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Introduction of Eurasian-Origin Influenza A(H8N4) Virus into North America by Migratory Birds

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We identified a Eurasian-origin influenza A(H8N4) virus in North America by sampling wild birds in western Alaska, USA. Evidence for repeated introductions of influenza A viruses into North America by migratory birds suggests that intercontinental dispersal might not be exceedingly rare and that our understanding of viral establishment is incomplete.

Research of and surveillance for influenza A viruses in wild birds inhabiting western Alaska have consistently provided support for the exchange of viruses between East Asia and North America via Beringia (*1*,*2*). Sampling of wild birds inhabiting Izembek National Wildlife Refuge (NWR) and surrounding areas in Alaska (≈55°N, 163°W) conducted during 2011–2015 has been used in recent research to identify the dispersal of influenza A(H9N2) viruses among China, South Korea, and Alaska (*3*); provide inference about the evolutionary pathways of economically important foreign-origin poultry pathogens introduced into North America (*4*); and identify sampling efficiencies for optimizing the detection of evidence for intercontinental virus exchange (*5*).

During September–October 2016, we collected 541 combined oral-pharyngeal and cloacal swab samples from hunter-harvested waterfowl (*Anseriformes* spp.) and 401 environmental fecal samples from monospecific flocks of either emperor geese (*Chen canagica*) or glaucous-winged gulls (*Larus glaucescens*) within and around Izembek NWR. Samples were deposited into viral transport media, placed in dry shippers charged with liquid nitrogen within 24 h, shipped, and stored frozen at –80°C before laboratory analysis. We screened samples for the influenza A virus matrix gene and subjected them to virus isolation; resultant isolates were genomically sequenced in accordance with previously reported methods (*5*). A total of 116 samples tested positive for the matrix gene, and 38 isolates were recovered of the following combined subtypes: H1N2, H3N2, H3N2/N6 (mixed infection), H3N8, H4N6, H5N2, H6N2, H7N3,

H8N4, and H12N2. We selected the single H8N4 isolate, A/northern pintail/Alaska/UGAI16-3997/2016(H8N4) (GenBank accession nos. MG976689–96), for genomic characterization as part of this investigation.

We queried sequence information for the complete coding region of each gene segment of A/northern pintail/Alaska/UGAI16-3997/2016(H8N4) against the GenBank database to identify strains sharing ≥99% nt identity. We then reconstructed maximum-likelihood phylogenetic trees for each gene segment in MEGA 7.0.21 (https://www.megasoftware.net/) by incorporating sequence information for representative reference sequences from avian-origin influenza A virus isolates from Eurasia and North America using the general time–reversible plus invariant sites (G+I) model with 1,000 bootstrap replications.

Gene segments for A/northern pintail/Alaska/UGAI16-3997/2016(H8N4), isolated from a sample collected from a hunter-harvested duck on September 6, 2016, shared ≥99% nt identity to those of ≥1 isolates recovered from wild and domestic birds sampled in East Asia during 2006–2016 (online Technical Appendix Table, https://wwwnc.cdc.gov/EID/article/24/10/18-0447-Techap1.pdf). This isolate also shared ≥99% nt identity with 1–4 isolates recovered from wild bird samples collected at Izembek NWR during 2012–2015 at the polymerase acidic and polymerase basic 2 gene segments (online Technical Appendix Table). A/northern pintail/Alaska/UGAI16–3997/2016(H8N4) did not, however, share ≥99% nt identity at all 8 gene segments with any other influenza A virus isolate for which genomic information was available, indicating that this H8N4 isolate might

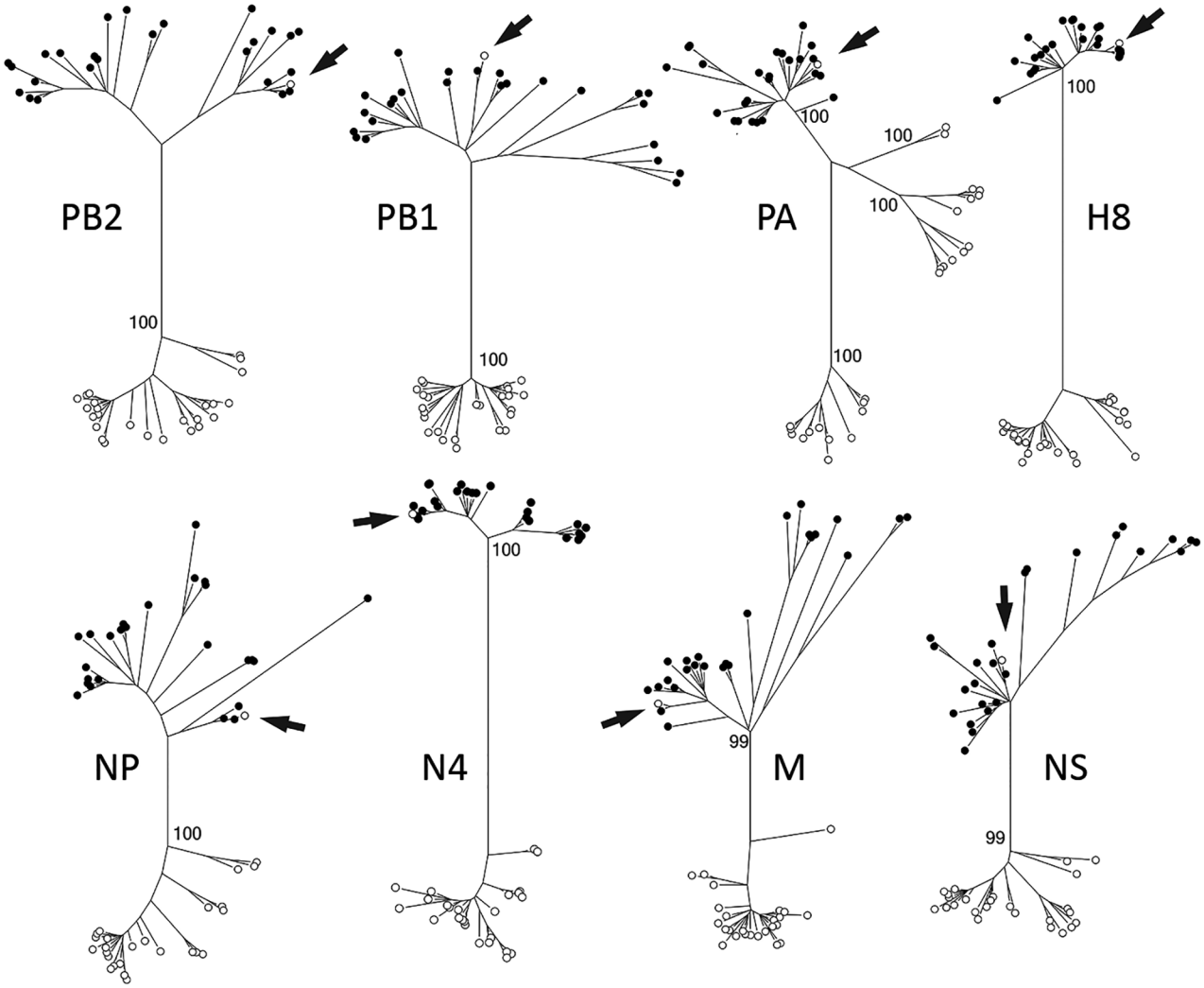

Figure. Maximum-likelihood phylogenetic trees showing inferred relationships among nucleotide sequences for the complete coding regions of gene segments for influenza A virus strain A/northern pintail/Alaska/UGAI16–3997/2016(H8N4) (white circle indicated with an arrow) and reference sequences from viruses isolated from birds in Eurasia (black circles) and North America (white circles). Bootstrap support values for continentally affiliated clades are shown. Phylogenetic trees with complete strain names as tip labels are provided in the online Technical Appendix Figure (https://wwwnc.cdc.gov/EID/article/24/10/18-0447-Techap1.pdf). H, hemagglutinin; M, matrix; N, neuraminidase; NP, nucleoprotein; NS, nonstructural; PA, polymerase acidic; PB, polymerase basic.

represent a previously unidentified or unreported genome constellation (online Technical Appendix Table).

Phylogenetic analyses strongly supported structuring of tree topologies into major clades by continental affiliation of reference sequences (bootstrap values ≥99; online Technical Appendix Figure). Sequence information for all 8 gene segments of A/northern pintail/Alaska/UGAI16-3997/2016(H8N4) clustered within clades composed of reference sequences for influenza A viruses originating from samples collected in Eurasia (Figure; online Technical Appendix Figure). Therefore, phylogenetic analyses provided support for Eurasian ancestry of this genomic constellation. We inferred our results to provide evidence for the introduction of this foreign-origin H8N4 virus into North America by migratory birds given previous support for intercontinental viral dispersal derived through genetic characterization of avian influenza A viruses originating from western Alaska (*1–3,5*), the intercontinental migratory tendencies of northern pintails (*6*,*7*) and other species inhabiting Izembek NWR at the time of sampling (*8*), the paucity of domestic poultry in this region, and the proximity of Izembek NWR to East Asia.

During 2010–2016, research and surveillance for influenza A viruses in wild birds inhabiting North America have provided evidence for the intercontinental dispersal of the following 4 viral genome constellations between Eurasia and North America: H16N3 (*9*), H9N2 (*3*), highly pathogenic clade 2.3.4.4 H5N8 (*10*), and H8N4 (this study). Four reports of independent purported intercontinental dispersal events for influenza A viruses via migratory birds during 7 years of sampling do not disprove the paradigm of restricted viral dispersal between Eurasia and North America. However, repeated detections of these viruses crossing the Bering Strait (*3*,*10*; this study) suggest that viral dispersal between East Asia and North America might not be exceedingly rare. Thus, a lack of selective advantage for comparatively rare foreign-origin influenza A viruses, purifying selection for endemic viruses, or both might be important mechanisms regulating the establishment of these viruses within the wild bird reservoir. Therefore, additional research directed toward understanding selection pressures regulating the establishment of these viruses might provide useful inference for informing surveillance and response activities for economically costly or potentially pandemic foreign-origin viruses in wild birds inhabiting North America.

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New Reassortant Clade 2.3.4.4b Avian Influenza A(H5N6) Virus in Wild Birds, South Korea, 2017–2018

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We isolated new reassortant avian influenza A(H5N6) viruses from feces of wild waterfowl in South Korea during 2017–18. Phylogenetic analysis suggested that reassortment occurred between clade 2.3.4.4b H5N8 and Eurasian low pathogenicity avian influenza viruses circulating in wild birds. Dissemination to South Korea during the 2017 fall migratory season followed.

Clade 2.3.4.4 H5 highly pathogenic avian influenza viruses (HPAIVs) have evolved by reassortment with different neuraminidase (NA) and internal genes of prevailing low pathogenicity avian influenza viruses (LPAIVs) and other HPAIVs to generate new genotypes and further evolved into genetic subgroups A–D since 2014 (*1*). Among these, subgroups A and B viruses were disseminated over vast geographic regions by migratory wild birds (*2*,*3*). Subgroup B influenza A(H5N8) viruses were detected in Qinghai Lake, China, and Uvs-Nuur Lake, Russia, during May–June 2016 (Qinghai/Uvs-like), followed by the identification of reassortant viruses in multiple Eurasian countries (*4*–*6*). Recently, subgroup B H5N6 viruses were isolated from birds in Greece during February 2017 and England, Germany, the Netherlands, Japan, and Taiwan during winter 2017–18 (*7*,*8*).

[1]These authors contributed equally to this article.

During December 2017–January 2018 in South Korea, we isolated 6 H5N6 HPAIVs from 231 fecal samples of wild birds collected from the banks of the Cheongmi-cheon River (37°06′56.9″N, 127°25′18.3″E) and 34 from 222 fecal samples collected from the banks of the Gokgyo-cheon River (36°45′12.3′N, 127°07′12.7′E) (online Technical Appendix 1, https://wwwnc.cdc.gov/EID/article/24/10/18-0461-Techapp1.pdf). These wild bird habitats are wintering sites of migratory waterfowl, including mallard (*Anas platyrhynchos*), spot-billed duck (*Anas poecilorhyncha*), Mandarin duck (*Aix galericulata*), and common teal (*Anas crecca*). The Gokgyo-cheon River is a major habitat site for Mandarin ducks, and numerous HPAIVs were detected in fecal samples from Mandarin ducks during 2011, 2015, and 2016 (*9*). We identified avian influenza virus–positive fecal samples from 38 Mandarin ducks and 2 mallards, based on DNA barcoding technique (*10*). We performed full-length genome sequencing and comparative phylogenetic analysis on 19 of the 40 isolates (online Technical Appendix 1; online Technical Appendix 2, https://wwwnc.cdc.gov/EID/article/24/10/18-0461-Techapp2.xlsx).

All H5N6 isolates shared high nucleotide sequence identities in all 8 gene segments (99.58%–100%) and were identified as HPAIVs based on the presence of multiple basic amino acids at the HA proteolytic cleavage site (PLREKRRKR/G). Searches of the GISAID (https://www.gisaid.org) and BLAST (https://blast.ncbi.nlm.nih.gov/Blast.cgi) databases indicated that all 8 genomes had the highest nucleotide identity with A/Great_Black-backed_Gull/Netherlands/1/2017 (Netherlands/1) clade 2.3.4.4 subgroup B H5N6 strain from December 2017 (99.17%–99.79%), rather than subgroup B H5N6 viruses from Japan and Taiwan collected during December 2017 (97.18%–99.27%).

In phylogenetic analysis, we identified 2 genotypes of subgroup B H5N6 viruses (online Technical Appendix 1 Figures 1, 2): genotypes B.N6.1 and B.N6.2. The genotype B.N6.1 viruses were identified from South Korea, Japan, Taiwan, Greece, and the Netherlands (Netherlands/1 strain), and the genotype B.N6.2 viruses were detected from England, Germany, and the Netherlands. For genotype B.N6.1, all genes except NA clustered with H5N8 HPAIV of previously reported genotypes, H5N8-NL cluster I in the Netherlands (*6*), Ger-11-16 in Germany (*5*), and Duck/Poland/82a/16-like in Italy (*4*). The NA gene clustered with LPAIVs circulating in wild birds in Eurasia and separated into 2 clusters, suggesting the potential for >2 independent reassortment events between H5N8 virus and unidentified wild bird origin N6 segments. Consistent clustering of South Korea isolates with the Netherlands/1 strain in maximum-likelihood (ML) phylogenies for each gene supported by high ML bootstrap values (86–100) suggests their close relationship. The genotype B.N6.2 viruses

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Technical Appendix

Technical Appendix Table. Virus isolates sharing ≥99% nt identity at ≥1 gene segments with A/northern pintail/Alaska/UGAI16–3997/2016(H8N4) as identified on National Center for Biotechnology Information GenBank database on March 12, 2018

Segment	GenBank accession no.	Strain name	Shared nucleotide identity
PB2	KY131326.1	A/northern pintail/Alaska/UGAI15-6994/2015(H6N1)	99%
PB2	KY131357.1	A/northern pintail/Alaska/UGAI15-7300/2015(H6N1)	99%
PB2	KX949521.1	A/northern pintail/Alaska/UGAI15-7403/2015(H3N8)	99%
PB2	LC053481.1	A/duck/Vietnam/LBM798/2014(H3N6)	99%
PB2	KU881717.1	A/Anseriformes/Anhui/L259/2014(H1N1)	99%
PB2	LC148827.1	A/duck/Hokkaido/W9/2015(H1N1)	99%
PB2	LC339728.1	A/duck/Hokkaido/10/2015(H3N6)	99%
PB2	KU881701.1	A/Anseriformes/Anhui/L25/2014(H1N1)	99%
PB2	KT717295.1	A/Anser fabalis/China/Anhui/L221/2014(H6N1)	99%
PB2	KY415872.1	A/duck/Hubei/ZYSYG15/2015(H6N2)	99%
PB2	KY415871.1	A/duck/Hubei/ZYSYG14/2015(H6N2)	99%
PB2	KY415870.1	A/duck/Hubei/ZYSYG1/2015(H6N2)	99%
PB2	KU143586.1	A/duck/Wuhan/WHYF05/2014(H9N2)	99%
PB2	KU881669.1	A/Anseriformes/Anhui/S3/2014(H1N1)	99%
PB2	KY415879.1	A/duck/Hubei/ZYSYF8/2015(H6N6)	99%
PB2	KX121185.1	A/bean goose/Hubei/SZY200/2016(H11N9)	99%
PB1	LC339617.1	A/duck/Hokkaido/W165/2015(H11N6)	99%
PA	LC371817.1	A/duck/Hokkaido/207/2014(H8N2)	99%
PA	KY130810.1	A/glaucous-winged gull/Alaska/473/2012(H3N8)	99%
PA	LC042057.1	A/duck/Hokkaido/W280/2014(H5N3)	99%
PA	LC042050.1	A/duck/Hokkaido/W240/2014(H5N3)	99%
PA	LC339634.1	A/duck/Hokkaido/W19/2013(H7N2)	99%
PA	KU160978.1	A/duck/Hunan/S1012/2009(H4N6)	99%
PA	KY971098.1	A/pigeon/Zhejiang/1120087/2014(H1N2)	99%
PA	KY971097.1	A/goose/Zhejiang/1120085/2014(H1N2)	99%
PA	KY971096.1	A/goose/Zhejiang/1120084/2014(H1N2)	99%
PA	KY971095.1	A/goose/Zhejiang/1120083/2014(H1N2)	99%
PA	KY971094.1	A/goose/Zhejiang/1120078/2014(H1N2)	99%
PA	KY971092.1	A/goose/Zhejiang/1120074/2014(H1N2)	99%
PA	LC339530.1	A/duck/Hokkaido/201/2014(H1N1)	99%
PA	KY971093.1	A/goose/Zhejiang/1120076/2014(H1N2)	99%
PA	KY971091.1	A/goose/Zhejiang/1120069/2014(H1N2)	99%
PA	JX454750.1	A/wild duck/Korea/SH5-26/2008(H4N6)	99%
PA	GU086282.1	A/duck/Korea/A93/2008(H5N2)	99%
PA	GQ325638.1	A/environment/Dongting Lake/Hunan/3-9/2007(H10N8)	99%
PA	GQ290468.1	A/environment/Dongting Lake/Hunan/3-9/2007(H10N8)	99%
PA	KU160938.1	A/duck/Henan/S1091/2010(H4N6)	99%
PA	JQ041395.1	A/duck/Hebei/0908/2009(H5N2)	99%
PA	JX454742.1	A/wild duck/Korea/PSC6-1/2009(H4N6)	99%
PA	HM745397.1	A/duck/Jiangxi/k0701/2009(H11N2)	99%
PA	KC899731.1	A/wild duck/SH38-64/2010(H2N8)	99%
PA	CY098237.1	A/aquatic bird/Korea/CN9/2009(H6N8)	99%
PA	GQ325654.1	A/environment/Dongting Lake/Hunan/3-9/2007(H10N8)	99%
PA	KP862040.1	A/duck/Hunan/S4280/2009(H10N8)	99%
PA	KC899729.1	A/wild duck/SH38-56/2010(H2N8)	99%
PA	KF260286.1	A/duck/Yunnan/87/2007(H7N6)	99%
PA	KF260249.1	A/duck/Jiangxi/21669/2009(H7N7)	99%
PA	KX297824.1	A/environment/Korea/W148/2006(H7N7)	99%
PA	KX297823.1	A/environment/Korea/W143/2006(H7N7)	99%
PA	KU160930.1	A/duck/Guizhou/S1167/2010(H4N6)	99%

Segment	GenBank accession no.	Strain name	Shared nucleotide identity
PA	KF260254.1	A/chicken/Jiangxi/2369/2010(H7N7)	99%
PA	JX454718.1	A/duck/Korea/DY104/2007(H4N6)	99%
PA	CY049803.1	A/gadwall/Altai/1326/2007(H3N8)	99%
PA	KU921397.1	A/duck/Shanghai/602/2009(H10N8)	99%
PA	KX297827.1	A/environment/Korea/W169/2007(H7N7)	99%
PA	KP287965.1	A/duck/Jiangxi/26141/2009(H10N7)	99%
PA	KF260251.1	A/duck/Jiangxi/23008/2009(H7N7)	99%
HA	LC339587.1	A/duck/Hokkaido/95/2014(H8N4)	99%
NP	LC339692.1	A/duck/Hokkaido/WZ1/2014(H11N2)	99%
NP	LC371795.1	A/duck/Hokkaido/166/2014(H5N2)	99%
NP	LC042066.1	A/duck/Hokkaido/WZ1/2014(H11N2)	99%
NP	LC339612.1	A/duck/Hokkaido/W150/2014(H4N6)	99%
NP	LC339596.1	A/duck/Hokkaido/W118/2014(H4N6)	99%
NP	CY079214.1	A/avian/Japan/8KI0195/2008(H6N8)	99%
NP	AB530993.1	A/mallard/Hokkaido/24/2009(H5N1)	99%
NP	KF259795.1	A/common teal/Hong Kong/MPK630/2009(H10N9)	99%
NP	KF259796.1	A/eurasian wigeon/Hong Kong/MPK653/2009(H11N9)	99%
NP	KF259784.1	A/eurasian wigeon/Hong Kong/MPK655/2009(H11N9)	99%
NP	JX570854.1	A/canvasback/Xianghai/428/2011(H5N2)	99%
NP	LC121485.1	A/duck/Hokkaido/W90/2007(H10N7)	99%
NP	JX570870.1	A/green-winged teal/Xianghai/430/2011(H5N2)	99%
NP	CY079238.1	A/avian/Japan/8KI0150/2008(H3N8)	99%
NP	AB546150.1	A/pintail/Aomori/422/2007(H1N1)	99%
NA	LC339589.1	A/duck/Hokkaido/95/2014(H8N4)	99%
N4	LC339565.1	A/duck/Hokkaido/238/2014(H8N4)	99%
N4	LC339557.1	A/duck/Hokkaido/222/2014(H8N4)	99%
N4	LC339549.1	A/duck/Hokkaido/221/2014(H8N4)	99%
N4	LC339541.1	A/duck/Hokkaido/220/2014(H8N4)	99%
N4	KU143355.1	A/duck/Wenzhou/YJYF78/2015(H1N4)	99%
N4	JN817552.1	A/wild bird/Korea/A02/2011(H10N4)	99%
M	KU881675.1	A/Anseriformes/Anhui/S3/2014(H1N1)	99%
M	KU881691.1	A/Anseriformes/Anhui/S107/2014(H1N1)	99%
M	KU881707.1	A/Anseriformes/Anhui/L25/2014(H1N1)	99%
M	KU881723.1	A/Anseriformes/Anhui/L259/2014(H1N1)	99%
M	KX066874.1	A/wild bird/Korea/SK14/2014(H1N1)	99%
M	KT717285.1	A/Anser fabalis/China/Anhui/L144/2014(H6N1)	99%
M	KT717301.1	A/Anser fabalis/China/Anhui/L221/2014(H6N1)	99%
M	KU143301.1	A/wild bird/Wuhan/CDHN09/2015(H6N2)	99%
M	KU143302.1	A/wild bird/Wuhan/CDHN15/2015(H6N2)	99%
M	LC053487.1	A/duck/Vietnam/LBM798/2014(H3N6)	99%
M	LC121311.1	A/duck/Mongolia/179/2015(H3N8)	99%
M	LC121303.1	A/duck/Mongolia/173/2015(H3N8)	99%
M	KU160854.1	A/duck/Chongqing/S2086/2012(H4N8)	99%
M	KJ907490.1	A/black-necked crane/Zhaotong/ZT-12/2013(H1N2)	99%
M	MF147259.1	A/mallard duck/Netherlands/8/2014(H7N5)	99%
M	KX978943.1	A/mallard duck/Netherlands/2/2015(H7N7)	99%
M	KX977880.1	A/mallard duck/Netherlands/3/2015(H7N7)	99%
M	LC121439.1	A/duck/Mongolia/709/2015(H10N7)	99%
M	LC121423.1	A/duck/Mongolia/626/2015(H10N7)	99%
M	LC121383.1	A/duck/Mongolia/499/2015(H10N7)	99%
M	KF462313.1	A/European teal/Chany/63/2011(H3N8)	99%
M	KY635804.1	A/duck/Bangladesh/24705/2015(H7N1)	99%
M	KY635683.1	A/duck/Bangladesh/24704/2015(H15N9)	99%
M	KY402068.1	A/hooded crane/Korea/1176/2016(H1N1)	99%
M	AB981453.1	A/muscovy duck/Quang Ninh/131/2013(H3N8)	99%
M	CY146551.1	A/duck/Hunan/S11090/2012(H4N6)	99%
NS	KU881716.1	A/Anseriformes/Anhui/L167/2014(H1N1)	99%
NS	KT717222.1	A/Anser fabalis/China/Anhui/S39/2014(H6N2)	99%
NS	KT717254.1	A/Anser fabalis/China/Anhui/S148/2014(H6N2)	99%
NS	KU143433.1	A/chicken/Wuhan/WHJF/2014(H5N2)	99%
NS	KT717230.1	A/Anser fabalis/China/Anhui/S45/2014(H6N2)	99%
NS	KT717246.1	A/Anser fabalis/China/Anhui/S104/2014(H6N2)	99%
NS	KU160967.1	A/duck/Hubei/S2213/2012(H4N2)	99%
NS	KJ526011.1	A/duck/Thailand/CU-11836C/2011(H1N3)	99%
NS	KC609961.1	A/mallard/Korea/NHG187/2008(H7N7)	99%
NS	MG367026.1	A/grey heron/Korea/VI1511105/2015(H3N8)	99%
NS	MG367025.1	A/mallard duck/Korea/VI1511095/2015(H4N6)	99%
NS	MG367024.1	A/mallard duck/Korea/VI1511090/2015(H4N6)	99%
NS	MG367023.1	A/great egret/Korea/VI1511065/2015(H4N6)	99%

Segment	GenBank accession no.	Strain name	Shared nucleotide identity
NS	MG367022.1	A/mallard duck/Korea/VI160646/2016(H6N5)	99%
NS	MG367021.1	A/mallard duck/Korea/VI160383/2016(H6N2)	99%
NS	MG367020.1	A/mallard duck/Korea/VI160266/2016(H10N1)	99%
NS	MG367019.1	A/falcata teal/Korea/VI160246/2016(H11N9)	99%
NS	MG367018.1	A/green-winged teal/Korea/VI160181/2016(H10N1)	99%
NS	MG367017.1	A/green-winged teal/Korea/VI160151/2016(H11N9)	99%
NS	MG367016.1	A/mallard duck/Korea/VI154461/2015(H4N6)	99%
NS	MG367015.1	A/mallard duck/Korea/VI152573/2015(H11N9)	99%
NS	MG367014.1	A/mallard duck/Korea/VI152538/2015(H5N3)	99%
NS	MG367013.1	A/mallard duck/Korea/VI152533/2015(H5N3)	99%
NS	MG367012.1	A/mallard duck/Korea/VI147540/2014(H11N9)	99%
NS	MG367011.1	A/mallard duck/Korea/VI147532/2014(H11N9)	99%
NS	MG367010.1	A/mallard duck/Korea/VI146993/2014(H3N8)	99%
NS	MG367009.1	A/mallard duck/Korea/VI142218/2014(H3N8)	99%
NS	MG367008.1	A/mallard duck/Korea/VI141432/2014(H3N8)	99%
NS	MG367007.1	A/mallard duck/Korea/VI141407/2014(H7N7)	99%
NS	MG367006.1	A/hooded crane/Korea/VI160792/2016(H4N8)	99%
NS	MG367005.1	A/mallard duck/Korea/VI150161/2015(H7N6)	99%
NS	MG367004.1	A/mallard duck/Korea/VI150051/2015(H7N1)	99%
NS	MG367003.1	A/mallard duck/Korea/CBU143781/2014(H1N8)	99%
NS	MG367002.1	A/mallard duck/Korea/CBU143751/2014(H4N1)	99%
NS	MG367001.1	A/mallard duck/Korea/CBU143501/2014(H4N1)	99%
NS	MG367000.1	A/mallard duck/Korea/CBU143491/2014(H4N6)	99%
NS	MG366999.1	A/mallard duck/Korea/CBU142416/2014(H3N6)	99%
NS	MG366998.1	A/hooded crane/Korea/VI1513992/2015(H3N8)	99%
NS	MG366997.1	A/Northern pintail/Korea/VI1511874/2015(H3N8)	99%
NS	MG366996.1	A/mallard duck/Korea/VI1511070/2015(H10N5)	99%
NS	MG366995.1	A/falcata teal/Korea/VI160216/2016(H2N5)	99%
NS	MG366994.1	A/mallard duck/Korea/VI146916/2014(H7N4)	99%
NS	MG366993.1	A/mallard duck/Korea/VI146688/2014(H6N8)	99%
NS	MG366992.1	A/mallard duck/Korea/VI146668/2014(H6N8)	99%
NS	MG366991.1	A/mallard duck/Korea/VI145825/2014(H7N7)	99%
NS	MG366990.1	A/mallard duck/Korea/VI142063/2014(H7N7)	99%
NS	MG366989.1	A/mallard duck/Korea/VI141417/2014(H3N8)	99%
NS	MG366988.1	A/hooded crane/Korea/VI160196/2016(H1N1)	99%
NS	MG366987.1	A/mallard duck/Korea/CBU142426/2014(H4N2)	99%
NS	MG366985.1	A/mallard duck/Korea/VI141467/2014(H3N8)	99%
NS	LC339735.1	A/duck/Hokkaido/10/2015(H3N6)	99%
NS	KC609960.1	A/Northern shoveler/Korea/SD175/2008(H7N3)	99%
NS	KC899765.1	A/wild duck/SH17-34/2008(H2N3)	99%
NS	KF260044.1	A/duck/Yunnan/2908/2009(H11N9)	99%
NS	JX454749.1	A/wild duck/Korea/SH5-26/2008(H4N6)	99%
NS	LC371790.1	A/duck/Hokkaido/162/2013(H2N1)	99%
NS	MG366986.1	A/mallard duck/Korea/VI141412/2014(H1N1)	99%
NS	KX162596.1	A/duck/Shanghai/408-1/2009(H4N6)	99%
NS	KF357802.1	A/duck/Zhejiang/4613/2013(H3N2)	99%
NS	KJ526003.1	A/duck/Thailand/CU-12677T/2012(H11N6)	99%
NS	JX570845.1	A/spot-billed duck/Xianghai/427/2011(H5N2)	99%
NS	JN852799.1	A/chicken/Korea/KNUSWR09/2009(H9N2)	99%
NS	JN852807.1	A/chicken/Korea/KNUWSJ09/2009(H9N2)	99%
NS	JN087364.1	A/environment/Korea/SH11-10/2009(H3N8)	99%
NS	HQ897969.1	A/mallard/Korea/KNU YP09/2009(H1N1)	99%
NS	GU086262.1	A/duck/Korea/A14/2008(H5N2)	99%
NS	KY785842.1	A/chicken/Korea/C47/2009(H9N2)	99%
NS	KX162597.1	A/duck/Shanghai/420-2/2009(H4N6)	99%
NS	KX297819.1	A/environment/Korea/W478/2014(H7N7)	99%
NS	KX121192.1	A/bean goose/Hubei/SZY200/2016(H11N9)	99%
NS	KJ525995.1	A/duck/Thailand/CU-12679C/2012(H4N6)	99%
NS	KJ525991.1	A/duck/Thailand/CU-12659T/2012(H4N6)	99%
NS	JN852791.1	A/chicken/Korea/KNUGJ09/2009(H9N2)	99%
NS	CY079247.1	A/avian/Japan/8KI0135/2008(H6N5)	99%
NS	GU086258.1	A/chicken/Korea/A170/2009(H9N2)	99%
NS	LC367414.1	A/duck/Mongolia/53/2011(H3N8)	99%
NS	LC367406.1	A/duck/Mongolia/50/2010(H10N8)	99%
NS	LC367398.1	A/duck/Mongolia/496/2010(H3N3)	99%
NS	LC367374.1	A/duck/Mongolia/46/2010(H10N8)	99%
NS	KT266946.1	A/duck/Guangxi/113/2012(H6N8)	99%
NS	KX297813.1	A/environment/Korea/W178/2007(H7N7)	99%
NS	KX297811.1	A/environment/Korea/W156/2006(H7N7)	99%

Segment	GenBank accession no.	Strain name	Shared nucleotide identity
NS	LC042061.1	A/duck/Hokkaido/W280/2014(H5N3)	99%
NS	LC042054.1	A/duck/Hokkaido/W240/2014(H5N3)	99%
NS	KF260030.1	A/northern shoveler/Hong Kong/MPC657/2006(H10N9)	99%
NS	KC693602.1	A/duck/Taiwan/DV1846/2010(H3N8)	99%
NS	JN244259.1	A/duck/Korea/A349/2009(H7N2)	99%
NS	JN852783.1	A/duck/Korea/KNUDPJ09/2009(H9N2)	99%
NS	AB593435.1	A/duck/Vietnam/G119/2006(H3N8)	99%
NS	FJ750868.1	A/mallard/Korea/GH170/2007(H7N7)	99%
NS	GQ414964.1	A/spot-billed duck/Korea/528/2008(H6N8)	99%
NS	LC339527.1	A/duck/Hokkaido/20/2015(H3N8)	99%
NS	LC332535.1	A/duck/Hokkaido/17/2015(H3N8)	99%
NS	LC332527.1	A/duck/Hokkaido/15/2015(H3N8)	99%
NS	LC332519.1	A/duck/Hokkaido/14/2015(H3N8)	99%
NS	LC332511.1	A/duck/Hokkaido/13/2015(H3N8)	99%
NS	LC332503.1	A/duck/Hokkaido/12/2015(H3N8)	99%
NS	GU086257.1	A/chicken/Korea/A146/2009(H9N2)	99%
NS	LC367502.1	A/duck/Mongolia/675/2010(H1N1)	99%
NS	LC367390.1	A/duck/Mongolia/493/2010(H10N8)	99%
NS	LC349403.1	A/duck/Mongolia/371/2010(H10N8)	99%
NS	LC349395.1	A/duck/Mongolia/340/2011(H4N8)	99%
NS	KY785818.1	A/chicken/Korea/C36/2009(H9N2)	99%
NS	KX297810.1	A/environment/Korea/W152/2006(H7N7)	99%
NS	KU158918.1	A/chicken/Nanjing/B854-2/2011(H3N8)	99%
NS	KU158917.1	A/duck/Nanjing/A1591-1/2010(H3N8)	99%
NS	KT318510.1	A/duck/Thailand/CU-11671C/2011(H3N8)	99%
NS	KF886485.1	A/wild bird/Jilin/SJ95/2012(H9N2)	99%
NS	LC000592.1	A/muscovy duck/Vietnam/LBM687/2014(H4N6)	99%
NS	KF260026.1	A/common teal/Hong Kong/MPL1075/2011(H11N9)	99%
NS	KF013922.1	A/duck/Guangxi/GXd-1/2011(H1N2)	99%
NS	KC876695.1	A/wild goose/Dongting/C1037/2011(H12N8)	99%
NS	JX273028.1	A/duck/Korea/J31/2009(H7N2)	99%
NS	AB593467.1	A/duck/Vietnam/G30/2008(H11N9)	99%
NS	GQ414969.1	A/spot-billed duck/Korea/546/2008(H6N1)	99%
NS	GQ414968.1	A/spot-billed duck/Korea/536/2008(H6N1)	99%
NS	GQ414965.1	A/mallard/Korea/L08-8/2008(H6N1)	99%
NS	GQ414963.1	A/spot-billed duck/Korea/527/2008(H6N1)	99%
NS	GQ414970.1	A/spot-billed duck/Korea/537/2008(H6N1)	99%
NS	LC367422.1	A/duck/Mongolia/565/2011(H8N4)	99%
NS	LC349339.1	A/duck/Mongolia/258/2011(H8N4)	99%
NS	LC339815.1	A/duck/Mongolia/121/2011(H10N7)	99%
NS	MG021169.1	A/duck/Jiangshu/YZ916/2016(H3N2)	99%
NS	KY785878.1	A/duck/Korea/D30/2009(H9N2)	99%
NS	KY785810.1	A/chicken/Korea/C31/2009(H9N2)	99%
NS	KU921413.1	A/duck/Fujian/1761/2010(H10N3)	99%
NS	KX867861.1	A/wild bird/Jiangxi/P419/2016(H6N8)	99%
NS	KX028846.1	A/duck/Zhejiang/727D26/2013(H11N3)	99%
NS	KX028845.1	A/duck/Zhejiang/727D25/2013(H11N3)	99%
NS	KX028844.1	A/duck/Zhejiang/727D22/2013(H11N3)	99%
NS	KX028842.1	A/duck/Zhejiang/727D7/2013(H11N3)	99%
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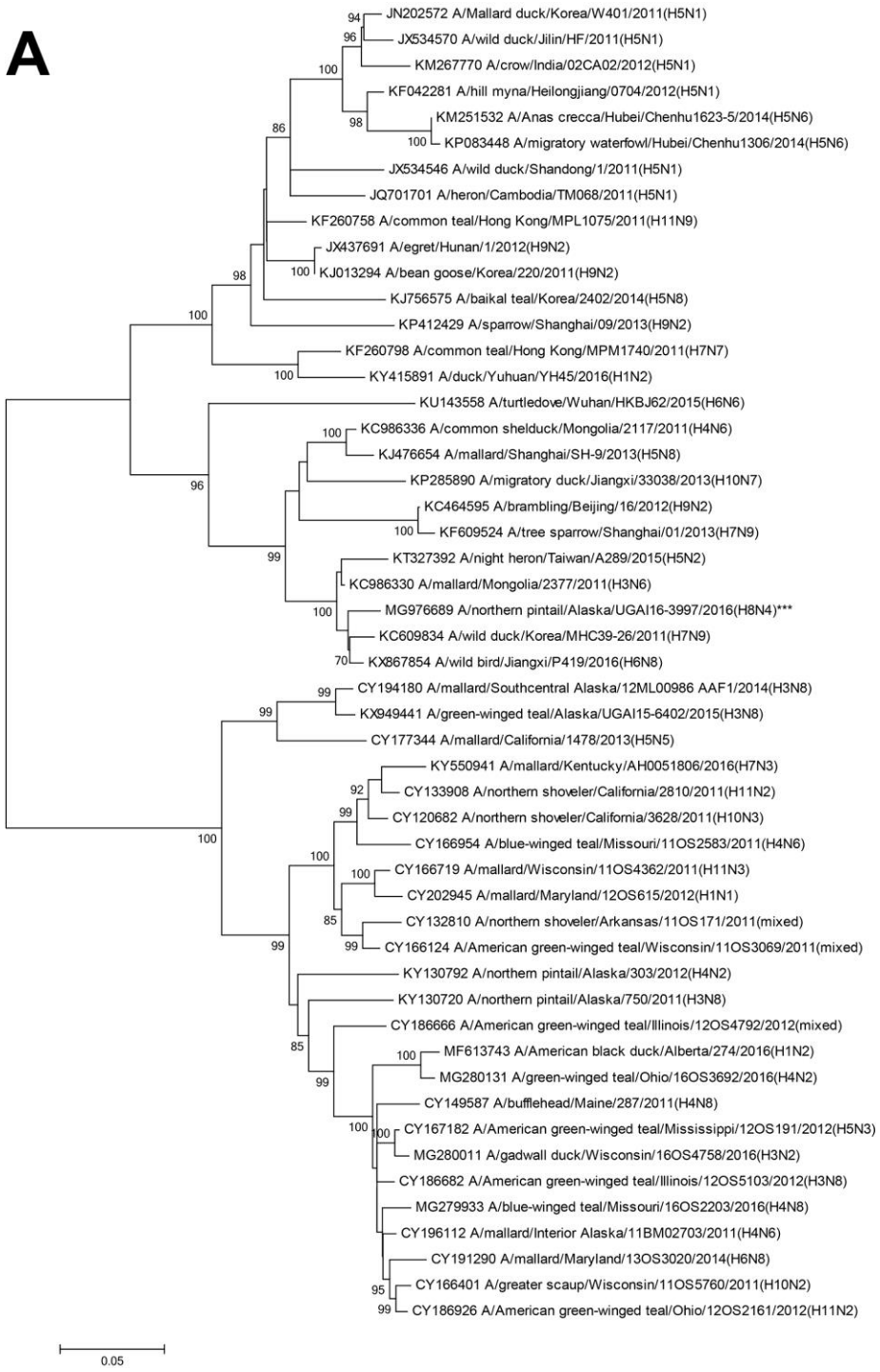
NS	KU161015.1	A/duck/Jiangxi/S21046/2012(H4N2)	99%
NS	KR265548.1	A/duck/Japan/11OG1032/2011(H5N2)	99%
NS	KR265556.1	A/duck/Japan/11OG1038/2011(H5N2)	99%
NS	KR265564.1	A/duck/Japan/11OG1083/2011(H5N2)	99%
NS	KR265572.1	A/duck/Japan/11OG1084/2011(H5N2)	99%
NS	KP416974.1	A/duck/Jiangxi/5416/2014(mixed)	99%
NS	KP285481.1	A/duck/Jiangxi/15846/2013(H10N3)	99%
NS	KC871461.1	A/mallard/Mongolia/1581/2010(H3N8)	99%
NS	KF260070.1	A/wild waterfowl/Hong Kong/MPM3375/2011(H7N6)	99%
NS	KF260001.1	A/duck/Jiangxi/13291/2009(H7N3)	99%
NS	CY146576.1	A/duck/Hunan/S11313/2012(H4N2)	99%
NS	KF013930.1	A/duck/Guangxi/GXd-4/2011(H1N2)	99%
NS	AB546184.1	A/pintail/Aomori/1130/2008(H1N3)	99%
NS	CY060339.1	A/mallard/Sweden/58/2003(H11N1)	99%
NS	FJ802405.1	A/duck/Thailand/AY-354/2008(H3N2)	99%
NS	EU580556.1	A/Anas querquedula/Astrakhan/3091/2002(H4N8)	99%
NS	EU158147.1	A/duck/Jiangxi/1742/03(H7N7)	99%
NS	GU086259.1	A/duck/Korea/A174/2009(H9N2)	99%

*M, matrix; N, neuraminidase; NP, nucleoprotein; NS, nonstructural; PA, polymerase acidic; PB, polymerase basic.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JX534570 A/wild duck/Jilin/HF/2011(H5N1)
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KF042281 A/hill myna/Heilongjiang/0704/2012(H5N1)
KM251532 A/Anas crecca/Hubei/Chenhu1623-5/2014(H5N6)
KP083448 A/migratory waterfowl/Hubei/Chenhu1306/2014(H5N6)
JX534546 A/wild duck/Shandong/1/2011(H5N1)
JQ701701 A/heron/Cambodia/TM068/2011(H5N1)
KF260758 A/common teal/Hong Kong/MPL1075/2011(H11N9)
JX437691 A/egret/Hunan/1/2012(H9N2)
KJ013294 A/bean goose/Korea/220/2011(H9N2)
KJ756575 A/baikal teal/Korea/2402/2014(H5N8)
KP412429 A/sparrow/Shanghai/09/2013(H9N2)
KF260798 A/common teal/Hong Kong/MPM1740/2011(H7N7)
KY415891 A/duck/Yuhuan/YH45/2016(H1N2)
KU143558 A/turtledove/Wuhan/HKBJ62/2015(H6N6)
KC986336 A/common shelduck/Mongolia/2117/2011(H4N6)
KJ476654 A/mallard/Shanghai/SH-9/2013(H5N8)
KP285890 A/migratory duck/Jiangxi/33038/2013(H10N7)
KC464595 A/brambling/Beijing/16/2012(H9N2)
KF609524 A/tree sparrow/Shanghai/01/2013(H7N9)
KT327392 A/night heron/Taiwan/A289/2015(H5N2)
KC986330 A/mallard/Mongolia/2377/2011(H3N6)
MG976689 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
KC609834 A/wild duck/Korea/MHC39-26/2011(H7N9)
KX867854 A/wild bird/Jiangxi/P419/2016(H6N8)
CY194180 A/mallard/Southcentral Alaska/12ML00986 AAF1/2014(H3N8)
KX949441 A/green-winged teal/Alaska/UGAI15-6402/2015(H3N8)
CY177344 A/mallard/California/1478/2013(H5N5)
KY550941 A/mallard/Kentucky/AH0051806/2016(H7N3)
CY133908 A/northern shoveler/California/2810/2011(H11N2)
CY120682 A/northern shoveler/California/3628/2011(H10N3)
CY166954 A/blue-winged teal/Missouri/11OS2583/2011(H4N6)
CY166719 A/mallard/Wisconsin/11OS4362/2011(H11N3)
CY202945 A/mallard/Maryland/12OS615/2012(H1N1)
CY132810 A/northern shoveler/Arkansas/11OS171/2011(mixed)
CY166124 A/American green-winged teal/Wisconsin/11OS3069/2011(mixed)
KY130792 A/northern pintail/Alaska/303/2012(H4N2)
KY130720 A/northern pintail/Alaska/750/2011(H3N8)
CY186666 A/American green-winged teal/Illinois/12OS4792/2012(mixed)
MF613743 A/American black duck/Alberta/274/2016(H1N2)
MG280131 A/green-winged teal/Ohio/16OS3692/2016(H4N2)
CY149587 A/bufflehead/Maine/287/2011(H4N8)
CY167182 A/American green-winged teal/Mississippi/12OS191/2012(H5N3)
MG280011 A/gadwall duck/Wisconsin/16OS4758/2016(H3N2)
CY186682 A/American green-winged teal/Illinois/12OS5103/2012(H3N8)
MG279933 A/blue-winged teal/Missouri/16OS2203/2016(H4N8)
CY196112 A/mallard/Interior Alaska/11BM02703/2011(H4N6)
CY191290 A/mallard/Maryland/13OS3020/2014(H6N8)
CY166401 A/greater scaup/Wisconsin/11OS5760/2011(H10N2)
CY186926 A/American green-winged teal/Ohio/12OS2161/2012(H11N2)
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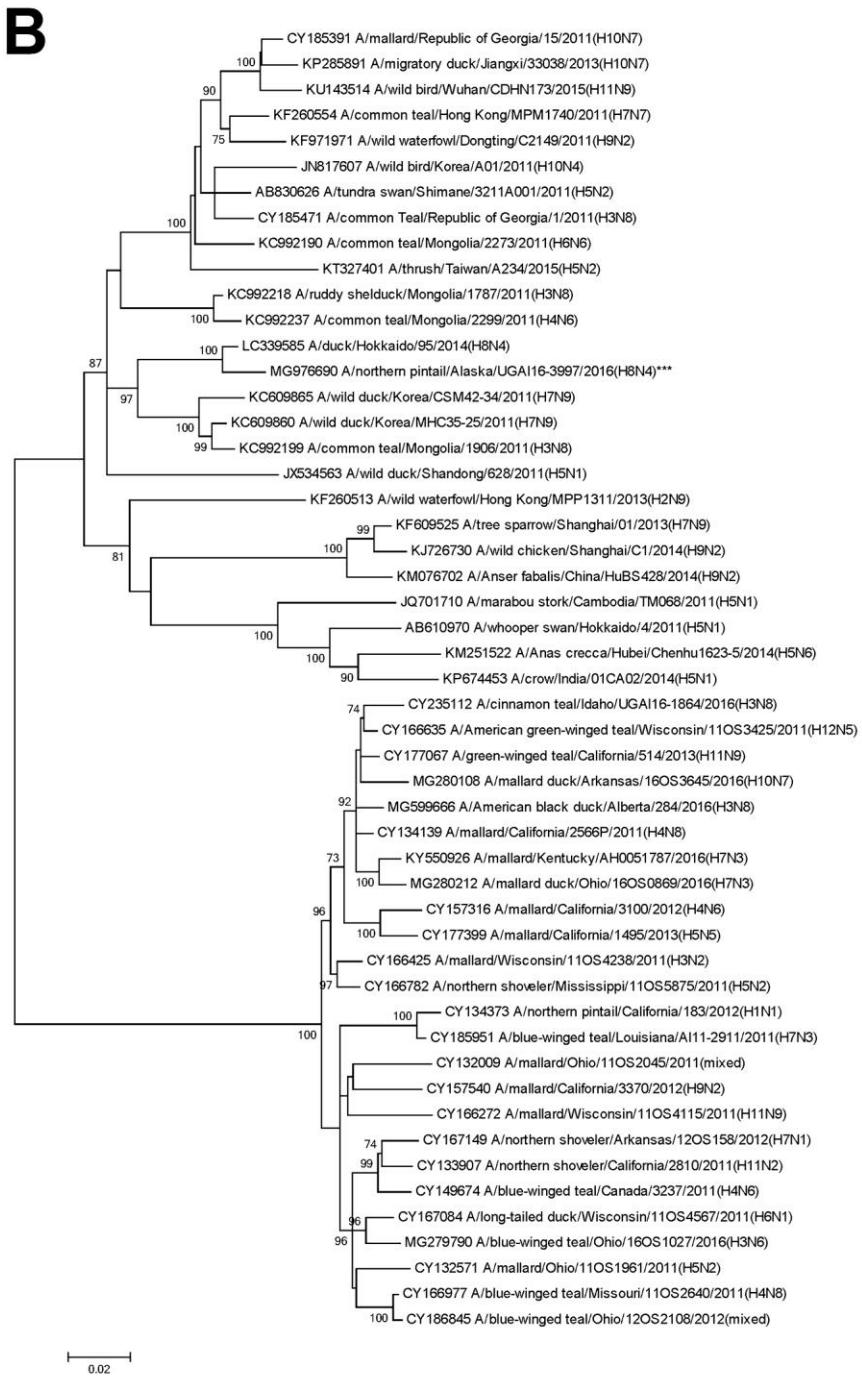
B
CY185391 A/mallard/Republic of Georgia/15/2011(H10N7)
KP285891 A/migratory duck/Jiangxi/33038/2013(H10N7)
KU143514 A/wild bird/Wuhan/CDHN173/2015(H11N9)
KF260554 A/common teal/Hong Kong/MPM1740/2011(H7N7)
KF971971 A/wild waterfowl/Dongting/C2149/2011(H9N2)
JN817607 A/wild bird/Korea/A01/2011(H10N4)
AB830626 A/tundra swan/Shimane/3211A001/2011(H5N2)
CY185471 A/common Teal/Republic of Georgia/1/2011(H3N8)
KC992190 A/common teal/Mongolia/2273/2011(H6N6)
KT327401 A/thrush/Taiwan/A234/2015(H5N2)
KC992218 A/ruddy shelduck/Mongolia/1787/2011(H3N8)
KC992237 A/common teal/Mongolia/2299/2011(H4N6)
LC339585 A/duck/Hokkaido/95/2014(H8N4)
MG976690 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
KC609865 A/wild duck/Korea/CSM42-34/2011(H7N9)
KC609860 A/wild duck/Korea/MHC35-25/2011(H7N9)
KC992199 A/common teal/Mongolia/1906/2011(H3N8)
JX534563 A/wild duck/Shandong/628/2011(H5N1)
KF260513 A/wild waterfowl/Hong Kong/MPP1311/2013(H2N9)
KF609525 A/tree sparrow/Shanghai/01/2013(H7N9)
KJ726730 A/wild chicken/Shanghai/C1/2014(H9N2)
KM076702 A/Anser fabalis/China/HuBS428/2014(H9N2)
JQ701710 A/marabou stork/Cambodia/TM068/2011(H5N1)
AB610970 A/whooper swan/Hokkaido/4/2011(H5N1)
KM251522 A/Anas crecca/Hubei/Chenhu1623-5/2014(H5N6)
KP674453 A/crow/India/01CA02/2014(H5N1)
CY235112 A/cinnamon teal/Idaho/UGAI16-1864/2016(H3N8)
CY166635 A/American green-winged teal/Wisconsin/11OS3425/2011(H12N5)
CY177067 A/green-winged teal/California/514/2013(H11N9)
MG280108 A/mallard duck/Arkansas/16OS3645/2016(H10N7)
MG599666 A/American black duck/Alberta/284/2016(H3N8)
CY134139 A/mallard/California/2566P/2011(H4N8)
KY550926 A/mallard/Kentucky/AH0051787/2016(H7N3)
MG280212 A/mallard duck/Ohio/16OS0869/2016(H7N3)
CY157316 A/mallard/California/3100/2012(H4N6)
CY177399 A/mallard/California/1495/2013(H5N5)
CY166425 A/mallard/Wisconsin/11OS4238/2011(H3N2)
CY166782 A/northern shoveler/Mississippi/11OS5875/2011(H5N2)
CY134373 A/northern pintail/California/183/2012(H1N1)
CY185951 A/blue-winged teal/Louisiana/AI11-2911/2011(H7N3)
CY132009 A/mallard/Ohio/11OS2045/2011(mixed)
CY157540 A/mallard/California/3370/2012(H9N2)
CY166272 A/mallard/Wisconsin/11OS4115/2011(H11N9)
CY167149 A/northern shoveler/Arkansas/12OS158/2012(H7N1)
CY133907 A/northern shoveler/California/2810/2011(H11N2)
CY149674 A/blue-winged teal/Canada/3237/2011(H4N6)
CY167084 A/long-tailed duck/Wisconsin/11OS4567/2011(H6N1)
MG279790 A/blue-winged teal/Ohio/16OS1027/2016(H3N6)
CY132571 A/mallard/Ohio/11OS1961/2011(H5N2)
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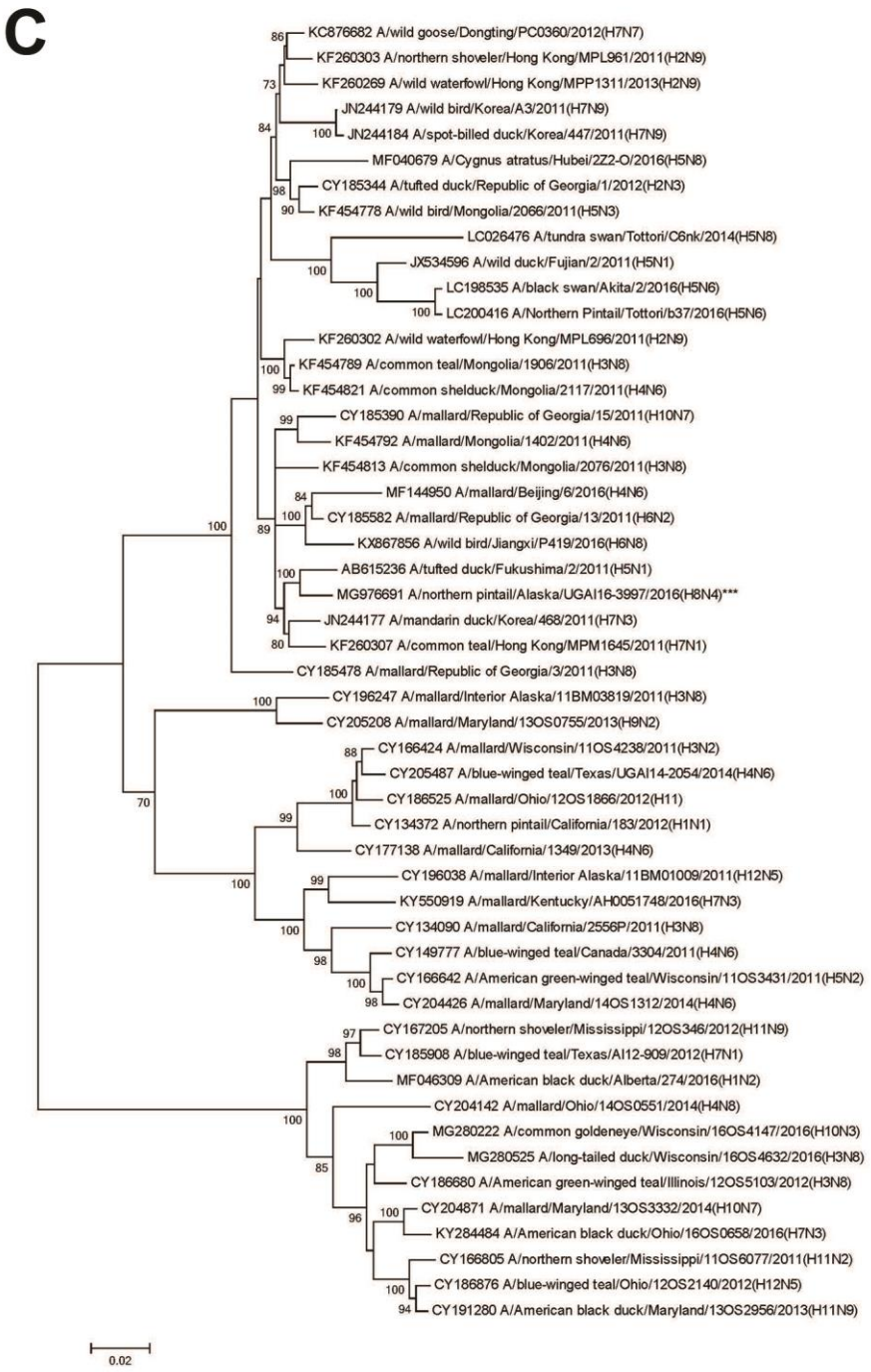
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JN244179 A/wild bird/Korea/A3/2011(H7N9)
JN244184 A/spot-billed duck/Korea/447/2011(H7N9)
MF040679 A/Cygnus atratus/Hubei/2Z2-O/2016(H5N8)
CY185344 A/tufted duck/Republic of Georgia/1/2012(H2N3)
KF454778 A/wild bird/Mongolia/2066/2011(H5N3)
LC026476 A/tundra swan/Tottori/C6nk/2014(H5N8)
JX534596 A/wild duck/Fujian/2/2011(H5N1)
LC198535 A/black swan/Akita/2/2016(H5N6)
LC200416 A/Northern Pintail/Tottori/b37/2016(H5N6)
KF260302 A/wild waterfowl/Hong Kong/MPL696/2011(H2N9)
KF454789 A/common teal/Mongolia/1906/2011(H3N8)
KF454821 A/common shelduck/Mongolia/2117/2011(H4N6)
CY185390 A/mallard/Republic of Georgia/15/2011(H10N7)
KF454792 A/mallard/Mongolia/1402/2011(H4N6)
KF454813 A/common shelduck/Mongolia/2076/2011(H3N8)
MF144950 A/mallard/Beijing/6/2016(H4N6)
CY185582 A/mallard/Republic of Georgia/13/2011(H6N2)
KX867856 A/wild bird/Jiangxi/P419/2016(H6N8)
AB615236 A/tufted duck/Fukushima/2/2011(H5N1)
MG976691 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
JN244177 A/mandarin duck/Korea/468/2011(H7N3)
KF260307 A/common teal/Hong Kong/MPM1645/2011(H7N1)
CY185478 A/mallard/Republic of Georgia/3/2011(H3N8)
CY196247 A/mallard/Interior Alaska/11BM03819/2011(H3N8)
CY205208 A/mallard/Maryland/13OS0755/2013(H9N2)
CY166424 A/mallard/Wisconsin/11OS4238/2011(H3N2)
CY205487 A/blue-winged teal/Texas/UGAI14-2054/2014(H4N6)
CY186525 A/mallard/Ohio/12OS1866/2012(H11)
CY134372 A/northern pintail/California/183/2012(H1N1)
CY177138 A/mallard/California/1349/2013(H4N6)
CY196038 A/mallard/Interior Alaska/11BM01009/2011(H12N5)
KY550919 A/mallard/Kentucky/AH0051748/2016(H7N3)
CY134090 A/mallard/California/2556P/2011(H3N8)
CY149777 A/blue-winged teal/Canada/3304/2011(H4N6)
CY166642 A/American green-winged teal/Wisconsin/11OS3431/2011(H5N2)
CY204426 A/mallard/Maryland/14OS1312/2014(H4N6)
CY167205 A/northern shoveler/Mississippi/12OS346/2012(H11N9)
CY185908 A/blue-winged teal/Texas/AI12-909/2012(H7N1)
MF046309 A/American black duck/Alberta/274/2016(H1N2)
CY204142 A/mallard/Ohio/14OS0551/2014(H4N8)
MG280222 A/common goldeneye/Wisconsin/16OS4147/2016(H10N3)
MG280525 A/long-tailed duck/Wisconsin/16OS4632/2016(H3N8)
CY186680 A/American green-winged teal/Illinois/12OS5103/2012(H3N8)
CY204871 A/mallard/Maryland/13OS3332/2014(H10N7)
KY284484 A/American black duck/Ohio/16OS0658/2016(H7N3)
CY166805 A/northern shoveler/Mississippi/11OS6077/2011(H11N2)
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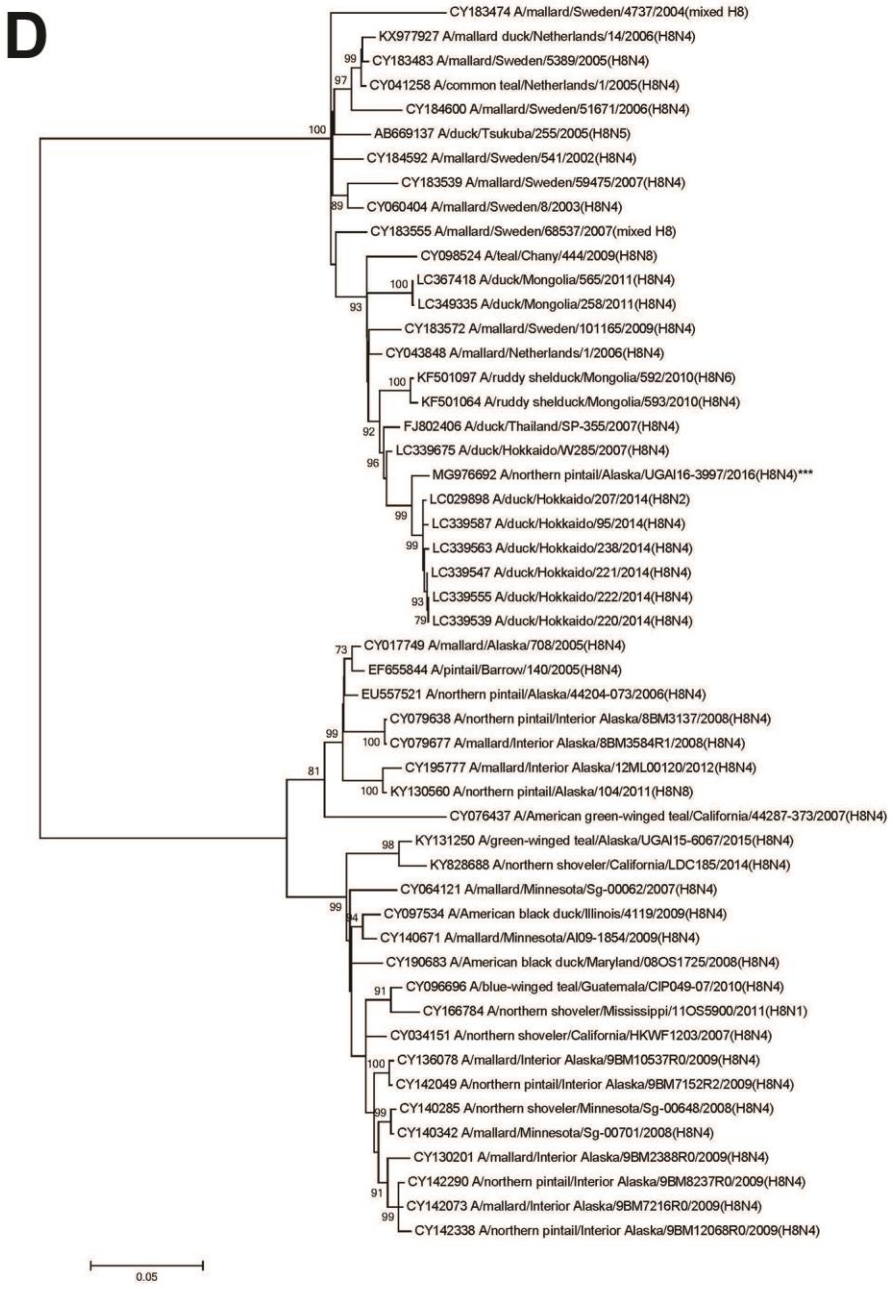
D
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CY183483 A/mallard/Sweden/5389/2005(H8N4)
CY041258 A/common teal/Netherlands/1/2005(H8N4)
CY184600 A/mallard/Sweden/51671/2006(H8N4)
AB669137 A/duck/Tsukuba/255/2005(H8N5)
CY184592 A/mallard/Sweden/541/2002(H8N4)
CY183539 A/mallard/Sweden/59475/2007(H8N4)
CY060404 A/mallard/Sweden/8/2003(H8N4)
CY183555 A/mallard/Sweden/68537/2007(mixed H8)
CY098524 A/teal/Chany/444/2009(H8N8)
LC367418 A/duck/Mongolia/565/2011(H8N4)
LC349335 A/duck/Mongolia/258/2011(H8N4)
CY183572 A/mallard/Sweden/101165/2009(H8N4)
CY043848 A/mallard/Netherlands/1/2006(H8N4)
KF501097 A/ruddy shelduck/Mongolia/592/2010(H8N6)
KF501064 A/ruddy shelduck/Mongolia/593/2010(H8N4)
FJ802406 A/duck/Thailand/SP-355/2007(H8N4)
LC339675 A/duck/Hokkaido/W285/2007(H8N4)
MG976692 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
LC029898 A/duck/Hokkaido/207/2014(H8N2)
LC339587 A/duck/Hokkaido/95/2014(H8N4)
LC339563 A/duck/Hokkaido/238/2014(H8N4)
LC339547 A/duck/Hokkaido/221/2014(H8N4)
LC339555 A/duck/Hokkaido/222/2014(H8N4)
LC339539 A/duck/Hokkaido/220/2014(H8N4)
CY017749 A/mallard/Alaska/708/2005(H8N4)
EF655844 A/pintail/Barrow/140/2005(H8N4)
EU557521 A/northern pintail/Alaska/44204-073/2006(H8N4)
CY079638 A/northern pintail/Interior Alaska/8BM3137/2008(H8N4)
CY079677 A/mallard/Interior Alaska/8BM3584R1/2008(H8N4)
CY195777 A/mallard/Interior Alaska/12ML00120/2012(H8N4)
KY130560 A/northern pintail/Alaska/104/2011(H8N8)
CY076437 A/American green-winged teal/California/44287-373/2007(H8N4)
KY131250 A/green-winged teal/Alaska/UGAI15-6067/2015(H8N4)
KY828688 A/northern shoveler/California/LDC185/2014(H8N4)
CY064121 A/mallard/Minnesota/Sg-00062/2007(H8N4)
CY097534 A/American black duck/Illinois/4119/2009(H8N4)
CY140671 A/mallard/Minnesota/AI09-1854/2009(H8N4)
CY190683 A/American black duck/Maryland/08OS1725/2008(H8N4)
CY096696 A/blue-winged teal/Guatemala/CIP049-07/2010(H8N4)
CY166784 A/northern shoveler/Mississippi/11OS5900/2011(H8N1)
CY034151 A/northern shoveler/California/HKWF1203/2007(H8N4)
CY136078 A/mallard/Interior Alaska/9BM10537R0/2009(H8N4)
CY142049 A/northern pintail/Interior Alaska/9BM7152R2/2009(H8N4)
CY140285 A/northern shoveler/Minnesota/Sg-00648/2008(H8N4)
CY140342 A/mallard/Minnesota/Sg-00701/2008(H8N4)
CY130201 A/mallard/Interior Alaska/9BM2388R0/2009(H8N4)
CY142290 A/northern pintail/Interior Alaska/9BM8237R0/2009(H8N4)
CY142073 A/mallard/Interior Alaska/9BM7216R0/2009(H8N4)
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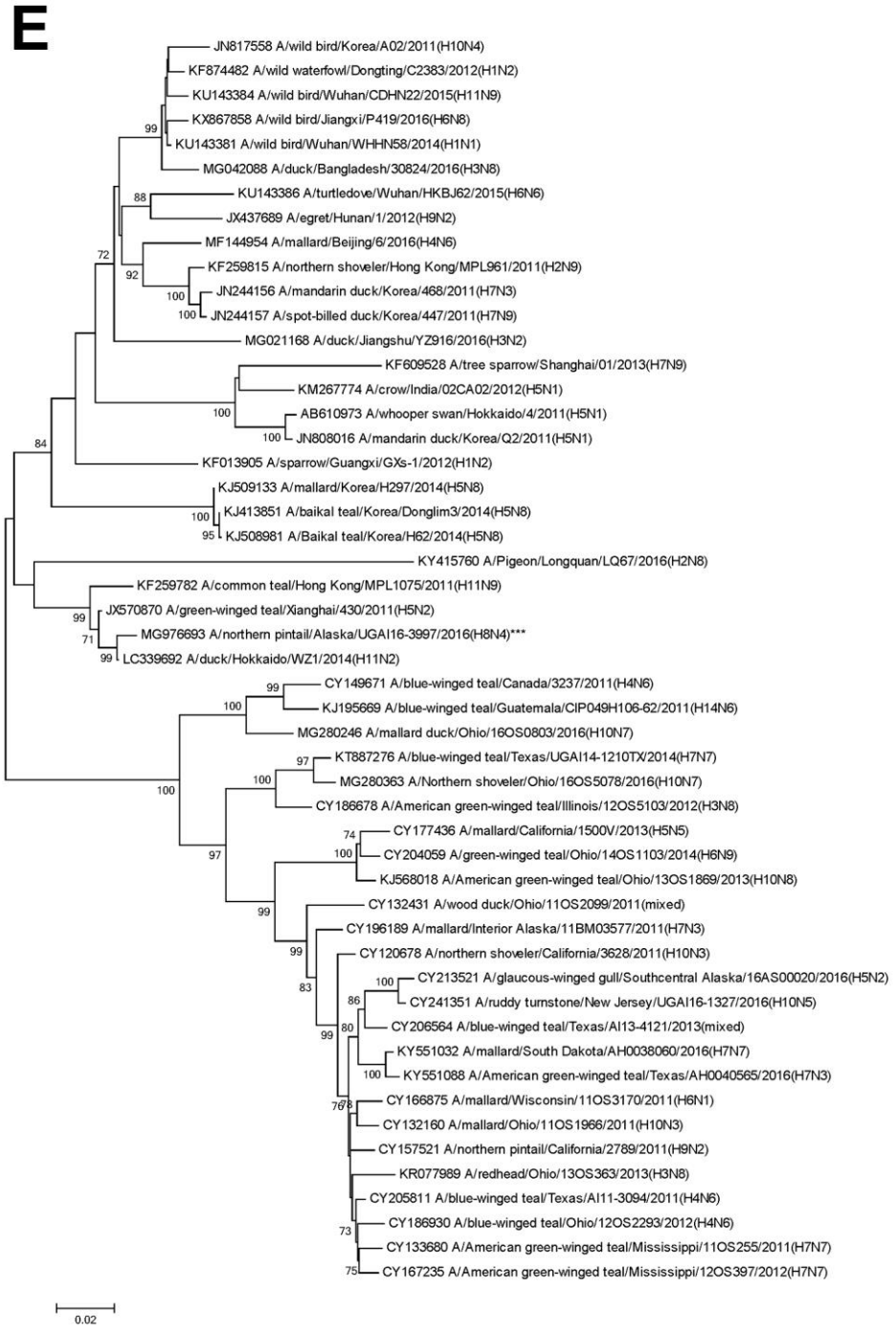
E
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KU143384 A/wild bird/Wuhan/CDHN22/2015(H11N9)
KX867858 A/wild bird/Jiangxi/P419/2016(H6N8)
KU143381 A/wild bird/Wuhan/WHHN58/2014(H1N1)
MG042088 A/duck/Bangladesh/30824/2016(H3N8)
KU143386 A/turtledove/Wuhan/HKBJ62/2015(H6N6)
JX437689 A/egret/Hunan/1/2012(H9N2)
MF144954 A/mallard/Beijing/6/2016(H4N6)
KF259815 A/northern shoveler/Hong Kong/MPL961/2011(H2N9)
JN244156 A/mandarin duck/Korea/468/2011(H7N3)
JN244157 A/spot-billed duck/Korea/447/2011(H7N9)
MG021168 A/duck/Jiangshu/YZ916/2016(H3N2)
KF609528 A/tree sparrow/Shanghai/01/2013(H7N9)
KM267774 A/crow/India/02CA02/2012(H5N1)
AB610973 A/whooper swan/Hokkaido/4/2011(H5N1)
JN808016 A/mandarin duck/Korea/Q2/2011(H5N1)
KF013905 A/sparrow/Guangxi/GXs-1/2012(H1N2)
KJ509133 A/mallard/Korea/H297/2014(H5N8)
KJ413851 A/baikal teal/Korea/Donglim3/2014(H5N8)
KJ508981 A/Baikal teal/Korea/H62/2014(H5N8)
KY415760 A/Pigeon/Longquan/LQ67/2016(H2N8)
KF259782 A/common teal/Hong Kong/MPL1075/2011(H11N9)
JX570870 A/green-winged teal/Xianghai/430/2011(H5N2)
MG976693 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
LC339692 A/duck/Hokkaido/WZ1/2014(H11N2)
CY149671 A/blue-winged teal/Canada/3237/2011(H4N6)
KJ195669 A/blue-winged teal/Guatemala/CIP049H106-62/2011(H14N6)
MG280246 A/mallard duck/Ohio/16OS0803/2016(H10N7)
KT887276 A/blue-winged teal/Texas/UGAI14-1210TX/2014(H7N7)
MG280363 A/Northern shoveler/Ohio/16OS5078/2016(H10N7)
CY186678 A/American green-winged teal/Illinois/12OS5103/2012(H3N8)
CY177436 A/mallard/California/1500V/2013(H5N5)
CY204059 A/green-winged teal/Ohio/14OS1103/2014(H6N9)
KJ568018 A/American green-winged teal/Ohio/13OS1869/2013(H10N8)
CY132431 A/wood duck/Ohio/11OS2099/2011(mixed)
CY196189 A/mallard/Interior Alaska/11BM03577/2011(H7N3)
CY120678 A/northern shoveler/California/3628/2011(H10N3)
CY213521 A/glaucous-winged gull/Southcentral Alaska/16AS00020/2016(H5N2)
CY241351 A/ruddy turnstone/New Jersey/UGAI16-1327/2016(H10N5)
CY206564 A/blue-winged teal/Texas/AI13-4121/2013(mixed)
KY551032 A/mallard/South Dakota/AH0038060/2016(H7N7)
KY551088 A/American green-winged teal/Texas/AH0040565/2016(H7N3)
CY166875 A/mallard/Wisconsin/11OS3170/2011(H6N1)
CY132160 A/mallard/Ohio/11OS1966/2011(H10N3)
CY157521 A/northern pintail/California/2789/2011(H9N2)
KR077989 A/redhead/Ohio/13OS363/2013(H3N8)
CY205811 A/blue-winged teal/Texas/AI11-3094/2011(H4N6)
CY186930 A/blue-winged teal/Ohio/12OS2293/2012(H4N6)
CY133680 A/American green-winged teal/Mississippi/11OS255/2011(H7N7)
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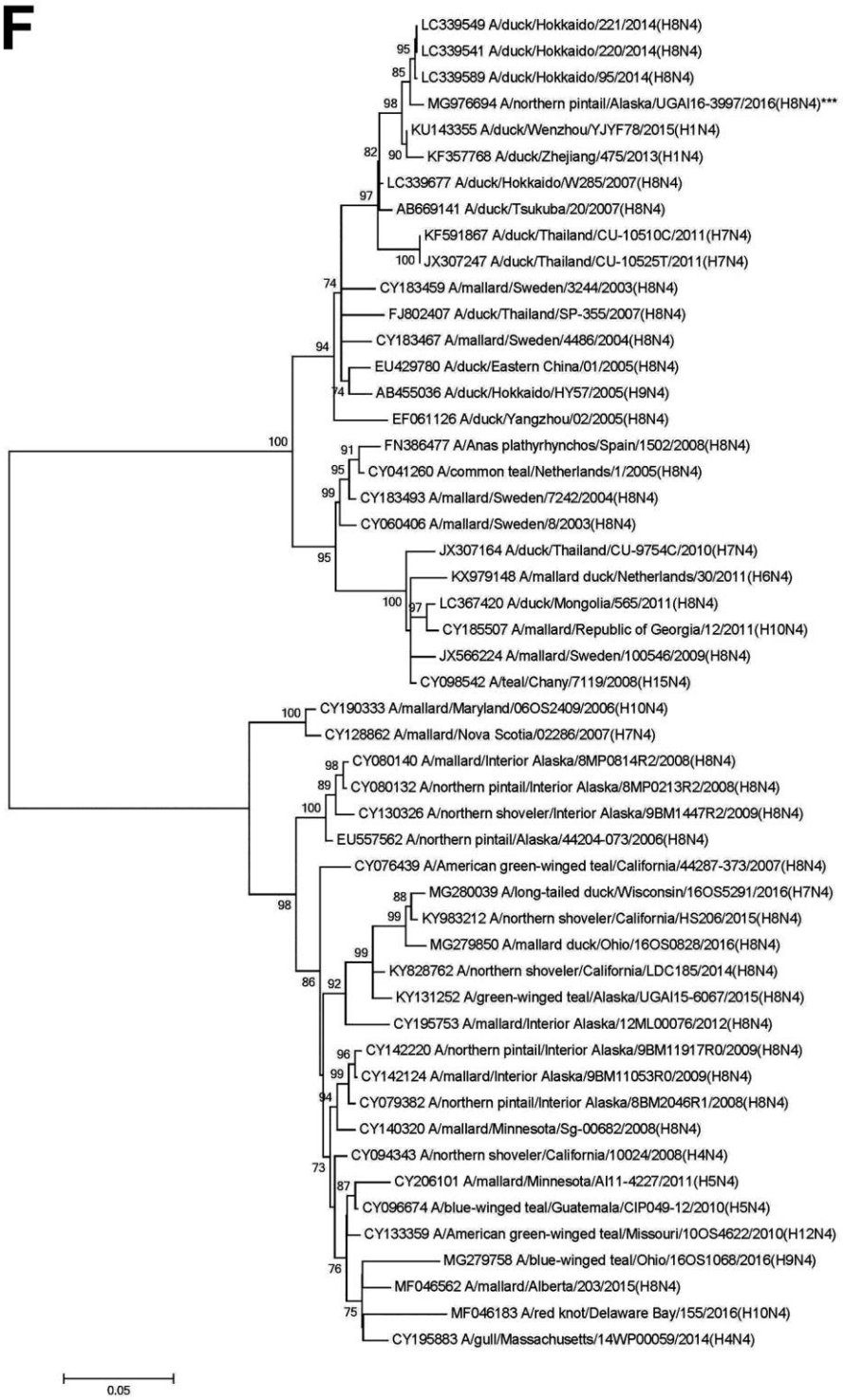
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LC339589 A/duck/Hokkaido/95/2014(H8N4)
MG976694 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
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KF357768 A/duck/Zhejiang/475/2013(H1N4)
LC339677 A/duck/Hokkaido/W285/2007(H8N4)
AB669141 A/duck/Tsukuba/20/2007(H8N4)
KF591867 A/duck/Thailand/CU-10510C/2011(H7N4)
JX307247 A/duck/Thailand/CU-10525T/2011(H7N4)
CY183459 A/mallard/Sweden/3244/2003(H8N4)
FJ802407 A/duck/Thailand/SP-355/2007(H8N4)
CY183467 A/mallard/Sweden/4486/2004(H8N4)
EU429780 A/duck/Eastern China/01/2005(H8N4)
AB455036 A/duck/Hokkaido/HY57/2005(H9N4)
EF061126 A/duck/Yangzhou/02/2005(H8N4)
FN386477 A/Anas plathyrhynchos/Spain/1502/2008(H8N4)
CY041260 A/common teal/Netherlands/1/2005(H8N4)
CY183493 A/mallard/Sweden/7242/2004(H8N4)
CY060406 A/mallard/Sweden/8/2003(H8N4)
JX307164 A/duck/Thailand/CU-9754C/2010(H7N4)
KX979148 A/mallard duck/Netherlands/30/2011(H6N4)
LC367420 A/duck/Mongolia/565/2011(H8N4)
CY185507 A/mallard/Republic of Georgia/12/2011(H10N4)
JX566224 A/mallard/Sweden/100546/2009(H8N4)
CY098542 A/teal/Chany/7119/2008(H15N4)
CY190333 A/mallard/Maryland/06OS2409/2006(H10N4)
CY128862 A/mallard/Nova Scotia/02286/2007(H7N4)
CY080140 A/mallard/Interior Alaska/8MP0814R2/2008(H8N4)
CY080132 A/northern pintail/Interior Alaska/8MP0213R2/2008(H8N4)
CY130326 A/northern shoveler/Interior Alaska/9BM1447R2/2009(H8N4)
EU557562 A/northern pintail/Alaska/44204-073/2006(H8N4)
CY076439 A/American green-winged teal/California/44287-373/2007(H8N4)
MG280039 A/long-tailed duck/Wisconsin/16OS5291/2016(H7N4)
KY983212 A/northern shoveler/California/HS206/2015(H8N4)
MG279850 A/mallard duck/Ohio/16OS0828/2016(H8N4)
KY828762 A/northern shoveler/California/LDC185/2014(H8N4)
KY131252 A/green-winged teal/Alaska/UGAI15-6067/2015(H8N4)
CY195753 A/mallard/Interior Alaska/12ML00076/2012(H8N4)
CY142220 A/northern pintail/Interior Alaska/9BM11917R0/2009(H8N4)
CY142124 A/mallard/Interior Alaska/9BM11053R0/2009(H8N4)
CY079382 A/northern pintail/Interior Alaska/8BM2046R1/2008(H8N4)
CY140320 A/mallard/Minnesota/Sg-00682/2008(H8N4)
CY094343 A/northern shoveler/California/10024/2008(H4N4)
CY206101 A/mallard/Minnesota/AI11-4227/2011(H5N4)
CY096674 A/blue-winged teal/Guatemala/CIP049-12/2010(H5N4)
CY133359 A/American green-winged teal/Missouri/10OS4622/2010(H12N4)
MG279758 A/blue-winged teal/Ohio/16OS1068/2016(H9N4)
MF046562 A/mallard/Alberta/203/2015(H8N4)
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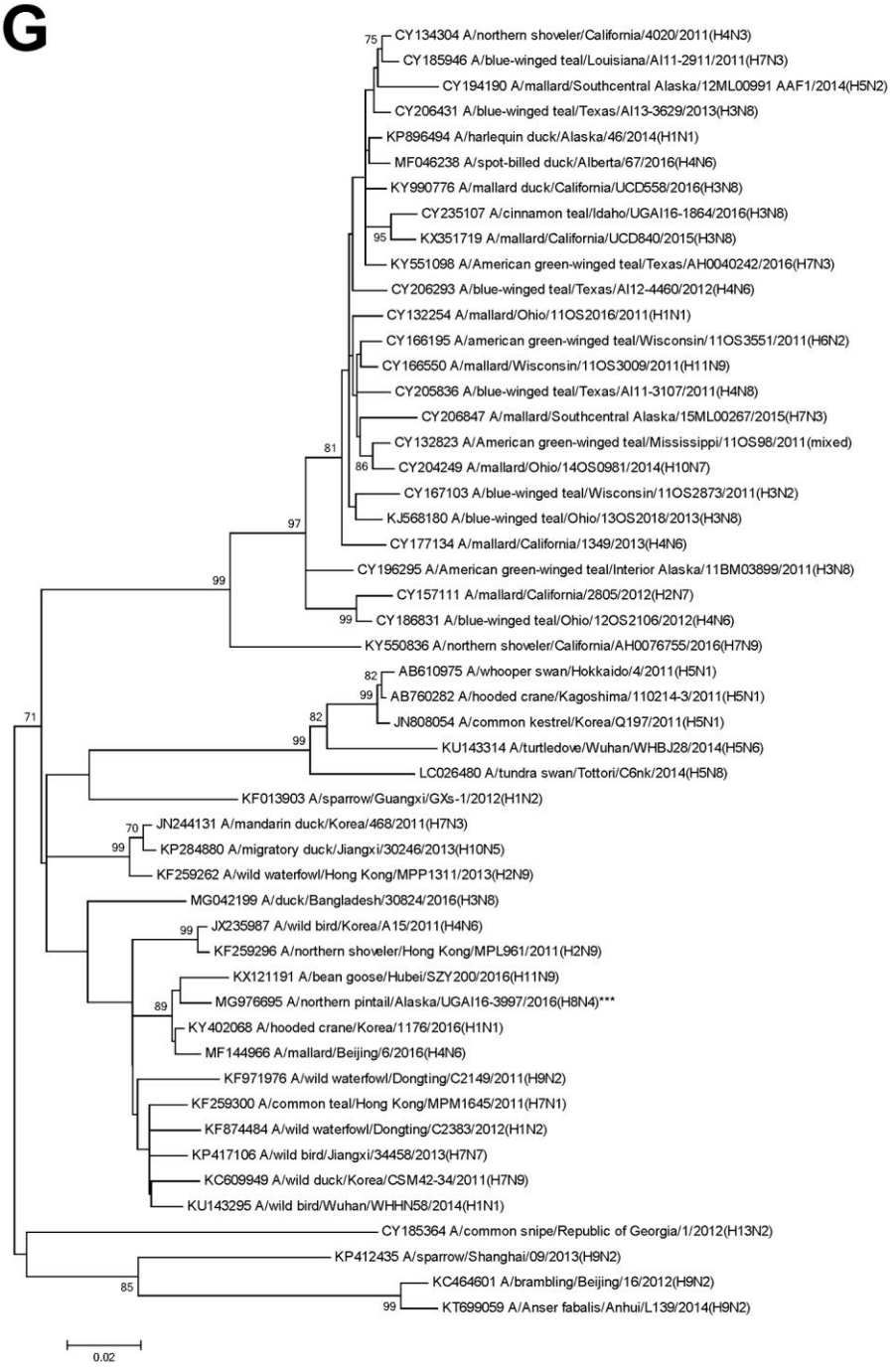
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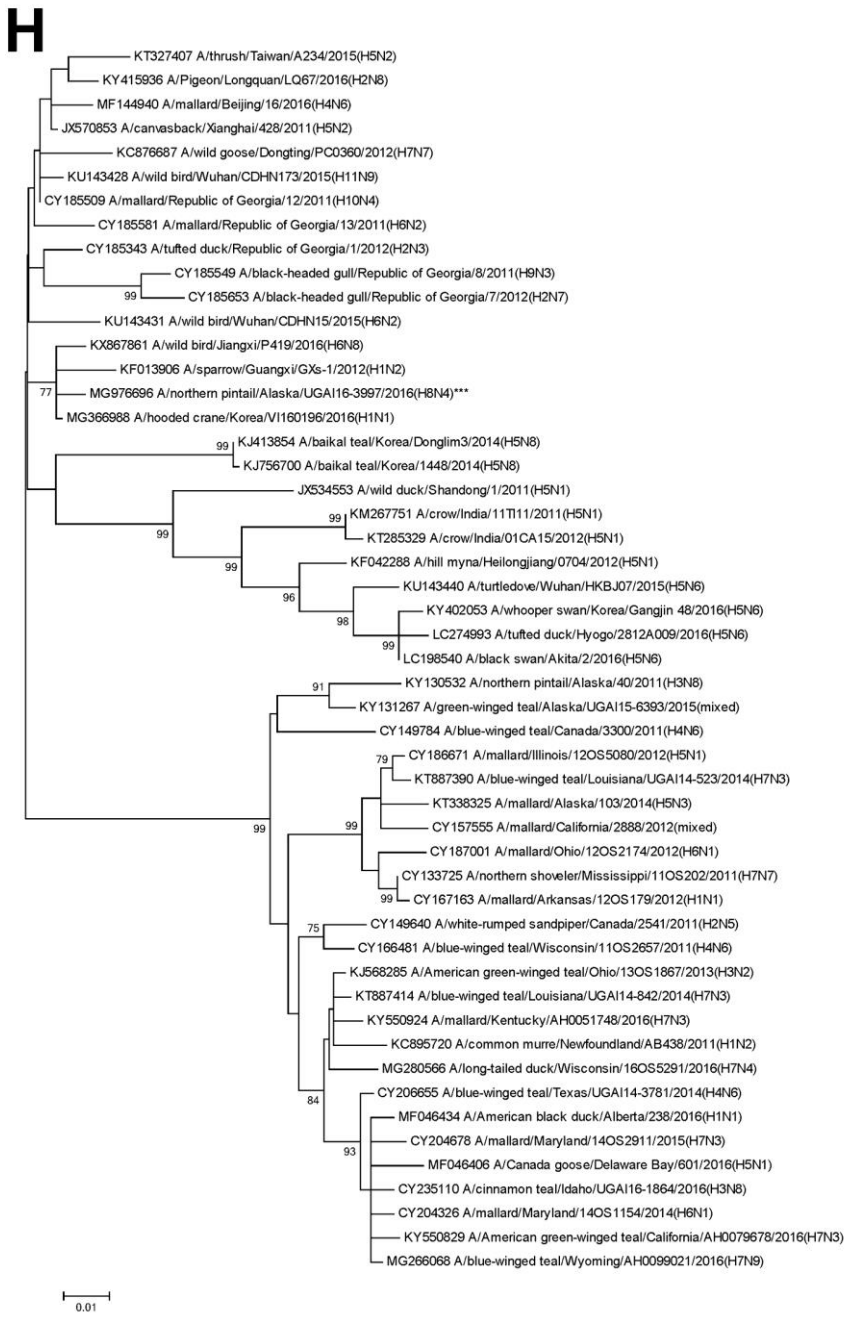
CY206431 A/blue-winged teal/Texas/AI13-3629/2013(H3N8)
KP896494 A/harlequin duck/Alaska/46/2014(H1N1)
MF046238 A/spot-billed duck/Alberta/67/2016(H4N6)
KY990776 A/mallard duck/California/UCD558/2016(H3N8)
CY235107 A/cinnamon teal/Idaho/UGAI16-1864/2016(H3N8)
KX351719 A/mallard/California/UCD840/2015(H3N8)
KY551098 A/American green-winged teal/Texas/AH0040242/2016(H7N3)
CY206293 A/blue-winged teal/Texas/AI12-4460/2012(H4N6)
CY132254 A/mallard/Ohio/11OS2016/2011(H1N1)
CY166195 A/american green-winged teal/Wisconsin/11OS3551/2011(H6N2)
CY166550 A/mallard/Wisconsin/11OS3009/2011(H11N9)
CY205836 A/blue-winged teal/Texas/AI11-3107/2011(H4N8)
CY206847 A/mallard/Southcentral Alaska/15ML00267/2015(H7N3)
CY132823 A/American green-winged teal/Mississippi/11OS98/2011(mixed)
CY204249 A/mallard/Ohio/14OS0981/2014(H10N7)
CY167103 A/blue-winged teal/Wisconsin/11OS2873/2011(H3N2)
KJ568180 A/blue-winged teal/Ohio/13OS2018/2013(H3N8)
CY177134 A/mallard/California/1349/2013(H4N6)
CY196295 A/American green-winged teal/Interior Alaska/11BM03899/2011(H3N8)
CY157111 A/mallard/California/2805/2012(H2N7)
CY186831 A/blue-winged teal/Ohio/12OS2106/2012(H4N6)
KY550836 A/northern shoveler/California/AH0076755/2016(H7N9)
AB610975 A/whooper swan/Hokkaido/4/2011(H5N1)
AB760282 A/hooded crane/Kagoshima/110214-3/2011(H5N1)
JN808054 A/common kestrel/Korea/Q197/2011(H5N1)
KU143314 A/turtledove/Wuhan/WHBJ28/2014(H5N6)
LC026480 A/tundra swan/Tottori/C6nk/2014(H5N8)
KF013903 A/sparrow/Guangxi/GXs-1/2012(H1N2)
JN244131 A/mandarin duck/Korea/468/2011(H7N3)
KP284880 A/migratory duck/Jiangxi/30246/2013(H10N5)
KF259262 A/wild waterfowl/Hong Kong/MPP1311/2013(H2N9)
MG042199 A/duck/Bangladesh/30824/2016(H3N8)
JX235987 A/wild bird/Korea/A15/2011(H4N6)
KF259296 A/northern shoveler/Hong Kong/MPL961/2011(H2N9)
KX121191 A/bean goose/Hubei/SZY200/2016(H11N9)
MG976695 A/northern pintail/Alaska/UGAI16-3997/2016(H8N4)***
KY402068 A/hooded crane/Korea/1176/2016(H1N1)
MF144966 A/mallard/Beijing/6/2016(H4N6)
KF971976 A/wild waterfowl/Dongting/C2149/2011(H9N2)
KF259300 A/common teal/Hong Kong/MPM1645/2011(H7N1)
KF874484 A/wild waterfowl/Dongting/C2383/2012(H1N2)
KP417106 A/wild bird/Jiangxi/34458/2013(H7N7)
KC609949 A/wild duck/Korea/CSM42-34/2011(H7N9)
KU143295 A/wild bird/Wuhan/WHHN58/2014(H1N1)
CY185364 A/common snipe/Republic of Georgia/1/2012(H13N2)
KP412435 A/sparrow/Shanghai/09/2013(H9N2)
KC464601 A/brambling/Beijing/16/2012(H9N2)
KT699059 A/Anser fabalis/Anhui/L139/2014(H9N2)
0.02



Technical Appendix Figure. Unrooted maximum-likelihood phylogenetic trees with complete strain names as tip labels showing inferred relationship among nucleotide sequences for the complete coding regions of the gene segments for influenza A virus strain A/northern pintail/Alaska/UGAI16–3997/2016(H8N4) (indicated with 3 asterisks) and reference sequences from viruses isolated from birds in Eurasia and North America. Bootstrap support values ≥70 are shown. H, hemagglutinin; M, matrix; N, neuraminidase; NP, nucleoprotein; NS, nonstructural; PA, polymerase acidic; PB, polymerase basic. Scale bar indicates nucleotide substitutions per site.