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- (54) **H3 INFLUENZA A VIRUS**
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(58) **Field of Classification Search**

None
See application file for complete search history.

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(57) **ABSTRACT**

The invention provides an isolated H3 equine influenza A virus, as well as methods of preparing and using the virus, and genes or proteins thereof.

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HAmino

MKTTIILILLTHWAYSQNPISGNNTATLCLGHHA VANGTLVKTISDDQIEVTNATE
LVQSISMGKICNNSYRILDGRNCTLIDAMLGDPHCDAFQYENWDLFIERSSAFSN
CYPYDIPDYASLR SIVASSGTLEFTAEGFTWTGVTQNGRSGACKRGSADSFPSRL
NWLTKSGSSYPTLNVTMPNNKNFDKLYIWGIHHPSSNQEQT KLYIQESGRVTVST
KRSQQTII PNIGSRPWVRGQSGRISYWTIVKPGDILMINSNGNLVAPRGYFKLKT
GKSSVMRSDVPIDICVSECITPNGSISNDKPFQNVNKVTY GKCPKYIRQNTLKLAT
GMRNVPEKQIRGIFGAIAGFIENGWEGMVDGWYGFYQNSEGTGQAADLKSTQ
AAIDQINGKLN RVIERTNEKFHQIEKEFSEVERRIQDLEKYVEDTKIDLWSYNAEL
LVALENQHTIDLDAEMNKLFETRRLRENAEDMGGGCFKIYHKCDNACIGSI
RNGTYDHYIYRDEALNNRFQIKGVELKSGYKDWILWISFAISCFLICVLLGFIM
WACQKGNIRCNICI

SEQ ID NO:1

FIG. 1A

NAmino

MNPNQKIIAIGFASLGILIIINVILHVVSII VTVLVLNNNR TDLNCKGTIIREYNETVR
VEKITQWYNTSTIKYIERPSNEY YMNTEPLCEA QGFAPFSKDNGIRIGSRGHV FV
IREPFVSCSPSECR TFFLTQGSLLNDKHSNGTVKDRSPYRTLMSVKIGQSPNVYQA
RFESVAWSATA CHDGKKWMTVGVTPDNQAIAVVNYGGVPVDIINSWAGDILR
TQESSCTCIKGD CYWVMTDGPANRQAKYRIFKAKDGRVIGQTDISFNNGGHIEECS
CYPNEGKVEVICRDNWTGTNR PILVISSDLSYTVGYLCAGIPTDTPRGEDSQFTGS
CTSPLGINKGYGVKGFGRQGT DVWAGRTISRTSRSGFEIIRNGWTQNSKDQIR
RQVIIDDPNWSGYSGSFTLPVELTKKGCLVPCFWVEMIRGKPEETTIWTSSSSIVM
CGVDHKIASWSWHDGAILPFDIDKM

SEQ ID NO:2

FIG. 1B

PB1amino

MDVNPTLLFLKVPQAQNAISTTFPYTGDPPYSHGTGTGYTMDTVNRTHQYSEK GK
WTTNTEIGAPQLNPIDGPLPEDNEPSGYAQTDCVLEAMAFLEESHHPGIFENSCL
MEVIQQTRVDKLTQGRQTYDWTLNRNQAATALANTIEVFRSNGLTSNESGRML
DFLKDVME SMNKEEMEITTFQRKRRVRDNMTKRMVTQRTIGKKKQRLNRKS
YLIRTLTLNTMTKDAERGLKRRRAIATPGMQIRGFVYFVETLARRICEKLEQSGL
PVG GNEKKAKLANVVRKMMTNSQDTELSFTITGDNTKWNENQNPRIFLAMITYI
TRNQPEWFRNVLSIAPIMFSNKMARLGKGYMFESKSMKLRTQIPAGMLASIDLK
YFNDPTKKKIEKIRPLLVDGTASLSPGMMMGMFNMLSTVLGVSILNLGQRKYTK
TTYWWDGLQSSDDEALIVNAPNHEGIQAGVDRFYRTCKLVGINMSKKKSYINRT
GTFEFTSFFYRYGFVANFSMELPSFGVSGINESADMSIGVTVIKNNMINNDLGPAT
AQMALQLFIKDYRYTYRCHRGD TQIQTRRSFELKKLWEQTRSKTG LLVSDGGPN
LYNIRNLHIPEVCLKWELMDEYKGR LCNPLNPFVSHKEIESVNSAVVMPAHGP
AKSMEYDAVATTHSWIPKRNRSILNTSQRGILEDEQMYQCCNLFEKFFPSSSYR
RPVGISSMVEAMVSRARIDARIDFESGRIKKDEFAEIMKICSTIEELRROK

SEQ ID NO:3

FIG. 1C

PB2amino

MERIKELRDLMLQSR TREILTKTTVDHMAIHKKYTSGRQEKNPALRMKWMMAM
KYPITADKRIMEMIPERNEQGQTLWSKTNDAGSDRVMVSPLAVTWWNRNGPTT
STIHYPKVYKTYFEKVERLKHGTFGPVHFRNQVKIRRRVDVNP GHADLSAKEAQ
DVIMEVVPNEVGARILTSESQLTITKEKKEELQDCKIAPLMVA YMLERELVRKT
RFLPVAGGTSSVYIEVLHLTQGT CWEQMYTPGGEVRNDDIDQSLIIAARNIVRRA
TVSADPLASLLEMCHSTQIGGIRMVDILKQNPTEEQAVDICKAAMGLRISSSFSG
GFTFKRTSGSSVKREEEMLTGNLQTLKIRVHEGYEEFTMVGRRATAILRKATRRL
IQLIVSGRDEQSLAEAIIVAMVFSQEDCMIKAVRGDLNFVN RANQRLNPMHQLLR
HFQKDAKVL FQNWGIEPIDNVMGMIGILPDMTPSTEMSLRGVRVSKMGVDEYSS
TERVVVSIDRFLRVRDQRGNILLSPEEVSETQGTEKLTIIYSSSMMWEINGPESVL
VNTYQWII RNWEIVKIQWSQDPTMLYNKIEFEPFQSLVPRATRSQYSGFVRTLFQ
QMRDVLGTFDTAQI KLLPFAAAPPEQSRMQFSSLTVNV RGS GMRILVRGNSPVF
NYNKATKRLTVLGKDAGALTEDPDEGTAGVESAVLRGFLILGKENKRYGPALSI
NELSKLAKGEKANVLIQGDVVLVMKRRKRDS SILTDSQTATKRIRMAIN

SEQ ID NO:4

FIG. 1D

PAmino

MEDFVRQCFNPMIVELAEKAMKEYGEDPKIETNKFAAICTHLEVCFMYSDFHFIN
ELSESVVIESGDPNALLKHRFEIIEGRDRTMAWTVVNSICNTTRAEPKFLPDLYD
YKENRFVEIGVTRREVHIYYLEKANKIKSEKTHIHIFSFTGEEMATKADYTLDEES
RARIKTRLFTIRQEMASRGLWDSFRQSERGEETIEERFEITGTMRKLANYSLPPNF
SSLENFRVYVDGFEPNGCIESKLSQMSKEVNARIEPFSKTTPRPLKMPGGPPCHQR
SKFLLMDALKLSIEDPSHEGEGIPLYDAIKCMKTFFGWKEPSIVKPHEKGINPNYL
QTWKQVLAELQDLENEEKDPKTKNMKKTSQLKWALSENMAPEKVD FEDCKDIS
DLKQYDSDEPETRSLASWIQSEFNKACELTDSSWIELDEIGEDVAPIEYIASMRN
YPTAEVSHCRATEYIMKGVYINTALLNASCAAMDEFQLIPMISKRCRTKEGRRKTN
LYGFIVKGRSHLRNDTDVNVFVSMEFSLTDPREFPHKWEKYCVLEIGDMLLRTA
VGQVSRPMFLYVRTNGTSKIKMKWGMEMRRCLLQSLQQIESMIEAESSVKEKD
MTKEFFENKSETWPIGESPKGVEEGSIGKVCRTLLAKSVFNSLYASPOLEGFSAES
RKLLLIVQALRDNLEPGTFDIGGLYESIEECLINDPWVLLNASWFNSFLTHALK

SEQ ID NO:5

FIG. 1E

NPamino

MASQGTKRSYEQMETDGERQNATEIRASVGRMVGGIGRFYVQMCTELKLNDEE
GRLIQNSITIERMVLSAFDERRNKYLEEHPSAGKDPKKTGGPIYRRKDGKWMREL
ILHDKEEIMRIWRQANNGEDATAGLTHMMIWHNSLNDDTTYQRTRALVRTGMDP
RMCSLMQGSTLPRRSGAAGA AVKGVGTMMELIRMIKRGINDRNFWRGNGR
RTRIAYERMCNILKGFQTA AQRAMMDQVREGRNPGNAEIEDLIFLARSALILRG
SVAHKSCLPACVYGLAVTSGYDFEKEGYSLVGIDPFKLLQNSQIFSLIRPKENPAH
KSQLVWMACHSAAFEDLRVLNFIKGTQVIPRGQLTTRGVQIASNENMETIDSSTL
ELRSKYWAIRTRSGGNTSQQRASAGQISVQPTFSVQRNLPFERATIMAAFTGNTE
GRTSDMRTEIIRMMENAKSEDVSFQGRGVFELSDEKATNPVPSFDMSNEGSYFF
GDNAEEFDS

SEQ ID NO:6

FIG. 1F

M1amino

MSLLTEVETYVLSIVPSGPLKAEIAQRLEDVFAGKNTDLEALMEWLKTRPILSPLT
KGILGFVFTLTVPSERGLQRRRFVQNALSGNGDPNNMDRAVKLYRKLKREITFH
GAKEVALSYSTGALASCMGLIYNRMGTVTTEVAFGLVCATCEQIADSQHRSHRQ
MVTITNPLIRHENRMVLA STTAKAMEQMAGSSEQAAEAMEVASRARQMVQAM
RTIGTHPSSSAGLKDDLLENLQAYQKRMGVQMQRFK

SEQ ID NO:7

FIG. 1G

NS1amino

MDSNTVSSSFQVDCFLWHVRKRFADQELGDAPFLDRLRRDQKSLRGRGSTLGDI
ETATHAGKQIVEQILEKESDEALKMTIASVPTSRYLTDMTLDEM SRDWFMLMPK
QKVTGSLCIRMDQAIMDKNIILKANFSVIFERLET LILLRAFTEEGAVVGEISPLPSL
PGHTNEDVKNAIGVLI GGLKWNDNTVRISETLQRF AWRSSHENGRPSFP SKQKR
KMERTIKPKI

SEQ ID NO:8

FIG. 1H

HA

TCATGAAGACAACCATTATTTTGATACTACTGACCCATTGGGCTTACAGTCAA
AACCCAATCAGTGGCAACAACACAGCCACATTGTGTCTGGGACACCATGCAG
TAGCAAATGGAACATTGGTAAAAACAATAAGTGATGATCAAATTGAGGTGAC
AAATGCTACAGAATTAGTTCAAAGCATTTCATGGGGAAAAATATGCAACAAC
TCATATAGAATTCTAGATGGAAGAAATTGCACATTAATAGATGCAATGCTAG
GAGACCCCTACTGTGACGCCTTTCAGTATGAGAATTGGGACCTCTTTATAGAA
AGAAGCAGCGCTTTCAGCAATTGCTACCCATATGACATCCCTGACTATGCATC
GCTCCGATCCATTGTAGCATCCTCAGGAACATTGGAATTCACAGCAGAGGGA
TTCACATGGACAGGTGTCACTCAAACGGAAGAAGTGGAGCCTGCAAAAAGG
GGATCAGCCGATAGTTTCTTTAGCCGACTGAATTGGCTAACAAAATCTGGAA
GCTCTTACCCACATTGAATGTGACAATGCCTAACAAATAAAAATTTGACAA
GCTATACATCTGGGGGATTCATCACCCGAGCTCAAATCAAGAGCAGACAAAA
TTGTACATCCAAGAATCAGGACGAGTAACAGTCTCAACAAAAAAGAAGTCAAC
AAACAATAATCCCTAACATCGGATCTAGACCGTGGGTCAGAGGTCAATCAGG
TAGGATAAGCATATACTGGACCATTGTAAAACCTGGAGATATCCTAATGATA
AACAGTAATGGCAACTTAGTTGCACCGCGGGGATATTTTAAATTGAAAACAG
GGAAAAGCTCTGTAATGAGATCAGATGTACCCATAGACATTTGTGTGTCTGA
ATGTATTACACCAAATGGAAGCATCTCCAACGACAAGCCATTCCAAATGTG
AACAAAGTTACATATGGAAAATGCCCAAGTATATCAGGCCAAAACACTTTAA
AGCTGGCCACTGGGATGAGGAATGTACCAGAAAAGCAAATCAGAGGAATCT
TTGGAGCAATAGCGGGATTCATCGAAAACGGCTGGGAAGGAATGGTTGATGG
GTGGTATGGGTTCCGATATCAAACCTCTGAAGGAACAGGGCAAGGTGCAGAT
CTAAAGAGCACTCAAGCAGCCATCGACCAGATTAATGGAAAGTTAAACAGA
GTGATTGAAAGAACCAATGAGAAATCCATCAAATAGAGAAGGAATTCTCAG
AAGTAGAAAGAAGAATTCAGGACTTGGAGAAATATGTAGAAGACACCAAAA
TAGACCTATGGTCTTACAATGCAGAATTGCTGGTGGCTCTAGAAAATCAACA
TACAATTGACTTAACAGATGCAGAAATGAATAAATTAATTTGAGAAGACTAGA
CGCCAGTTAAGAGAAAACGCAGAAGACATGGGAGGTGGATGTTTCAAGATTT
ACCACAAATGTGATAATGCATGCATTGGATCAATAAGAAATGGGACATATGA
CCATTACATATACAGAGATGAAGCATTAAACAACCGATTTTCAGATCAAAGGT
GTAGAGTTGAAATCAGGCTACAAAGATTGGATACTGTGGATTTCAATTCGCCA
TATCATGCTTCTTAATTTGCGTTGTTCTATTGGGTTTCATTATGTGGGCTTGCC
AAAAAGGCAACATCAGATGCAACATTTGCATTTGAG

SEQ ID NO:9

FIG. 11

NA

ATGAATCCAAATCAAAAGATAATAGCAATTGGATTTGCATCATTGGGGATAT
TAATCATTAAATGTCATTCTCCATGTAGTCAGCATTATAGTAACAGTACTGGTC
CTCAATAACAATAGAACAGATCTGAACTGCAAAGGGACGATCATAAGAGAG
TACAATGAAACAGTAAGAGTAGAAAAAATTACTCAATGGTATAATACCAGTA
CAATTAAGTACATAGAGAGACCTTCAAATGAATACTACATGAACAACACTGA
ACCACFTTGTGAGGGCCCAAGGCTTTGCACCATTTTCCAAAGATAATOGAATAC
GAATTGGGTCGAGAGGCCATGTTTTTGTGATAAGAGAACCCTTTTGTATCATGT
TCGCCCTCAGAATGTAGAACCTTTTTCTCACACAGGGCTCATTACTCAATGA
CAAACATTCTAACGGCACAGTAAAGGACCGAAGTCCGTATAGGACTTTGATG
AGTGTCAAAATAGGGCAATCACCTAATGTATATCAAGCTAGGTTTGAATCGG
TGGCATGGTCAGCAACAGCATGCCATGATGGAAAAAATGGATGACAGTTGG
AGTCACAGGGCCCGACAATCAAGCAATTGCAGTAGTGAACATGAGGTTGTT
CCGTTGATATTATTAATTCATGGGCAGGGGATATTTTAAGAACCCAAGAAT
CATCATGCACCTGCATTAAAGGAGACTGTTATTGGGTAATGACTGATGGACC
GGCAAATAGGCAAGCTAAATATAGGATATTCAAAGCAAAGATGGAAGAGT
AATTGGACAGACTGATATAAGTTTCAATGGGGGACACATAGAGGAGTGTCT
TGTTACCCCAATGAAGGGGAAGGTGGAATGCATATGCAGGGACAATTGGACTG
GAACAAATAGACCAATTCTGGTAATATCTTCTGATCTATCGTACACAGTTGGA
TATTTGTGTGCTGGCATTCCCCTGACACTCCTAGGGGAGAGGATAGTCAATT
CACAGGCTCATGTACAAGTCCTTTGGGAAATAAAGGATACGGTGTAAAAGGT
TTCGGGTTTCGACAAGGAACTGACGTATGGGCCGGAAGGACAATTAGTAGGA
CTTCAAGATCAGGATTCGAAATAATAAAAATCAGGAATGGTTGGACACAGAA
CAGTAAAGACCAAATCAGGAGGCAAGTGATTATCGATGACCCAAATTGGTCA
GGATATAGCGGTTCTTTCACATTGCCGTTGAACTAACAAAAAAGGGATGTT
TGGTCCCCTGTTTCTGGGTTGAAATGATTAGAGGTAAACCTGAAGAAACAAC
AATATGGACCTCTAGCAGCTCCATTGTGATGTGTGGAGTAGATCATAAAATT
GCCAGTTGGTCATGGCAGATGGAGCTATTCTTCCCTTTGACATCGATAAGAT
GTAA

SEQ ID NO:10

FIG. 1J

PBI

ATGGATGTCAATCCGACTCTACTTTTCTTAAAGGTGCCAGCGCAAAATGCTAT
AAGCACAAACATTTCTTATACTGGAGATCCTCCCTACAGTCATGGAACAGGG
ACAGGATACACCATGGATACTGTCAACAGAACACACCAATATTCAGAAAAAG
GGAAATGGACAACAAACTGAGATTGGAGCACCACAACCTTAATCCAATCGA
TGGACCACTTCTGAAGACAATGAACCAAGTGGGTACGCCCAAACAGATTGT
GTATTGGAAGCAATGGCTTTCTTGAAGAATCCCATCCCGGAATCTTTGAAAA
TTCTGTCTTGAACGATGGAGGTGATTCAGCAGACAAGAGTGGACAAACTA
ACACAAGGCCGACAACTTATGATTGGACCTTGAATAGGAATCAACCTGCCG
CAACAGCACTTGCTAATACGATTGAAGTATTCAGATCAAATGGTCTGACTTCC
AATGAATCGGGGAGATTGATGGACTTCTTCAAAGATGTCATGGAGTCCATGA
ACAAGGAAGAAATGGAAATAACAACACACTTCCAACGGAAGAGAAGAGTAA
GAGACAACATGACAAAGAGAATGGTAACACAGAGAACCATAGGGAAGAAAA
AACAAACGATTAAACAGAAAGAGCTATCTAATCAGAACATTAACCTAAACAC
AATGACCAAGGACGCTGAGAGAGGGAAATTGAAACGACGAGCAATCGCTAC
CCCAGGGATGCAGATAAGAGGGTTTGTATATTTTGTGAAACACTAGCCCGA
AGAATATGTGAAAAGCTTGAACAATCAGGATTGCCAGTTGGCGGTAATGAGA
AAAAGGCCAAACTGGCTAATGTCGTCAGAAAAATGATGACTAATCCCAAGA
CACTGAACTCTCTTACCATCACTGGGGACAATACCAAATGGAATGAAAAT
CAGAACCCACGCATATTCCTGGCAATGATCACATACATAACTAGAAACCAGC
CAGAAATGGTTCAGAAATGTTCTAAGCATTGCACCGATTATGTTCTCAAATAAA
ATGGCAAGACTGGGGAAAGGATATATGTTTGAAGCAAAAGTATGAAATTG
AGAACTCAAATACCAGCAGGAATGCTTGAAGCATTGACCTGAAATATTTCA
ATGATCCAACAAAAAGAAAATTGAAAAGATACGACCCTTCTGGTTGACGG
GACTGCTTCACTGAGTCCCTGGCATGATGATGGGAATGTTCAACATGTTGAGC
ACTGTGCTAGGTGTATCCATATTAACCTGGGCCAGAGGAAATACACAAAGA
CCACATACTGGTGGGATGGTCTGCAATCATCCGATGACTTTGCTTTGATAGTG
AATGCGCCTAATCATGAAGGAATACAAGCTGGAGTAGACAGATTCTATAGGA
CTTGCAAACCTGGTCCGGATCAACATGAGCAAAAAGAAAGTCTACATAAATAG
AACTGGAACATTTCGAATTCACAAGCTTTTCTACCGGTATGGTTTTGTAGCCA
ATTTGAGCATGGAACCTACCAGTTTTGGGGTTTTCCGGAATAAATGAATCTGCA
GACATGAGCATTGGAGTGACAGTCATCAAAAACAACATGATAAATAATGATC
TCGGTCTGCCACGGCACAAATGGCACTCCAACCTTTCATTAAGGATTATCGG
TACACATACCGGTGCCATAGAGGTGATACCCAGATACAAACCAGAAGATCTT
TTGAGTTGAAGAACTGTGGGAACAGACTCGATCAAAGACTGGTCTACTGGT
ATCAGATGGGGGTCCAAACCTATATAACATCAGAAACCTACACATCCCGGAA
GTCTGTTTAAAAATGGGAGCTAATGGATGAAGATTATAAGGGGAGGCTATGCA
ATCCATTGAATCCTTTTCGTTAGTCACAAAGAAATTGAATCAGTCAACAGTGCA
GTAGTAATGCCTGCGCATGGCCCTGCCAAAAGCATGGAGTATGATGCTGTTG
CAACAACACATTCTTGGATCCCCAAGAGGAACCGGTCCATATTGAACACAAG
CCAAAGGGGAATACTCGAAGATGAGCAGATGTATCAGAAATGCTGCAACCTG
TTGAAAAATTTCTTCCCCAGCAGCTCATACAGAAGACCAGTCCGGATTCTAG
TATGGTTGAGGCCATGGTGTCCAGGGCCCGCATTGATGCACGAATTGACTTC
GAATCTGGACGGATAAAGAAGGATGAGTTCGCTGAGATCATGAAGATCTGTT
CCACCATTGAAGAGCTCAGACGGCAAAAATAGTGA

SEQ ID NO:11

FIG. 1K

PB2

ATGGAGAGAATAAAAAGAACTGAGAGATCTGATGTTACAATCCCGCACCCGCG
AGATACTAACAAAACTACTGTGGACCACATGGCCATAATCAAGAAATACAC
ATCAGGAAGACAAGAGAAGAACCCTGCACTTAGGATGAAATGGATGATGGC
AATGAAATACCCAATTACAGCAGATAAGAGGATAATGGAGATGATTCTTGAG
AGAAATGAACAGGGACAAACCCTTTGGAGCAAAACGAACGATGCTGGCTCA
GACCGCGTAATGGTATCACCTCTGGCAGTGACATGGTGGAAATAGGAATGGAC
CAACAACAAGCACAAATTCATTATCCAAAAGTCTACAAAACCTATTTTAAAA
GGTTGAAAGATTGAAACACGGAACCTTTGGCCCCGTTTCATTTTAGGAATCAA
GTCAAGATAAGACGAAGAGTTGATGTAAACCCTGGTCACGCGGACCTCAGTG
CCAAAGAAGCACAAGATGTGATCATGGAAGTTGTTTTCCCAAATGAAGTGGG
AGCCAGAATTCTAACATCGGAATCACAACCTAACATAACCAAAGAGAAAAA
GGAAGAACTTCAGGACTGCAAAATTGCTCCCTTGATGGTAGCATAACATGCTA
GAAAGAGAGTTGGTCCGAAAAACAAGGTTCCCTCCAGTAGCAGGCGGAACA
AGCAGTGTATACATTGAAGTGTTCATCTGACTCAGGGAACATGCTGGGAGC
AAATGTACACCCCGAGGAGAGAAGTTAGAAAACGATGATATTGATCAAAGTTT
AATTATTGCAGCCCCGGAACATAGTGAGAAGAGCAACAGTATCAGCAGATCCA
CTAGCATCCCTACTGGAAATGTGCCACAGTACACAGATTGGTGGAAATAAGGA
TGGTAGACATCCTTAAGCAGAATCCAACAGAGGAACAAGCTGTGGATATATG
CAAAGCAGCAATGGGATTGAGAATTAGCTCATCATTGAGCTTTGGTGGATTG
ACCTTCAAGAGAACAAGTGGATCATCAGTCAAGAGAGAAGAAGAAATGCTT
ACGGGCAACCTTCAAACATTGAAAATAAGAGTGCATGAGGGCTATGAAGAAT
TCACAATGGTTCGGAAGAAGAGCAACAGCCATTCTCAGAAAGGCAACCAGAA
GATTGATTCAATTGATAGTAAGTGGGAGAGATGAACAGTCAATTGCTGAAGC
AATAATTGTAGCCATGGTGTTCGCAAGAAGATTGCATGATAAAAGCAGTT
CGAGGCGATTTGAACTTTGTTAATAGAGCAAATCAGCGCTTGAACCCCATGC
ATCAACTCTTGAGGCATTTCCAAAAGGATGCAAAAGTGCTTTTCCAAAATTG
GGGGATTGAACCCATCGACAATGTAATGGGAATGATTGGAATATTCCCTGAC
ATGACCCCAAGCACCCGAGATGTCATTGAGAGGAGTGAGAGTCAGCAAAATG
GGAGTGGATGAGTACTCCAGCACTGAGAGAGTGGTGGTGGAGCATTGACCGTT
TTTTAAGAGTTCGGGATCAAAGGGGAAACATACTACTGTCCCCTGAAGAAGT
CAGTGAACACAAGGAACGGAAAAGCTGACAATAATTTATTCGTCATCAATG
ATGTGGGAGATTAATGGTCCCGAATCAGTGTGGTCAATACTTATCAATGGAT
CATCAGGAACCTGGGAAATTGTAATAAATTCAGTGGTTCACAGGACCCCAATG
TTATAACAATAAGATAGAATTTGAGCCATTCCAATCCCTGGTCCCTAGGGCTAC
CAGAAGCCAATACAGCGGTTTCGTAAGAACCCTGTTTCAGCAAATGCGAGAT
GTACTTGGAACATTTGATACTGCTCAAATAATAAACTCCTCCCTTTTGCCGC
TGCTCCTCCGGAACAGAGTAGGATGCAGTTCCTCTTCTTTGACTGTTAATGTAA
GAGGTTCCGGGAATGAGGATACTTGTAAGAGGCAATTCCCCAGTGTTCAACTA
CAATAAAGCCACTAAAAGGCTCACAGTCCCTCGGAAAGGATGCAGGTGCGCTT
ACTGAGGACCCAGATGAAGGTACGGCTGGAGTAGAATCTGCTGTTCTAAGAG
GGTTTCTCATTTTAGGTAAGAAAATAAGAGATATGGCCCAGCACTAAGCAT
CAATGAACTAAGCAAACCTTGCAAAAGGGGAGAAAGCCAATGTACTAATTGG
GCAAGGGGACGTAGTGTGGTAATGAAACGGAAACGTGACTCTAGCATACTT
ACTGACAGCCAGACAGCGACCAAAAAGGATTCGGATGGCCATCAATTAGT

SEQ ID NO:12

FIG. 1L

PA

ATGGAAGACTTTGTGCGACAATGCTTCAATCCAATGATCGTCGAGCTTGCGG
AAAAGCCAATGAAAGAATATGGAGAGGACCCGAAAATCGAAAACAAACAAAT
TTGCAGCAATATGCCTCCTTGGAAAGTCTGCTTCATGTACTCGGATTTCCAC
TTTATTAATGAACTGAGTGAGTCAGTGGTCATAGAGTCTGGTGACCCAAATG
CTCTTTTGAACACAGATTTGAAATCATTGAGGGGAGAGATCGAACAATGGC
ATGGACAGTAGTAAACAGCATCTGCAACACCACAAGAGCTGAAAAACCTAA
ATTTCTTCCAGATTTATACGACTATAAGGAGAACAGATTTGTTGAAATTGGTG
TGACAAGGAGAGAAGTTCACATATACTACCTGGAGAAGGCCAACAAAATAA
AGTCTGAGAAAACACATATCCACATTTTCTCATTACAGGAGAGGAAATGGC
TACAAAAGCGGACTATACTCTTGATGAAGAGAGTAGAGCCAGGATCAAGACC
AGACTATTCATAAAGACAAGAAATGGCCAGTAGAGGCCTCTGGGATTCTT
TTCGTCAGTCCGAGAGAGGGCGAAGAGACAATTGAAGAAAGATTTGAAATCAC
AGGGACGATGCGCAAGCTTGCCAATTACAGTCTCCCACCGAACTTCTCCAGC
CTTGAAAATTTTAGAGTCTATGTGGATGGATTGGAACCGAACGGCTGCATTG
AGAGTAAGCTTTCTCAAATGTCCAAAGAAGTAAATGCCAGAATCGAACCAAT
TTCAAAGACAACACCCCGACCACTCAAATGCCAGGTGGTCCACCCTGCCAT
CAGCGATCTAAATTCCTGCTAATGGATGCTCTGAAACTGAGCATTGAGGACC
CAAGTCACGAGGGGAGAGGGGAATACCACTATATGATGCCATCAAATGCATGAA
AACTTTCTTTGGATGGAAAGAGCCCAGTATTGTTAAACCACATGAAAAGGGT
ATAAACCCGAACCTATCTCCAACTTGGAAAGCAAGTATTAGCAGAATTACAAG
ACCTTGAGAACGAAGAAAAGGACCCCAAGACCAAGAATATGAAAAAAACAA
GCCAATTGAAATGGGCACTTAGTGAAAATATGGCACCAGAGAAAGTGGATT
TGAGGATTGTAAGACATCAGTGATTTAAAACAGTATGACAGTGATGAGCCA
GAAACAAGGTCTCTTGCAAGTTGGATTCAAAGTGAGTTCAACAAAGCTTGTG
AACTGACAGATTCAAGCTGGATAGAGCTCGATGAAATTGGGGAGGATGTTGC
CCCAATAGAATACATTGCGAGCATGAGGAGAAATTATTTACTGCTGAGGTT
TCCCATTGTAGAGCAACAGAATATATAATGAAGGGAGTGTACATCAACACTG
CTCTACTCAATGCATCCTGTGCTGCGATGGATGAATTCCAATTAATTCCGATG
ATAAGTAAATGCAGGACCAAGAAGGGGAGAAGGAAGACAAATTTATATGGA
TTCATAGTAAAGGGGAAGGTCCCATTTAAGAAATGATACTGACGTGGTGAAC
TTGTAAGTATGGAATTTCTCTCACTGATCCAAGATTTGAGCCACACAAATGG
GAAAAATACTGCGTTCTAGAAATTTGGAGACATGCTTCTAAGAACTGCTGTAG
GTCAAGTGTCAAGACCCATGTTTTTGTATGTAAGGACAAATGGAACCTCTAA
AATTAAGTAAATGAAATGGGGAATGGAAATGAGGCGCTGCCTCCTTCAGTCTCTG
CAACAGATTGAAAGCATGATCGAAGCTGAGTCCTCAGTCAAAGAAAAGGAC
ATGACCAAAGAATTTTTTGGAGAACAATCAGAGACATGGCCTATAGGAGAGT
CCCCAAAGGAGTGGAAAGAGGGCTCAATCGGGAAGGTTTGCAGGACCTTATT
AGCAAAAATCTGTGTTTAAACAGTTTGTATGCATCTCCACAACCTGGAAGGGTTT
CAGCTGAATCTAGGAAATTAATTTCTCATTGTTTCAAGGCTCTTAGGGATAACCTG
GAACCTGGAACCTTTGATATTGGGGGGTTATATGAATCAATTGAGGAGTGCC
TGATTAATGATCCCTGGGTTTTGCTTAAATGCATCTTGGTTCAACTCCTTCCTTA
CACATGCACTGAAGTAGTTGTGGCAATGCTACTATTTGCTATCCATACTGTCC
AAAAAAGTACCTTGTCTTACT

SEQ ID NO:13

FIG. 1M

NP

ATGGCGTCTCAAGGCACCAAACGATCCTATGAACAGATGGAAACTGATGGGG
AACGCCAGAATGCAACTGAAATCAGAGCATCTGTCCGAAGGATGGTGGGAG
GAATCGGCCGGTTTTATGTTTCAGATGTGTACTGAGCTTAAACTAAACGACCAT
GAAGGGCCGGCTGATTCAGAACAGCATAACAATAGAAAGGATGGTACTTTCCG
CATTTCGACGAAAGAAGAAACAAGTATCTCGAGGAGCATCCCAGTGCTGGGA
AAGACCCTAAGAAAACAGGAGGCCCGATATACAGAAGGAAAGATGGGAAAT
GGATGAGGGAACCTCATCCTCCATGATAAAGAAGAAATCATGAGAATCTGGCG
TCAGGCCAACAAATGGTGAAGACGCTACTGCTGGTCTTACTCATATGATGATCT
GGCACTCCAATCTCAATGACACCACATAACAAAGAACAAGGGCTCTTGTTCG
GACTGGGATGGATCCCAGAATGTGCTCTCTGATGCAAGGCTCAACCCCTCCCA
CGGAGATCTGGAGCCGCTGGTGCTGCAGTAAAAGGTGTTGGAACAATGGTAA
TGGAACCTCATCAGAATGATCAAACCGCGGAATAAATGATCGGAATTTCTGGAG
AGGTGAAAATGGTTCGAAGAACCAGAATTGCTTATGAAAGAATGTGCAATATC
CTCAAAGGGAAATTTTCAGACAGCAGCACAAACGGGCTATGATGGACCAGGTG
AGGGAAGGCCGCAATCCTGGAAACGCTGAGATTGAGGATCTCATTTTCTTGG
CACGATCAGCACTTATTTTGAGAGGATCAGTAGCCATAAATCATGCCTACCT
GCCTGTGTTTATGGCCTTGCAGTAAACCAGTGGGTATGACTTTGAGAAGGAAG
GATACTCTCTGGTTGGAATTGATCCTTTCAAACTACTCCAGAACAGTCAAATT
TTCAGTCTAATCAGACCAAAGAAAACCCAGCACACAAGAGCCAGTTGGTGT
GGATGGCATGCCATTCTGCAGCATTGAGGACCTGAGAGTTTTAAATTTCAAT
AGAGGAACCAAAGTAATCCCAAGAGGACAGTTAACAACCAGAGGAGTTCAA
ATAGCTTCAAATGAAAACATGGAGACAATAGATTCTAGCACACTTGAACCTGA
GAAGCAAATATTGGGCAATAAGGACCAGAAGCGGAGGAAACACCAGTCAAC
AGAGAGCATCTGCAGGACAGATAAGTGTGCAACCTACTTTCTCAGTACAGAG
AAATCTTCCCTTTGAGAGAGCAACCATTATGGCTGCATTCACTGGTAACACTG
AAGGGAGGACTTCCGACATGAGAACGGAAATCATAAGGATGATGGAAAATG
CCAAATCAGAAGATGTGTCTTTCAGGGGCCGGGGAGTCTTCGAGCTCTCGGA
CGAAAAGGCAACGAACCCGATCGTGCCCTTCCCTTTCGACATGAGCAATGAAGGG
TCTTATTTCTTCGGAGACAATGCTGAGGAGTTTGACAGTTAAA

SEQ ID NO:14

FIG. 1N

M

ATGAGTCTTCTAACCAGGTCGAAACGTACGTTCTCTCTATCGTACCATCAGG
CCCCCTCAAAGCCGAGATCGCGCAGAGACTTGAAGATGTCTTTGCAGGGAAG
AACACCGATCTTGAGGCACTCATGGAATGGCTAAAGACAAGACCAATCCTGT
CACCTCTGACTAAAGGGATTTTAGGATTTGTATTCACGCTCACCGTGCCCAGT
GAGCGAGGACTGCAGCGTAGACGCTTTGTCCAAAATGCCCTTAGTGGAACG
GAGATCCAAACAACATGGACAGAGCAGTAAAACGTACAGGAAGCTTAAAA
GAGAAATAACATTCCATGGGGCAAAAGAGGTTGGCACTCAGCTATTCCACTGG
TGCACTAGCCAGCTGCATGGGACTCATATACAACAGAATGGGAACGTGTACA
ACCGAAGTGGCATTGGCCTGGTATGCGCCACATGTGAACAGATTGCTGATT
CCCAGCATCGGTCTCACAGGCAGATGGTGACAACAACCAACCCATTAATCAG
ACATGAAAACAGAATGGTATTAGCCAGTACCACGGCTAAAGCCATGGAACA
GATGGCAGGATCGAGTGAGCAGGCAGCAGAGGCCATGGAGGTTGCTAGTAG
GGCTAGGCAGATGGTACAGGCAATGAGAACCATTGGGACCCACCCTAGCTCC
AGTGCCGGTTTGAAAGATGATCTCCTTGAAAATTTACAGGCCTACCAGAAAC
GGATGGGAGTGCAAATGCAGCGATTCAAGTGATCCTCTCGTTATTGCAGCAA
GTATCATTGGGATCTTGCACTTGATATTGTGGATTCTTGATCGICTTTTCTTCA
AATTCATTTATCGTCGCCTTAAATACGGGTTGAAAAGAGGGCCTTCTACGGA
AGGAGTACCTGAGTCTATGAGGGAAGAATATCGGCAGGAACAGCAGAATGC
TGTGGATGTTGACGATGGTCATTTGTCAACATAGAGCTGGAGTAA

SEQ ID NO:15

FIG. 10

NS

ATGGATTCCAACACTGTGTCAAGCTTTCAGGTAGACTGTTTTCTTTGGCATGT
CCGCAAACGATTTCGCAGACCAAGAAGTGGGTGATGCCCCATTCCTTGACCGG
CTTCGCCGAGACCAGAAGTCCCTAAGGGGAAGAGGTAGCACTCTTGGTCTGG
ACATCGAAACAGCCACTCATGCAGGAAAGCAGATAGTGGAGCAGATTCTGG
AAAAGGAATCAGATGAGGCACCTTAAAATGACCATTGCCTCTGTTCTACTTC
ACGCTACTTAACTGACATGACTCTTGATGAGATGTCAAGAGACTGGTTCATGC
TCATGCCCAAGCAAAAAGTAAACAGGCTCCCTATGTATAAGAATGGACCAGGC
AATCATGGATAAGAACATCATACTTAAAGCAAACCTTGTAGTGTGATTTTCGAA
AGGCTGGAAACACTAATACTACTTAGAGCCTTCACCGAAGAAGGAGCAGTCG
TTGGCGAAATTCACCATTACCTTCTCTCCAGGACATACTAATGAGGATGTC
AAAATGCAATTGGGGTCCTCATCGGAGGACTTAAATGGAATGATAATACGG
TTAGAATCTCTGAAACTCTACAGAGATTTCGCTTGGAGAAGCAGTCATGAGAA
TGGGAGACCTTCATTCCCTTCAAAGCAGAAACGAAAAATGGAGAGAACAATT
AAGCCAAAAATTTGAAGAAATAAGATGGTTGATTGAAGAAGTGGCAGATAG
ATTGAAAAATACAGAAAATAGTTTTGAACAAATAACATTTATGCAAGCCTTA
CAACTATTGCTTGAAGTAGAACAAGAGATAAGAACTTCTCGTTTCAGCTTAT
TTAA

SEQ ID NO:16

FIG. 1P

M2amino

MSLLTEVETPTRNGWECKCSDSSDPLVIAASIIIGILHLILWILDRLFFKFIYRRLKY
GLKRGVSTEGVPEMREERYRQEQNAVDVDDGHEVNIELE

SEQ ID NO:17

FIG. 1Q

NS2amino

MDSNTVSSFQLMRMSKMQLGSSSEDLNGMIIRLESCLKLYRDSLGEAVMRMGDL
HSLQSRNEKWREQLSQKFEEIRWLIBVRHRLKNTENSFEQITFMQALQLLLEVE
QEIRTFSFQLI

SEQ ID NO:18

FIG. 1R

MKTTIILLILLTHWAYSQNPISGNNTATLCL A/Equine/WI/1/03
 MKTTIILLILLTHWAYSQNPISGNNTATLCL A/Equine/New York/99

GHHAVANGTLVKTISDDQIEVTNATELVQS A/Equine/WI/1/03
 GHHAVANGTLVKTISDDQIEVTNATELVQS A/Equine/New York/99

ISMKGKICNNSYRILDGRNCTFLIDAMLGDPH A/Equine/WI/1/03
 ISMKGKICNNSYRILDGRNCTFLIDAMLGDPH A/Equine/New York/99

CDAPQYENWDLFIERS S S A F S N C Y F Y D I P D Y A/Equine/WI/1/03
 CD[V]FQYENWDLFIERS S S A F S N C Y F Y D I P D Y A/Equine/New York/99

ASLRSIVASSGTLEFTAEGFTWTGVTQNGR A/Equine/WI/1/03
 ASLRSIVASSGTLEFTAEGFTWTGVTQNGR A/Equine/New York/99

SGACKRGSADSPFSRLNWLTKSGSSYPTLN A/Equine/WI/1/03
 SGACKRGSADSPFSRLNWLTKSG[N]SYPTLN A/Equine/New York/99

VTMPNNKNFDEKLYIWGIHHPSSNQEQTKLY A/Equine/WI/1/03
 VTMPNNKNFDEKLYIWGIHHPSSNQEQTKLY A/Equine/New York/99

IQESGRVTVSTKRSEQQTIIIPNIGSRPWVVG A/Equine/WI/1/03
 IQESGRVTVSTKRSEQQTIIIPNIGSRPWVVG A/Equine/New York/99

QSGRISIIYWTIVKPGDILMINSNGNLVAPR A/Equine/WI/1/03
 QSGRISIIYWTIVKPGDILMINSNGNLVAPR A/Equine/New York/99

GYFKLKTGKSSVMRSDVPIDICVSECITPN A/Equine/WI/1/03
 GYFKLKTGKSSVMRSD[A]PIDICVSECITPN A/Equine/New York/99

GSISNDKPFQNVNKV TYGKCPKYIRQNTLK A/Equine/WI/1/03
 GSISNDKPFQNVNKV TYGKCPKYIRQNTLK A/Equine/New York/99

LATGMRNVPEKQIR A/Equine/WI/1/03
 LATGMRNVPEKQIR A/Equine/New York/99

FIG. 2

H3 INFLUENZA A VIRUS**CROSS-REFERENCE TO RELATED APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 14/255,719, filed Apr. 17, 2014, which is a continuation of U.S. patent application Ser. No. 13/839,111, filed Mar. 15, 2013, which is a continuation of U.S. patent application Ser. No. 12/503,712, filed Jul. 15, 2009, which is a divisional of U.S. patent application Ser. No. 11/033,248, filed Jan. 11, 2005, which application is incorporated herein by reference.

STATEMENT OF GOVERNMENT RIGHTS

The invention was made, at least in part, with a grant from the Government of the United States of America (grant 2001-35204-10184 from the United States Department of Agriculture). The Government may have certain rights to the invention.

BACKGROUND

Influenza is a major respiratory disease in some mammals including horses and is responsible for substantial morbidity and economic losses each year. In addition, influenza virus infections can cause severe systemic disease in some avian species, leading to death. The segmented nature of the influenza virus genome allows for reassortment of segments during virus replication in cells infected with two or more influenza viruses. The reassortment of segments, combined with genetic mutation and drift, can give rise to a myriad of divergent strains of influenza virus over time. The new strains exhibit antigenic variation in their hemagglutinin (HA) and/or neuraminidase (NA) proteins, and in particular the gene coding for the HA protein has a high rate of variability. The predominant current practice for the prevention of flu is vaccination. Most commonly, whole virus vaccines are used. As the influenza HA protein is the major target antigen for the protective immune responses of a host to the virus and is highly variable, the isolation of influenza virus and the identification and characterization of the HA antigen in viruses associated with recent outbreaks is important for vaccine production. Based on prevalence and prediction, a vaccine is designed to stimulate a protective immune response against the predominant and expected influenza virus strains (Park et al., 2004).

There are three general types of influenza viruses, type A, Type B and Type C, which are defined by the absence of serological crossreactivity between their internal proteins. Influenza Type A viruses are further classified into subtypes based on antigenic and genetic differences of their glycoproteins, the HA and NA proteins. All the known HA and NA subtypes (H1 to H15 and N1 to N9) have been isolated from aquatic birds, which are thought to act as a natural reservoir for influenza. H7N7 and H3N8 Type A viruses are the most common causes of equine influenza, and those subtypes are generally incorporated into equine influenza vaccines.

Thus, there is a continuing need to isolate new influenza virus isolates, e.g., for vaccine production.

SUMMARY OF THE INVENTION

The invention provides isolated H3 equine derived influenza type A virus that was isolated from a foal that suc-

cumbed to a fatal pneumonia, which virus has characteristic substitutions at residues 78 and 159 of HA (numbering of positions is that in the mature protein which lacks a 15 amino acid signal peptide), i.e., the residue at position 78 of HA is not valine and the residue at position 159 is not asparagine. In one embodiment, the isolated H3 influenza A virus of the invention has a conservative substitution at residue 78, e.g., a valine to an alanine substitution, and a nonconservative substitution at residue 159, e.g., an asparagine to a serine substitution. In one embodiment, the isolated H3 influenza A virus of the invention has a residue other than methionine at position 29, e.g., a nonconservative substitution, a residue other than lysine at position 54, e.g., a nonconservative substitution, a residue other than serine at position 83, e.g., a nonconservative substitution, a residue other than asparagine at position 92, e.g., a nonconservative substitution, a residue other than leucine at position 222, e.g., a nonconservative substitution, a residue other than alanine at position 272, e.g., a conservative substitution, and/or a residue other than threonine at position 328, e.g., a conservative substitution. Conservative amino acid substitutions refer to the interchangeability of residues having similar side chains. For example, a group of amino acids having aliphatic side chains is glycine, alanine, valine, leucine, and isoleucine; a group of amino acids having aliphatic-hydroxyl side chains is serine and threonine; a group of amino acids having amide-containing side chains is asparagine and glutamine; a group of amino acids having aromatic side chains is phenylalanine, tyrosine and tryptophan; a group of amino acids having basic side chains is lysine, arginine and histidine; and a group of amino acids having sulfur-containing side chain is cysteine and methionine. In one embodiment, conservative amino acid substitution groups are: threonine-valine-leucine-isoleucine-alanine; phenylalanine-tyrosine; lysine-arginine; alanine-valine; glutamic-aspartic; and asparagine-glutamine.

In one embodiment, the influenza virus of the invention includes one or more viral proteins (polypeptides) having substantially the same amino acid sequence as one of SEQ ID NOs:1-8, 17 and/or 18, so long as the HA has the characteristic substitutions at residues 78 and 159. An amino acid sequence which is substantially the same as a reference sequence has at least 95%, e.g., 96%, 97%, 98% or 99%, amino acid sequence identity to that reference sequence, and may include sequences with deletions, e.g., those that result in a deleted viral protein having substantially the same activity or capable of being expressed at substantially the same level as the corresponding full-length, mature viral protein, insertions, e.g., those that result in a modified viral protein having substantially the same activity or capable of being expressed at substantially the same level as the corresponding full-length, mature viral protein, and/or substitutions, e.g., those that result in a viral protein having substantially the same activity or capable of being expressed at substantially the same level as the reference protein. In one embodiment, the one or more residues which are not identical to those in the reference sequence may be conservative or nonconservative substitutions which one or more substitutions do not substantially alter the expressed level or activity of the protein with the substitution(s), and/or the level of virus obtained from a cell infected with a virus having that protein. As used herein, "substantially the same expressed level or activity" includes a detectable protein level that is about 80%, 90% or more, the protein level, or a measurable activity that is about 30%, 50%, 90%, e.g., up to 100% or more, the activity, of a full-length mature polypeptide corresponding to one of SEQ ID NOs:1-8, 17 or

18. In one embodiment, the virus comprises a polypeptide with one or more, for instance, 2, 5, 10, 15, 20 or more, amino acid substitutions, e.g., conservative substitutions of up to 5% of the residues of the full-length, mature form of a polypeptide having SEQ ID NOs:1-8, 17 or 18. The isolated virus of the invention may be employed alone or with one or more other virus isolates, e.g., other influenza virus isolates, in a vaccine, to raise virus-specific antisera, in gene therapy, and/or in diagnostics. Accordingly, the invention provides host cells infected with the virus of the invention, and isolated antibody specific for the virus.

The invention also provides an isolated nucleic acid molecule (polynucleotide) comprising a nucleic acid segment corresponding to at least one of the proteins of the virus of the invention, a portion of the nucleic acid segment for a viral protein having substantially the same level or activity as a corresponding polypeptide encoded by one of SEQ ID NOs:1-8, 17 or 18, or the complement of the nucleic acid molecule. In one embodiment, the isolated nucleic acid molecule encodes a polypeptide which has substantially the same amino acid sequence, e.g., has at least 95%, e.g., 96%, 97%, 98% or 99%, contiguous amino acid sequence identity to a polypeptide having one of SEQ ID NOs:1-8, 17 or 18. In one embodiment, the isolated nucleic acid molecule comprises a nucleotide sequence which is substantially the same as, e.g., has at least 50%, e.g., 60%, 70%, 80% or 90% or more, contiguous nucleic acid sequence identity to, one of SEQ ID NOs:9-16, or the complement thereof, and encodes a polypeptide having at least 95%, e.g., 96%, 97%, 98% or 99%, contiguous amino acid sequence identity to a polypeptide having one of SEQ ID NOs:1-8, 17 or 18.

The isolated nucleic acid molecule of the invention may be employed in a vector to express influenza proteins, e.g., for recombinant protein vaccine production or to raise antisera, as a nucleic acid vaccine, for use in diagnostics or for vRNA production, to prepare chimeric genes, e.g., with other viral genes including other influenza virus genes, and/or to prepare recombinant virus, e.g., see Neumann et al. (1999) which is incorporated by reference herein. Thus, the invention also provides isolated viral polypeptides, recombinant virus, and host cells contacted with the nucleic acid molecule(s) and/or recombinant virus of the invention, as well as isolated virus-specific antibodies, for instance, obtained from mammals infected with the virus or immunized with an isolated viral polypeptide or polynucleotide encoding one or more viral polypeptides.

The invention further provides at least one of the following isolated vectors, for instance, one or more isolated influenza virus vectors, or a composition comprising the one or more vectors: a vector comprising a promoter operably linked to an influenza virus PA DNA for a PA having substantially the same amino acid sequence as SEQ ID NO:5 linked to a transcription termination sequence, a vector comprising a promoter operably linked to an influenza virus PB1 DNA for a PB1 having substantially the same amino acid sequence as SEQ ID NO:3 linked to a transcription termination sequence, a vector comprising a promoter operably linked to an influenza virus PB2 DNA for a PB2 having substantially the same amino acid sequence as SEQ ID NO:4 linked to a transcription termination sequence, a vector comprising a promoter operably linked to an influenza virus HA DNA for a HA having substantially the same amino acid sequence as SEQ ID NO:1 linked to a transcription termination sequence, a vector comprising a promoter operably linked to an influenza virus NP DNA for a NP having substantially the same amino acid sequence as SEQ ID NO:6 linked to a transcription termination sequence, a vector

comprising a promoter operably linked to an influenza virus NA DNA for a NA having substantially the same amino acid sequence as SEQ ID NO:2 linked to a transcription termination sequence, a vector comprising a promoter operably linked to an influenza virus M DNA for a M having substantially the same amino acid sequence as SEQ ID NO:7 (M1) and/or SEQ ID NO:17 (M2), linked to a transcription termination sequence, and/or a vector comprising a promoter operably linked to an influenza virus NS DNA for a NS having substantially the same amino acid sequence as SEQ ID NO:8 (NS1) and/or SEQ ID NO:18 (NS2), linked to a transcription termination sequence. Optionally, two vectors may be employed in place of the vector comprising a promoter operably linked to an influenza virus M DNA linked to a transcription termination sequence, e.g., a vector comprising a promoter operably linked to an influenza virus M1 DNA linked to a transcription termination sequence and a vector comprising a promoter operably linked to an influenza virus M2 DNA linked to a transcription termination sequence. Optionally, two vectors may be employed in place of the vector comprising a promoter operably linked to an influenza virus NS DNA linked to a transcription termination sequence, e.g., a vector comprising a promoter operably linked to an influenza virus NS1 DNA linked to a transcription termination sequence and a vector comprising a promoter operably linked to an influenza virus NS2 DNA linked to a transcription termination sequence. An influenza virus vector is one which includes at least 5' and 3' noncoding influenza virus sequences.

Hence, the invention provides vectors, e.g., plasmids, which encode influenza virus proteins, and/or encode influenza vRNA, both native and recombinant vRNA. Thus, a vector of the invention may encode an influenza virus protein (sense) or vRNA (antisense). Any suitable promoter or transcription termination sequence may be employed to express a protein or peptide, e.g., a viral protein or peptide, a protein or peptide of a nonviral pathogen, or a therapeutic protein or peptide. In one embodiment, to express vRNA, the promoter is a RNA polymerase I promoter, a RNA polymerase II promoter, a RNA polymerase III promoter, a T3 promoter or a T7 promoter. Optionally the vector comprises a transcription termination sequence such as a RNA polymerase I transcription termination sequence, a RNA polymerase II transcription termination sequence, a RNA polymerase III transcription termination sequence, or a ribozyme.

A composition of the invention may also comprise a gene or open reading frame of interest, e.g., a foreign gene encoding an immunogenic peptide or protein useful as a vaccine. Thus, another embodiment of the invention comprises a composition of the invention as described above in which one of the influenza virus genes in the vectors is replaced with a foreign gene, or the composition further comprises, in addition to all the influenza virus genes, a vector comprising a promoter linked to 5' influenza virus sequences linked to a desired nucleic acid sequence, e.g., a cDNA of interest, linked to 3' influenza virus sequences linked to a transcription termination sequence, which, when contacted with a host cell permissive for influenza virus replication optionally results in recombinant virus. In one embodiment, the DNA of interest is in an antisense orientation. The DNA of interest, whether in a vector for vRNA or protein production, may encode an immunogenic epitope, such as an epitope useful in a cancer therapy or vaccine, or a peptide or polypeptide useful in gene therapy.

A plurality of the vectors of the invention may be physically linked or each vector may be present on an individual plasmid or other, e.g., linear, nucleic acid delivery vehicle.

The invention also provides a method to prepare influenza virus. The method comprises contacting a cell, e.g., an avian or a mammalian cell, with the isolated virus of the invention or a plurality of the vectors of the invention, e.g., sequentially or simultaneously, for example, employing a composition comprising a plurality of the vectors, in an amount effective to yield infectious influenza virus. The invention also includes isolating virus from a cell infected with the virus or contacted with the vectors and/or composition. The invention further provides a host cell infected with the virus of the invention or contacted with the composition or vectors of the invention. In one embodiment, a host cell is infected with an attenuated (e.g., cold adapted) donor virus and a virus of the invention to prepare a cold-adapted reassortant virus useful as a cold-adapted live virus vaccine.

The invention also provides a method to induce an immune response in a mammal, e.g., to immunize a mammal, against one more pathogens, e.g., against a virus of the invention and optionally a bacteria, a different virus, or a parasite or other antigen. An immunological response to a composition or vaccine is the development in the host organism of a cellular and/or antibody-mediated immune response to a viral polypeptide, e.g., an administered viral preparation, polypeptide or one encoded by an administered nucleic acid molecule, which can prevent or inhibit infection to that virus or a closely (structurally) related virus. Usually, such a response consists of the subject producing antibodies, B cell, helper T cells, suppressor T cells, and/or cytotoxic T cells directed specifically to an antigen or antigens included in the composition or vaccine of interest. The method includes administering to the host organism, e.g., a mammal, an effective amount of the influenza virus of the invention, e.g., an attenuated, live virus, optionally in combination with an adjuvant and/or a carrier, e.g., in an amount effective to prevent or ameliorate infection of an animal such as a mammal by that virus or an antigenically closely related virus. In one embodiment, the virus is administered intramuscularly while in another embodiment, the virus is administered intranasally. In some dosing protocols, all doses may be administered intramuscularly or intranasally, while in others a combination of intramuscular and intranasal administration is employed. The vaccine may further contain other isolates of influenza virus including recombinant influenza virus, other pathogen(s), additional biological agents or microbial components, e.g., to form a multivalent vaccine. In one embodiment, intranasal vaccination with inactivated equine influenza virus and a mucosal adjuvant, e.g., the non-toxic B chain of cholera toxin, may induce virus-specific IgA and neutralizing antibody in the nasopharynx as well as serum IgG.

The equine influenza vaccine may employed with other anti-virals, e.g., amantadine, rimantadine, and/or neuraminidase inhibitors, e.g., may be administered separately in conjunction with those anti-virals, for instance, administered before, during and/or after.

Further provided is a diagnostic method which employs a virus of the invention, an isolated viral protein encoded thereby, or antisera specific for the virus or protein, to detect viral specific antibodies or viral specific proteins.

BRIEF DESCRIPTION OF THE FIGURES

FIGS. 1A-1R. Sequences of A/Equine/Wisconsin/1/03. SEQ ID NOs:1-8, 17 and 18 represent the deduced amino

acid sequence for HA, NA, PB1, PB2, PA, NP, M1, NS1, M2, and NS2, respectively, of A/Equine/Wisconsin/1/03. SEQ ID NOs:9-16 represent the mRNA sense nucleotide sequence for HA, NA, PB1, PB2, PA, NP, M (M1 and M2) and NS (NS1 and NS2), respectively, of A/Equine/Wisconsin/1/03.

FIG. 2. Sequence alignment of HA-1 of A/Equine/NewYork/99 (SEQ ID NO: 19) and A/Equine/Wisconsin/1/03 (SEQ ID NO:20).

DETAILED DESCRIPTION OF THE INVENTION

Definitions

As used herein, the term "isolated" refers to in vitro preparation and/or isolation of a nucleic acid molecule, e.g., vector or plasmid, peptide or polypeptide (protein), or virus of the invention, so that it is not associated with in vivo substances, or is substantially purified from in vitro substances. An isolated virus preparation is generally obtained by in vitro culture and propagation, and is substantially free from other infectious agents.

As used herein, "substantially purified" means the object species is the predominant species, e.g., on a molar basis it is more abundant than any other individual species in a composition, and preferably is at least about 80% of the species present, and optionally 90% or greater, e.g., 95%, 98%, 99% or more, of the species present in the composition.

As used herein, "substantially free" means below the level of detection for a particular infectious agent using standard detection methods for that agent.

A "recombinant" virus is one which has been manipulated in vitro, e.g., using recombinant DNA techniques, to introduce changes to the viral genome.

As used herein, the term "recombinant nucleic acid" or "recombinant DNA sequence or segment" refers to a nucleic acid, e.g., to DNA, that has been derived or isolated from a source, that may be subsequently chemically altered in vitro, so that its sequence is not naturally occurring, or corresponds to naturally occurring sequences that are not positioned as they would be positioned in the native genome. An example of DNA "derived" from a source, would be a DNA sequence that is identified as a useful fragment, and which is then chemically synthesized in essentially pure form. An example of such DNA "isolated" from a source would be a useful DNA sequence that is excised or removed from said source by chemical means, e.g., by the use of restriction endonucleases, so that it can be further manipulated, e.g., amplified, for use in the invention, by the methodology of genetic engineering.

Influenza Virus Type A Structure and Propagation

Influenza A viruses possess a genome of eight single-stranded negative-sense viral RNAs (vRNAs) that encode at least ten proteins. The influenza virus life cycle begins with binding of the hemagglutinin (HA) to sialic acid-containing receptors on the surface of the host cell, followed by receptor-mediated endocytosis. The low pH in late endosomes triggers a conformational shift in the HA, thereby exposing the N-terminus of the HA2 subunit (the so-called fusion peptide). The fusion peptide initiates the fusion of the viral and endosomal membrane, and the matrix protein (M1) and RNP complexes are released into the cytoplasm. RNPs consist of the nucleoprotein (NP), which encapsidates vRNA, and the viral polymerase complex, which is formed by the PA, PB1, and PB2 proteins. RNPs are transported into

the nucleus, where transcription and replication take place. The RNA polymerase complex catalyzes three different reactions: synthesis of an mRNA with a 5' cap and 3' polyA structure, of a full-length complementary RNA (cRNA), and of genomic vRNA using the cRNA as a template. Newly synthesized vRNAs, NP, and polymerase proteins are then assembled into RNPs, exported from the nucleus, and transported to the plasma membrane, where budding of progeny virus particles occurs. The neuraminidase (NA) protein plays a crucial role late in infection by removing sialic acid from sialyloligosaccharides, thus releasing newly assembled virions from the cell surface and preventing the self aggregation of virus particles. Although virus assembly involves protein-protein and protein-vRNA interactions, the nature of these interactions is largely unknown.

Any cell, e.g., any avian or mammalian cell, such as a human, canine, bovine, equine, feline, swine, ovine, mink, e.g., MvLu1 cells, or non-human primate cell, including mutant cells, which supports efficient replication of influenza virus can be employed to isolate and/or propagate influenza viruses. Isolated viruses can be used to prepare a reassortant virus, e.g., an attenuated virus. In one embodiment, host cells for vaccine production are those found in avian eggs. In another embodiment, host cells for vaccine production are continuous mammalian or avian cell lines or cell strains. It is preferred to establish a complete characterization of the cells to be used, so that appropriate tests for purity of the final product can be included. Data that can be used for the characterization of a cell includes (a) information on its origin, derivation, and passage history; (b) information on its growth and morphological characteristics; (c) results of tests of adventitious agents; (d) distinguishing features, such as biochemical, immunological, and cytogenetic patterns which allow the cells to be clearly recognized among other cell lines; and (e) results of tests for tumorigenicity. Preferably, the passage level, or population doubling, of the host cell used is as low as possible.

It is preferred that the virus produced by the host cell is highly purified prior to vaccine or gene therapy formulation. Generally, the purification procedures result in the extensive removal of cellular DNA, other cellular components, and adventitious agents. Procedures that extensively degrade or denature DNA can also be used.

Equine Influenza Virus Detection

Disease causing equine influenza viruses are generally Type A influenza viruses of the H7N7 (equi-1) and H3N8 (equi-2) subtypes. These generally differ from the subtypes that cause infection in man (H1N1, H2N2 and H3N2). Equine influenza is contracted by either inhalation or contact with secretions (e.g., physiological fluid) containing live virus. The virus infects the epithelial cells of the upper and lower airways and can cause deciliation of large areas of the respiratory tract within 4 to 6 days. As a result, the mucociliary clearance mechanism is compromised and tracheal clearance rates may be reduced for up to 32 days following infection. Bronchitis and bronchiolitis develop followed by interstitial pneumonia accompanied by congestion, edema and leukocyte infiltration. In general, H3N8 viruses cause more severe disease than H7N7 viruses; viruses of the H3N8 subtype are more pneumotropic and have also been associated with myocarditis.

Clinical signs in previously influenza-naïve animals are easily recognizable. Influenza is characterized by its sudden onset with an incubation period of 1 to 3 days. The first sign is an elevation of body temperature (up to 41° C.), which is usually biphasic. This is followed by a deep dry cough that releases large quantities of virus into the atmosphere often

accompanied by a serous nasal discharge, which may become mucopurulent due to secondary bacterial infection. The other most commonly observed clinical signs are myalgia, inappetance, and enlarged submandibular lymph nodes. Edema of the legs and scrotum is observed very rarely. The severity of the disease varies with the dose and strain of virus and the immune status of the horse.

Previously healthy, immunocompetent adult horses usually recover from uncomplicated influenza within 10 days, although coughing may persist for longer. If secondary bacterial infection occurs, it can prolong the recovery period. However, relatively high mortality rates have been recorded in foals, animals in poor condition and donkeys. If maternal antibody is absent at the time of exposure, young foals may develop a viral pneumonia leading to death. Deaths among adult animals are usually a consequence of secondary bacterial infection leading to pleuritis, suppurative pneumonia or rarely, purpura haemorrhagica. Sequelae of equine influenza can include chronic pharyngitis, chronic bronchiolitis, myocarditis, and alveolar emphysema, which can contribute to heaves, and secondary sinus and guttural pouch infections.

Clinical signs in animals partially immune as a result of vaccination or previous infection are more difficult to recognize as there may be little or no coughing or pyrexia. Whereas spread of infection throughout a group of naïve animals is always rapid, there have been outbreaks in which the infection circulated subclinically in vaccinated horses for 18 days before inducing recognizable clinical signs.

Outbreaks of infectious respiratory disease may be caused by various agents, including equine herpes viruses, rhinoviruses, adenoviruses, and arteritis viruses, *Streptococcus equi*, or *S. zooepidemicus*. A presumptive diagnosis of influenza based on clinical signs should be confirmed by virus isolation or detection, or by serological testing. Laboratory confirmation of a clinical diagnosis may be by traditional isolation of virus from nasopharyngeal swabs or serology to demonstrate seroconversion, or by rapid diagnostic tests which detect the presence of viral antigens, viral nucleic acid, or virally infected cells in respiratory secretions. Rapid diagnostic tests, despite their convenience and ease of use, provide little or no information about genetic or antigenic characteristics of the infecting strain of virus and do not allow isolation of the virus.

Nasopharyngeal swabs for virus isolation or detection should be taken as promptly as possible. Results of experimental challenge studies suggest that peak viral titers are obtained during the initial 24 to 48 hours of fever, on the second or third day after infection, and the duration of viral shedding is usually not more than 4 or 5 days. Nasal swab samples are taken by passing a swab as far as possible into the horse's nasopharynx via the ventral meatus to absorb respiratory secretions. Swabs should be transferred immediately to a container with virus transport medium and transported on ice to maintain viability of the virus. Virus is unlikely to survive if dry swabs are taken and there is an increased chance of contamination if bacterial transport medium is used. Nasal swab samples may be inoculated into the allantoic (or amniotic) cavity of 9- to 11-day-old embryonated hens' eggs. After incubation at 33-35° C. for 3 days, the allantoic fluid is harvested and tested for haemagglutinating activity. Alternatively, cell culture may be used to isolate viruses. Influenza infection can also be diagnosed by comparison of the results of serological testing of an acute serum sample taken as soon as possible after the onset of clinical signs and a convalescent serum sample taken 2 to 4 weeks later.

The haemagglutination inhibition (HI) test measures the capacity of influenza-specific antibody present in serum samples to inhibit the agglutination of red blood cells by virus. Sera are heat-inactivated and pre-treated to reduce non-specific reactions and serially diluted prior to incubation with a standard dose of virus in a U-bottomed microtiter plate. A suspension of red blood cells is added and, after a further incubation period, examined for agglutination. A four-fold rise in virus-specific antibodies indicates infection. Whole virus antigen may be used for H7N7 viruses, but Tween 80-ether disrupted antigen is usually required to enhance the sensitivity of the assay for H3N8 viruses. In repeatedly vaccinated horses, infection may fail to stimulate a 4-fold increase in HI titer.

The single-radial haemolysis (SRH) test, although less strain-specific, is more reproducible and less error prone than the HI test and, as it is a linear test, is more sensitive, enabling detection of smaller increases in antibody induced by infection in heavily vaccinated horses. The SRH test is based on the ability of influenza-specific antibodies to lyse virus-coated red blood cells in the presence of complement. Test sera are added to wells punched in agarose containing coated red blood cells and complement and allowed to diffuse through the agarose for 20 hours. The areas of clear zones of haemolysis around the wells are proportional to the level of influenza antibody present in the serum samples.

If horses are vaccinated in the face of infection, it may not be possible, using the HI and SRH assays, to determine whether any increase in antibody levels is due to vaccination or infection.

Influenza Vaccines

A vaccine of the invention includes an isolated influenza virus of the invention, and optionally one or more other isolated viruses including other isolated influenza viruses, West Nile virus, equine herpes virus, equine arteritis virus, equine infectious anemia lentivirus, rabies virus, Eastern and/or Western and/or Venezuelan equine encephalitis virus, one or more immunogenic proteins or glycoproteins of one or more isolated influenza viruses or one or more other pathogens, e.g., an immunogenic protein from one or more bacteria, non-influenza viruses, yeast or fungi, or isolated nucleic acid encoding one or more viral proteins (e.g., DNA vaccines) including one or more immunogenic proteins of the isolated influenza virus of the invention. In one embodiment, the influenza viruses of the invention may be vaccine vectors for influenza virus or other pathogens.

A complete virion vaccine may be concentrated by ultrafiltration and then purified by zonal centrifugation or by chromatography. It is inactivated before or after purification using formalin or beta-propiolactone, for instance.

A subunit vaccine comprises purified glycoproteins. Such a vaccine may be prepared as follows: using viral suspensions fragmented by treatment with detergent, the surface antigens are purified, by ultracentrifugation for example. The subunit vaccines thus contain mainly HA protein, and also NA. The detergent used may be cationic detergent for example, such as hexadecyl trimethyl ammonium bromide (Bachmeyer, 1975), an anionic detergent such as ammonium deoxycholate (Laver & Webster, 1976); or a nonionic detergent such as that commercialized under the name TRITON X100. The hemagglutinin may also be isolated after treatment of the virions with a protease such as bromelain, then purified by a method such as that described by Grand and Skehel (1972).

A split vaccine comprises virions which have been subjected to treatment with agents that dissolve lipids. A split vaccine can be prepared as follows: an aqueous suspension

of the purified virus obtained as above, inactivated or not, is treated, under stirring, by lipid solvents such as ethyl ether or chloroform, associated with detergents. The dissolution of the viral envelope lipids results in fragmentation of the viral particles. The aqueous phase is recuperated containing the split vaccine, constituted mainly of hemagglutinin and neuraminidase with their original lipid environment removed, and the core or its degradation products. Then the residual infectious particles are inactivated if this has not already been done.

Inactivated Vaccines.

Inactivated influenza virus vaccines are provided by inactivating replicated virus using known methods, such as, but not limited to, formalin or β -propiolactone treatment. Inactivated vaccine types that can be used in the invention can include whole-virus (WV) vaccines or subvirion (SV) (split) vaccines. The WV vaccine contains intact, inactivated virus, while the SV vaccine contains purified virus disrupted with detergents that solubilize the lipid-containing viral envelope, followed by chemical inactivation of residual virus.

In addition, vaccines that can be used include those containing the isolated HA and NA surface proteins, which are referred to as surface antigen or subunit vaccines.

Live Attenuated Virus Vaccines.

Live, attenuated influenza virus vaccines can be used for preventing or treating influenza virus infection. Attenuation may be achieved in a single step by transfer of attenuated genes from an attenuated donor virus to a replicated isolate or reassorted virus according to known methods (see, e.g., Murphy, 1993). Since resistance to influenza A virus is mediated primarily by the development of an immune response to the HA and/or NA glycoproteins, the genes coding for these surface antigens must come from the reassorted viruses or clinical isolates. The attenuated genes are derived from the attenuated parent. In this approach, genes that confer attenuation preferably do not code for the HA and NA glycoproteins.

Viruses (donor influenza viruses) are available that are capable of reproducibly attenuating influenza viruses, e.g., a cold adapted (ca) donor virus can be used for attenuated vaccine production. Live, attenuated reassortant virus vaccines can be generated by mating the ca donor virus with a virulent replicated virus. Reassortant progeny are then selected at 25° C., (restrictive for replication of virulent virus), in the presence of an appropriate antiserum, which inhibits replication of the viruses bearing the surface antigens of the attenuated ca donor virus. Useful reassortants are: (a) infectious, (b) attenuated for seronegative non-adult mammals and immunologically primed adult mammals, (c) immunogenic and (d) genetically stable. The immunogenicity of the ca reassortants parallels their level of replication. Thus, the acquisition of the six transferable genes of the ca donor virus by new wild-type viruses has reproducibly attenuated these viruses for use in vaccinating susceptible mammals both adults and non-adult.

Other attenuating mutations can be introduced into influenza virus genes by site-directed mutagenesis to rescue infectious viruses bearing these mutant genes. Attenuating mutations can be introduced into non-coding regions of the genome, as well as into coding regions. Such attenuating mutations can also be introduced into genes other than the HA or NA, e.g., the PB2 polymerase gene (Subbarao et al., 1993). Thus, new donor viruses can also be generated bearing attenuating mutations introduced by site-directed mutagenesis, and such new donor viruses can be used in the production of live attenuated reassortants vaccine candidates in a manner analogous to that described above for the ca

donor virus. Similarly, other known and suitable attenuated donor strains can be reassorted with influenza virus to obtain attenuated vaccines suitable for use in the vaccination of mammals (Enami et al., 1990; Muster et al., 1991; Subbarao et al., 1993).

It is preferred that such attenuated viruses maintain the genes from the virus that encode antigenic determinants substantially similar to those of the original clinical isolates. This is because the purpose of the attenuated vaccine is to provide substantially the same antigenicity as the original clinical isolate of the virus, while at the same time lacking pathogenicity to the degree that the vaccine causes minimal chance of inducing a serious disease condition in the vaccinated mammal.

The virus can thus be attenuated or inactivated, formulated and administered, according to known methods, as a vaccine to induce an immune response in an animal, e.g., a mammal. Methods are well-known in the art for determining whether such attenuated or inactivated vaccines have maintained similar antigenicity to that of the clinical isolate or high growth strain derived therefrom. Such known methods include the use of antisera or antibodies to eliminate viruses expressing antigenic determinants of the donor virus; chemical selection (e.g., amantadine or rimantidine); HA and NA activity and inhibition; and nucleic acid screening (such as probe hybridization or PCR) to confirm that donor genes encoding the antigenic determinants (e.g., HA or NA genes) are not present in the attenuated viruses. See, e.g., Robertson et al., 1988; Kilbourne, 1969; Aymard-Henry et al., 1985; Robertson et al., 1992.

Pharmaceutical Compositions

Pharmaceutical compositions of the present invention, suitable for inoculation, e.g., nasal, parenteral or oral administration, comprise one or more influenza virus isolates, e.g., one or more attenuated or inactivated influenza viruses, a subunit thereof, isolated protein(s) thereof, and/or isolated nucleic acid encoding one or more proteins thereof, optionally further comprising sterile aqueous or non-aqueous solutions, suspensions, and emulsions. The compositions can further comprise auxiliary agents or excipients, as known in the art. See, e.g., Berkow et al., 1987; *Avery's Drug Treatment*, 1987; Osol, 1980. The composition of the invention is generally presented in the form of individual doses (unit doses).

Conventional vaccines generally contain about 0.1 to 200 µg, e.g., 30 to 100 µg, of HA from each of the strains entering into their composition. The vaccine forming the main constituent of the vaccine composition of the invention may comprise a single influenza virus, or a combination of influenza viruses, for example, at least two or three influenza viruses, including one or more reassortant(s).

Preparations for parenteral administration include sterile aqueous or non-aqueous solutions, suspensions, and/or emulsions, which may contain auxiliary agents or excipients known in the art. Examples of non-aqueous solvents are propylene glycol, polyethylene glycol, vegetable oils such as olive oil, and injectable organic esters such as ethyl oleate. Carriers or occlusive dressings can be used to increase skin permeability and enhance antigen absorption. Liquid dosage forms for oral administration may generally comprise a liposome solution containing the liquid dosage form. Suitable forms for suspending liposomes include emulsions, suspensions, solutions, syrups, and elixirs containing inert diluents commonly used in the art, such as purified water. Besides the inert diluents, such compositions can also include adjuvants, wetting agents, emulsifying and suspend-

ing agents, or sweetening, flavoring, or perfuming agents. See, e.g., Berkow et al., 1992; Avery's, 1987; and Osol, 1980.

When a composition of the present invention is used for administration to an individual, it can further comprise salts, buffers, adjuvants, or other substances which are desirable for improving the efficacy of the composition. For vaccines, adjuvants, substances which can augment a specific immune response, can be used. Normally, the adjuvant and the composition are mixed prior to presentation to the immune system, or presented separately, but into the same site of the organism being immunized. Examples of materials suitable for use in vaccine compositions are provided in Osol (1980).

Heterogeneity in a vaccine may be provided by mixing replicated influenza viruses for at least two influenza virus strains, such as 2-20 strains or any range or value therein. Influenza A virus strains having a modern antigenic composition are preferred. Vaccines can be provided for variations in a single strain of an influenza virus, using techniques known in the art.

A pharmaceutical composition according to the present invention may further or additionally comprise at least one chemotherapeutic compound, for example, for gene therapy, immunosuppressants, anti-inflammatory agents or immune enhancers, and for vaccines, chemotherapeutics including, but not limited to, gamma globulin, amantadine, guanidine, hydroxybenzimidazole, interferon- α , interferon- β , interferon- γ , tumor necrosis factor-alpha, thio semicarbazones, methisazone, rifampin, ribavirin, a pyrimidine analog, a purine analog, foscarnet, phosphonoacetic acid, acyclovir, dideoxynucleosides, a protease inhibitor, or ganciclovir.

The composition can also contain variable but small quantities of endotoxin-free formaldehyde, and preservatives, which have been found safe and not contributing to undesirable effects in the organism to which the composition is administered.

Pharmaceutical Purposes

The administration of the composition (or the antisera that it elicits) may be for either a "prophylactic" or "therapeutic" purpose. When provided prophylactically, the compositions of the invention which are vaccines are provided before any symptom or clinical sign of a pathogen infection becomes manifest. The prophylactic administration of the composition serves to prevent or attenuate any subsequent infection. When provided prophylactically, the gene therapy compositions of the invention, are provided before any symptom or clinical sign of a disease becomes manifest. The prophylactic administration of the composition serves to prevent or attenuate one or more symptoms or clinical signs associated with the disease.

When provided therapeutically, an attenuated or inactivated viral vaccine is provided upon the detection of a symptom or clinical sign of actual infection. The therapeutic administration of the compound(s) serves to attenuate any actual infection. See, e.g., Berkow et al., 1992; and Avery, 1987. When provided therapeutically, a gene therapy composition is provided upon the detection of a symptom or clinical sign of the disease. The therapeutic administration of the compound(s) serves to attenuate a symptom or clinical sign of that disease.

Thus, an attenuated or inactivated vaccine composition of the present invention may be provided either before the onset of infection (so as to prevent or attenuate an anticipated infection) or after the initiation of an actual infection. Similarly, for gene therapy, the composition may be pro-

vided before any symptom or clinical sign of a disorder or disease is manifested or after one or more symptoms are detected.

A composition is said to be "pharmacologically acceptable" if its administration can be tolerated by a recipient mammal. Such an agent is said to be administered in a "therapeutically effective amount" if the amount administered is physiologically significant. A composition of the present invention is physiologically significant if its presence results in a detectable change in the physiology of a recipient patient, e.g., enhances at least one primary or secondary humoral or cellular immune response against at least one strain of an infectious influenza virus.

The "protection" provided need not be absolute, i.e., the influenza infection need not be totally prevented or eradicated, if there is a statistically significant improvement compared with a control population or set of mammals. Protection may be limited to mitigating the severity or rapidity of onset of symptoms or clinical signs of the influenza virus infection.

Pharmaceutical Administration

A composition of the present invention may confer resistance to one or more pathogens, e.g., one or more influenza virus strains, by either passive immunization or active immunization. In active immunization, an inactivated or attenuated live vaccine composition is administered prophylactically to a host (e.g., a mammal), and the host's immune response to the administration protects against infection and/or disease. For passive immunization, the elicited antisera can be recovered and administered to a recipient suspected of having an infection caused by at least one influenza virus strain. A gene therapy composition of the present invention may yield prophylactic or therapeutic levels of the desired gene product by active immunization.

In one embodiment, the vaccine is provided to a mammalian female (at or prior to pregnancy or parturition), under conditions of time and amount sufficient to cause the production of an immune response which serves to protect both the female and the fetus or newborn (via passive incorporation of the antibodies across the placenta or in the mother's milk).

The present invention thus includes methods for preventing or attenuating a disorder or disease, e.g., an infection by at least one strain of pathogen. As used herein, a vaccine is said to prevent or attenuate a disease if its administration results either in the total or partial attenuation (i.e., suppression) of a clinical sign or condition of the disease, or in the total or partial immunity of the individual to the disease. As used herein, a gene therapy composition is said to prevent or attenuate a disease if its administration results either in the total or partial attenuation (i.e., suppression) of a clinical sign or condition of the disease, or in the total or partial immunity of the individual to the disease.

At least one influenza virus isolate of the present invention, including one which is inactivated or attenuated, one or more isolated viral proteins thereof, one or more isolated nucleic acid molecules encoding one or more viral proteins thereof, or a combination thereof, may be administered by any means that achieve the intended purposes.

For example, administration of such a composition may be by various parenteral routes such as subcutaneous, intravenous, intradermal, intramuscular, intraperitoneal, intranasal, oral or transdermal routes. Parenteral administration can be accomplished by bolus injection or by gradual perfusion over time.

A typical regimen for preventing, suppressing, or treating an influenza virus related pathology, comprises administra-

tion of an effective amount of a vaccine composition as described herein, administered as a single treatment, or repeated as enhancing or booster dosages, over a period up to and including between one week and about 24 months, or any range or value therein.

According to the present invention, an "effective amount" of a composition is one that is sufficient to achieve a desired effect. It is understood that the effective dosage may be dependent upon the species, age, sex, health, and weight of the recipient, kind of concurrent treatment, if any, frequency of treatment, and the nature of the effect wanted. The ranges of effective doses provided below are not intended to limit the invention and represent dose ranges.

The dosage of a live, attenuated or killed virus vaccine for an animal such as a mammalian adult organism can be from about 10^2 - 10^{15} , e.g., 10^3 - 10^{12} , plaque forming units (PFU)/kg, or any range or value therein. The dose of inactivated vaccine can range from about 0.1 to 1000, e.g., 30 to 100 μ g, of HA protein. However, the dosage should be a safe and effective amount as determined by conventional methods, using existing vaccines as a starting point.

The dosage of immunoreactive HA in each dose of replicated virus vaccine can be standardized to contain a suitable amount, e.g., 30 to 100 μ g or any range or value therein, or the amount recommended by government agencies or recognized professional organizations. The quantity of NA can also be standardized, however, this glycoprotein may be labile during purification and storage.

Compositions and Dosing for Equine Influenza Vaccines

Equine influenza vaccines generally include representative strains of H7N7 and H3N8 subtypes either as inactivated whole virus or their subunits. They provide protection against influenza by inducing antibody to the surface glycoproteins, in particular to HA, which is essential for viral attachment and entry into cells, and/or potentially important cell-mediated immune responses to other viral proteins. Vaccination is helpful in preventing influenza but the protection is short-lived (3-4 months using conventional inactivated virus vaccines), so the frequency of vaccination varies according to how often the horse will likely come in contact with the virus (see Table 1). The usual procedure for the primary course is vaccination with a single dose followed 3 to 6 weeks later with a second dose. Vaccine manufacturers recommend that booster vaccinations be given at 6- to 12-month intervals thereafter. Alternatively, a horse is administered one 1 to 2 ml dose, e.g., via intramuscular (IM) injection, a second 1 to 2 ml dose 3 to 4 weeks later at a different injection site, e.g., via IM injection, and optionally a third 1 to 2 ml dose, e.g., IM or intranasal (IN) administration. Each 1 to 2 ml dose of vaccine may contain approximately 1-500 billion virus particles, and preferably 100 billion particles. Horses in contact with a large number of horses, for example, at a boarding stable, training centers, racetracks, shows, and other such events, are often vaccinated every 2-3 months. A three-dose primary series has been shown to induce a higher and more persistent immunity than the recommended two-dose series regardless of the age.

Using conventional vaccines, it is advisable to vaccinate young horses, particularly racehorses and other competition horses, at 4 to 6 month intervals for several years after their primary course of vaccinations. It has been demonstrated that inclusion of an additional booster vaccination between the second and third vaccination recommended by the vaccine manufacturers is of benefit to young horses. An annual booster will usually suffice for older horses such as show jumpers and brood mares that have been vaccinated regularly since they were foals. Vaccination in the face of an

ongoing outbreak is sometimes practiced, but is not likely to be effective without an interval of at least 7 to 10 days before the freshly vaccinated horses are exposed to infection. Equine influenza outbreaks are not seasonal as in man but are frequently associated with sales or race meets where horses from different regions congregate and mix. It may therefore be advantageous to time additional booster vaccinations to be given prior to such events.

Brood mares should be vaccinated in the later stages of pregnancy, but not later than 2 weeks prior to foaling, to ensure a good supply of colostral antibodies for the foal. Foal vaccinations should begin at 3-6 months of age, with a booster at 4-7 months, again at 5-8 months, and repeated every three months if the foal is at high risk of exposure.

TABLE 1

| | Foals & Weanlings from Vaccinated Mares | Foal & Weanlings from non-Vaccinated Mares | Yearlings | Performance Horse | Pleasure Horses | Brood-mares |
|--|--|---|------------------|-------------------|---|--|
| Influenza inactivated injectable | 1st Dose: 9 months 2nd Dose: 10 months 3rd Dose: 11-12 months Then at 3 month intervals | 1st Dose: 6 months 2nd Dose: 7 months 3rd Dose: 8 months Then at 3 month intervals | Every 3-4 months | Every 3-5 months | Annual with Boosters prior to likely exposure | At least semi-annual, with 1 Booster 4-6 weeks prepartum |
| Influenza intranasal cold-adapted live virus | 1st Dose: 12 months; has been safely administered to foals less than 11 months | 1st Dose: 12 months; has been safely administered to foals less than 11 months | Every 4-6 months | Every 4-6 months | Every 4-6 months | Annual before breeding |

Influenza vaccines may be combined with tetanus or herpesvirus antigens as well as other pathogens, e.g., equine pathogens. The immune response elicited by tetanus toxoid is much more durable than that induced by influenza antigen. In an intensive influenza vaccination program, vaccines containing influenza only are thus preferred.

Levels of antibody (measured by the SRH assay) required for protection of horses have been identified through vaccination and challenge studies and from field data. Because the vaccine-induced antibody response to HA in horses is remarkably short-lived, adjuvants such as aluminum hydroxide or carbomer are normally included to enhance the amplitude and duration of the immune response to whole virus vaccines. Subunit equine influenza vaccines containing immune stimulating complexes (ISCOMs) are also immunogenic.

Historically, antigenic content in inactivated vaccines has been expressed in terms of chick cell agglutinating (CCA) units of HA and potency in terms of HI antibody responses induced in guinea pigs and horses, neither of which yields reproducible results. The single radial diffusion (SRD) assay is an improved in vitro potency test that measures the concentration of immunologically active HA (expressed in terms of micrograms of HA) and can be used for in-process testing before the addition of adjuvant.

The invention will be further described by the following non-limiting example.

EXAMPLE

An approximately 36-hour-old Morgan/Friesian colt was referred to the large animal hospital at the University of Wisconsin for an evaluation of altered mentation (mental status), first noticed shortly after birth. Parturition had been unobserved, but the foal had been found separated from the mare by a fence at a few hours of age. The foal was ambulatory and able to nurse when first discovered but showed progressive disorientation, apparent blindness, and aimless wandering during the following 36-hour period. A SNAP immunoglobulin G (IgG) assay (Idexx Laboratories, Westbrook, Me.) at 24 hours of age had shown an IgG concentration >800 mg/dL, and a CBC performed at that

time was normal. The foal was treated twice with dimethyl sulfoxide 1 g/kg IV, diluted in 5% dextrose before referral.

At presentation, the colt wandered aimlessly, bumped into objects, and appeared blind with sluggish but intact pupillary light responses. When positioned under the mare, the foal nursed successfully. Physical examination was unremarkable. A CBC and serum biochemistry were normal, including a serum IgG concentration of 937 mg/dL measured by radioimmunodiffusion.

Initial treatment for presumptive hypoxemic, ischemic encephalopathy included a 250 mL loading dose of 20% magnesium sulfate for 1 hour, followed by a constant rate infusion at 42 mL/h and thiamine hydrochloride 2.2 mg/kg IV q24 h. Antimicrobial therapy consisted of amikacin 20 mg/kg IV q24 h and procaine penicillin G 22,000 U/kg IM q12 h. Omeprazole 1 mg/kg PO q24 h also was administered to the foal to help prevent the development of gastric ulcers.

The foal's mental status remained static during the next 24 hours, and additional treatment with mannitol 1 g/kg IV q24 h and dexamethasone sodium phosphate 0.1 mg/kg IV q24 h on days 2 and 3 of hospitalization was not associated with improvement. On day 3, the foal underwent general anesthesia for a computerized tomographic scan of the skull and proximal spine, which was normal. A cerebrospinal fluid sample was obtained from the lumbosacral space and was normal on cytologic evaluation and had a normal protein concentration.

On day 4 of hospitalization, the foal developed a right-sided head tilt but otherwise remained static through day 5

of hospitalization. Magnesium sulfate therapy was discontinued on day 5, but the remainder of the therapeutic regimen was unchanged. On day 6, the foal had 2 brief, generalized seizures that were controlled with midazolam 0.05 mg/kg IV. Between seizures, the foal was still bright, afebrile, and nursing.

On day 7 of hospitalization, the foal became febrile (40° C.) and developed a mucopurulent nasal discharge and progressive tachypnea with diffuse adventitious crackles and wheezes on auscultation. Fever, mucopurulent nasal discharge, and coughing had been noted in several other mares and foals in the neonatal care unit during the previous 7 days. Antimicrobial therapy was changed to ticarcillin/clavulanic acid 50 mg/kg IV q8 h had gentamicin 6.6 mg/kg IV q24 h, and the foal was treated with polyionic fluids, although it was still nursing. During days 8-10, the foal's neurologic status continued to improve, with a resolution of the head tilt and a return to normal mentation, but the tachypnea, dyspnea, and adventitious lung sounds worsened. Thoracic radiography at this time showed a severe, diffuse bronchointerstitial pattern. Aminophylline 0.5 mg/kg IV q12 h by slow infusion and nasal insufflation of oxygen were instituted on days 9 and 10 of hospitalization. Serial arterial blood gas analysis identified severe hypoxemia (PaO₂, 52 mm Hg), hypercapnia (PaCO₂, 68.4 mm Hg), and reduced oxygen saturation (76%) by the end of day 10. Consequently, the foal was placed on a mechanical ventilator. Ventilatory support and total parenteral nutrition were continued for 48 hours, during which time arterial blood gas values normalized on 100% oxygen. Antimicrobial therapy was continued as before. When challenged on day 13 by the removal of ventilatory support, the foal developed severe dyspnea and cyanosis and was euthanized at the owner's request. An aerobic culture of a transtracheal aspirate obtained on day 13 grew *Klebsiella pneumoniae* and *Escherichia coli* resistant to ticarcillin/clavulanic acid and gentamicin.

A complete gross and histopathologic postmortem examination was performed, as well as a real-time quantitative polymerase chain reaction (PCR) evaluation for the presence of equine herpes virus (EHV)-1 and EHV-4 in samples of nasal secretions; serologic tests to determine if there was exposure to equine viral arteritis virus; and a Directigen Flu A assay (Bectin Dickinson and Co., Franklin, N.J.) and virus isolation from samples of nasal secretions to test for the presence of influenza virus. Samples of nasal secretions were collected with Dacron swabs that were subsequently placed in 2 mL of viral transport media containing phosphate-buffered saline, 0.5% bovine serum albumin, and penicillin G, streptomycin, nystatin, and gentamicin. The nasal swab samples were collected on day 8 of hospitalization. Follow-up evaluations for the influenza virus included immunohistochemistry on snap-frozen and formalin-fixed lung, abdominal viscera, and central nervous system tissues for the presence of influenza nucleoprotein (NP) expression, virus isolation from frozen lung tissue, and viral sequence analyses. Gross post-mortem examination identified severe diffuse interstitial pneumonia and subdural hemorrhage on the caudal ventral surface of the brain around the pituitary gland but no evidence of sepsis or pathology in other organs. Histopathologic examination of the lung identified necrotizing bronchitis and bronchiolitis, diffuse squamous metaplasia, and multifocal interstitial pneumonia. A mild mononuclear infiltrate lined the lower airways and, occasionally, areas of alveolar collapse associated with congestion and exudate. Evaluation of the brain tissue revealed a mild dilatation of the ventricular system with diffuse white matter

vacuolation, particularly in the cerebellum. Cresyl violet staining for the presence of myelin was performed on multiple sections and showed diminished but present myelin throughout the brain and spinal cord when compared to tissues from an age-matched control stained in parallel. Additional histopathologic abnormalities in the central nervous system included an apparent absence of the molecular layer within the cerebellum. Serologic tests for equine viral arteritis and a real-time PCR assay for EHV-1 and EHV-4 DNA were negative.

The presence of influenza virus in nasal secretions initially was confirmed by a positive Directigen assay. Previous studies have documented the sensitivity and specificity of this assay when applied to equine nasal secretion samples (Morely et al., 1995 and Chambers et al., 1994). Samples of the nasal swab transport media also were inoculated into the allantoic cavity of embryonated chicken eggs and onto Madin-Darby canine kidney (MDCK) cells growing in 24-well cell culture plates. Cytopathologic effects consistent with influenza virus growth were observed in the inoculated MDCK cells, and an agent that caused the hemagglutination of chicken red blood cells was isolated from the inoculated eggs (Palmar et al., 1975). The presence of influenza virus in the MDCK cell cultures was confirmed by the immunocytochemical staining (Landolt et al., 2003) of the inoculated cells with an anti-NP monoclonal antibody (Mab 68D2 (kindly provided by Dr. Yoshihiro Kawaoka, University of Wisconsin-Madison School of Veterinary Medicine) with positive (swine influenza virus inoculated) and negative (mock inoculated) control cells included on the same plate. The identity of the virus as an H3-subtype equine influenza virus was confirmed by reverse transcription-PCR amplification of the hemagglutinin (HA) gene from the isolate, with primers described in Olsen et al. (1997), followed by cycle sequencing of the full-length protein coding region of the HA gene and pairwise comparisons to viral sequences available in GenBank (DNASTAR software, version 4.0 for Win32, Bestfit, Madison, Wis.). The virus was shown to be derived from the North American lineage of H3 equine influenza viruses by a phylogenetic analysis that used a maximum parsimony bootstrap analysis (PAUP software, version 4.0b6; David Swofford, Smithsonian Institution, Washington, D.C.) of the HA sequence compared to reference virus strains with a fast-heuristic search of 1,000 bootstrap replicates. Similar analyses of portions of the nucleotide sequences of the nonstructural protein gene (544 nucleotides sequenced) and the NP gene (885 nucleotides sequenced) further confirmed the identity of the virus as a North American-lineage equine influenza virus. This virus is now defined as A/Equine/Wisconsin/1/03. FIG. 1 provides sequences for the coding region of each gene of that virus.

The presence of influenza virus also was assessed in the lungs and other tissues of the foal. Specifically, immunohistochemistry with Mab 68D2 showed scattered, widely dispersed areas of influenza virus NP expression (predominantly localized around airways) in the frozen as well as the formalin-fixed lung tissue samples. NP expression was not shown in the other viscera or in the central nervous system. In addition, influenza virus was isolated in MDCK cells (and confirmed by immunocytochemistry and HA gene sequencing) from a sample of the frozen lung tissue.

Acute respiratory distress syndrome (ARDS) in neonatal foals has been documented as a consequence of bacterial sepsis (Wilkins, 2003; Hoffman et al., 1993), perinatal EHV-1 (Frymus et al., 1986; Gilkerson et al., 1999) and EHV-4 (Gilkerson et al., 1999), and equine viral arteritis infection (Del Piero et al., 1997). Less severe lower airway

disease occasionally is documented with adenovirus and EHV-2 infections, particularly in the immunocompromised patient (Webb et al., 1981; Murray et al., 1996). Bronchointerstitial pneumonia and ARDS are high-mortality respiratory diseases of older foals with several potential causes, including bacterial and viral infections (Lakritz et al., 1993). Whether it occurs in neonates experiencing septic shock or in older foals with diffuse bronchointerstitial pneumonia, ARDS is characterized by acute-onset, rapidly progressive, severe tachypnea. The increased respiratory effort, worsening cyanosis, hypoxemia, and hypercapnia that accompany ARDS frequently are poorly responsive to aggressive therapy (Wilkins, 2003; Lakritz et al., 1993). It is a category of respiratory disease with several potential etiologies and a mortality rate that frequently exceeds 30% despite intensive treatment with antimicrobials, oxygen, anti-inflammatory agents, bronchodilators, and thermoregulatory control. Equine influenza is a well-documented cause of upper respiratory disease in horses worldwide (Wilkins, 2003; Van Maanen et al., 2002; Wilson, 1993), but very little information exists in the literature about the manifestations of this disease in neonates. A single report describes bronchointerstitial pneumonia in a 7-day-old foal from which equine influenza A was isolated (Britton et al., 2002); this foal resembles the foal described herein.

The foal detailed in this study was one of several hospitalized horses that developed fever, mucopurulent nasal discharge, and coughing during a 2- or 3-week period. Clinical signs in the other affected horses, including high-risk neonates, generally were confined to the upper respiratory tract, except for mild systemic signs of fever and inappetance. The reason for the severity of the pulmonary failure in this foal is unclear. Treatment did include the potentially immunosuppressive drug dexamethasone and general anesthesia for a diagnostic procedure, both of which may have predisposed the foal to the development of pneumonia. The impact of the foal's neurologic disease on the development and progression of respiratory disease also is unclear. The histologic findings of diffuse vacuolization, decreased myelin throughout the central nervous system, and absent molecular layer within the cerebellum do not fit any specific clinical or histopathologic diagnosis. The foal could have had impaired central control of respiration, because the areas of the brain involved in the control of respiration (the pons and medulla oblongata) showed diffuse vacuolization and diminished myelin staining. Any subsequent impairment of ventilation would likely have been a terminal event given the normalcy of ventilatory function until several days after hospitalization. However, the abnormal mentation from birth, the vacuolization, the decreased myelinization in the central nervous system, and the cerebellar abnormalities are suggestive of a concurrent, congenital neurologic abnormality, which may have compromised the foal's ability to respond to worsening respiratory function. The focal hemorrhage observed on the caudal ventral aspect of the brain was mild and was possibly a consequence of trauma during one of the seizures the foal experienced.

The mare had been vaccinated semiannually against influenza for the past 2 years with a killed product and was given a booster vaccination in late pregnancy. Considering the evidence of adequate passive transfer in this foal, these antibodies apparently did not confer adequate protection for the foal. Furthermore, phylogenetic analysis of the isolate obtained from the foal characterized it as an H3N8 subtype, and the commercial product used to vaccinate the mare in late pregnancy contained an influenza virus strain of the

same subtype, suggesting that passive transfer cannot be guaranteed to protect against natural infection under certain circumstances. This lack of vaccine efficacy is consistent with a recent study by Mumford et al. (2003) that describes the failure of commercially available H7N7 and H3N8 equine influenza virus vaccines to protect adults against clinical respiratory disease that results from a natural infection with certain H3N8 virus strains. The transtracheal recovery of 2 bacterial species that were resistant to the antimicrobial regimen in place at the time of death confounds the conclusion that influenza was the sole cause of death. However, postmortem examination identified no gross or histopathologic evidence of sepsis, and synergism occurs between the influenza virus and some bacterial pathogens, combining to cause pneumonia with increased mortality (McCullers et al., 2003; Simonsen, 1999). Furthermore, the isolation of the infectious virus and the immunohistochemical demonstration of viral antigen from the lung tissue obtained postmortem, 6 days after the virus initially was recovered by a nasopharyngeal swab, provide strong evidence of a pathologic contribution from influenza virus in this foal's respiratory failure.

To compare the growth characteristics of avian, equine, human, and porcine lineage viruses in primary canine respiratory epithelial cells and to investigate the species influence on their growth characteristics, cultured cells were infected at an MOI of 3 with viruses including A/Equine/Wisconsin/1/03 and incubated for up to 10 hours. The other viruses included six human and swine influenza A virus isolates (A/Phillippines/08/98, A/Panama/2002/99, A/Costa Rica/07/99, A/Swine/NorthCarolina/44173/00, A/Swine/Minnesota/593/99, A/Swine/Ontario/00130/97, and two equine influenza viruses (A/Equine/Kentucky/81 and A/Equine/Kentucky/91). At the end of the experiment, the cells were formalin fixed for immunocytochemistry and flow cytometry analyses.

The six human and swine influenza virus isolates mentioned above readily infected substantially all (80-90%) of the canine respiratory epithelial cells and grew to high titers ($10^{5.3}$ - 10^7 TCID₅₀/ml) in those cells. A/Equine/Kentucky/81 and A/Equine/Kentucky/91 were highly restricted in their infectivity (<10% of the cells infected) with little ($10^{1.7}$ TCID₅₀/ml for A/Equine/Kentucky/81) or no (for A/Equine/Kentucky/91) detectable viral growth. In contrast, A/Equine/Wisconsin/1/03 infected a larger percentage (about 30%) of the primary canine respiratory epithelial cells and grew to substantially higher titers (about $10^{4.8}$ TCID₅₀/ml) in those cells. The results demonstrated that all influenza A viruses tested were able to infect canine primary respiratory epithelial cells. However, the infectivity and replication characteristics of the viruses were strongly lineage-dependent.

Dubovi et al. (2004) noted recurrent outbreaks of severe respiratory disease characterized by coughing and fever in greyhound dogs at racing kennels in Florida. Most affected dogs recovered, but some succumbed to a fatal hemorrhagic pneumonia. Lung tissues from 5 of the dogs that died from the hemorrhagic pneumonia syndrome were subjected to virus isolation studies in African green monkey kidney epithelial cells (Vero), Madin-Darby canine kidney epithelial cells (MDCK), primary canine kidney epithelial cells, primary canine lung epithelial cells, primary bovine testicular epithelial cells, canine tumor fibroblasts (A-72), and human colorectal adenocarcinoma epithelial cells (HRT-18) (Dubovi et al., 2004). Cytopathology in the MDCK cells was noted on the first passage of lung homogenate from one of the dogs, and the loss of cytopathology upon subsequent passage to cells cultured without trypsin coupled with the

presence of hemagglutinating activity in culture supernatants suggested the presence of an influenza virus (Dubovi et al., 2004). The virus was initially identified as influenza virus by PCR using primers specific for the matrix gene. The canine influenza virus has been designated as the A/Canine/Florida/43/04 strain. Based on virus isolation from the lungs, the presence of viral antigens in lung tissues by immunohistochemistry, and seroconversion data, Dubovi et al. (2004) concluded that the isolated influenza virus was most likely the etiological agent responsible for the fatal hemorrhagic pneumonia in racing greyhounds during the Jacksonville 2004 outbreak, and that this was the first report of an equine influenza virus associated with respiratory disease in dogs (Dubovi et al., 2004). The HA protein of the canine isolate differs from the A/Equine/Wisconsin/1/03 strain by only 6 amino acids.

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All publications, patents and patent applications are incorporated herein by reference. While in the foregoing specification this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purposes of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein may be varied considerably without departing from the basic principles of the invention.

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| Tyr | Gln | Lys | Cys | Cys | Asn | Leu | Phe | Glu | Lys | Phe | Phe | Pro | Ser | Ser | Ser |
| | 690 | | | | | 695 | | | | | | | 700 | | |
| Tyr | Arg | Arg | Pro | Val | Gly | Ile | Ser | Ser | Met | Val | Glu | Ala | Met | Val | Ser |
| | 705 | | | | 710 | | | | | 715 | | | | | 720 |
| Arg | Ala | Arg | Ile | Asp | Ala | Arg | Ile | Asp | Phe | Glu | Ser | Gly | Arg | Ile | Lys |
| | | | 725 | | | | | | 730 | | | | | 735 | |
| Lys | Asp | Glu | Phe | Ala | Glu | Ile | Met | Lys | Ile | Cys | Ser | Thr | Ile | Glu | Glu |
| | | | 740 | | | | | | 745 | | | | | 750 | |
| Leu | Arg | Arg | Gln | Lys | | | | | | | | | | | |
| | | | 755 | | | | | | | | | | | | |

<210> SEQ ID NO 4

<211> LENGTH: 759

<212> TYPE: PRT

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 4

| | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Met | Glu | Arg | Ile | Lys | Glu | Leu | Arg | Asp | Leu | Met | Leu | Gln | Ser | Arg | Thr |
| 1 | | | | 5 | | | | | 10 | | | | | 15 | |
| Arg | Glu | Ile | Leu | Thr | Lys | Thr | Thr | Val | Asp | His | Met | Ala | Ile | Ile | Lys |
| | | | 20 | | | | | | 25 | | | | 30 | | |
| Lys | Tyr | Thr | Ser | Gly | Arg | Gln | Glu | Lys | Asn | Pro | Ala | Leu | Arg | Met | Lys |
| | | 35 | | | | | 40 | | | | | | 45 | | |
| Trp | Met | Met | Ala | Met | Lys | Tyr | Pro | Ile | Thr | Ala | Asp | Lys | Arg | Ile | Met |
| | 50 | | | | | 55 | | | | | 60 | | | | |
| Glu | Met | Ile | Pro | Glu | Arg | Asn | Glu | Gln | Gly | Gln | Thr | Leu | Trp | Ser | Lys |
| | 65 | | | | | 70 | | | | 75 | | | | | 80 |
| Thr | Asn | Asp | Ala | Gly | Ser | Asp | Arg | Val | Met | Val | Ser | Pro | Leu | Ala | Val |
| | | | | 85 | | | | | 90 | | | | | 95 | |
| Thr | Trp | Trp | Asn | Arg | Asn | Gly | Pro | Thr | Thr | Ser | Thr | Ile | His | Tyr | Pro |
| | | | 100 | | | | | | 105 | | | | | 110 | |
| Lys | Val | Tyr | Lys | Thr | Tyr | Phe | Glu | Lys | Val | Glu | Arg | Leu | Lys | His | Gly |
| | | | 115 | | | | | | 120 | | | | | 125 | |
| Thr | Phe | Gly | Pro | Val | His | Phe | Arg | Asn | Gln | Val | Lys | Ile | Arg | Arg | Arg |
| | | | | | | 135 | | | | | | | 140 | | |
| Val | Asp | Val | Asn | Pro | Gly | His | Ala | Asp | Leu | Ser | Ala | Lys | Glu | Ala | Gln |
| | 145 | | | | | 150 | | | | | 155 | | | | 160 |
| Asp | Val | Ile | Met | Glu | Val | Val | Phe | Pro | Asn | Glu | Val | Gly | Ala | Arg | Ile |
| | | | | 165 | | | | | 170 | | | | | 175 | |
| Leu | Thr | Ser | Glu | Ser | Gln | Leu | Thr | Ile | Thr | Lys | Glu | Lys | Lys | Glu | Glu |
| | | | 180 | | | | | | 185 | | | | | 190 | |
| Leu | Gln | Asp | Cys | Lys | Ile | Ala | Pro | Leu | Met | Val | Ala | Tyr | Met | Leu | Glu |
| | | | 195 | | | | | | 200 | | | | | 205 | |
| Arg | Glu | Leu | Val | Arg | Lys | Thr | Arg | Phe | Leu | Pro | Val | Ala | Gly | Gly | Thr |
| | | | 210 | | | | | | | | | | | 220 | |
| Ser | Ser | Val | Tyr | Ile | Glu | Val | Leu | His | Leu | Thr | Gln | Gly | Thr | Cys | Trp |
| | | | | | 230 | | | | | | 235 | | | | 240 |
| Glu | Gln | Met | Tyr | Thr | Pro | Gly | Gly | Glu | Val | Arg | Asn | Asp | Asp | Ile | Asp |
| | | | | | 245 | | | | | 250 | | | | | 255 |

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Gln Ser Leu Ile Ile Ala Ala Arg Asn Ile Val Arg Arg Ala Thr Val
 260 265 270
 Ser Ala Asp Pro Leu Ala Ser Leu Leu Glu Met Cys His Ser Thr Gln
 275 280 285
 Ile Gly Gly Ile Arg Met Val Asp Ile Leu Lys Gln Asn Pro Thr Glu
 290 295 300
 Glu Gln Ala Val Asp Ile Cys Lys Ala Ala Met Gly Leu Arg Ile Ser
 305 310 315 320
 Ser Ser Phe Ser Phe Gly Gly Phe Thr Phe Lys Arg Thr Ser Gly Ser
 325 330 335
 Ser Val Lys Arg Glu Glu Glu Met Leu Thr Gly Asn Leu Gln Thr Leu
 340 345 350
 Lys Ile Arg Val His Glu Gly Tyr Glu Glu Phe Thr Met Val Gly Arg
 355 360 365
 Arg Ala Thr Ala Ile Leu Arg Lys Ala Thr Arg Arg Leu Ile Gln Leu
 370 375 380
 Ile Val Ser Gly Arg Asp Glu Gln Ser Ile Ala Glu Ala Ile Ile Val
 385 390 395 400
 Ala Met Val Phe Ser Gln Glu Asp Cys Met Ile Lys Ala Val Arg Gly
 405 410 415
 Asp Leu Asn Phe Val Asn Arg Ala Asn Gln Arg Leu Asn Pro Met His
 420 425 430
 Gln Leu Leu Arg His Phe Gln Lys Asp Ala Lys Val Leu Phe Gln Asn
 435 440 445
 Trp Gly Ile Glu Pro Ile Asp Asn Val Met Gly Met Ile Gly Ile Leu
 450 455 460
 Pro Asp Met Thr Pro Ser Thr Glu Met Ser Leu Arg Gly Val Arg Val
 465 470 475 480
 Ser Lys Met Gly Val Asp Glu Tyr Ser Ser Thr Glu Arg Val Val Val
 485 490 495
 Ser Ile Asp Arg Phe Leu Arg Val Arg Asp Gln Arg Gly Asn Ile Leu
 500 505 510
 Leu Ser Pro Glu Glu Val Ser Glu Thr Gln Gly Thr Glu Lys Leu Thr
 515 520 525
 Ile Ile Tyr Ser Ser Ser Met Met Trp Glu Ile Asn Gly Pro Glu Ser
 530 535 540
 Val Leu Val Asn Thr Tyr Gln Trp Ile Ile Arg Asn Trp Glu Ile Val
 545 550 555 560
 Lys Ile Gln Trp Ser Gln Asp Pro Thr Met Leu Tyr Asn Lys Ile Glu
 565 570 575
 Phe Glu Pro Phe Gln Ser Leu Val Pro Arg Ala Thr Arg Ser Gln Tyr
 580 585 590
 Ser Gly Phe Val Arg Thr Leu Phe Gln Gln Met Arg Asp Val Leu Gly
 595 600 605
 Thr Phe Asp Thr Ala Gln Ile Ile Lys Leu Leu Pro Phe Ala Ala Ala
 610 615 620
 Pro Pro Glu Gln Ser Arg Met Gln Phe Ser Ser Leu Thr Val Asn Val
 625 630 635 640
 Arg Gly Ser Gly Met Arg Ile Leu Val Arg Gly Asn Ser Pro Val Phe
 645 650 655
 Asn Tyr Asn Lys Ala Thr Lys Arg Leu Thr Val Leu Gly Lys Asp Ala
 660 665 670
 Gly Ala Leu Thr Glu Asp Pro Asp Glu Gly Thr Ala Gly Val Glu Ser

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| | | | | | | | | | | | | | | | |
|---|-----|-----|--|--|--|--|--|--|-----|--|--|--|--|--|-----|
| 675 | 680 | 685 | | | | | | | | | | | | | |
| Ala Val Leu Arg Gly Phe Leu Ile Leu Gly Lys Glu Asn Lys Arg Tyr | | | | | | | | | | | | | | | |
| 690 | | 695 | | | | | | | 700 | | | | | | |
| Gly Pro Ala Leu Ser Ile Asn Glu Leu Ser Lys Leu Ala Lys Gly Glu | | | | | | | | | | | | | | | |
| 705 | | 710 | | | | | | | 715 | | | | | | 720 |
| Lys Ala Asn Val Leu Ile Gly Gln Gly Asp Val Val Leu Val Met Lys | | | | | | | | | | | | | | | |
| | | 725 | | | | | | | 730 | | | | | | 735 |
| Arg Lys Arg Asp Ser Ser Ile Leu Thr Asp Ser Gln Thr Ala Thr Lys | | | | | | | | | | | | | | | |
| | | 740 | | | | | | | 745 | | | | | | 750 |
| Arg Ile Arg Met Ala Ile Asn | | | | | | | | | | | | | | | |
| | | 755 | | | | | | | | | | | | | |

<210> SEQ ID NO 5

<211> LENGTH: 716

<212> TYPE: PRT

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 5

| | | | | | | | | | | | | | | | |
|---|--|--|-----|---|--|--|--|--|-----|--|--|--|--|--|-----|
| Met Glu Asp Phe Val Arg Gln Cys Phe Asn Pro Met Ile Val Glu Leu | | | | | | | | | | | | | | | |
| 1 | | | | 5 | | | | | 10 | | | | | | 15 |
| Ala Glu Lys Ala Met Lys Glu Tyr Gly Glu Asp Pro Lys Ile Glu Thr | | | | | | | | | | | | | | | |
| | | | 20 | | | | | | 25 | | | | | | 30 |
| Asn Lys Phe Ala Ala Ile Cys Thr His Leu Glu Val Cys Phe Met Tyr | | | | | | | | | | | | | | | |
| | | | 35 | | | | | | 40 | | | | | | 45 |
| Ser Asp Phe His Phe Ile Asn Glu Leu Ser Glu Ser Val Val Ile Glu | | | | | | | | | | | | | | | |
| | | | 50 | | | | | | 55 | | | | | | 60 |
| Ser Gly Asp Pro Asn Ala Leu Leu Lys His Arg Phe Glu Ile Ile Glu | | | | | | | | | | | | | | | |
| | | | 65 | | | | | | 70 | | | | | | 75 |
| Gly Arg Asp Arg Thr Met Ala Trp Thr Val Val Asn Ser Ile Cys Asn | | | | | | | | | | | | | | | |
| | | | | | | | | | 85 | | | | | | 90 |
| Thr Thr Arg Ala Glu Lys Pro Lys Phe Leu Pro Asp Leu Tyr Asp Tyr | | | | | | | | | | | | | | | |
| | | | 100 | | | | | | 105 | | | | | | 110 |
| Lys Glu Asn Arg Phe Val Glu Ile Gly Val Thr Arg Arg Glu Val His | | | | | | | | | | | | | | | |
| | | | 115 | | | | | | 120 | | | | | | 125 |
| Ile Tyr Tyr Leu Glu Lys Ala Asn Lys Ile Lys Ser Glu Lys Thr His | | | | | | | | | | | | | | | |
| | | | 130 | | | | | | 135 | | | | | | 140 |
| Ile His Ile Phe Ser Phe Thr Gly Glu Glu Met Ala Thr Lys Ala Asp | | | | | | | | | | | | | | | |
| | | | 145 | | | | | | 150 | | | | | | 155 |
| Tyr Thr Leu Asp Glu Glu Ser Arg Ala Arg Ile Lys Thr Arg Leu Phe | | | | | | | | | | | | | | | |
| | | | 165 | | | | | | 170 | | | | | | 175 |
| Thr Ile Arg Gln Glu Met Ala Ser Arg Gly Leu Trp Asp Ser Phe Arg | | | | | | | | | | | | | | | |
| | | | 180 | | | | | | 185 | | | | | | 190 |
| Gln Ser Glu Arg Gly Glu Glu Thr Ile Glu Glu Arg Phe Glu Ile Thr | | | | | | | | | | | | | | | |
| | | | 195 | | | | | | 200 | | | | | | 205 |
| Gly Thr Met Arg Lys Leu Ala Asn Tyr Ser Leu Pro Pro Asn Phe Ser | | | | | | | | | | | | | | | |
| | | | 210 | | | | | | 215 | | | | | | 220 |
| Ser Leu Glu Asn Phe Arg Val Tyr Val Asp Gly Phe Glu Pro Asn Gly | | | | | | | | | | | | | | | |
| | | | 225 | | | | | | 230 | | | | | | 235 |
| Cys Ile Glu Ser Lys Leu Ser Gln Met Ser Lys Glu Val Asn Ala Arg | | | | | | | | | | | | | | | |
| | | | | | | | | | 245 | | | | | | 250 |
| Ile Glu Pro Phe Ser Lys Thr Thr Pro Arg Pro Leu Lys Met Pro Gly | | | | | | | | | | | | | | | |
| | | | 260 | | | | | | 265 | | | | | | 270 |
| Gly Pro Pro Cys His Gln Arg Ser Lys Phe Leu Leu Met Asp Ala Leu | | | | | | | | | | | | | | | |
| | | | 275 | | | | | | 280 | | | | | | 285 |

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Lys Leu Ser Ile Glu Asp Pro Ser His Glu Gly Glu Gly Ile Pro Leu
 290 295 300
 Tyr Asp Ala Ile Lys Cys Met Lys Thr Phe Phe Gly Trp Lys Glu Pro
 305 310 315 320
 Ser Ile Val Lys Pro His Glu Lys Gly Ile Asn Pro Asn Tyr Leu Gln
 325 330 335
 Thr Trp Lys Gln Val Leu Ala Glu Leu Gln Asp Leu Glu Asn Glu Glu
 340 345 350
 Lys Asp Pro Lys Thr Lys Asn Met Lys Lys Thr Ser Gln Leu Lys Trp
 355 360 365
 Ala Leu Ser Glu Asn Met Ala Pro Glu Lys Val Asp Phe Glu Asp Cys
 370 375 380
 Lys Asp Ile Ser Asp Leu Lys Gln Tyr Asp Ser Asp Glu Pro Glu Thr
 385 390 395 400
 Arg Ser Leu Ala Ser Trp Ile Gln Ser Glu Phe Asn Lys Ala Cys Glu
 405 410 415
 Leu Thr Asp Ser Ser Trp Ile Glu Leu Asp Glu Ile Gly Glu Asp Val
 420 425 430
 Ala Pro Ile Glu Tyr Ile Ala Ser Met Arg Arg Asn Tyr Phe Thr Ala
 435 440 445
 Glu Val Ser His Cys Arg Ala Thr Glu Tyr Ile Met Lys Gly Val Tyr
 450 455 460
 Ile Asn Thr Ala Leu Leu Asn Ala Ser Cys Ala Ala Met Asp Glu Phe
 465 470 475 480
 Gln Leu Ile Pro Met Ile Ser Lys Cys Arg Thr Lys Glu Gly Arg Arg
 485 490 495
 Lys Thr Asn Leu Tyr Gly Phe Ile Val Lys Gly Arg Ser His Leu Arg
 500 505 510
 Asn Asp Thr Asp Val Val Asn Phe Val Ser Met Glu Phe Ser Leu Thr
 515 520 525
 Asp Pro Arg Phe Glu Pro His Lys Trp Glu Lys Tyr Cys Val Leu Glu
 530 535 540
 Ile Gly Asp Met Leu Leu Arg Thr Ala Val Gly Gln Val Ser Arg Pro
 545 550 555 560
 Met Phe Leu Tyr Val Arg Thr Asn Gly Thr Ser Lys Ile Lys Met Lys
 565 570 575
 Trp Gly Met Glu Met Arg Arg Cys Leu Leu Gln Ser Leu Gln Gln Ile
 580 585 590
 Glu Ser Met Ile Glu Ala Glu Ser Ser Val Lys Glu Lys Asp Met Thr
 595 600 605
 Lys Glu Phe Phe Glu Asn Lys Ser Glu Thr Trp Pro Ile Gly Glu Ser
 610 615 620
 Pro Lys Gly Val Glu Glu Gly Ser Ile Gly Lys Val Cys Arg Thr Leu
 625 630 635 640
 Leu Ala Lys Ser Val Phe Asn Ser Leu Tyr Ala Ser Pro Gln Leu Glu
 645 650 655
 Gly Phe Ser Ala Glu Ser Arg Lys Leu Leu Leu Ile Val Gln Ala Leu
 660 665 670
 Arg Asp Asn Leu Glu Pro Gly Thr Phe Asp Ile Gly Gly Leu Tyr Glu
 675 680 685
 Ser Ile Glu Glu Cys Leu Ile Asn Asp Pro Trp Val Leu Leu Asn Ala
 690 695 700
 Ser Trp Phe Asn Ser Phe Leu Thr His Ala Leu Lys

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705              710              715

<210> SEQ ID NO 6
<211> LENGTH: 498
<212> TYPE: PRT
<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 6

Met Ala Ser Gln Gly Thr Lys Arg Ser Tyr Glu Gln Met Glu Thr Asp
  1             5             10            15

Gly Glu Arg Gln Asn Ala Thr Glu Ile Arg Ala Ser Val Gly Arg Met
  20            25            30

Val Gly Gly Ile Gly Arg Phe Tyr Val Gln Met Cys Thr Glu Leu Lys
  35            40            45

Leu Asn Asp His Glu Gly Arg Leu Ile Gln Asn Ser Ile Thr Ile Glu
  50            55            60

Arg Met Val Leu Ser Ala Phe Asp Glu Arg Arg Asn Lys Tyr Leu Glu
  65            70            75            80

Glu His Pro Ser Ala Gly Lys Asp Pro Lys Lys Thr Gly Gly Pro Ile
  85            90            95

Tyr Arg Arg Lys Asp Gly Lys Trp Met Arg Glu Leu Ile Leu His Asp
  100           105           110

Lys Glu Glu Ile Met Arg Ile Trp Arg Gln Ala Asn Asn Gly Glu Asp
  115           120           125

Ala Thr Ala Gly Leu Thr His Met Met Ile Trp His Ser Asn Leu Asn
  130           135           140

Asp Thr Thr Tyr Gln Arg Thr Arg Ala Leu Val Arg Thr Gly Met Asp
  145           150           155           160

Pro Arg Met Cys Ser Leu Met Gln Gly Ser Thr Leu Pro Arg Arg Ser
  165           170           175

Gly Ala Ala Gly Ala Ala Val Lys Gly Val Gly Thr Met Val Met Glu
  180           185           190

Leu Ile Arg Met Ile Lys Arg Gly Ile Asn Asp Arg Asn Phe Trp Arg
  195           200           205

Gly Glu Asn Gly Arg Arg Thr Arg Ile Ala Tyr Glu Arg Met Cys Asn
  210           215           220

Ile Leu Lys Gly Lys Phe Gln Thr Ala Ala Gln Arg Ala Met Met Asp
  225           230           235           240

Gln Val Arg Glu Gly Arg Asn Pro Gly Asn Ala Glu Ile Glu Asp Leu
  245           250           255

Ile Phe Leu Ala Arg Ser Ala Leu Ile Leu Arg Gly Ser Val Ala His
  260           265           270

Lys Ser Cys Leu Pro Ala Cys Val Tyr Gly Leu Ala Val Thr Ser Gly
  275           280           285

Tyr Asp Phe Glu Lys Glu Gly Tyr Ser Leu Val Gly Ile Asp Pro Phe
  290           295           300

Lys Leu Leu Gln Asn Ser Gln Ile Phe Ser Leu Ile Arg Pro Lys Glu
  305           310           315           320

Asn Pro Ala His Lys Ser Gln Leu Val Trp Met Ala Cys His Ser Ala
  325           330           335

Ala Phe Glu Asp Leu Arg Val Leu Asn Phe Ile Arg Gly Thr Lys Val
  340           345           350

Ile Pro Arg Gly Gln Leu Thr Thr Arg Gly Val Gln Ile Ala Ser Asn
  355           360           365

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Glu Asn Met Glu Thr Ile Asp Ser Ser Thr Leu Glu Leu Arg Ser Lys
 370 375 380
 Tyr Trp Ala Ile Arg Thr Arg Ser Gly Gly Asn Thr Ser Gln Gln Arg
 385 390 395 400
 Ala Ser Ala Gly Gln Ile Ser Val Gln Pro Thr Phe Ser Val Gln Arg
 405 410 415
 Asn Leu Pro Phe Glu Arg Ala Thr Ile Met Ala Ala Phe Thr Gly Asn
 420 425 430
 Thr Glu Gly Arg Thr Ser Asp Met Arg Thr Glu Ile Ile Arg Met Met
 435 440 445
 Glu Asn Ala Lys Ser Glu Asp Val Ser Phe Gln Gly Arg Gly Val Phe
 450 455 460
 Glu Leu Ser Asp Glu Lys Ala Thr Asn Pro Ile Val Pro Ser Phe Asp
 465 470 475 480
 Met Ser Asn Glu Gly Ser Tyr Phe Phe Gly Asp Asn Ala Glu Glu Phe
 485 490 495

Asp Ser

<210> SEQ ID NO 7

<211> LENGTH: 252

<212> TYPE: PRT

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 7

Met Ser Leu Leu Thr Glu Val Glu Thr Tyr Val Leu Ser Ile Val Pro
 1 5 10 15
 Ser Gly Pro Leu Lys Ala Glu Ile Ala Gln Arg Leu Glu Asp Val Phe
 20 25 30
 Ala Gly Lys Asn Thr Asp Leu Glu Ala Leu Met Glu Trp Leu Lys Thr
 35 40 45
 Arg Pro Ile Leu Ser Pro Leu Thr Lys Gly Ile Leu Gly Phe Val Phe
 50 55 60
 Thr Leu Thr Val Pro Ser Glu Arg Gly Leu Gln Arg Arg Arg Phe Val
 65 70 75 80
 Gln Asn Ala Leu Ser Gly Asn Gly Asp Pro Asn Asn Met Asp Arg Ala
 85 90 95
 Val Lys Leu Tyr Arg Lys Leu Lys Arg Glu Ile Thr Phe His Gly Ala
 100 105 110
 Lys Glu Val Ala Leu Ser Tyr Ser Thr Gly Ala Leu Ala Ser Cys Met
 115 120 125
 Gly Leu Ile Tyr Asn Arg Met Gly Thr Val Thr Thr Glu Val Ala Phe
 130 135 140
 Gly Leu Val Cys Ala Thr Cys Glu Gln Ile Ala Asp Ser Gln His Arg
 145 150 155 160
 Ser His Arg Gln Met Val Thr Thr Thr Asn Pro Leu Ile Arg His Glu
 165 170 175
 Asn Arg Met Val Leu Ala Ser Thr Thr Ala Lys Ala Met Glu Gln Met
 180 185 190
 Ala Gly Ser Ser Glu Gln Ala Ala Glu Ala Met Glu Val Ala Ser Arg
 195 200 205
 Ala Arg Gln Met Val Gln Ala Met Arg Thr Ile Gly Thr His Pro Ser
 210 215 220
 Ser Ser Ala Gly Leu Lys Asp Asp Leu Leu Glu Asn Leu Gln Ala Tyr
 225 230 235 240

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Gln Lys Arg Met Gly Val Gln Met Gln Arg Phe Lys
 245 250

<210> SEQ ID NO 8
 <211> LENGTH: 230
 <212> TYPE: PRT
 <213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 8

Met Asp Ser Asn Thr Val Ser Ser Phe Gln Val Asp Cys Phe Leu Trp
 1 5 10 15
 His Val Arg Lys Arg Phe Ala Asp Gln Glu Leu Gly Asp Ala Pro Phe
 20 25 30
 Leu Asp Arg Leu Arg Arg Asp Gln Lys Ser Leu Arg Gly Arg Gly Ser
 35 40 45
 Thr Leu Gly Leu Asp Ile Glu Thr Ala Thr His Ala Gly Lys Gln Ile
 50 55 60
 Val Glu Gln Ile Leu Glu Lys Glu Ser Asp Glu Ala Leu Lys Met Thr
 65 70 75 80
 Ile Ala Ser Val Pro Thr Ser Arg Tyr Leu Thr Asp Met Thr Leu Asp
 85 90 95
 Glu Met Ser Arg Asp Trp Phe Met Leu Met Pro Lys Gln Lys Val Thr
 100 105 110
 Gly Ser Leu Cys Ile Arg Met Asp Gln Ala Ile Met Asp Lys Asn Ile
 115 120 125
 Ile Leu Lys Ala Asn Phe Ser Val Ile Phe Glu Arg Leu Glu Thr Leu
 130 135 140
 Ile Leu Leu Arg Ala Phe Thr Glu Glu Gly Ala Val Val Gly Glu Ile
 145 150 155 160
 Ser Pro Leu Pro Ser Leu Pro Gly His Thr Asn Glu Asp Val Lys Asn
 165 170 175
 Ala Ile Gly Val Leu Ile Gly Gly Leu Lys Trp Asn Asp Asn Thr Val
 180 185 190
 Arg Ile Ser Glu Thr Leu Gln Arg Phe Ala Trp Arg Ser Ser His Glu
 195 200 205
 Asn Gly Arg Pro Ser Phe Pro Ser Lys Gln Lys Arg Lys Met Glu Arg
 210 215 220
 Thr Ile Lys Pro Lys Ile
 225 230

<210> SEQ ID NO 9
 <211> LENGTH: 1701
 <212> TYPE: DNA
 <213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 9

tcatgaagac aaccattatt ttgatactac tgaccattg ggcttacagt caaaacccaa 60
 tcagtgga caacacagcc acattgtgtc tgggacacca tgcagtagca aatggaacat 120
 tggtaaaac aataagtgat gatcaaattg aggtgacaaa tgctacagaa ttagttcaaa 180
 gcatttcaat ggggaaaata tgcaacaact catatagaat tctagatgga agaaattgca 240
 cattaataga tgcaatgcta ggagaccccc actgtgacgc ctttcagtat gagaattggg 300
 acctctttat agaaagaagc agcgctttca gcaattgcta cccatgatgc atccctgact 360
 atgcatcgct ccgatccatt gtagcatcct caggaacatt ggaattcaca gcagagggat 420
 tcacatggac aggtgtcact caaacggaa gaagtggagc ctgcaaaagg ggatcagccg 480

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atagtttctt tagcgcactg aattggctaa caaaatctgg aagctcttac cccacattga 540
atgtgacaat gcctaacaat aaaaatttcg acaagctata catctggggg attcatcacc 600
cgagctcaaa tcaagagcag acaaaattgt acatccaaga atcaggacga gtaacagtct 660
caacaaaaag aagtaacaaa acaataatcc ctaacatcgg atctagaccg tgggtcagag 720
gtcaatcagg taggataagc atatactgga ccattgtaaa acctggagat atcctaataga 780
taaacagtaa tggcaactta gttgcaccgc ggggatattt taaattgaaa acagggaaaa 840
gctctgtaat gagatcagat gtaccatag acatttgtgt gtctgaatgt attacaccaa 900
atggaagcat ctccaacgac aagccattcc aaaatgtgaa caaagttaca tatggaaaat 960
gccccaahta tatcaggcaa aacactttaa agctggccac tgggatgagg aatgtaccag 1020
aaaagcaaat cagaggaatc tttggagcaa tagcgggatt catcgaaaac ggctgggaag 1080
gaatggttga tgggtggtat gggttccgat atcaaaactc tgaaggaaca gggcaagctg 1140
cagatctaaa gagcactcaa gcagccatcg accagattaa tggaaaagta aacagagtga 1200
ttgaaagaac caatgagaaa ttccatcaaa tagagaagga attctcagaa gtagaaagaa 1260
gaattcagga cttggagaaa tatgtagaag acaccaaata agacctatgg tcctacaatg 1320
cagaattgct ggtggctcta gaaaatcaac atacaattga cttaacagat gcagaaatga 1380
ataaattatt tgagaagact agacgccagt taagagaaaa cgcagaagac atgggagggtg 1440
gatgtttcaa gatttaccac aaatgtgata atgcatgcat tggatcaata agaaatggga 1500
catatgacca ttacatatac agagatgaag cattaacaaa ccgatttcag atcaaagggtg 1560
tagagttgaa atcaggctac aaagattgga tactgtggat ttcattcgcc atatcatgct 1620
tcttaatttg cgttgttcta ttgggtttca ttatgtgggc ttgccccaaa ggcaacatca 1680
gatgcaacat ttgcatttga g 1701

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<210> SEQ ID NO 10

<211> LENGTH: 1413

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 10

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atgaatccaa atcaaaagat aatagcaatt ggatttgcatt cattggggat attaatcatt 60
aatgtcattc tccatgtagt cagcattata gtaacagtac tggtcctcaa taacaataga 120
acagatctga actgcaaagg gacgatcata agagagtaca atgaaacagt aagagtagaa 180
aaaattactc aatggtataa taccagtaca attaagtaca tagagagacc tcaaatgaa 240
tactacatga acaacactga accacttgtg gaggcccaag gctttgcacc attttccaaa 300
gataatggaa tacgaattgg gtcgagaggc catgtttttg tgataagaga accttttgta 360
tcatgttcgc cctcagaatg tagaaccttt ttctcacac agggctcatt actcaatgac 420
aaacattcta acggcacagt aaaggaccga agtccgtata ggactttgat gagtgtcaaa 480
atagggcaat cacctaattg atatacaagct aggtttgaaat cgggtggcatg gtcagcaaca 540
gcatgccatg atggaaaaaa atggatgaca gttggagtca cagggcccca caatcaagca 600
attgcagtag tgaactatgg aggtgttccg gttgatatta ttaattcatg ggcaggggat 660
atthtaagaa cccaagaatc atcatgcacc tgcattaaag gagactgtta ttgggtaatg 720
actgatggac cggcaaatag gcaagctaaa tataggatat tcaaagcaaa agatggaaga 780
gtaattggac agactgatat aagtttcaat gggggacaca tagaggagtg ttcttgttac 840

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cccaatgaag ggaaggtgga atgcatatgc agggacaatt ggactggaac aaatagacca 900
attctggtaa tatcttctga tctatcgtac acagttggat atttgtgtgc tggcattccc 960
actgacactc ctaggggaga ggatagtcaa ttcacaggct catgtacaag tcctttggga 1020
aataaaggat acggtgtaaa aggtttcggg tttcgacaag gaactgacgt atgggccgga 1080
aggacaatta gtaggacttc aagatcagga ttcgaaataa taaaatcag gaatggttg 1140
acacagaaca gtaaagacca aatcaggagg caagtgatta tcgatgacc aaattggtca 1200
ggatatagcg gttctttcac attgccggtt gaactaaca aaaaggatg tttggtcccc 1260
tgtttctggg ttgaaatgat tagaggtaaa cctgaagaaa caacaatag gacctctagc 1320
agctccattg tgatgtgtgg agtagatcat aaaattgcca gttggtcatg gcacgatgga 1380
gctattcttc cctttgacat cgataagatg taa 1413

```

<210> SEQ ID NO 11

<211> LENGTH: 2277

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 11

```

atggatgtca atccgactct acttttctta aaggtgccag cgcaaaatgc tataagcaca 60
acatttcctt atactggaga tcctccctac agtcatgga cagggacagg atacaccatg 120
gatactgtca acagaacaca ccaatattca gaaaaaggga aatggacaac aaacactgag 180
attggagcac cacaacttaa tccaatcgat ggaccacttc ctgaagacaa tgaaccaagt 240
gggtacgccc aaacagattg tgtattgga gcaatggctt tccttgaaga atcccatccc 300
ggaatctttg aaaattcgtg tcttgaaacg atggagggtg ttcagcagac aagagtggac 360
aaactaacac aaggccgaca aacttatgat tggaccttga ataggaatca acctgccgca 420
acagcacttg ctaatacgat tgaagtattc agatcaaatg gtctgacttc caatgaatcg 480
gggagattga tggacttctc caaagatgtc atggagtcca tgaacaagga agaaatggaa 540
ataacaacac acttccaacg gaagagaaga gtaagagaca acatgacaaa gagaatggta 600
acacagagaa ccatagggaa gaaaaaaca cgattaaaca gaaagagcta tctaatacaga 660
acattaaccc taaacacaat gaccaaggac gctgagagag ggaaattgaa acgacgagca 720
atcgctacc cagggatgca gataagaggg tttgtatatt ttgttgaac actagcccga 780
agaatatgtg aaaagcttga acaatcagga ttgccagttg gcggtaatga gaaaaaggcc 840
aaactggcta atgtcgtcag aaaaatgatg actaattccc aagacactga actctccttc 900
accatcactg gggacaatac caaatggaat gaaaatcaga acccaccgat attcctggca 960
atgatcaca acataactag aaaccagcca gaatggttca gaaatgttct aagcattgca 1020
ccgattatgt tctcaataa aatggcaaga ctggggaaag gatatatgtt tgaaagcaaa 1080
agtatgaaat tgagaactca aataccagca ggaatgcttg caagcattga cctgaaatat 1140
ttcaatgatc caacaaaaa gaaaattgaa aagatacgac cacttctggt tgacgggact 1200
gcttcactga gtcctggcat gatgatggga atgttcaaca tgttgagcac tgtgctaggt 1260
gtatccatat taaacctggg ccagaggaaa tacacaaaga ccacatactg gtgggatggt 1320
ctgcaatcat ccgatgactt tgctttgata gtgaatgctc ctaatcatga aggaatacaa 1380
gctggagtag acagatteta taggacttgc aaactggctg ggatcaacat gagcaaaaag 1440
aagtcctaca taaatagaac tggaacattc gaattcaca gctttttcta ccggtatggt 1500
ttttagacca atttcagcat ggaactacc agttttgggg tttccggaat aatgaaatct 1560

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gcagacatga gcattggagt gacagtcate aaaaacaaca tgataataa tgatctcggg 1620
cctgccacgg cacaaatggc actccaactc ttcattaagg attatcggta cacataccgg 1680
tgccatagag gtgataccca gatacaaacc agaagatctt ttgagttgaa gaaactgtgg 1740
gaacagactc gatcaaagac tggctctactg gtatcagatg ggggtccaaa cctatataac 1800
atcagaaacc tacacatccc ggaagtctgt ttaaaatggg agctaattgga tgaagattat 1860
aaggggaggc tatgcaatcc attgaatcct ttcggttagtc acaaagaaat tgaatcagtc 1920
aacagtgcag tagtaatgcc tgcgcatggc cctgccaaaa gcatggagta tgatgctggt 1980
gcaacaacac attcttggat ccccaagagg aaccggtcca tattgaacac aagccaaagg 2040
ggaatactcg aagatgagca gatgtatcag aaatgctgca acctgtttga aaaattcttc 2100
cccagcagct catacagaag accagtcggg atttctagta tggttgaggc catggtgtcc 2160
agggcccgcg ttgatgcacg aattgacttc gaatctggac ggataaagaa ggatgagttc 2220
gtgagatca tgaagatctg ttccaccatt gaagagctca gacggcaaaa atagtga 2277

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<210> SEQ ID NO 12

<211> LENGTH: 2281

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 12

```

atggagagaa taaaagaact gagagatctg atgttacaat cccgcaccog cgagatacta 60
acaaaaacta ctgtggacca catggccata atcaagaaat acacatcagg aagacaagag 120
aagaaccctg cacttaggat gaaatggatg atggcaatga aatacccaat tacagcagat 180
aagaggataa tggagatgat tcctgagaga aatgaacagg gacaaacctt ttggagcaaa 240
acgaacgatg ctggctcaga ccgctgaatg gtatcacctc tggcagtgac atggtggaat 300
aggaatggac caacaacaag cacaaattcat tatccaaaag tctacaaaac ttattttgaa 360
aaggttgaaa gattgaaaca cggaaccttt ggccccgttc attttaggaa tcaagtcaag 420
ataagacgaa gagttgatgt aaacctggt caccgaggac tcagtgccaa agaagcacia 480
gatgtgatca tggaaattgt tttcccaaat gaagtgggag ccagaattct aacatcggaa 540
tcacaactaa caataaccaa agagaaaaag gaagaacttc aggactgcaa aattgctccc 600
ttgatggtag catacatgct agaaagagag ttgggtccgaa aaacaaggtt cctcccagta 660
gcaggcggaa caagcagtgat atacattgaa gtgttgcate tgactcaggg aacatgctgg 720
gagcaaatgt acaccccagg aggagaagtt agaaacgatg atattgatca aagtttaatt 780
attgcagccc ggaacatagt gagaagagca acagtatcag cagatccact agcatcccta 840
ctggaatgt gccacagtac acagattggt ggaataagga tggtagacat ccttaagcag 900
aatccaacag aggaacaagc tgtggatata tgcaaagcag caatgggatt gagaattagc 960
tcatcattca gctttggtgg attcaccttc aagagaacaa gtggatcacc agtcaagaga 1020
gaagaagaaa tgcttacggg caaccttcaa acattgaaaa taagagtgca tgagggctat 1080
gaagaattca caatggctcg aagaagagca acagccattc tcagaaaggc aaccagaaga 1140
ttgattcaat tgatagtaag tgggagagat gaacagtcaa ttgctgaagc aataattgta 1200
gccatggtgt tttcgcaaga agattgcatg ataaaagcag ttcgaggcga tttgaacttt 1260
gttaatagag caaatcagcg cttgaacccc atgcatcaac tcttgaggca tttccaaaag 1320
gatgcaaaag tgcttttcca aaattggggg attgaacca tcgacaatgt aatgggaatg 1380

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| | | | | | | |
|------------|------------|------------|-------------|------------|------------|------|
| attggaatat | tgcctgacat | gacccaagc | accgagatgt | cattgagagg | agtgagagtc | 1440 |
| agcaaatgg | gagtgatga | gtactccagc | actgagagag | tggtggtgag | cattgaccgt | 1500 |
| ttttaagag | ttcggatca | aaggggaaac | atactactgt | cccctgaaga | agtcagtgaa | 1560 |
| acacaaggaa | cggaaaagct | gacaataatt | tattcgtcat | caatgatgtg | ggagattaat | 1620 |
| ggtcccgaat | cagtgttgg | caatacttat | caatggatca | tcaggaactg | ggaaattgta | 1680 |
| aaaattcagt | ggtcacagga | cccacaatg | ttatacaata | agatagaatt | tgagccattc | 1740 |
| caatccctgg | tccttagggc | taccagaagc | caatacagcg | gtttcgtgaa | aacctgttt | 1800 |
| cagcaaatgc | gagatgtact | tggaacattt | gatactgctc | aaataataaa | actcctccct | 1860 |
| tttgccgtg | ctcctccgga | acagagtagg | atgcagttct | cttctttgac | tgtaaatgta | 1920 |
| agaggttcgg | gaatgaggat | acttgtaaga | ggcaattccc | cagtgttcaa | ctacaataaa | 1980 |
| gccactaaaa | ggctcacagt | cctcggaag | gatgcaggtg | cgcttactga | ggaccagat | 2040 |
| gaaggtacgg | ctggagtaga | atctgctggt | ctaagaggtt | ttctcatttt | aggtaaagaa | 2100 |
| aataagagat | atggcccagc | actaagcatc | aatgaactaa | gcaacttgc | aaaaggggag | 2160 |
| aaagccaatg | tactaattgg | gcaaggggac | gtagtgttgg | taatgaaacg | gaaacgtgac | 2220 |
| tctagcatac | ttactgacag | ccagacagcg | acccaaaagga | ttcggatggc | catcaattag | 2280 |
| t | | | | | | 2281 |

<210> SEQ ID NO 13

<211> LENGTH: 2209

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 13

| | | | | | | |
|------------|------------|-------------|------------|------------|------------|------|
| atggaagact | ttgtgcgaca | atgcttcaat | ccaatgatcg | tcgagcttgc | ggaaaaggca | 60 |
| atgaaagaat | atggagagga | cccgaaaatc | gaaacaaaca | aatttgcagc | aatatgcact | 120 |
| cacttggaag | tctgcttcat | gtactcggat | ttccacttta | ttaatgaact | gagtgagtca | 180 |
| gtggtcatag | agtctggtga | cccaaatgct | cttttgaaac | acagatttga | aatcattgag | 240 |
| gggagagatc | gaacaatggc | atggacagta | gtaaacagca | tctgcaacac | cacaagagct | 300 |
| gaaaaaccta | aatttcttcc | agattttatac | gactataagg | agaacagatt | tgttgaaatt | 360 |
| ggtgtgacaa | ggagagaagt | tcacatatac | tacctggaga | aggccaacaa | aataaagtct | 420 |
| gagaaaacac | atatccacat | tttctcattt | acaggagagg | aatggctac | aaaagcggac | 480 |
| tatactcttg | atgaagagag | tagagccagg | atcaagacca | gactattcac | tataagacaa | 540 |
| gaaatggcca | gtagaggcct | ctgggattcc | tttctcagt | ccgagagagg | cgaagagaca | 600 |
| attgaagaaa | gatttgaat | cacagggacg | atgcaagc | ttgccaatta | cagtctccca | 660 |
| ccgaacttct | ccagccttga | aaattttaga | gtctatgtgg | atggattcga | accgaacggc | 720 |
| tgcatgaga | gtaagcttcc | tcaaatgtcc | aaagaagtaa | atgccagaat | cgaaccattt | 780 |
| tcaaagacaa | caccccgacc | actcaaaatg | ccaggtggtc | cacctgcca | tcagcgatct | 840 |
| aaattcctgc | taattgatgc | tctgaaactg | agcattgagg | acccaagtca | cgagggagag | 900 |
| ggaataccac | tatatgatgc | catcaaatgc | atgaaaactt | tctttggatg | gaaagagccc | 960 |
| agtattgtta | aaccacatga | aaaggggtata | aaccegaact | atctccaaac | ttggaagcaa | 1020 |
| gtattagcag | aattacaaga | ccttgagaac | gaagaaaagg | acccaagac | caagaatatg | 1080 |
| aaaaaaacaa | gccaattgaa | atgggcactt | agtgaaaata | tggcaccaga | gaaagtggat | 1140 |
| tttgaggatt | gtaaagacat | cagtgattta | aaacagtatg | acagtgatga | gccagaaaca | 1200 |

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aggtctcttg caagttggat tcaaagtgag tcaacaaaag cttgtgaact gacagattca 1260
agctggatag agctcgatga aattggggag gatgttgccc caatagaata cattgcgagc 1320
atgaggagaa attattttac tgctgaggtt tcccattgta gagcaacaga atatataatg 1380
aaggagtggt acatcaacac tgctctactc aatgcatcct gtgctgcatg ggatgaattc 1440
caattaattc cgatgataag taaatgcagg accaaagaag ggagaaggaa gacaaattta 1500
tatggattca tagtaaaggg aaggctccat ttaagaaatg atactgacgt ggtgaacttt 1560
gtaagtatgg aattttctct cactgatcca agatttgagc cacacaaatg ggaaaaatac 1620
tgcgttctag aaattggaga catgcttcta agaactgctg taggtcaagt gtcaagacct 1680
atgtttttgt atgtaaggac aaatggaacc tctaaaatta aaatgaaatg gggaatggaa 1740
atgaggcgct gcctccttca gtctctgcaa cagattgaaa gcatgatcga agctgagtc 1800
tcagtcaaag aaaaggacat gaccaaagaa ttttttgaga acaaatcaga gacatggcct 1860
ataggagagt ccccaaaagg agtggaaagag ggctcaatcg ggaagggttg caggacctta 1920
ttagcaaaat ctgtgtttaa cagtttgatg gcatctccac aactggaagg gttttcagct 1980
gaatctagga aattacttct cattgttcag gctcttaggg ataacctgga acctggaacc 2040
tttgatattg gggggttata tgaatcaatt gaggagtgcc tgattaatga tcctggggtt 2100
ttgcttaatg catcttggtt caactccttc cttacacatg cactgaagta gttgtggcaa 2160
tgctactatt tgctatccat actgtccaaa aaagtacctt gtttctact 2209

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<210> SEQ ID NO 14

<211> LENGTH: 1498

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 14

```

atggcgctctc aaggcaccac acgatcctat gaacagatgg aaactgatgg ggaacgccag 60
aatgcaactg aaatcagagc atctgtcggg aggatggtgg gaggaatcgg ccggttttat 120
gttcagatgt gtactgagct taaactaac gaccatgaag ggcggctgat tcagaacagc 180
ataacaatag aaaggatggt actttcggca ttcgacgaaa gaagaacaa gtatctcgag 240
gagcatcca gtgctgggaa agaccctaag aaaacaggag gcccgatata cagaaggaaa 300
gatgggaaat ggatgagggg actcatcctc catgataaag aagaaatcat gagaatctgg 360
cgtcaggcca acaatggtga agacgctact gctggtctta ctcatatgat gatctggcac 420
tccaatctca atgacaccac ataccaaga acaagggctc ttgttcggac tgggatggat 480
cccagaatgt gctctctgat gcaaggctca accctcccac ggagatctgg agccgctggt 540
gctgcagtaa aagggtgttg aacaatggta atggaactca tcagaatgat caaacgcgga 600
ataaatgatc ggaatttctg gagaggtgaa aatggtcga gaaccagaat tgcttatgaa 660
agaatgtgca atatcctcaa agggaaattt cagacagcag cacaacgggc tatgatggac 720
caggtgaggg aaggccgcaa tcctggaaac gctgagattg aggatctcat tttcttgcca 780
cgatcagcac ttattttgag aggatcagta gccataaat catgcctacc tgctgtggt 840
tatggccttg cagtaaccag tgggtatgac tttgagaagg aaggatactc tctggttgg 900
attgatcctt tcaaactact ccagaacagt caaattttca gtctaatacag accaaaagaa 960
aaccagcac acaagagcca gttggtgtgg atggcatgcc attctgcagc atttgaggac 1020
ctgagagttt taaatttcat tagaggaacc aaagtaatcc caagaggaca gttaacaacc 1080

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| | |
|---|------|
| agaggagttc aaatagcttc aaatgaaaac atggagacaa tagattctag cacacttgaa | 1140 |
| ctgagaagca aatattgggc aataaggacc agaagcggag gaaacaccag tcaacagaga | 1200 |
| gcatctgcag gacagataag tgtgcaacct actttctcag tacagagaaa tcttcccttt | 1260 |
| gagagagcaa ccattatggc tgcattcact ggtaaacctg aagggaggac ttccgacatg | 1320 |
| agaacggaaa tcataaggat gatggaaaat gccaaatcag aagatgtgtc tttccagggg | 1380 |
| cggggagtct tcgagctctc ggaacgaaaag gcaacgaacc cgatcgtgcc ttctttgac | 1440 |
| atgagcaatg aagggcttta tttcttcgga gacaatgctg aggagtttga cagttaa | 1498 |

<210> SEQ ID NO 15

<211> LENGTH: 982

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 15

| | |
|---|-----|
| atgagtcttc taaccgaggt cgaaacgtac gttctctcta tcgtaccatc aggccccctc | 60 |
| aaagccgaga tcgcgcagag acttgaagat gtctttgcag ggaagaacac cgatcttgag | 120 |
| gcactcatgg aatggctaaa gacaagacca atcctgtcac ctctgactaa agggatttta | 180 |
| ggatttgat tcacgctcac cgtgccagc gagcggagc tgcagcgtag acgctttgtc | 240 |
| caaatgccc ttagtggaag cggagatcca aacaacatgg acagagcagt aaaactgtac | 300 |
| aggaagctta aaagagaaat aacattccat ggggcaaaag aggtggcact cagctattcc | 360 |
| actggtgcac tagccagctg catgggactc atatacaaca gaatgggaa tggtacaacc | 420 |
| gaagtggcat ttggcctgg atgcgccaca tgtgaacaga ttgctgattc ccagcatcgg | 480 |
| tctcacaggc agatgggtgac aacaaccaac ccattaatca gacatgaaa cagaatggta | 540 |
| ttagccagta ccacggctaa agccatggaa cagatggcag gatcgagtga gcaggcagca | 600 |
| gaggccatgg aggttgctag tagggctagg cagatggtag aggcaatgag aaccattggg | 660 |
| accaccctta gctccagtc cggtttgaaa gatgatctcc ttgaaaattt acaggcctac | 720 |
| cagaaacgga tgggagtgca aatgcagcga ttcaagtgat cctctcgta ttgcagcaag | 780 |
| tatcattggg atcttgcact tgatattgtg gattcttgat cgtctttct tcaaattcat | 840 |
| ttatcgtcgc cttaaatcag ggttgaaaag agggccttct acggaaggag tacctgagtc | 900 |
| tatgagggaa gaatatcgcc aggaacagca gaatgctgtg gatgttgacg atggtcattt | 960 |
| tgtcaacata gagctggagt aa | 982 |

<210> SEQ ID NO 16

<211> LENGTH: 838

<212> TYPE: DNA

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 16

| | |
|--|-----|
| atggattcca aactgtgtc aagctttcag gtagactgtt ttctttggca tgtccgcaaa | 60 |
| cgattcgcag accaagaact gggatgatgc ccattccttg accggcttcg ccgagaccag | 120 |
| aagtccctaa ggggaagagg tagcactctt ggtctggaca tcgaaacagc cactcatgca | 180 |
| ggaaagcaga tagtggagca gattctggaa aaggaatcag atgaggcact taaaatgacc | 240 |
| attgctctg ttcctacttc acgctactta actgacatga ctcttgatga gatgtcaaga | 300 |
| gactggttca tgctcatgcc caagcaaaaa gtaacaggct ccctatgtat aagaatggac | 360 |
| caggcaatca tggataagaa catcactact aaagcaaaact ttagtgtgat tttcgaaagg | 420 |
| ctggaacac taatactact tagagccttc accgaagaag gagcagctcg tggcgaatt | 480 |

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tcaccattac cttctcttcc aggacatact aatgaggatg tcaaaaatgc aattggggtc 540
ctcatcggag gacttaaatg gaatgataat acggttagaa tctctgaaac tctacagaga 600
ttcgcttgga gaagcagtc tgaagaatggg agaccttcat tcccttcaaa gcagaaaacga 660
aaaatggaga gaacaattaa gccaaaaatt tgaagaaata agatggttga ttgaagaagt 720
gcgacataga ttgaaaaata cagaaaatag ttttgaacaa ataacattta tgcaagcctt 780
acaactattg cttgaagtag aacaagagat aagaacttcc tcggttccagc ttatttaa 838

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<210> SEQ ID NO 17
<211> LENGTH: 97
<212> TYPE: PRT
<213> ORGANISM: Influenza A Virus

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<400> SEQUENCE: 17

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```

Met Ser Leu Leu Thr Glu Val Glu Thr Pro Thr Arg Asn Gly Trp Glu
 1           5           10           15
Cys Lys Cys Ser Asp Ser Ser Asp Pro Leu Val Ile Ala Ala Ser Ile
 20           25           30
Ile Gly Ile Leu His Leu Ile Leu Trp Ile Leu Asp Arg Leu Phe Phe
 35           40           45
Lys Phe Ile Tyr Arg Arg Leu Lys Tyr Gly Leu Lys Arg Gly Pro Ser
 50           55           60
Thr Glu Gly Val Pro Glu Ser Met Arg Glu Glu Tyr Arg Gln Glu Gln
 65           70           75           80
Gln Asn Ala Val Asp Val Asp Asp Gly His Phe Val Asn Ile Glu Leu
 85           90           95

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Glu

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<210> SEQ ID NO 18
<211> LENGTH: 119
<212> TYPE: PRT
<213> ORGANISM: Influenza A Virus

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<400> SEQUENCE: 18

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Met Asp Ser Asn Thr Val Ser Ser Phe Gln Leu Met Arg Met Ser Lys
 1           5           10           15
Met Gln Leu Gly Ser Ser Ser Glu Asp Leu Asn Gly Met Ile Ile Arg
 20           25           30
Leu Glu Ser Leu Lys Leu Tyr Arg Asp Ser Leu Gly Glu Ala Val Met
 35           40           45
Arg Met Gly Asp Leu His Ser Leu Gln Ser Arg Asn Glu Lys Trp Arg
 50           55           60
Glu Gln Leu Ser Gln Lys Phe Glu Glu Ile Arg Trp Leu Ile Glu Glu
 65           70           75           80
Val Arg His Arg Leu Lys Asn Thr Glu Asn Ser Phe Glu Gln Ile Thr
 85           90           95
Phe Met Gln Ala Leu Gln Leu Leu Leu Glu Val Glu Gln Glu Ile Arg
 100          105          110
Thr Phe Ser Phe Gln Leu Ile
 115

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<210> SEQ ID NO 19
<211> LENGTH: 344
<212> TYPE: PRT
<213> ORGANISM: Influenza A Virus

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<400> SEQUENCE: 19

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Met Lys Thr Thr Ile Ile Leu Ile Leu Leu Thr His Trp Ala Tyr Ser
 1           5           10           15

Gln Asn Pro Ile Ser Gly Asn Asn Thr Ala Thr Leu Cys Leu Gly His
 20           25           30

His Ala Val Ala Asn Gly Thr Leu Val Lys Thr Ile Ser Asp Asp Gln
 35           40           45

Ile Glu Val Thr Asn Ala Thr Glu Leu Val Gln Ser Ile Ser Met Gly
 50           55           60

Lys Ile Cys Asn Asn Ser Tyr Arg Ile Leu Asp Gly Arg Asn Cys Thr
 65           70           75           80

Leu Ile Asp Ala Met Leu Gly Asp Pro His Cys Asp Ala Phe Gln Tyr
 85           90           95

Glu Asn Trp Asp Leu Phe Ile Glu Arg Ser Ser Ala Phe Ser Asn Cys
100          105          110

Tyr Pro Tyr Asp Ile Pro Asp Tyr Ala Ser Leu Arg Ser Ile Val Ala
115          120          125

Ser Ser Gly Thr Leu Glu Phe Thr Ala Glu Gly Phe Thr Trp Thr Gly
130          135          140

Val Thr Gln Asn Gly Arg Ser Gly Ala Cys Lys Arg Gly Ser Ala Asp
145          150          155          160

Ser Phe Phe Ser Arg Leu Asn Trp Leu Thr Lys Ser Gly Ser Ser Tyr
165          170          175

Pro Thr Leu Asn Val Thr Met Pro Asn Asn Lys Asn Phe Asp Lys Leu
180          185          190

Tyr Ile Trp Gly Ile His His Pro Ser Ser Asn Gln Glu Gln Thr Lys
195          200          205

Leu Tyr Ile Gln Glu Ser Gly Arg Val Thr Val Ser Thr Lys Arg Ser
210          215          220

Gln Gln Thr Ile Ile Pro Asn Ile Gly Ser Arg Pro Trp Val Arg Gly
225          230          235          240

Gln Ser Gly Arg Ile Ser Ile Tyr Trp Thr Ile Val Lys Pro Gly Asp
245          250          255

Ile Leu Met Ile Asn Ser Asn Gly Asn Leu Val Ala Pro Arg Gly Tyr
260          265          270

Phe Lys Leu Lys Thr Gly Lys Ser Ser Val Met Arg Ser Asp Val Pro
275          280          285

Ile Asp Ile Cys Val Ser Glu Cys Ile Thr Pro Asn Gly Ser Ile Ser
290          295          300

Asn Asp Lys Pro Phe Gln Asn Val Asn Lys Val Thr Tyr Gly Lys Cys
305          310          315          320

Pro Lys Tyr Ile Arg Gln Asn Thr Leu Lys Leu Ala Thr Gly Met Arg
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Asn Val Pro Glu Lys Gln Ile Arg
340

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<210> SEQ ID NO 20

<211> LENGTH: 344

<212> TYPE: PRT

<213> ORGANISM: Influenza A Virus

<400> SEQUENCE: 20

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Met Lys Thr Thr Ile Ile Leu Ile Leu Leu Thr His Trp Ala Tyr Ser
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-continued

Gln Asn Pro Ile Ser Gly Asn Asn Thr Ala Thr Leu Cys Leu Gly His
20 25 30

His Ala Val Ala Asn Gly Thr Leu Val Lys Thr Ile Ser Asp Asp Gln
35 40 45

Ile Glu Val Thr Asn Ala Thr Glu Leu Val Gln Ser Ile Ser Met Gly
50 55 60

Lys Ile Cys Asn Asn Ser Tyr Arg Ile Leu Asp Gly Arg Asn Cys Thr
65 70 75 80

Leu Ile Asp Ala Met Leu Gly Asp Pro His Cys Asp Val Phe Gln Tyr
85 90 95

Glu Asn Trp Asp Leu Phe Ile Glu Arg Ser Ser Ala Phe Ser Asn Cys
100 105 110

Tyr Pro Tyr Asp Ile Pro Asp Tyr Ala Ser Leu Arg Ser Ile Val Ala
115 120 125

Ser Ser Gly Thr Leu Glu Phe Thr Ala Glu Gly Phe Thr Trp Thr Gly
130 135 140

Val Thr Gln Asn Gly Arg Ser Gly Ala Cys Lys Arg Gly Ser Ala Asp
145 150 155 160

Ser Phe Phe Ser Arg Leu Asn Trp Leu Thr Lys Ser Gly Asn Ser Tyr
165 170 175

Pro Thr Leu Asn Val Thr Met Pro Asn Asn Lys Asn Phe Asp Lys Leu
180 185 190

Tyr Ile Trp Gly Ile His His Pro Ser Ser Asn Gln Glu Gln Thr Lys
195 200 205

Leu Tyr Ile Gln Glu Ser Gly Arg Val Thr Val Ser Thr Lys Arg Ser
210 215 220

Gln Gln Thr Ile Ile Pro Asn Ile Gly Ser Arg Pro Trp Val Arg Gly
225 230 235 240

Gln Ser Gly Arg Ile Ser Ile Tyr Trp Thr Ile Val Lys Pro Gly Asp
245 250 255

Ile Leu Met Ile Asn Ser Asn Gly Asn Leu Val Ala Pro Arg Gly Tyr
260 265 270

Phe Lys Leu Lys Thr Gly Lys Ser Ser Val Met Arg Ser Asp Ala Pro
275 280 285

Ile Asp Ile Cys Val Ser Glu Cys Ile Thr Pro Asn Gly Ser Ile Ser
290 295 300

Asn Asp Lys Pro Phe Gln Asn Val Asn Lys Val Thr Tyr Gly Lys Cys
305 310 315 320

Pro Lys Tyr Ile Arg Gln Asn Thr Leu Lys Leu Ala Thr Gly Met Arg
325 330 335

Asn Val Pro Glu Lys Gln Ile Arg
340

What is claimed is:

1. A method of preparing a vaccine, comprising

providing an isolated live H3 influenza virus comprising a gene segment with sequences for a HA having SEQ ID NO: 1 or a HA having at least 98% amino acid sequence identity to SEQ ID NO:1 which HA does not have a valine at position 78 or an asparagine at position 159;

combining the isolated H3 influenza virus with an adjuvant or treating the isolated H3 influenza virus with an agent that inactivates the virus, thereby providing a composition; and

55 providing an individual dose of the composition comprising an amount effective to immunize a mammal.

2. The method of claim 1 wherein the mammal is a horse.

3. The method of claim 1 wherein the mammal is a canine.

4. The method of claim 1 wherein the composition comprises inactivated virus.

5. The method of claim 1 wherein the H3 influenza virus comprises at least one of the following gene segments: a gene segment with sequences for a NA having SEQ ID NO:2 or having at least 95% amino acid sequence identity to SEQ ID NO:2, a gene segment with sequences for a PB1 having SEQ ID NO:3 or having at least 95% amino acid sequence identity to SEQ ID NO:3, a gene segment with sequences for

63

a PB2 having SEQ ID NO:4 or having at least 95% amino acid sequence identity to SEQ ID NO:4, a gene segment with sequences for a PA having SEQ ID NO:5 or having at least 95% amino acid sequence identity to SEQ ID NO:5, a gene segment with sequences for a NP having SEQ ID NO:6 or having at least 95% amino acid sequence identity to SEQ ID NO:6, a gene segment with sequences for a M1 having SEQ ID NO:7 or having at least 95% amino acid sequence identity to SEQ ID NO:7, a gene segment with sequences for a M2 having SEQ ID NO:17 or having at least 95% amino acid sequence identity to SEQ ID NO: 17, a gene segment with sequences for a NS1 having SEQ ID NO:8 or having at least 95% amino acid sequence identity to SEQ ID NO:8, or a gene segment with sequences for a NS2 having SEQ ID NO: 18 or having at least 95% amino acid sequence identity to SEQ ID NO: 18.

6. The method of claim 1 wherein the composition further comprises a different isolated influenza virus.

7. The method of claim 1 wherein the composition further comprises a pathogen other than the H3 influenza virus.

8. The method of claim 1 wherein the composition comprises the adjuvant.

9. The method of claim 1 further comprises a pharmaceutically acceptable carrier.

10. The method of claim 9 wherein the carrier is suitable for intramuscular administration.

11. The method of claim 1 wherein the composition is freeze-dried.

64

12. A method of preparing a vaccine, comprising providing an isolated live H3 influenza virus comprising a gene segment with sequences for a HA having SEQ ID NO: 1 or a HA having at least 95% amino acid sequence identity to SEQ ID NO:1 which HA has an alanine at position 78 and a serine at position 159; combining the isolated H3 influenza virus with an adjuvant or treating the isolated H3 influenza virus with an agent that inactivates the virus, thereby providing a composition; and

providing an individual dose of the composition comprising an amount effective to immunize a mammal.

13. The method of claim 12 wherein the mammal is a horse.

14. The method of claim 12 wherein the mammal is a canine.

15. The method of claim 12 wherein the composition comprises inactivated virus.

16. The method of claim 12 wherein the carrier is suitable for intranasal administration.

17. The method of claim 12 wherein the composition further comprises a different isolated influenza virus.

18. The method of claim 12 wherein the composition further comprises a pathogen other than the H3 influenza virus.

19. The method of claim 12 wherein the composition comprises the adjuvant.

20. The method of claim 12 further comprising a pharmaceutically acceptable carrier suitable for intramuscular or intranasal administration.

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