

WHAT IS CLAIMED IS:

1. A polynucleotide encoding one or more viral proteins or one or more fragments thereof of a parent SARS-CoV-2 coronavirus:
 - wherein the polynucleotide is recoded compared to its parent SARS-CoV-2 coronavirus polynucleotide, and
 - wherein the amino acid sequence of the one or more viral proteins, or one or more fragments thereof of the parent SARS-CoV-2 coronavirus encoded by the polynucleotide remains the same, or
 - wherein the amino acid sequence of the one or more viral proteins or one or more fragments thereof of the parent SARS-CoV-2 coronavirus encoded by the polynucleotide comprises up to 20 amino acid substitutions, additions, or deletions.
2. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is a wild-type SARS-CoV-2.
3. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is a natural isolate SARS-CoV-2.
4. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is Washington isolate of SARS-CoV-2 coronavirus having a nucleic acid sequence of GenBank accession no. MN985325.1.
5. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is BetaCoV/Wuhan/IVDC-HB-01/2019 isolate of SARS-CoV-2 coronavirus (SEQ ID NO:1).
6. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is a SARS-CoV-2 variant.
7. A polynucleotide of claim 1, wherein the parent SARS-CoV-2 coronavirus is a SARS-CoV-2 variant selected from the group consisting of U.K. variant, South Africa variant, and Brazil variant.
8. A polynucleotide of any one of claims 1-7, wherein the polynucleotide is recoded by reducing codon-pair bias (CPB) or reducing codon usage bias compared to its parent SARS-CoV-2 coronavirus polynucleotide.
9. A polynucleotide of any one of claim 1-7, wherein the polynucleotide is recoded by increasing the number of CpG or UpA di-nucleotides compared to its parent SARS-CoV-2 coronavirus polynucleotide.
10. A polynucleotide of any one of the above claims, wherein each of the recoded one or more viral proteins, or each of the recoded one or more fragments thereof has a codon pair bias less than, -0.05, less than -0.1, less than -0.2, less than -0.3, or less than -0.4.
11. A polynucleotide of any one of the above claims, wherein the polynucleotide is CPB deoptimized compared to its parent SARS-CoV-2 coronavirus polynucleotide.

12. A polynucleotide of any one of the above claims, wherein the polynucleotide is codon deoptimized compared to its parent SARS-CoV-2 coronavirus polynucleotide.
13. A polynucleotide of any one of claims 11-12, wherein the codon-deoptimized or CPB deoptimized is based on frequently used codons or CPB in humans.
14. A polynucleotide of any one of claims 11-12, wherein the codon-deoptimized or CPB deoptimized is based on frequently used codons or CPB in a coronavirus.
15. A polynucleotide of any one of claims 11-12, wherein the codon-deoptimized or CPB deoptimized is based on frequently used codons or CPB in a SARS-CoV-2 coronavirus.
16. A polynucleotide of any one of claims 11-12, wherein the codon-deoptimized or CPB deoptimized is based on frequently used codons or CPB in a wild-type SARS-CoV-2 coronavirus.
17. A polynucleotide of any one of the above claims, comprising a recoded nucleotide sequence selected from RNA-dependent RNA polymerase (RdRP), a fragment of RdRP, a spike protein, a fragment of spike protein, and combinations thereof.
18. A polynucleotide of any one of the above claims, comprising at least one CPB deoptimized region selected from bp 11294-12709, bp 14641-15903, bp 21656-22306, bp 22505-23905, and bp 24110-25381 of SEQ ID NO:1 or SEQ ID NO:2.
19. A polynucleotide of any one of the above claims, comprising a recoded spike protein or a fragment of spike protein wherein the furin cleavage site is eliminated.
20. A polynucleotide of claim 1, having SEQ ID NO:4, nucleotides 1-29,834 of SEQ ID NO:4, SEQ ID NO:7, or nucleotides 1-29,834 of SEQ ID NO:7.
21. A polynucleotide of claim 20, further comprising one or more consecutive adenines on the 3' end.
22. A polynucleotide of claim 1, having SEQ ID NO:3.
23. A bacterial artificial chromosome (BAC) comprising a polynucleotide of any one of claims 1-22.
24. A vector comprising a polynucleotide of any one of claims 1-22.
25. A cell comprising a polynucleotide of any one of claims 1-22, a BAC of claim 23, or a vector of 24.
26. The cell of claim 25, wherein the cell is Vero cell or baby hamster kidney (BHK) cell.
27. A polypeptide encoded by a polynucleotide of any one of claims 1-22.
28. A modified SARS-CoV-2 coronavirus comprising a polynucleotide of any one of claims 1-22.
29. A modified SARS-CoV-2 coronavirus comprising a polypeptide encoded by a polynucleotide of any one of claims 1-22.
30. A modified SARS-CoV-2 coronavirus of claim 28 or claim 29, wherein expression of one or more of its viral proteins is reduced compared to its parent SARS-CoV-2 coronavirus.

31. A modified SARS-CoV-2 coronavirus of any one of claims 28-30, wherein the reduction in the expression of one or more of its viral proteins is reduced as the result of recoding a region selected from RdRP, spike protein and combinations thereof.
32. A modified SARS-CoV-2 coronavirus comprising a polynucleotide having SEQ ID NO:4, or nucleotides 1-29,834 of SEQ ID NO:4, or nucleotides 1-29,834 of SEQ ID NO:4 and one or more consecutive adenines on the 3' end.
33. A modified SARS-CoV-2 coronavirus comprising a polypeptide encoded by a polynucleotide having SEQ ID NO:4, or nucleotides 1-29,834 of SEQ ID NO:4, or nucleotides 1-29,834 of SEQ ID NO:4 and one or more consecutive adenines on the 3' end.
34. A vaccine composition for inducing a protective an immune response in a subject, comprising:
 - a modified SARS-CoV-2 coronavirus of any one of claims 28-33.
35. The vaccine composition of claim 34, further comprising a pharmaceutically acceptable carrier or excipient.
36. An immune composition for eliciting an immune response in a subject, comprising:
 - a modified SARS-CoV-2 coronavirus of any one of claims 28-33.
37. The immune composition of claim 36, further comprising a pharmaceutically acceptable carrier or excipient.
38. A method of eliciting an immune response in a subject, comprising:
 - administering to the subject a dose of:
 - a modified SARS-CoV-2 coronavirus of any one of claims 28-33, or
 - a vaccine composition of claim 34 or claim 35, or
 - an immune composition of claim 36 or claim 37.
39. A method of eliciting an immune response in a subject, comprising:
 - administering to the subject a prime dose of a modified SARS-CoV-2 coronavirus of any one of claims 28-33, or a vaccine composition of claim 34 or claim 35, or an immune composition of claim 36 or claim 37; and
 - administering to the subject one or more boost doses of a modified SARS-CoV-2 coronavirus of any one of claims 28-33, or a vaccine composition of claim 34 or claim 35, or an immune composition of claim 36 or claim 37.
40. A method of any one of claims 38-39, wherein the immune response is a protective immune response.
41. A method of any one of claims 38-40, wherein the dose is a prophylactically effective or therapeutically effective dose.
42. A method of any one of claims 38-41, wherein administering is via a nasal route.
43. A method of any one of claims 38-41, wherein administering is via nasal drop.

44. A method of any one of claims 38-41, wherein administering is via nasal spray.
45. A method of any one of claims 38-45, wherein the dose is about 10^4 - 10^6 PFU, or the prime dose is about 10^4 - 10^6 PFU and the one or more boost dose is about 10^4 - 10^6 PFU.
46. A method of making a modified SARS-CoV-2 coronavirus, comprising:
 - obtaining a nucleotide sequence encoding one or more proteins of a parent SARS-CoV-2 coronavirus or one or more fragments thereof;
 - recoding the nucleotide sequence to reduce protein expression of the one or more proteins, or the one or more fragments thereof; and
 - substituting a nucleic acid having the recoded nucleotide sequence into the parent SARS-CoV-2 coronavirus genome to make the modified SARS-CoV-2 coronavirus genome,
 - wherein expression of the recoded nucleotide sequence is reduced compared to the parent virus.
47. The method of claim 46, wherein the parent SARS-CoV-2 coronavirus sequence is a wild-type (wt) viral nucleic acid.
48. A method of claim 46, wherein the modified SARS-CoV-2 coronavirus is any one of claims 28-33.