTCTGGAGGTGGAGGAAGCGGGGGCGGTGGA (SEQ ID NO: 28)

M S S G G G G S G G G G (SEQ ID NO: 29)

20 ATGAGCTCTGGAAGCGGAAGCGGGGGCGGTGGA (SEQ ID NO: 30)

M S S G S G S G G G G (SEQ ID NO: 31)

ATGAGCTCTGGAGGTGGAGGA (SEQ ID NO: 32)

M S S G G G G (SEQ ID NO: 33)

25 ATGAGCAGCGGGGGCGGTGGA (SEQ ID NO: 34)

M S S G G G G (SEQ ID NO: 33)

Example 5: Immunogenic Composition Formulation Optimization

ISCOMATRIX formulated vaccines generate a rapid immune response resulting in a reduction in the number of dosages required to achieve a greater than 4 fold response rate as measured in a serum bactericidal assay. Groups of five rhesus macaques were immunized with different formulations of a bivalent non-lipidated rP2086 vaccine. The vaccine included a non-pyruvylated non-lipidated A05 variant (SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 55 encoded by SEQ ID NO: 54) and a non-pyruvylated non-lipidated B44 variant (SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 44 encoded by SEQ ID NO: 51). The adjuvant units are as follows: AlPO₄ is 250 mcg, ISCOMATRIX is between 10 and 100 mcg. The adjuvant units for AlPO₄ shown in Tables 2-5 are shown as milligram units, and are therefore shown as 0.25 (milligram) as opposed to 250 mcg.

The immunization schedule was 0, 4 and 24 wks with bleeds at 0, 4, 6 and 26 weeks. There were no increases in SBA titers at post dose one for any of the groups. At post dose two, an increase in SBA titers and the number of responders as defined by a 4 fold increase in SBA titer above baseline was observed for formulations containing the ISCOMATRIX adjuvant. Tables 2 and 3 provide the SBA GMTs observed for a fHBP Subfamily A and B strain respectively. SBA GMTs for the ISCOMATRIX formulations were 3-19 and 4 - 24 fold higher than those observed for the AlPO₄ formulation for the A and B subfamily strains respectively. Enhanced titers were also observed at post dose three for the ISCOMATRIX formulations at 13-95 and 2 - 10 for a fHBP Subfamily A and B strain respectively compared to the AlPO₄ formulation. Analysis of the responder rates, as defined by a four fold or greater increase in SBA titer over baseline revealed a similar trend (Tables 4 and 5).

Table 2: SBA titers (GMTs) obtained for against a MnB LP2086 Subfamily A strain immune serum from rhesus macaques immunized with different formulations of a bivalent rP2086 vaccine							
Vaccine lipidation		Adjuvant		Geometric Mean titer (GMT)			
		AIPO4	ISCOMATRIX®	wk0	wk4	wk6	wk26
A05/B44	-	0.25	-	-	-	-	+
		-	10	-	-	+	+++
		0.25	10	-	-	+	++
		-	100	-	-	++	++++
		0.25	100	-	-	+	+++
Five monkeys per group; Immunization schedule: 0, 4, 24 weeks; bleed schedule 0, 4, 6 and 26 wks. SBA test strain MnB M98 250771. "- " < 8; "+" 8-32; "++" 33-128; "+++" 129-512; "++++" >512							

Table 3: SBA titers (GMTs) obtained for against a MnB LP2086 Subfamily B strain immune serum from rhesus macaques immunized with different formulations of a bivalent rP2086 vaccine							
Vaccine lipidation		Adjuvant		Geometric Mean titer (GMT)			
		AIPO4	ISCOMATRIX®	wk0	wk4	wk6	wk26
A05/B44	-	0.25	-	-	-	+	+++
		-	10	-	-	+++	++++
		0.25	10	-	-	+++	++++
		-	100	-	-	+++	++++
		0.25	100	-	-	++	++++

Five monkeys per group; Immunization schedule: 0, 4, 24 weeks; bleed schedule 0, 4, 6 and 26 wks. SBA test strain MnB CDC1127.
“-” < 8; “+” 8-32; “++” 33-128; “+++” 129-512; “++++” >512

Table 4: Number of rhesus macaques with a ≥ 4 fold rise in SBA Titer using a MnB LP2086 Subfamily A strain							
Vaccine lipidation		Adjuvant		No. of responders ^b			
		AIPO4	ISCOMATRIX®	wk0	wk4	wk6	wk26
A05/B44	-	0.25	-	0	0	0	2
		-	10	0	0	3	5
		0.25	10	0	0	2	5
		-	100	0	0	4	5
		0.25	100	0	0	2	5

Table 5: Number of rhesus macaques with a ≥ 4 fold rise in SBA Titer using a MnB LP2086 Subfamily B strain							
Vaccine lipidation		Adjuvant		No. of responders ^b			
		AIPO4	ISCOMATRIX®	wk0	wk4	wk6	wk26
A05/B44	-	0.25	-	0	0	3	5
		-	10	0	0	5	5
		0.25	10	0	0	5	5
		-	100	0	0	4	4
		0.25	100	0	0	3	5

Example 6: Immunoprotection conferred by Lipidated and Non-Lipidated Variants

A recombinantly expressed non-lipidated P2086 variant (B44) induces broad protection as measured by SBA against strains that represent diverse fHBP variants (from about 85% to about <92% ID) LP2086 sequences. These response rates were obtained for a non lipidated vaccine formulated with AlPO_4 . See Table 6, which shows SBA response rates to a subfamily B fHBP MnB strain generated by a bivalent fHBP vaccine. The non-lipidated vaccine (represented by a "-" under the "lipidation" column) included 1mcg per protein of a non-pyruvylated non-lipidated A05 variant (SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is deleted) and a non-pyruvylated non-lipidated B44 variant (SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted) .

Alternatively, a recombinantly expressed non-lipidated P2086 variant (B44) induces greater immune responses as measured by SBA titer than a lipidated variant (B01) against strains bearing similar (>92% ID) and diverse (<92% ID) LP2086 sequences. Higher response rates (as defined by a four fold increase or greater in SBA titers over baseline) was observed for the vaccine containing the non-lipidated rP2086 B44 compared to the lipidated rLP2086 B01 vaccine (Table 6).

According to Table 6, non-lipidated B44 is a preferred subfamily B component of fHBP in a composition for providing broad coverage against (e.g., eliciting bactericidal antibodies against) multiple LP2086 variant strains.

Surprisingly, the inventors noted that LP2086 B09 variant strains are particularly unlikely to have positive SBA response rates with regard to heterologous (non-B09) ORF2086 polypeptides. In particular, the inventors found that LP2086 B09 is an exception in terms of an assay strain against which the A05/B44 immunogenic composition described in Table 6 elicited bactericidal antibodies. Therefore, in a preferred embodiment an immunogenic composition of the invention includes a B09 polypeptide, in particular in the context of a composition including more than one ORF2086 subfamily B polypeptide. In a preferred embodiment an immunogenic composition that includes a non lipidated B44 may also include a non-lipidated B09 polypeptide.

Table 6: SBA response rates to a Subfamily B fHBP MnB strains generated by bivalent fHBP vaccines
Immune serum from rhesus macaques.

Adjuvant	LP2086 Variant of Assay Strain	Vaccine	lipidation	% ID to Matched Subfamily for non-lipidated Vaccine Component	% responders PD3 Wk 26
	B02	A05/B01	+		80
		A05/B44	-	99.6	100
AIPO4 0.25mg	B03	A05/B01	+	86.7	50
		A05/B44	-		80
	B09	A05/B01	+	86.3	0
		A05/B44	-		0
	B15	A05/B01	+	86.7	25
		A05/B44	-		80
	B16	A05/B01	+	87.1	0
		A05/B44	-		50
	B16	A05/B01	+	87.1	0
		A05/B44	-		60
	B24	A05/B01	+	85.9	0
		A05/B44	-		60
ISCOMATRIX® (10 mcg)	B44	A05/B01	+	100	100
		A05/B44	-		100
ISCOMATRIX® (100 mcg)	A05	A05/B44	-	100	100
ISCOMATRIX® (10 mcg)	A22	A05/B44	-	88.9	80
ISCOMATRIX® (100 mcg)	A22	A05/B44	-	88.9	100

Five monkeys per group; Immunization schedule: 0, 4, 24 weeks; bleed schedule 0, 4, 6, and 26 wks.

Example 7: Codon Optimization of the B44 and B09 Variants

Although the expression levels achieved in the preceding examples were adequate for many applications, further optimization was desirable, and *E. coli* expression constructs containing additional codon optimization over the full length of the protein were prepared and tested. One such improved sequence for expression of a non-Cys B44 protein was found to be the nucleic acid sequence set forth in SEQ ID NO: 43. As shown in Example 9, the expression construct containing SEQ ID NO: 43 showed enhanced expression compared to that of the non-optimized wild type sequence.

Expression of the N-terminal Cys deleted B09 protein was improved by applying codon changes from the above optimized B44 (SEQ ID NO: 43) construct to B09 (SEQ ID NO: 48). To generate optimized B09 sequences, the B44 optimized DNA sequence (SEQ ID NO: 43) was first aligned to the DNA sequence of the B09 allele (SEQ ID NO: 48). The entire non-lipidated coding sequence of the B09 allele (SEQ ID NO: 48) was optimized to reflect the codon changes seen in the B44 optimized allele (SEQ ID NO: 43) wherever the amino acids between B44 (SEQ ID NO: 44) and B09 (SEQ ID NO: 49) were identical. Codon sequences in the B09 allele corresponding to the identical amino acids between the B09 allele and the B44 allele were changed to reflect the codon used in the B44 optimized sequence (SEQ ID NO: 43). Codon sequences for amino acids that differ between B09 (SEQ ID NO: 49) and B44 (SEQ ID NO: 44) were not changed in the B09 DNA sequence.

Additionally, the non-lipidated B44 amino acid sequence (SEQ ID NO: 44) contains two sequential serine-glycine repeat sequences (S-G-G-G-G)(SEQ ID NO: 56)(see also amino acids 2 to 6 of SEQ ID NO: 44) at its N-terminus, whereas the B09 allele contains only one serine-glycine repeat at the N-terminus (see amino acids 2 to 6 and amino acids 7 to 11 of SEQ ID NO: 49). The two serine-glycine repeats at the N-terminus of B44 (amino acids 2 to 6 and amino acids 7 to 11 of SEQ ID NO: 44) also have different codon usage (see nucleotides 4 to 18 and nucleotides 19 to 33 of SEQ ID NO: 43), and different combinations of the optimized B44 serine-glycine repeat (e.g., either nucleotides 4 to 18 of SEQ ID NO: 43, or nucleotides 19 to 33 of SEQ ID NO: 43, or a combination thereof) were applied to the B09 DNA sequence (SEQ ID NO: 48, e.g., applied to nucleotides 4 to 18 of SEQ ID NO: 48) in order to examine the effect on recombinant protein expression.

Three different versions of optimized B09 were constructed: SEQ ID NO: 45 contains both serine-glycine repeats (GS1 and GS2) (nucleic acids 4 to 33 of SEQ ID NO: 43) from the optimized B44, SEQ ID NO: 46 contains GS1 (nucleic acids 4 to 18 of SEQ ID NO: 43), and SEQ ID NO: 47 contains GS2 (nucleic acids 19 to 33 of SEQ ID NO: 43). The DNA for all of the above codon optimized sequences were chemically synthesized using standard in the art chemistry. The resulting DNA was cloned into appropriate plasmid expression vectors and tested for expression in *E. coli* host cells as described in Examples 8 and 9.

Example 8: Method for Expressing ORF2086, B09 variant

Cells of *E. coli* K-12 strain (derivatives of wild-type W3110 (CGSC4474) having deletions in *recA*, *thiA* and *araA*) were transformed with plasmid pEB063, which includes SEQ ID NO: 45, pEB064, which includes SEQ ID NO: 46, plasmid pEB065, which includes SEQ ID NO: 47, or plasmid pLA134, which includes SEQ ID NO: 48. The preferred modifications to the K-12 strain are helpful for fermentation purposes but are not required for expression of the proteins.

Cells were inoculated to a glucose-salts defined medium. After 8 hours of incubation at 37°C a linear glucose feed was applied and incubation was continued for an additional 3 hours. Isopropyl β -D-1-thiogalactopyranoside (IPTG) was added to the culture to a final concentration of 0.1 mM followed by 12 hours of incubation at 37°C. Cells were collected by centrifugation at 16,000xg for 10 minutes and lysed by addition of Easy-Lyse™ Cell Lysing Kit" from Lienco Technologies (St. Louis, MO) and loading buffer. The cleared lysates were analyzed for expression of B09 by Coomassie staining of SDS-PAGE gels and/or Western blot analysis with quantitation by a scanning densitometer. The results from scanning densitometry are below in Table 7:

Table 7: Expression data in <i>E. coli</i>			
Protein	Host cell	Plasmid	Percentage of total cell protein at 12 hours post IPTG induction, as measured by SDS-PAGE, scanning densitometry
B09	<i>E. coli</i> K-12	pEB063 SEQ ID NO: 45	24%
B09	<i>E. coli</i> K-12	pEB065 SEQ ID NO: 47	12%
B09	<i>E. coli</i> K-12	pEB064 SEQ ID NO: 46	38%
B09	<i>E. coli</i> K-12	pLA134 SEQ ID NO: 48	13%

Example 9: Method for Expressing ORF2086, B44 variant

Cells of *E. coli* B strain (BLR(DE3), Novagen) were transformed with plasmid pLN056, which includes SEQ ID NO: 51. Cells of *E. coli* K-12 strain (derivative of wild-type W3110) were transformed with plasmid pDK087, which includes SEQ ID NO: 43.

- 5 Cells were inoculated to a glucose-salts defined medium. After 8 hours of incubation at 37°C a linear glucose feed was applied and incubation was continued for an additional 3 hours. Isopropyl β -D-1-thiogalactopyranoside (IPTG) was added to the culture to a final concentration of 0.1 mM followed by 12 hours of incubation at 37°C. Cells were collected by centrifugation at 16,000xg for 10 minutes and lysed by addition of Easy-Lyse™ Cell Lysing Kit[®] from Lienco Technologies (St. Louis, MO) and loading buffer.
- 10 The supernatants were analyzed for expression of B09 by Coomassie staining of SDS-PAGE gels and/or Western blot analysis, with quantitation by a scanning densitometer. The results from scanning densitometry are below in Table 8:

Table 8: Expression data in <i>E. coli</i>			
Protein	Host cell	Plasmid	Percentage of total cell protein at 12 hours post IPTG induction, as measured by SDS-PAGE, scanning densitometry.
B44	<i>E. coli</i> B	pLN056 SEQ ID NO: 51	1%
B44	<i>E. coli</i> K-12	pDK087 SEQ ID NO: 43	17%

Example 10: Pyruvylation

The present example demonstrates that the N-terminal Cys residue of non-lipidated ORF2086 proteins can become pyruvylated when expressed in, for example, *E. coli*.

5 Heterologous protein accumulation during production of variants A05 (SEQ ID NO: 13) and B44 (SEQ ID NO: 21) were monitored using reverse-phase high performance liquid chromatography (RP-HPLC). This separation was interfaced with a quadrupole time-of-flight mass spectrometer (QTOF-MS) to provide a means of monitoring formation of product related variants.

10 After being expressed in the *E. coli* B and/or K-12 host cells, products derived from these fermentations underwent a purification procedure during which a product modification was observed. Deconvolution of the mass spectra characterized the variants as exhibiting mass shifts of +70 Da, as compared to native products of 27640 and 27572 Da for A05 and B44, respectively.

15 Published literature indicated that a +70 Da mass shift had previously been observed in proteins and has been attributed to pyruvylation of the amino-terminal residue.

The presence and location of the pyruvate group was confirmed using the mass spectral fragmentation data (MS/MS). The data indicated that the modification was on an amino-terminal cysteine residue, i.e., amino acid at position 1, according to A05 and
20 B44. For A05, the percentage of pyruvylated polypeptides was about 30%, as compared to the total number of A05 polypeptides (SEQ ID NO: 13). For B44 the percentage of pyruvylated polypeptides was about 25%, as compared to the total number of B44 polypeptides (SEQ ID NO: 21).

25 When A05 (SEQ ID NO: 13 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 55) and B44 variants (SEQ ID NO: 21 wherein the N-terminal Cys at position 1 is deleted or SEQ ID NO: 44), which do not contain an amino-terminal cysteine, were purified, there was no detectable pyruvylation (+70 Da).

Example 11: Immunogenicity of B09 and B44, individually and in combination

5 -10 groups of rhesus macaques monkeys were immunized with B09 variant (SEQ ID NO: 49 encoded by SEQ ID NO: 48) or B44 variant (SEQ ID NO: 44 encoded by SEQ ID NO: 43), or the A05, B09 and B44 (SEQ ID NO: 55, SEQ ID NO: 49 encoded by SEQ ID NO: 48, and SEQ ID NO: 44 encoded by SEQ ID NO: 43, respectively) formulated with 250 mcg of AlPO₄ per dose. The monkeys were vaccinated via the intramuscular route at weeks 0, 4 and 8 with 10 mcg each of non-lipidated fHBP alone or in combination as listed in Table 9 and 10. Both weeks 0 and 12 serum samples were analyzed in SBAs against MnB strains with either subfamily A or subfamily B fHBP variants. Responders were recorded as animals with a 4 x rise in titer. The B44 variant tested was the optimized construct (SEQ ID NO: 43) and the broad response rates that were observed in previous studies (table above) were maintained for the optimized construct (Table 9) the B44 vaccine alone or in combination with B09. The B09 vaccine alone (Table 10) could also generate broadly cross reactive immune responses (Table 10).

Table 9: Response rates obtained for non lipidated fHBP vaccines in rhesus macaques

Vaccine (10 mcg per protein;	% ≥ 4 X Rise Against Test Variant (PD3; 10 rhesus macaques per group)				
	A05 (SEQ ID NO: 13)	B44 (SEQ ID NO: 21)	B16 (SEQ ID NO: 60)	B24 (SEQ ID NO: 20)	B09 (SEQ ID NO: 18)
B44	0	80	30	40	30
B44 + B09 +A05	60	80	40	50	30

Rhesus macaques (n= 10) were immunized i.m. at weeks 0, 4 and 8 with 10 mcg each of non-lipidated fHBP alone or in combination as listed in the Vaccine column in formulation with 250 mcg of AlPO₄. Both weeks 0 and 10 serum samples were

analyzed in SBAs against the MnB strains listed in the table. Responders are recorded as animals with a 4 x rise in titer.

Table 9 indicates, for example, that a composition including a combination of non-pyruvylated non-lipidated B44, B09, and A05 showed higher cross-coverage against the test variants as compared to the cross-coverage from a composition including B44 alone. In view of results shown in the present application, including in particular Table 6 and Table 9 together, compositions including B44, B09 and A05 alone or in combination are preferred embodiments of the present invention. In particular, compositions including both B44 and B09 are disclosed. Such composition preferably further includes a subfamily A polypeptide, such as in particular A05.

Table 10: Response rates obtained for non lipidated fHBP B09 vaccine in rhesus macaques

Vaccine (10 mcg per protein)	% $\geq$ 4 X Rise Against Test Variant (PD3; 5 rhesus macaques per group)				
	A05	B44	B16	B24	B09
B09	40	60	40	60	60

Rhesus macaques (n= 5) were immunized i.m. at weeks 0, 4 and 8 with 10 mcg each of non-lipidated fHBP alone or in combination as listed in the Vaccine column in formulation with 250 mcg of AlPO₄. Both weeks 0 and 10 serum samples were analyzed in SBAs against the MnB strains listed in the table. Responders are recorded as animals with a 4 x rise in titer.

Example 12: Immunoprotection conferred by Lipidated and Non-Lipidated Variants construct

Twenty female New Zealand white rabbits, 2.5-3.5 kg, obtained from Charles River Canada, were pre-screened by whole cell ELISA and 10 animals were selected for this study based on their low background titers against the test strains representing fHBP variants B02 (SEQ ID NO: 16) and B44 (SEQ ID NO: 21) (Table 11). Group of three animals were i.m. immunized with 100 µg of each protein formulated with 50 µg ISCOMATRIX per 0.5 ml dose at weeks 0, 4 and 9 (Table 12). Group 1 was vaccinated with non-lipidated B44 (SEQ ID NO: 44). A control group was included that was vaccinated with lipidated B01 formulated with AIP04 (250 mcg) Rabbits were bled at weeks 0, 4, 9 and 10. Individual sera from week 10 were prepared and analyzed by serum bactericidal assay against multiple serogroup B meningococcal strains from the fHBP B subfamily.

Table 11: Rabbits Used in The Study

Species:	Rabbit
Strain:	New Zealand white
Source: ^a	Charles River Laboratory
No. of Animals Per Group:	3
Total No. of Animals:	9
Age and Sex:	Female
Weight:	2.5-3.5 kg

Table 12

Group	# of animals	Variant	lipidated	rfHBP ($\mu\text{g}/0.5$ ml dose)	ISCOMATRIX ($\mu\text{g}/0.5$ ml dose)	Aluminium Phosphate ($\mu\text{g}/0.5$ ml dose)
1	3	B44	-	100	50	
2	3	B01	-	100	50	
3	3	B01	+	100	-	100

Immunization schedule Weeks 0, 4, 9; Bleed schedule Weeks 0, 4, 9,10

Serum Bactericidal Assay (SBA): A microcolony-based serum bactericidal assay (SBA) against multiple serogroup B meningococcal strains (Table 13) was performed on individual serum samples. Human sera from donors were qualified as the complement source for the strain tested in the assay. Complement-mediated antibody-dependent bactericidal titers were interpolated and expressed as the reciprocal of the dilution of the test serum that killed 50% of the meningococcal cells in the assay. The limit of detection of the assay was an SBA titer of 4. An SBA titer of <4 was assigned number of 2. A ≥ 4 -fold rise of SBA titers in the week 10 sera in comparison to the titers in the pre-bleed was calculated and compared.

Serum bactericidal antibody activity as measured in the SBA is the immunologic surrogate of protection against meningococcal disease. The ability of immunization with non-lipidated rHBP to elicit bactericidal antibodies in rabbits was determined by SBA. SBA measures the level of antibodies in a serum sample by mimicking the complement-mediated bacterial lysis that occurs naturally. Rabbit serum samples collected from week 10 were analyzed by SBA against strains with a B44 fHBP or a B02 fHBP. As shown in Table 13, one week after the third immunization (week 10), all serum samples displayed bactericidal activity against both test strains. (Table 13). The non-lipidated B44 (SEQ ID NO: 44) was more immunogenic than non-lipidated B01 in New Zealand Rabbits against these strains. The non lipidated B44 (SEQ ID NO: 44) formulated with the iscomatrix adjuvant gave comparable titers to the lipidated B01 formulated with aluminium phosphate against these strains. Rabbit pre-bleed sera showed generally no pre-existing bactericidal activity against the tested strains.

Table 13: Serum Bactericidal Activity against fHBP Subfamily B Strains in New Zealand White Rabbits Vaccinated with Recombinant Non-lipidated fHBP

Subfamily B variant (formulation)	GMT SBA Titer against test variant	
	B44 (SEQ ID NO: 21)	B02 (SEQ ID NO: 16)
Non lipidated B44 (SEQ ID NO: 44)(Iscomatrix)	6675	7140
Non lipidated B01 (ISCOMATRIX)	625	1052
Lipidated B01 (AlPO ₄)	10099	10558

Example 13: Immunogenicity of six non-lipidated factor H binding proteins in New Zealand white rabbits.

Groups of 5 rabbits were immunized with non-lipidated fHBP variants as described in Table 14. Vaccines were administered at 0, 4 and 9 weeks. Rabbit serum samples collected from weeks 0 and 10 were analyzed by SBA against the strains with homologous and heterologous fHBP sequences. Table 14 shows the percent responders post the third immunization. One week after the third immunization (week 10), all serum samples displayed bactericidal activity against the homologous strains as well as other test strains from the same fHBP subfamily. Rabbits pre-bleed sera showed generally no pre-existing bactericidal activity against the tested strains.

Table 14: Post Dose Three Percent of Responders in New Zealand White Rabbits Vaccinated with Recombinant Non-lipidated fHBPs

MnB fHBP	Dose/0.5 mL	AlPO ₄ /0.5 mL	n	B09	B16	B24	B44	A05	A12	A22
A05	100 mcg	0.25 mg	5					100	80	100
A12	100 mcg	0.25 mg	5					100	100	100
A22	100 mcg	0.25 mg	5					80	80	80
B09	100 mcg	0.25 mg	5	100	80	60	80			
B22	100 mcg	0.25 mg	5	40	100	60	100			
B44	100 mcg	0.25 mg	5	0	60	40	100			
A05, A12, B22, B44	100 mcg each/400 mcg total	0.25 mg	5	100	100	60	100	100	100	100

MnB fHBP Proteins Used

A05	SEQ ID NO: 13, wherein the Cys at position 1 is deleted, or SEQ ID NO: 55 encoded by SEQ ID NO: 54
A12	SEQ ID NO: 14, wherein the Cys at position 1 is deleted
A22	SEQ ID NO: 15, wherein the Cys at position 1 is deleted

B09	SEQ ID NO: 18, wherein the Cys at position 1 is deleted, or SEQ ID NO: 49 encoded by SEQ ID NO: 48.
B22	SEQ ID NO: 19, wherein the Cys at position 1 is deleted
B44	SEQ ID NO: 21, wherein the Cys at position 1 is deleted, or SEQ ID NO: 44 encoded by SEQ ID NO: 51

Test variants in Table 14:

B09 (SEQ ID NO: 18)	B16 (SEQ ID NO: 60)	B24 (SEQ ID NO: 20)	B44 (SEQ ID NO: 21)	A05 (SEQ ID NO: 13)	A12 (SEQ ID NO: 14)	A22 (SEQ ID NO: 15)
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The invention also provides the following embodiments as defined in the clauses below:

C1. An immunogenic composition comprising a P2086 polypeptide, wherein the P2086 is a B44, a B02, a B03, a B22, a B24, a B09, an A05, an A04, an A12, or an A22 variant.

C2. An immunogenic composition comprising a P2086 Subfamily B polypeptide, wherein the P2086 Subfamily B polypeptide is a B44, a B02, a B03, a B22, a B24 or a B09 variant.

C3. The immunogenic composition of C2 further comprising a P2086 Subfamily A polypeptide.

C4. The immunogenic composition of C3, wherein the P2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.

C5. The immunogenic composition of any one of C1-4, wherein the composition further comprises an adjuvant.

C6. The immunogenic composition of C5, wherein the adjuvant is selected from the group consisting of:

- a) an aluminum adjuvant;
- b) a saponin
- c) a CpG nucleotide sequence; and
- d) any combination of a), b) and c).

C7. The immunogenic composition according to C6, wherein the aluminum adjuvant is selected from the group consisting of AlPO_4 , $\text{Al}(\text{OH})_3$, $\text{Al}_2(\text{SO}_4)_3$ and alum.

C8. The immunogenic composition according to C6 or C7, wherein the concentration of aluminum is between 0.125 $\mu\text{g/ml}$ and 0.5 $\mu\text{g/ml}$.

C9. The immunogenic composition according to C8, wherein the concentration of aluminum is 0.25 $\mu\text{g/ml}$.

C10. The immunogenic composition according to any one of C6-9, wherein the saponin concentration is between 1 $\mu\text{g/ml}$ and 250 $\mu\text{g/ml}$.

C11. The immunogenic composition according to C10, wherein the saponin concentration is between 10 $\mu\text{g/ml}$ and 100 $\mu\text{g/ml}$.

C12. The immunogenic composition according to C10, wherein the saponin concentration is 10 $\mu\text{g/ml}$.

C13. The immunogenic composition according to C10, wherein the saponin concentration is 100 $\mu\text{g/ml}$.

C14. The immunogenic composition according to any one of C6-13, wherein the saponin is QS-21 or ISCOMATRIX.

C15. The immunogenic composition according to any one of C1-14, wherein the composition confers the ability to raise an immunogenic response to a *Neisseria meningitidis* bacteria after administration of multiple doses to a subject.

C16. The immunogenic composition according to C15, wherein the immunogenic response to the *Neisseria meningitidis* bacteria is conferred after administration of 2 doses to the subject.

C17. The immunogenic composition according to C15, wherein the immunogenic response to the *Neisseria meningitidis* bacteria is conferred after administration of 3 doses to the subject.

C18. A composition conferring increased immunogenicity on a non-lipidated P2086 antigen, wherein the composition comprises a saponin and at least one non-lipidated P2086 antigen.

C19. The immunogenic composition according to C18, wherein the saponin concentration is between 1 µg/ml and 250 µg/ml.

C20. The immunogenic composition according to C19, wherein the saponin concentration is between 10 µg/ml and 100 µg/ml.

C21. The immunogenic composition according to C19, wherein the saponin concentration is 10 µg/ml.

C22. The immunogenic composition according to C19, wherein the saponin concentration is 100 µg/ml.

C23. The immunogenic composition according to any one of C18-22, wherein the saponin is QS-21 or ISCOMATRIX.

C24. The immunogenic composition according to any one of C18-23 further comprising aluminum.

C25. The immunogenic composition according to C24, wherein the concentration aluminum is between 0.125 µg/ml and 0.5 µg/ml.

C26. The immunogenic composition according to C25, wherein the concentration of aluminum is 0.25 µg/ml.

C27. The immunogenic composition according to any one of C18-26, wherein the composition confers an immunogenic response to a *Neisseria meningitidis* bacteria after administration of multiple doses to the subject.

C28. The immunogenic composition according to C27, wherein the immunogenic response to the *Neisseria meningitidis* bacteria is conferred after administration of 2 doses to the subject.

C29. The immunogenic composition according to C27, wherein the immunogenic response to the *Neisseria meningitidis* bacteria is conferred after administration of 3 doses to the subject.

C30. The immunogenic composition according any one of C18-29, wherein the non-lipidated P2086 antigen is a non-lipidated P2086 Subfamily B polypeptide.

C31. The immunogenic composition according to C30, wherein the non-lipidated P2086 Subfamily B polypeptide is a B44, a B02, a B03, a B22, a B24 or a B09 variant.

C32. The immunogenic composition according any one of C18-29, wherein the non-lipidated P2086 antigen is a non-lipidated P2086 Subfamily A polypeptide.

C33. The immunogenic composition according to C32, wherein the non-lipidated P2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.

C34. The immunogenic composition according any one of C18-33, wherein the composition comprises at least two non-lipidated P2086 antigens, wherein the two non-lipidated P2086 antigens are at least one non-lipidated P2086 Subfamily A polypeptide and at least one non-lipidated P2086 Subfamily B polypeptide.

C35. The immunogenic composition according to C34, wherein the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B44 variant.

C36. The immunogenic composition according to C34, wherein the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B22 variant.

C37. The immunogenic composition according to C34, wherein the non-lipidated P2086 Subfamily A polypeptide is an A05 variant and the non-lipidated P2086 Subfamily B polypeptide is a B09 variant.

C38. A method for conferring immunity to a subject against a *Neisseria meningitidis* bacteria, wherein the method comprises the step of administering to the subject an immunogenic composition comprising a P2086 Subfamily B polypeptide, wherein the P2086 Subfamily B polypeptide is a B44, a B02, a B03, a B22, a B24 or a B09 variant.

C39. The method according to C38, wherein the immunogenic composition further comprises an a P2086 Subfamily A polypeptide.

C40. The method according to C39, wherein the P2086 Subfamily A polypeptide is an A05, an A04, an A12, or an A22 variant.

C41. The method according to any one of C38-40, wherein the immunogenic composition further comprises an adjuvant.

C42. The method according to C41, wherein the adjuvant is selected from the group consisting of:

- a) an aluminum adjuvant;
- b) a saponin
- c) a CpG nucleotide sequence; and
- d) any combination of a), b) and c).

C43. The method according to C42, wherein the aluminum adjuvant is selected from the group consisting of AlPO_4 , $\text{Al}(\text{OH})_3$, $\text{Al}_2(\text{SO}_4)_3$ and alum.

C44. The method according to C42 or 43, wherein the concentration of aluminum is between 0.125 $\mu\text{g/ml}$ and 0.5 $\mu\text{g/ml}$.

C45. The method according to C44, wherein the concentration of aluminum is 0.25 $\mu\text{g/ml}$.

C46. The method according to any one of C42-45, wherein the saponin concentration is between 1 $\mu\text{g/ml}$ and 250 $\mu\text{g/ml}$.

C47. The method according to C46, wherein the saponin concentration is between 10 $\mu\text{g/ml}$ and 100 $\mu\text{g/ml}$.

C48. The method according to C47, wherein the saponin concentration is 10 $\mu\text{g/ml}$.

C49. The method according to C48, wherein the saponin concentration is 100 $\mu\text{g/ml}$.

C50. The method according to any one of C42-49, wherein the saponin is QS-21 or ISCOMATRIX.

C51. The method according to C38-50, wherein the immunogenic composition is administered to the subject in multiple doses over a dosing schedule.

C52. The method according to C51, wherein the immunogenic composition is administered to the subject in 2 doses over a dosing schedule.

C53. The method according to C51, wherein the immunogenic composition is administered to the subject in 3 doses over a dosing schedule.

C54. A method for producing a non-lipidated P2086 variant polypeptide comprising the steps of:

- a) cloning the ORF2086 variant nucleic acid sequence into an *E. coli* expression vector;
- b) transforming bacteria with the ORF2086 expression vector;

- c) inducing expression; and
- d) isolating the expressed P2086 protein;

wherein, the ORF2086 expression vector does not comprise a lipidation control sequence.

C55. The method according to C54, wherein the codon encoding the N-terminal Cys of the ORF2086 variant is deleted.

C56. The method according to C54, wherein the codon encoding the N-terminal Cys of the ORF2086 variant is mutated to generate an Ala, Gly, or Val codon.

C57. The method according to C55 or 56, wherein the ORF2086 variant is an A05, a B01, or a B44 variant.

C58. The method according to any one of C54-57, wherein the N-terminal tail is mutated to add Ser and Gly residues to extend the Gly/Ser stalk immediately downstream of the N-terminal Cys.

C59. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 7.

C60. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 8.

C61. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 9.

C62. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 10.

C63. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 11.

C64. The method according to C58, wherein the total number of Gly and Ser residues in the Gly/Ser stalk is at least 12.

C65. The method according to any one of C54-57, wherein the codons of the N-terminal tail of the ORF2086 variant are optimized by point mutagenesis such that the codon encoding the fifth amino acid of the ORF2086 variant is 100% identical to nucleotides 13-15 of SEQ ID NO: 8 and the codon encoding the thirteenth amino acid of the ORF2086 variant is 100% identical to nucleotides 37-39 of SEQ ID NO: 8.

C66. The method according to C65, wherein the codons of the N-terminal tail of the ORF2086 variant are 100% identical to nucleotides 1-45 of SEQ ID NO: 8.

C67. The method according to C65, wherein the codons of the N-terminal tail of the ORF2086 variant are 100% identical to nucleotides 4-45 of SEQ ID NO: 8.

C68. The method according to C65, wherein the codons of the N-terminal tail of the ORF2086 variant are 100% identical to nucleotides 4-42 of SEQ ID NO: 8.

C69. The method according to C65, wherein the N-terminal tail of the protein encoded by the ORF2086 variant comprises at least one amino acid substitution compared to amino acids 1-15 of SEQ ID NO: 18.

C70. The method according to C65, wherein the N-terminal tail of the protein encoded by the ORF2086 variant comprises at least one amino acid substitution compared to amino acids 2-15 of SEQ ID NO: 18.

C71. The method according to C65, wherein the N-terminal tail of the protein encoded by the ORF2086 variant comprises two amino acid substitutions compared to amino acids 1-15 of SEQ ID NO: 18.

C72. The method according to C65, wherein the N-terminal tail of the protein encoded by the ORF2086 variant comprises two amino acid substitutions compared to amino acids 2-15 of SEQ ID NO: 18.

C73. The method according to any one of C69-72, wherein the amino acid substitutions are conservative amino acid substitutions.

C74. The method according to any one of C65-73, wherein the ORF2086 variant is an A22 or a B22 variant.

C75. The method according to any one of C55-74 wherein expression is induced by addition of IPTG.

C76. The method according to any one of C55-75, wherein the bacteria is *E. coli*.

What is Claimed is:

1. A composition comprising an isolated non-pyruvylated non-lipidated ORF2086 polypeptide wherein the polypeptide comprises the amino acid sequence consisting of SEQ ID NO:12, wherein the cysteine at position 1 is deleted or substituted.
2. The composition of claim 1, wherein the composition is immunogenic.
3. The composition of claim 1, wherein the polypeptide comprises a deletion of an N-terminal Cys compared to the corresponding wild-type non-lipidated ORF2086 polypeptide.
4. The composition of claim 1, further comprising a second polypeptide that comprises the amino acid sequence selected from the group consisting of SEQ ID NO:13, SEQ ID NO:14, SEQ ID NO:15, SEQ ID NO:16, SEQ ID NO:17, SEQ ID NO:18, SEQ ID NO:19, SEQ ID NO: 20, and SEQ ID NO: 21, wherein the cysteine at position 1 is deleted.
5. The composition of claim 4, wherein the second polypeptide comprises the amino acid sequence selected from the group consisting of SEQ ID NO: 44, SEQ ID NO: 49, SEQ ID NO: 50, and SEQ ID NO: 55.
6. The composition of claim 1, wherein the polypeptide is encoded by a nucleotide sequence that is operatively linked to an expression system, wherein said expression system is capable of being expressed in a bacterial cell.
7. The composition of claim 6, wherein the expression system is a plasmid expression system.
8. The composition of claim 6, wherein the bacterial cell is an *E. coli* cell.
9. The composition of claim 6, wherein the nucleotide sequence is linked to a regulatory sequence that controls expression of said nucleotide sequence.

10. The composition of claim 1, wherein the polypeptide comprises a substitution of an N-terminal Cys compared to the corresponding wild-type non-lipidated ORF2086 polypeptide.
11. A composition comprising a non-pyruvylated non-lipidated ORF2086 polypeptide obtainable by a process comprising expressing a nucleotide sequence encoding a polypeptide having the amino acid sequence of SEQ ID NO:12, wherein the cysteine at position 1 is deleted, wherein the nucleotide sequence is operatively linked to an expression system that is capable of being expressed in a bacterial cell.
12. The composition of claim 11, wherein the bacterial cell is *E. coli*.
13. The composition according to any of claims 1-12, wherein the composition is immunogenic.
14. The composition of claim 1, further comprising an ORF2086 subfamily A polypeptide from serogroup B *Neisseria meningitidis*.
15. The composition according to any of claims 1-12, wherein the composition elicits a bactericidal immune response in a mammal against an ORF2086 subfamily B polypeptide from serogroup B *Neisseria meningitidis*.