CLAIMS

What is claimed:

1. A nanoparticle comprising at least four species of fusion protein, wherein each fusion protein comprises at least one immunogenic portion of an influenza virus hemagglutinin (HA) protein joined to a monomeric subunit protein capable of self-assembling to form the nanoparticle;

wherein the sequence of the immunogenic potion of the HA protein in each species of fusion protein differs from the sequence of the immunogenic portion of the HA protein in the other species of fusion proteins and comprises an HA receptor-binding domain (RBD) amino acid sequence at least 80% identical to any one of SEQ ID NOs: 32-62; and

the nanoparticle displays on its surface the immunogenic portions of the at least four species of fusion protein.

2. The nanoparticle of claim 1, wherein the sequence of the immunogenic portion of the HA protein in each species of fusion protein comprises an amino acid sequence at least 90% identical to any one of SEQ ID NOs: 32-62.

3. The nanoparticle of claim 1, wherein the sequence of the immunogenic portion of the HA protein in each species of fusion protein comprises an amino acid sequence at least 95% identical to any one of SEQ ID NOs: 32-62.

4. The nanoparticle of claim 1, wherein the sequence of the immunogenic portion of the HA protein in each species of fusion protein comprises an amino acid sequence at least 99% identical to any one of SEQ ID NOs: 32-62.

5. The nanoparticle of claim 1, wherein the sequence of the immunogenic portion of the HA protein in each species of fusion protein comprises an amino acid sequence set forth as any one of SEQ ID NOs: 32-62.

6. The nanoparticle of any one of claims 1-5, wherein the monomeric subunit protein is selected from a monomeric ferritin subunit protein, a monomeric encapsulin protein, a monomeric 03-33 protein, a monomeric SOR protein, a monomeric LS protein, a monomeric PDC protein and a Chikungunya virus structural polyprotein.

7. The nanoparticle of claim 6, wherein the monomeric ferritin subunit protein comprises an amino acid sequence comprises an amino acid sequence set forth as SEQ ID NO:64, SEQ ID NO:67, SEQ ID NO:70, SEQ ID NO:73, or SEQ ID NO:76.

8. The nanoparticle of any one of claims 1-7, wherein the at least four species of fusion proteins comprise immunogenic portions obtained from HA proteins from at least four different subtypes of influenza virus.

9. The nanoparticle of any one of claims 1-7, wherein the at least four species of fusion proteins comprise immunogenic portions obtained from HA proteins from at least four different strains of influenza virus.

10. The nanoparticle of any one of claims 1-9, wherein the nanoparticle elicits an immune response to an influenza virus strain that is heterologous to the strains of influenza viruses from which the HA immunogenic portions were obtained.

11. The nanoparticle of any one of claims 1-10, wherein each fusion protein comprises an amino acid sequence at least 80% identical to a sequence selected from SEQ ID NO:97, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:106, SEQ ID NO:109, SEQ ID NO:112, SEQ ID NO:115, SEQ ID NO:118, SEQ ID NO:121, SEQ ID NO:124, SEQ ID NO:127, SEQ ID NO:130, SEQ ID NO:133, SEQ ID NO:136, SEQ ID NO:139, SEQ ID NO:142, SEQ ID NO:145, SEQ ID NO:148, SEQ ID NO:151, SEQ ID NO:154, SEQ ID NO:157, SEQ ID NO:160, SEQ ID NO:163, SEQ ID NO:166, SEQ ID NO:169, SEQ ID NO:172, SEQ ID NO:175, SEQ ID NO:178, SEQ ID NO:181, SEQ ID NO:184, SEQ ID NO:187 and SEQ ID NO:190.

12. The nanoparticle of any one of claims 1-10, wherein each fusion protein comprises an amino acid sequence at least 90% identical to a sequence selected from SEQ ID NO:97, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:106, SEQ ID NO:109, SEQ ID NO:112, SEQ ID NO:115, SEQ ID NO:118, SEQ ID NO:121, SEQ ID NO:124, SEQ ID NO:127, SEQ ID NO:130, SEQ ID NO:133, SEQ ID NO:136, SEQ ID NO:139, SEQ ID NO:142, SEQ ID NO:145, SEQ ID NO:148, SEQ ID NO:151, SEQ ID NO:154, SEQ ID NO:157, SEQ ID NO:160, SEQ ID NO:163, SEQ ID NO:166, SEQ ID NO:169, SEQ ID NO:172, SEQ ID NO:175, SEQ ID NO:178, SEQ ID NO:181, SEQ ID NO:184, SEQ ID NO:187 and SEQ ID NO:190.

13. The nanoparticle of any one of claims 1-10, wherein each fusion protein comprises an amino acid sequence at least 95% identical to a sequence selected from SEQ ID NO:97, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:106, SEQ ID NO:109, SEQ ID NO:112, SEQ ID NO:115, SEQ ID NO:118, SEQ ID NO:121, SEQ ID NO:124, SEQ ID NO:127, SEQ ID NO:130, SEQ ID NO:133, SEQ ID NO:136, SEQ ID NO:139, SEQ ID NO:142, SEQ ID NO:145, SEQ ID NO:148, SEQ ID NO:151, SEQ ID NO:154, SEQ ID NO:157, SEQ ID NO:160, SEQ ID NO:163, SEQ ID NO:166, SEQ ID NO:169, SEQ ID NO:172, SEQ ID NO:175, SEQ ID NO:178, SEQ ID NO:181, SEQ ID NO:184, SEQ ID NO:187 and SEQ ID NO:190.

14. The nanoparticle of any one of claims 1-10, wherein each fusion protein comprises an amino acid sequence at least 99% identical to a sequence selected from SEQ ID NO:97, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:106, SEQ ID NO:109, SEQ ID NO:112, SEQ ID NO:115, SEQ ID NO:118, SEQ ID NO:121, SEQ ID NO:124, SEQ ID NO:127, SEQ ID NO:130, SEQ ID NO:133, SEQ ID

NO:136, SEQ ID NO:139, SEQ ID NO:142, SEQ ID NO:145, SEQ ID NO:148, SEQ ID NO:151, SEQ ID NO:154, SEQ ID NO:157, SEQ ID NO:160, SEQ ID NO:163, SEQ ID NO:166, SEQ ID NO:169, SEQ ID NO:172, SEQ ID NO:175, SEQ ID NO:178, SEQ ID NO:181, SEQ ID NO:184, SEQ ID NO:187 and SEQ ID NO:190.

15. The nanoparticle of any one of claims 1-10, wherein each fusion protein comprises an amino acid sequence selected from SEQ ID NO:97, SEQ ID NO:100, SEQ ID NO:103, SEQ ID NO:106, SEQ ID NO:109, SEQ ID NO:112, SEQ ID NO:115, SEQ ID NO:118, SEQ ID NO:121, SEQ ID NO:124, SEQ ID NO:127, SEQ ID NO:130, SEQ ID NO:133, SEQ ID NO:136, SEQ ID NO:139, SEQ ID NO:142, SEQ ID NO:145, SEQ ID NO:148, SEQ ID NO:151, SEQ ID NO:154, SEQ ID NO:157, SEQ ID NO:160, SEQ ID NO:163, SEQ ID NO:166, SEQ ID NO:169, SEQ ID NO:172, SEQ ID NO:175, SEQ ID NO:178, SEQ ID NO:181, SEQ ID NO:184, SEQ ID NO:187 and SEQ ID NO:190.

16. A kit for use in vaccinating an individual against influenza virus comprising the nanoparticle of any one of claims 1-15.

17. A pharmaceutical composition comprising the nanoparticle of any one of claims 1-15 for use in vaccinating an individual against influenza virus.

18. A method for producing a nanoparticle of any one of claims 1-8, the method comprising introducing one or more nucleic acid molecules encoding said fusion proteins into a cell, and incubating the cell under conditions suitable for expressing the encoded proteins and forming nanoparticles.

19. Use of the nanoparticles of any one of claims 1-8, or a nanoparticle produced according to the method of claim10, in the preparation of a medicament for vaccinating an individual against an infectious agent from the same taxonomic family.

20. A nucleic acid molecule comprising a nucleic acid sequence encoding a species of fusion protein of claim.