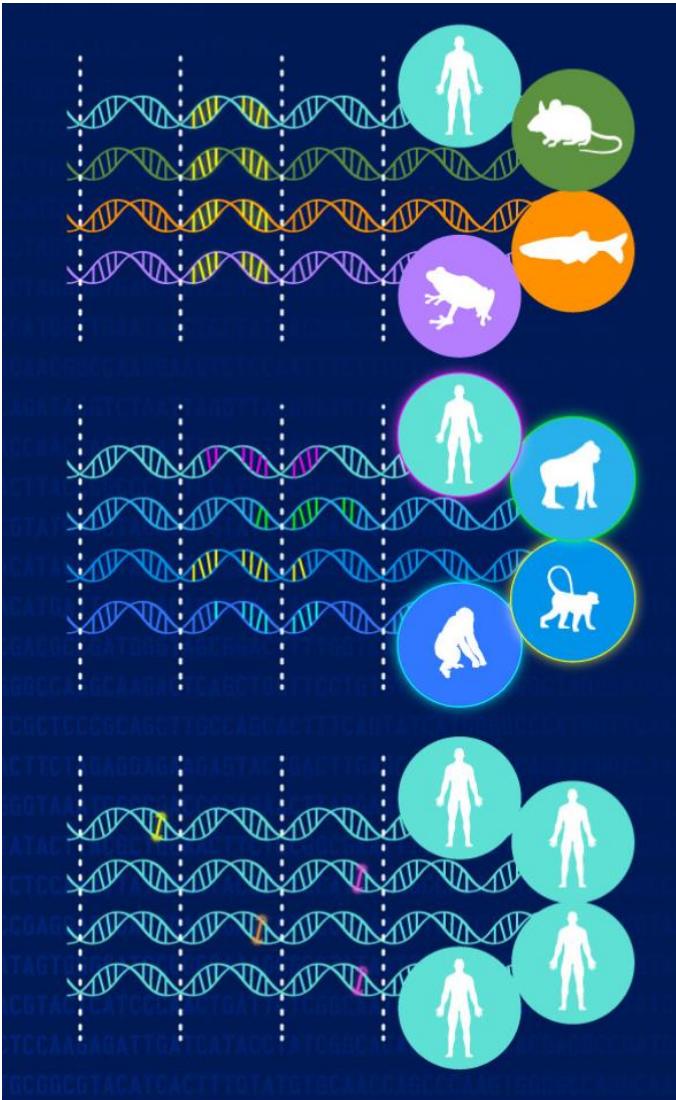


Overview of Comparative Genomics & Bird 10,000 Genomes (B10K) Project

- Shaohong Feng, PhD
- BGI research
- 2021.10.23

What are the questions that comparative genomics can answer?

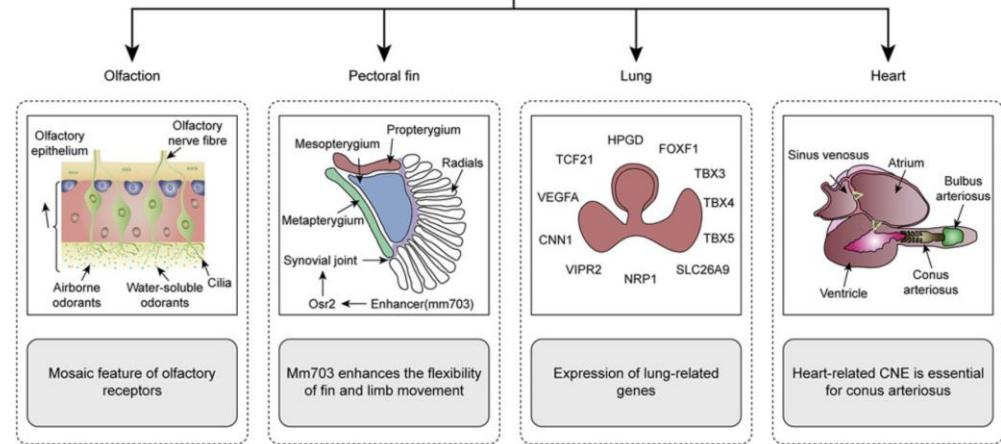
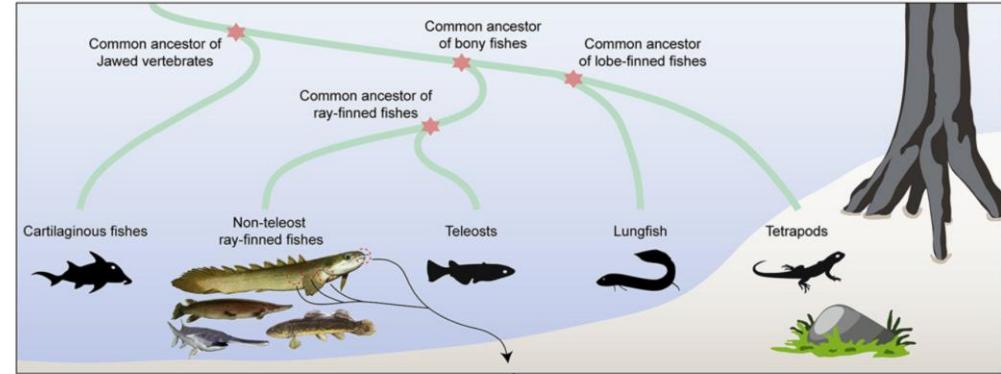


Common features of different organisms are often encoded within the DNA evolutionarily conserved between them.

Looking at **closely related species** shows which genomic elements are unique to each.

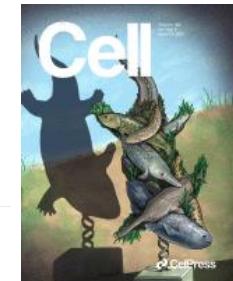


Genetic differences **within one species** can reveal variants with a role in disease.

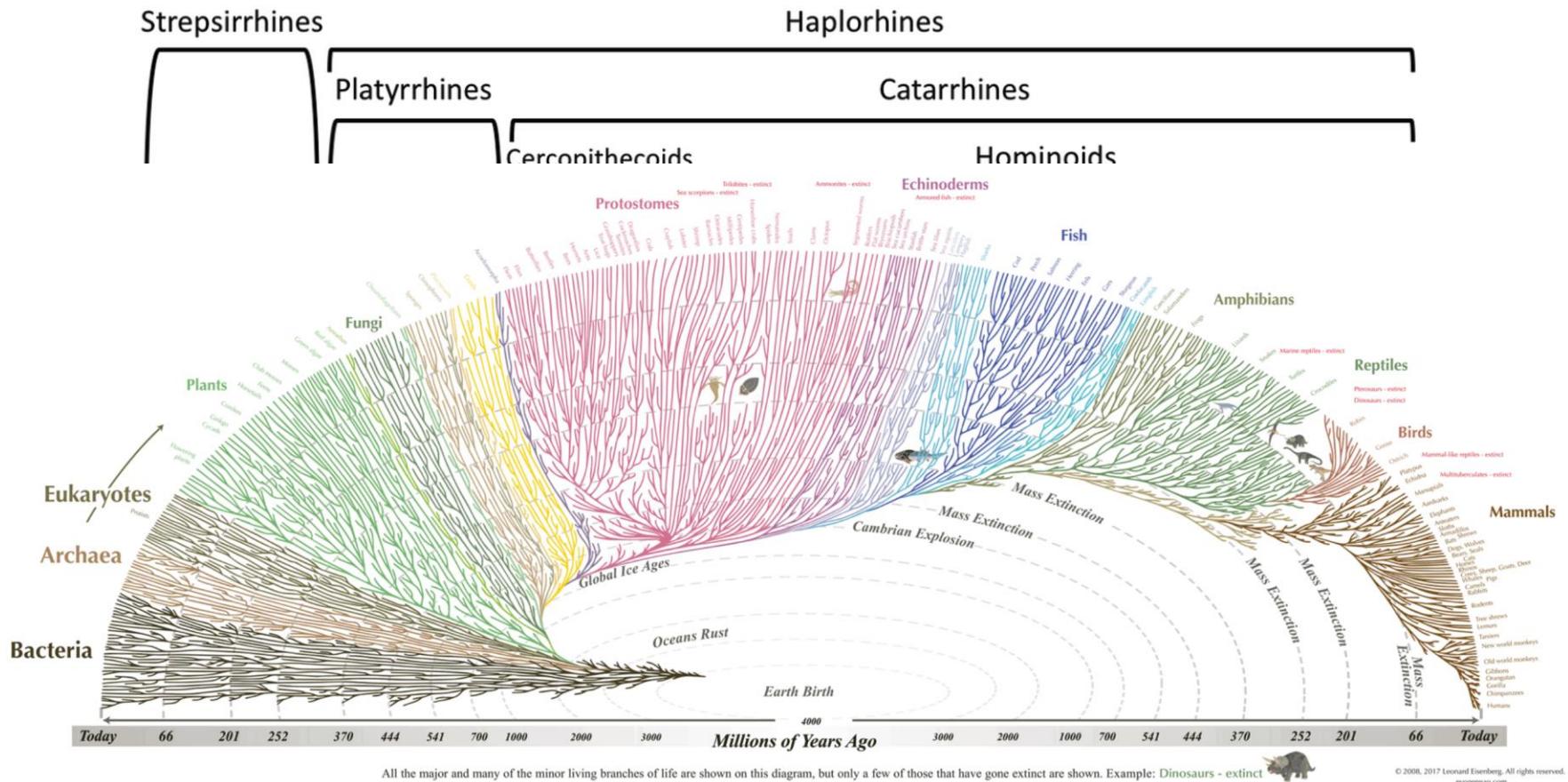
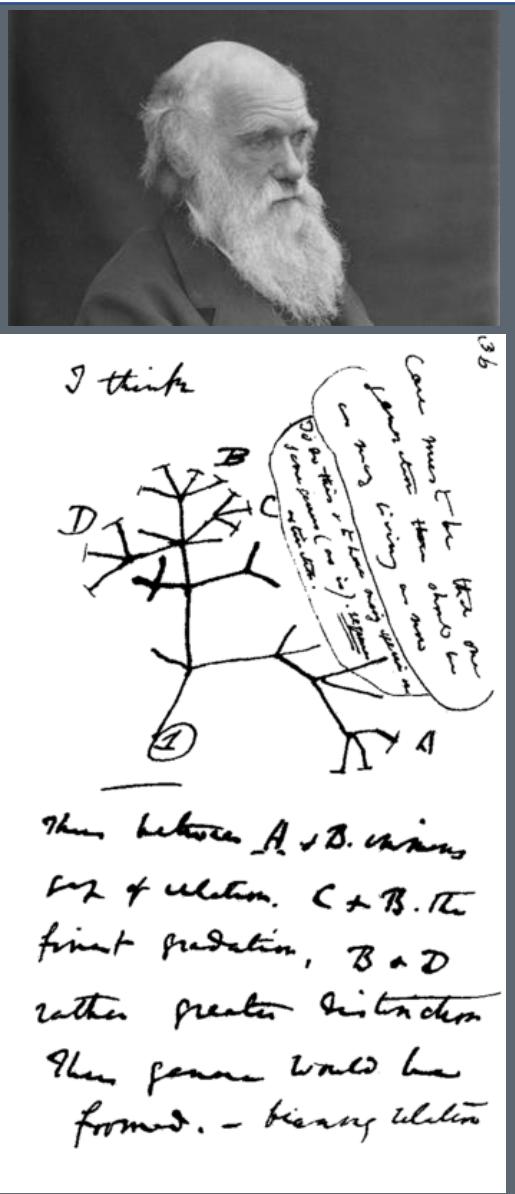


Tracing the genetic footprints of vertebrate landing in non-teleost ray-finned fishes
Xupeng Bi, Kun Wang, Liandong Yang, Hailin Pan, ... Guojie Zhang
Pages 1377-1391.e14

African lungfish genome sheds light on the vertebrate water-to-land transition
Kun Wang, Jun Wang, Chenglong Zhu, Liandong Yang, ... Wen Wang
Pages 1362-1376.e18



Tree of Life



Krupenye, C. (2021). The evolution of mentalizing in humans and other primates. In *The Neural Basis of Mentalizing* (pp. 107-129). Springer, Cham.

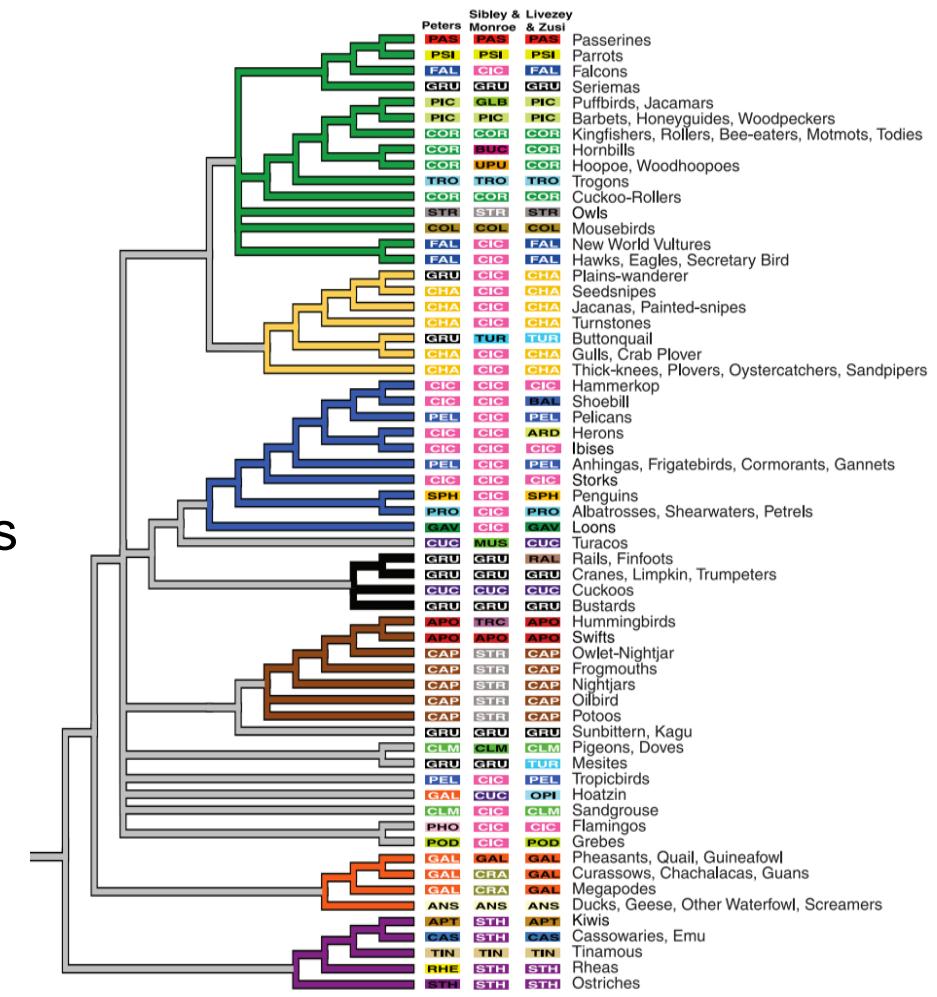
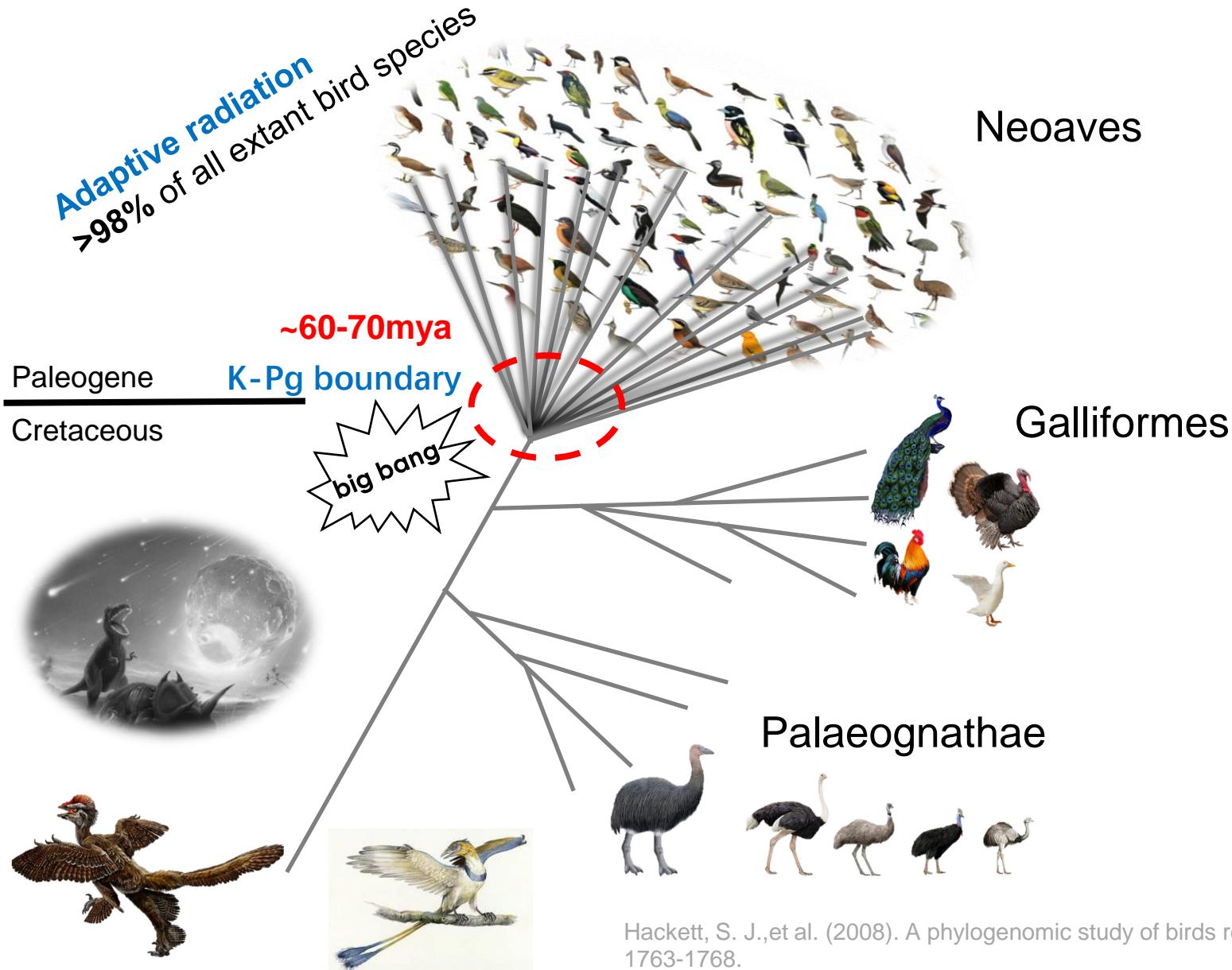
- Sensitivity to perception and knowledge
 - Sensitivity to social cues

Which birds are the closest relatives to the pigeon?

These relationships are still unknown for 90% of birds in the world



Rapid radiation after K-PG mass extinction



Differs from and agrees with previous classifications

Unsolved && Conflicts

Avian Phylogenomics Project (2011-2014)

B10K order phase program

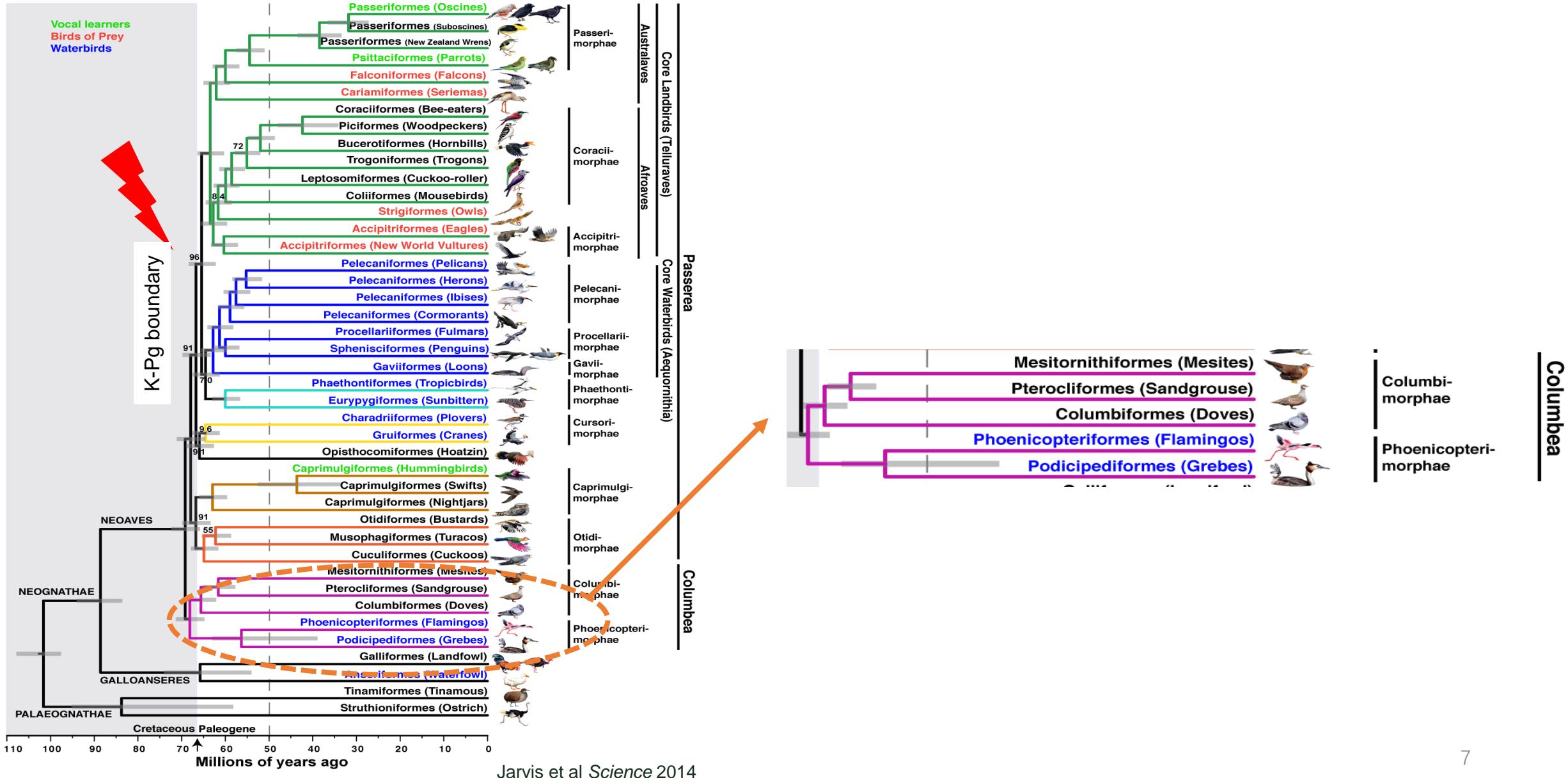


A flock of
Genomes

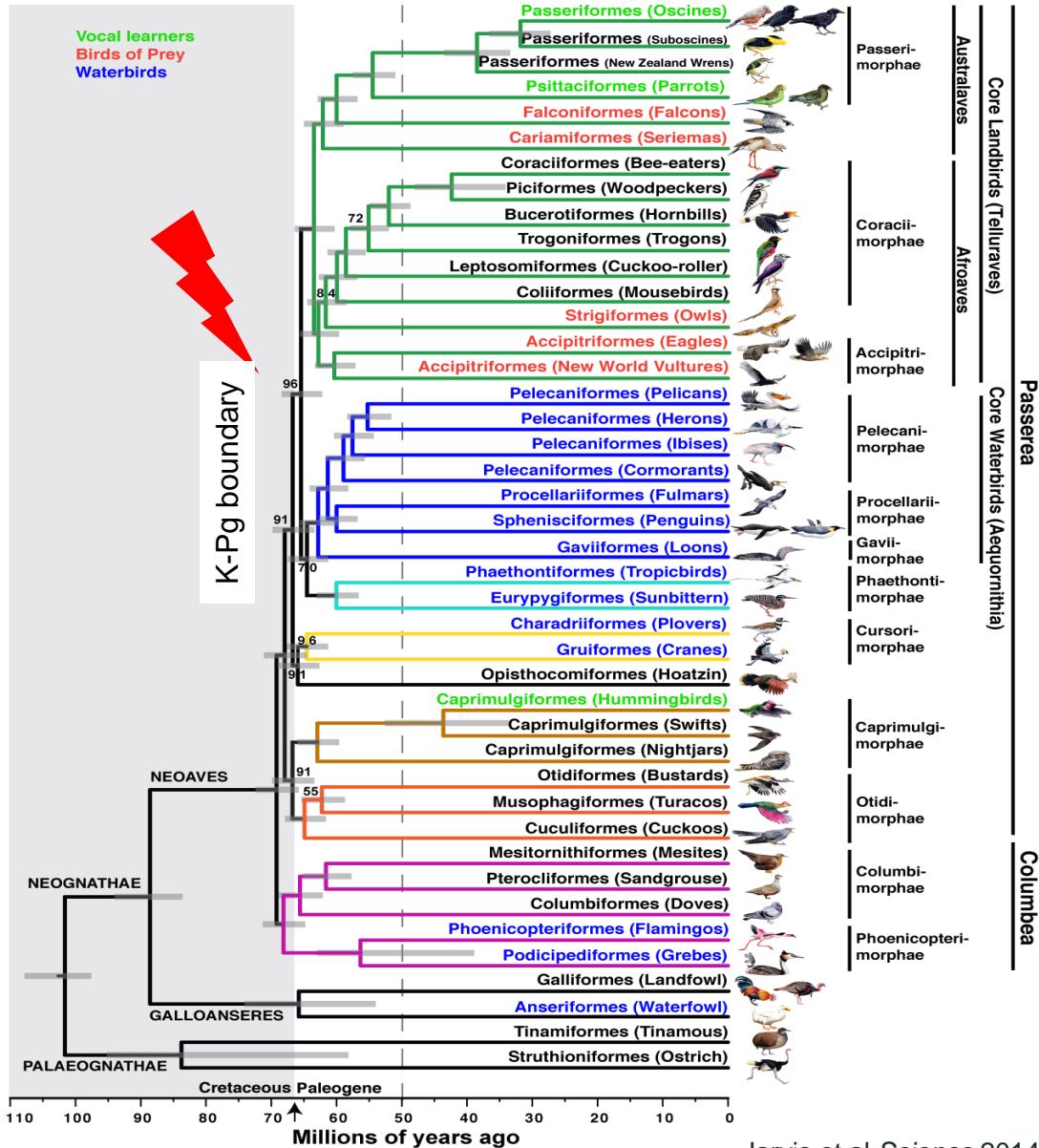
- ❖ 48 bird genomes
 - ❖ 8 papers in Science as special issue
 - ❖ >40 accompanying papers in other journals
-
- When and how did the big bang speciation occur?
 - How does the small genome made birds fly good?
 - How did the bird sex evolve?
 - How did vocal learning evolve in song birds?
 - How did the dinosaur bird lose teeth?
 - What genes control the evolution of feathers?



Phylogenetic position for 90% of birds was changed!



Phylogenetic position for 90% of birds was changed!



After the dinosaurs went extinct 66 million years ago, bird diversity skyrocketed; within the first five million years, 70 percent of the new bird lineages evolved.

All core landbirds share an ancestor that was an "apex predator," a carnivore at the top of its food chain.

How to Read a Phylogenetic Tree

This type of tree represents the evolutionary relationships among birds. Nodes are common ancestors from which descendants branch off. Bird groups that share nearest nodes are more closely related than those connected by more distant nodes.

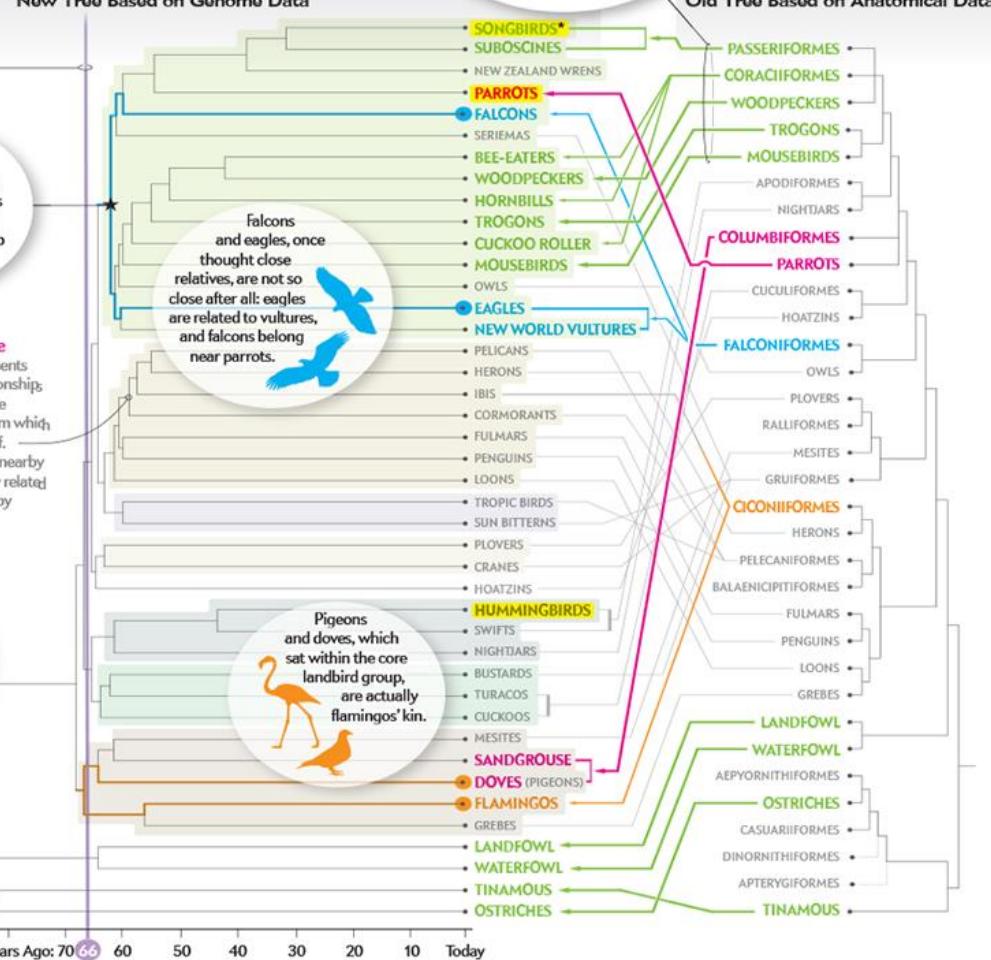
Vocal learners
Three lineages of birds—hummingbirds, parrots and songbirds—evolved the ability to imitate and develop new sounds independently.

The common ancestor of all birds finished its teeth-to-beak transition by 116 million years ago.

New Tree Based on Genome Data

The arrangement of ancient and recent branches of the tree (*green*) went largely untouched. Other groups, such as doves and parrots (*magenta*), saw major reshuffling based on genomic information.

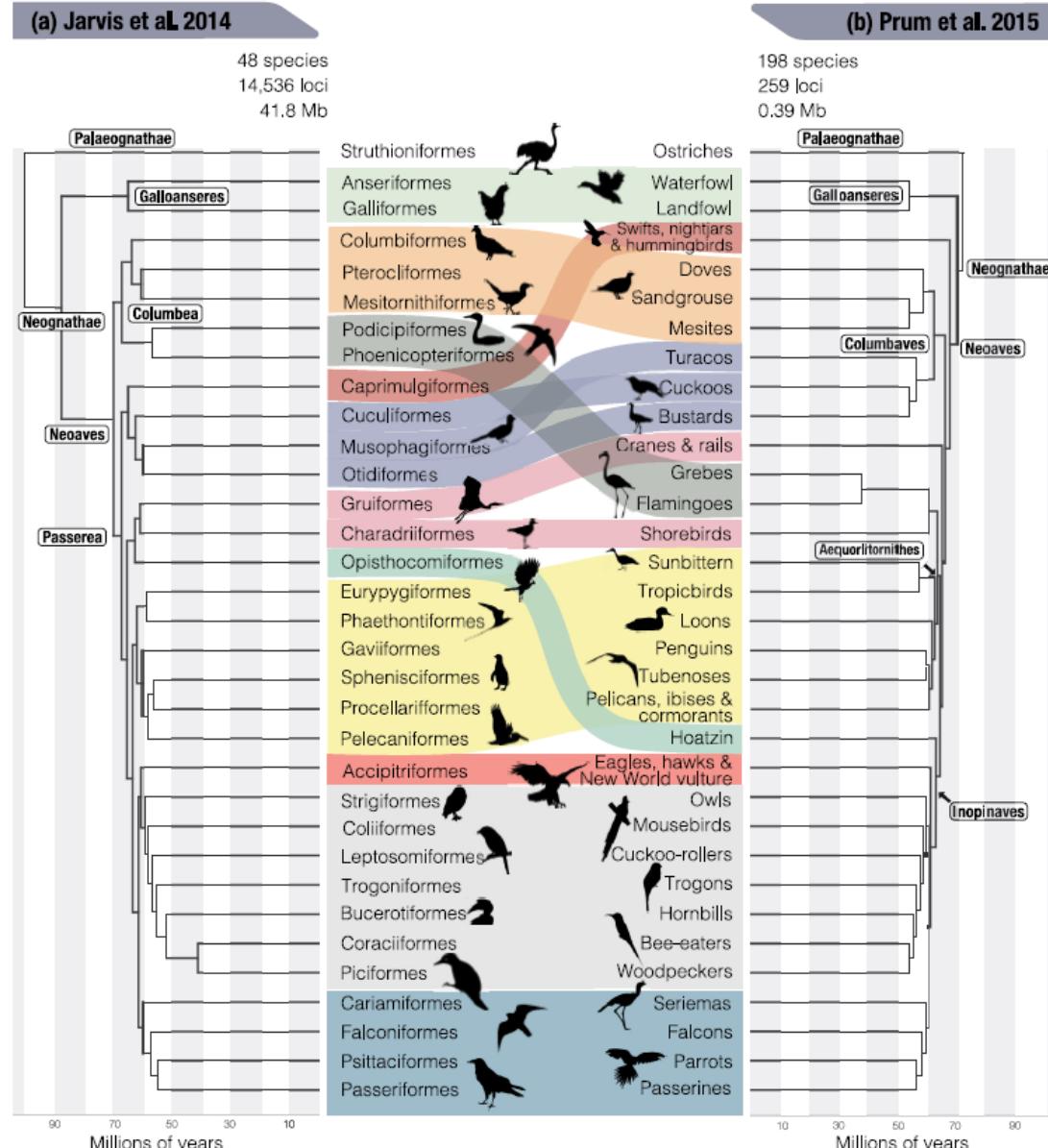
SCIENTIFIC AMERICAN



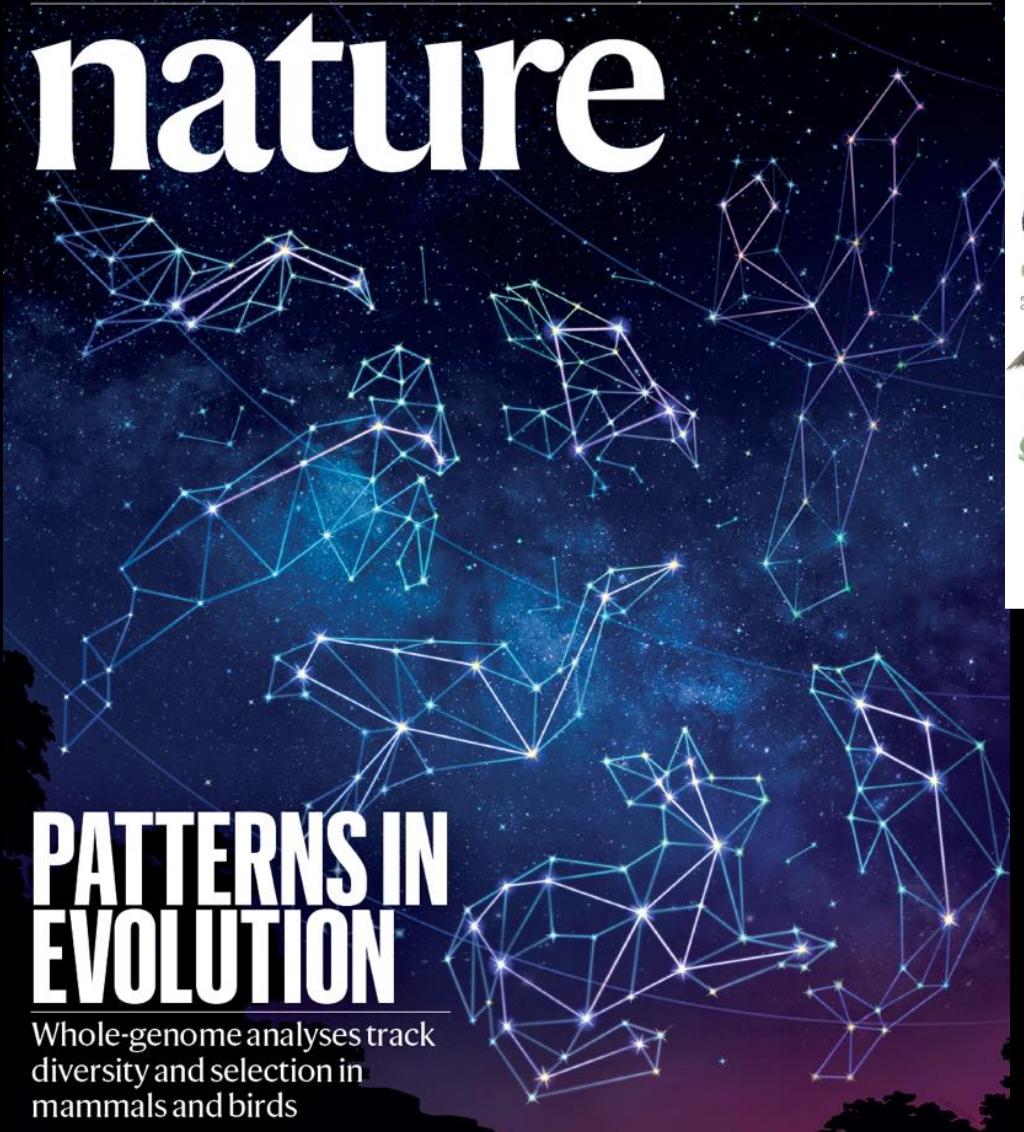
*In most cases, the more familiar English terms for bird groups are used on this chart. Some labels ("iformes") indicate the more formal taxonomic order.

Rapid radiation causes discordance along the Neoaves backbone

Result of low taxon sampling?



Result of low genomic sampling?

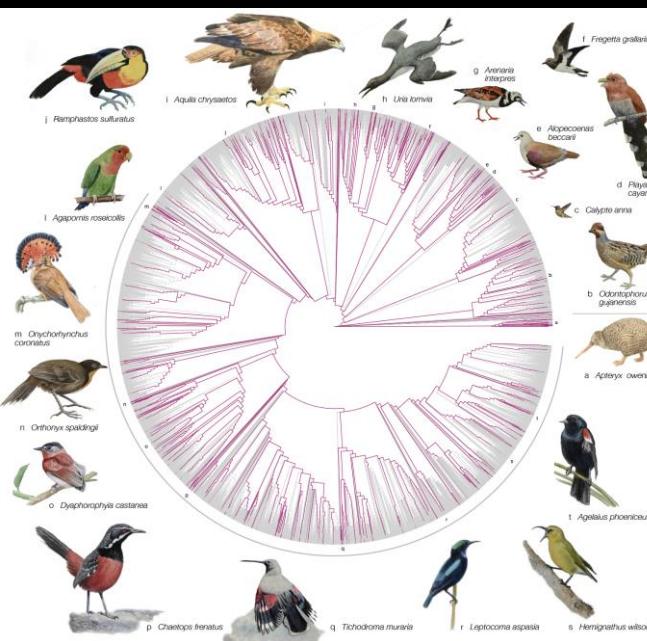


Coronavirus
Five key steps nations need to take for vaccine distribution

Climate change
Warming sea surface helps hurricanes to last longer on land

DNA distortions
Mismatched bases aid protein binding by reshaping the helix

Vol. 587 No. 7833
nature.com
9 770028 083095



Article | Open Access | Published: 11 November 2020

Dense sampling of bird diversity increases power of comparative genomics

Shaohong Feng, Josefina Stiller, [...] Guojie Zhang✉

Nature 587, 252–257(2020) | Cite this article

30k Accesses | 1 Citations | 819 Altmetric | Metrics

Article | Open Access | Published: 11 November 2020

Progressive Cactus is a multiple-genome aligner for the thousand-genome era

Joel Armstrong, Glenn Hickey, Mark Diekhans, Ian T. Fiddes, Adam M. Novak, Alden Deran, Qi Fang, Duo Xie, Shaohong Feng, Josefina Stiller, Diane Genereux, Jeremy Johnson, Voichita Dana Marinescu, Jessica Alföldi, Robert S. Harris, Kerstin Lindblad-Toh, David Haussler, Elinor Karlsson, Erich D. Jarvis, Guojie Zhang✉ & Benedict Paten✉

Nature 587, 246–251(2020) | Cite this article

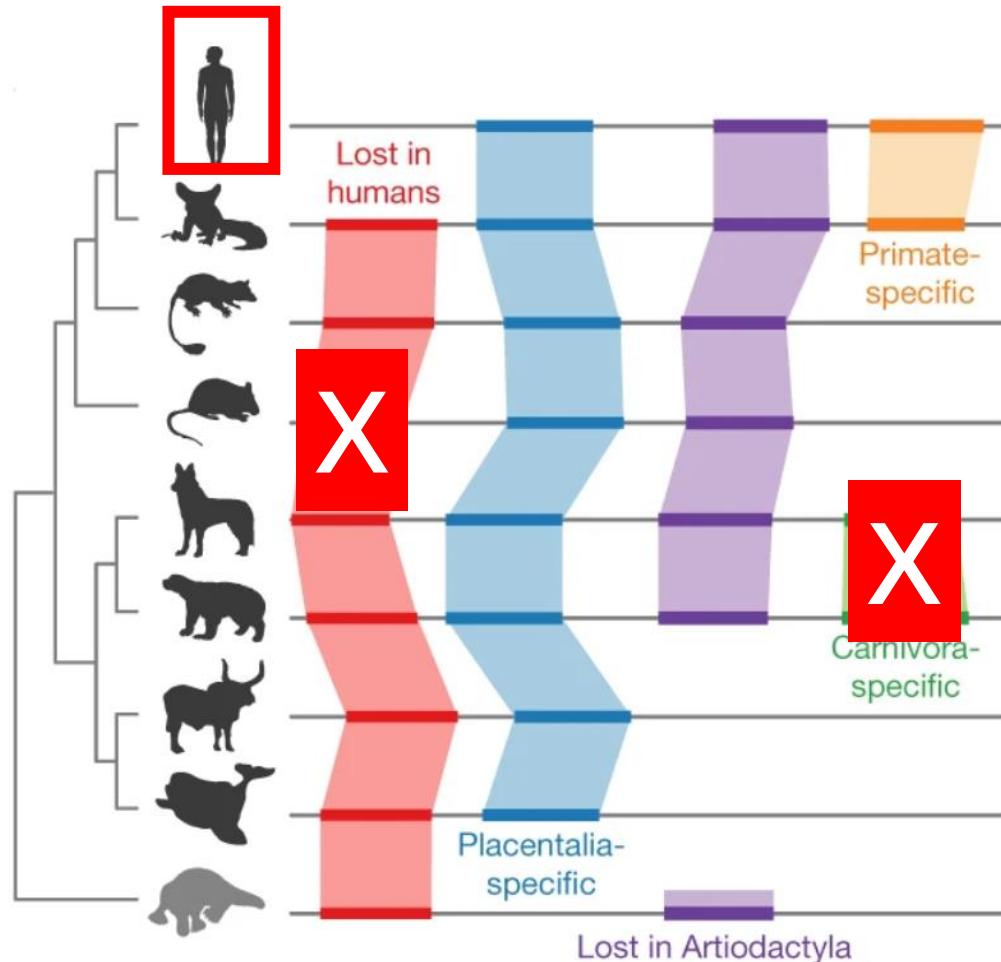
12k Accesses | 2 Citations | 299 Altmetric | Metrics

**Another milestone
Of B10K Family phase program**

363 genomes from 92% of bird families

Challenges for large-scale comparative genomics analyses

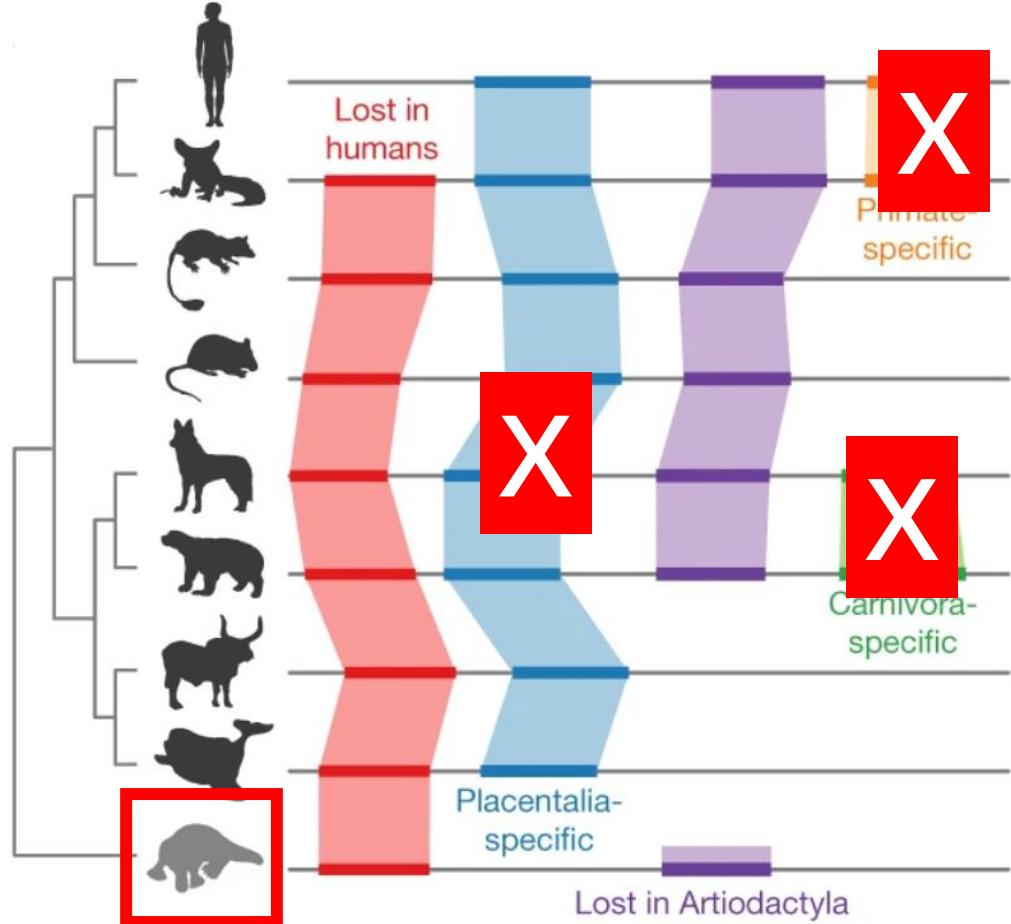
How to efficiently and correctly identify the orthologous sequences across broad taxa?



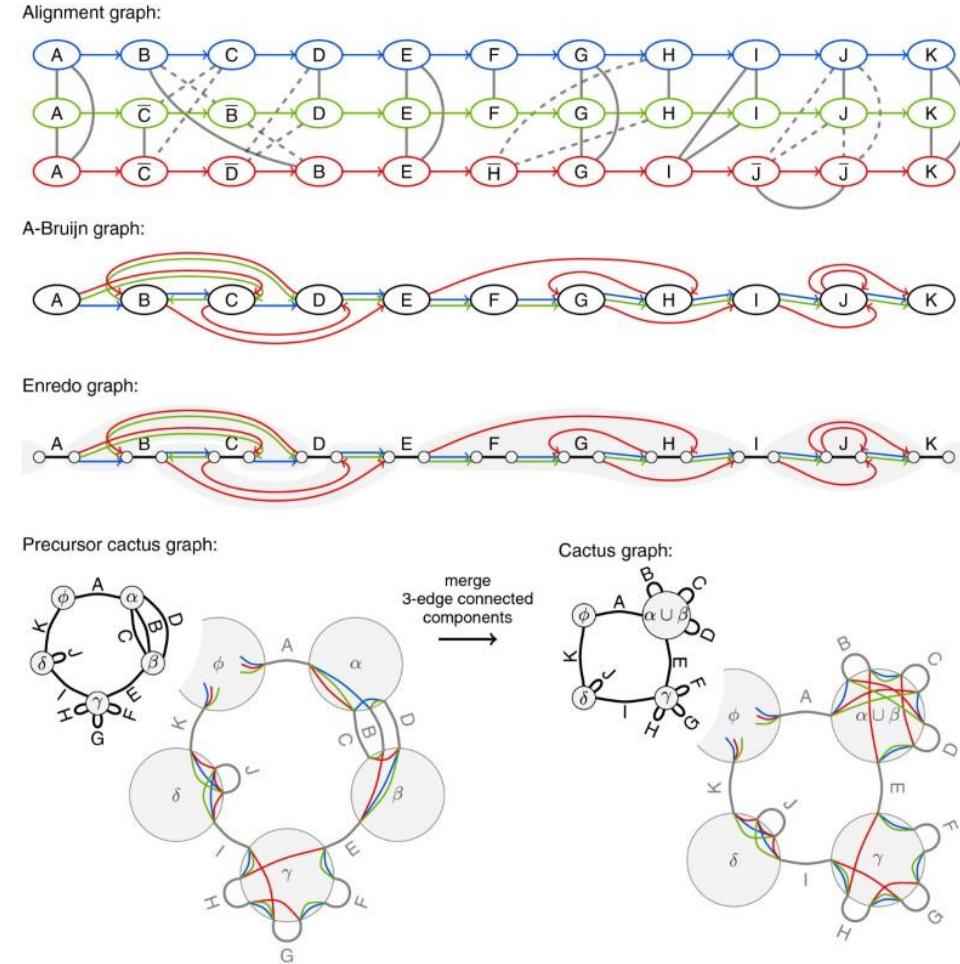
Limitations of the traditional reference-based method

Challenges for large-scale comparative genomics analyses

How to efficiently and correctly identify the orthologous sequences across broad taxa?

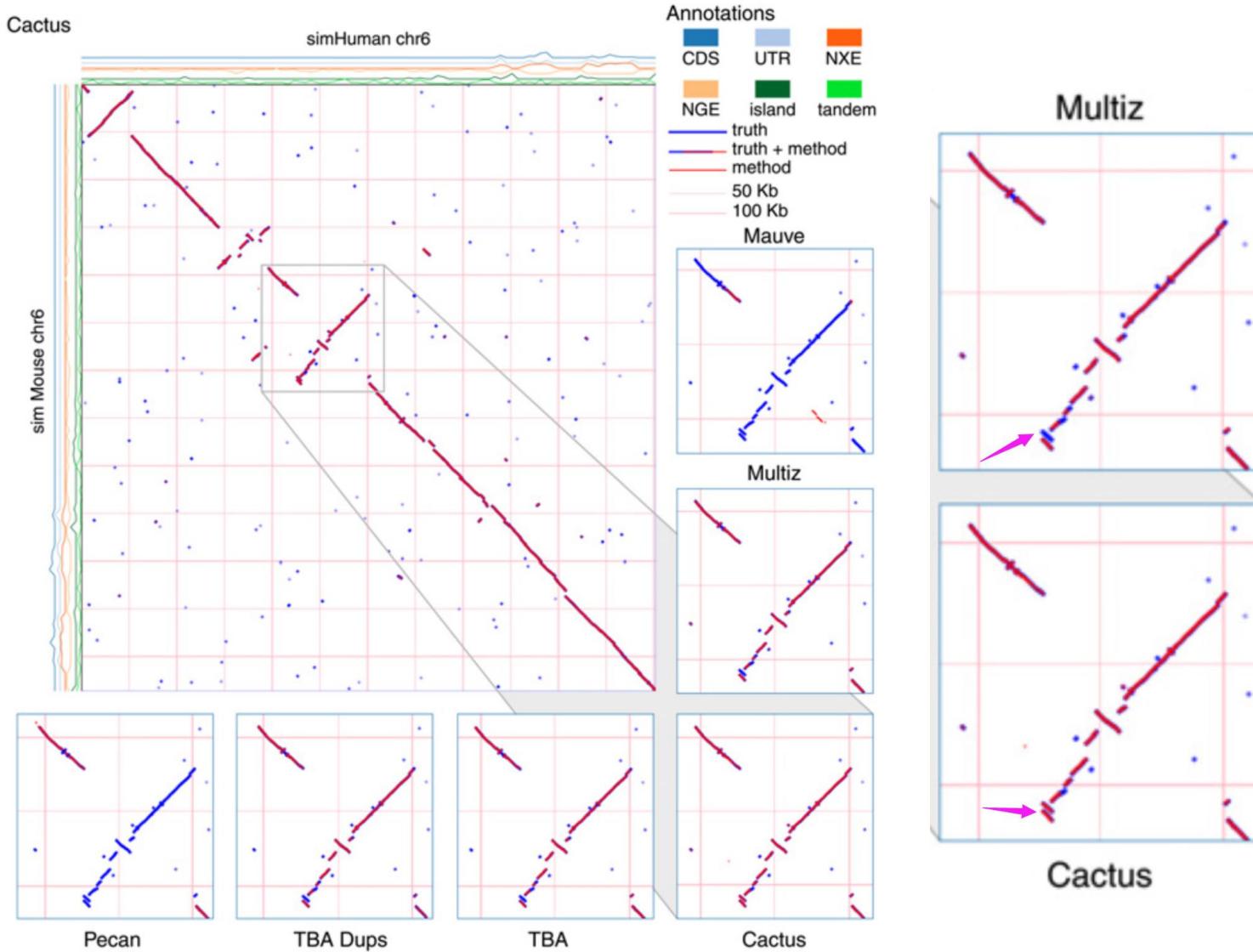


Limitations of the traditional reference-based method



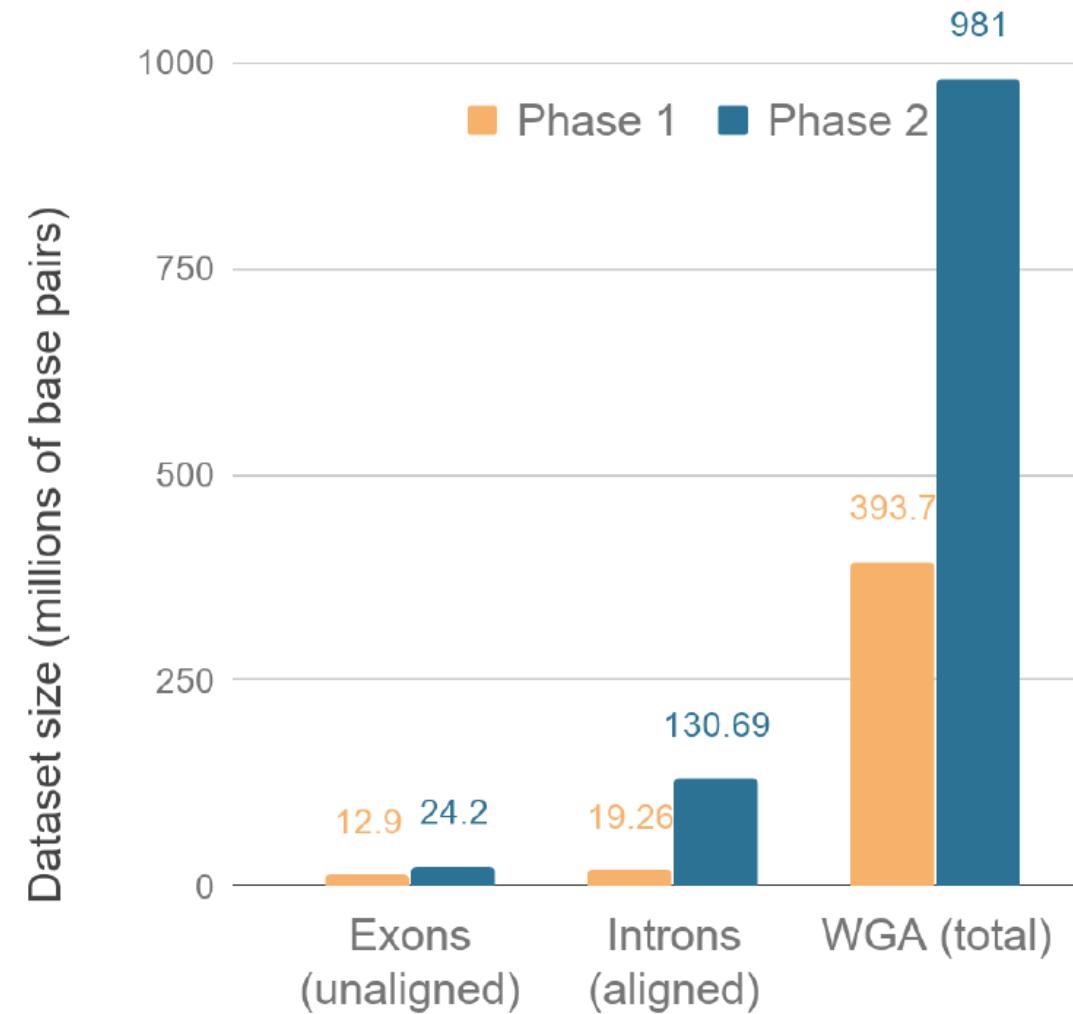
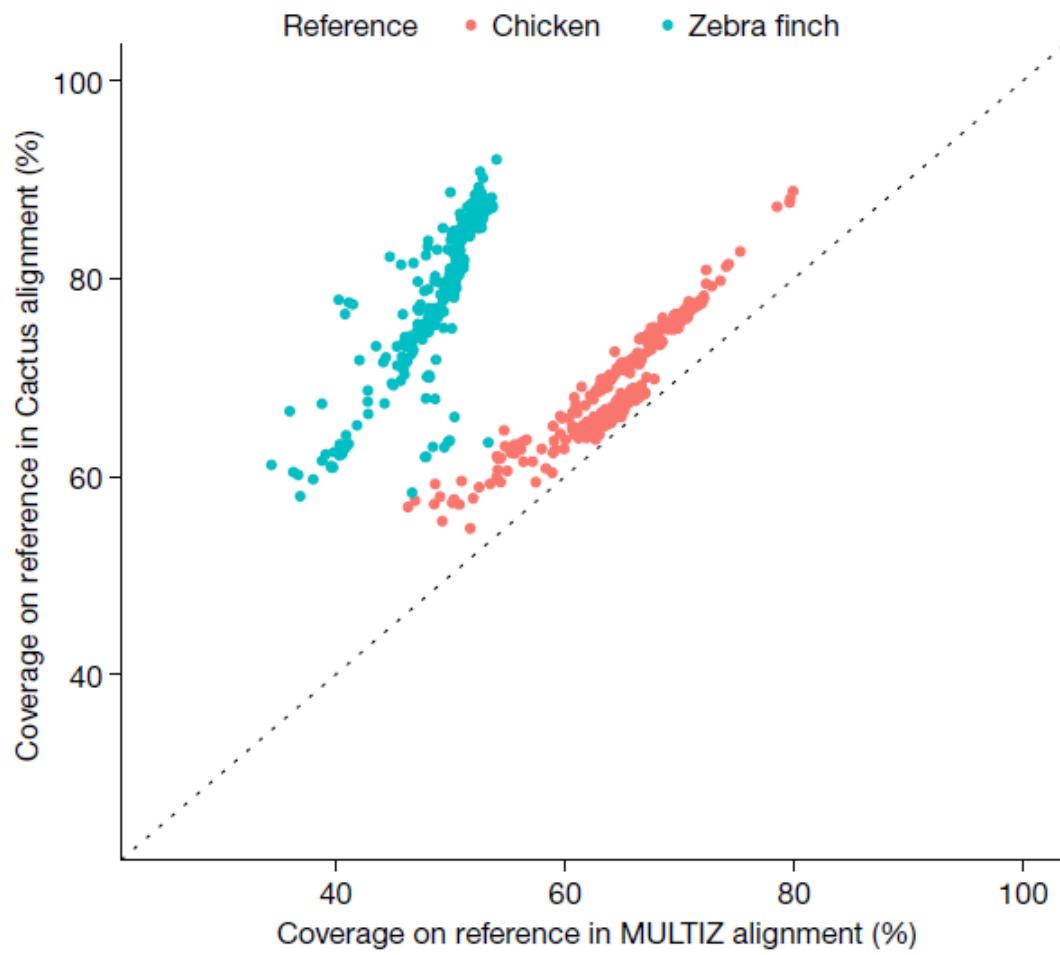
Reference-free CACTUS alignment

Cactus alignments cover more genomic regions



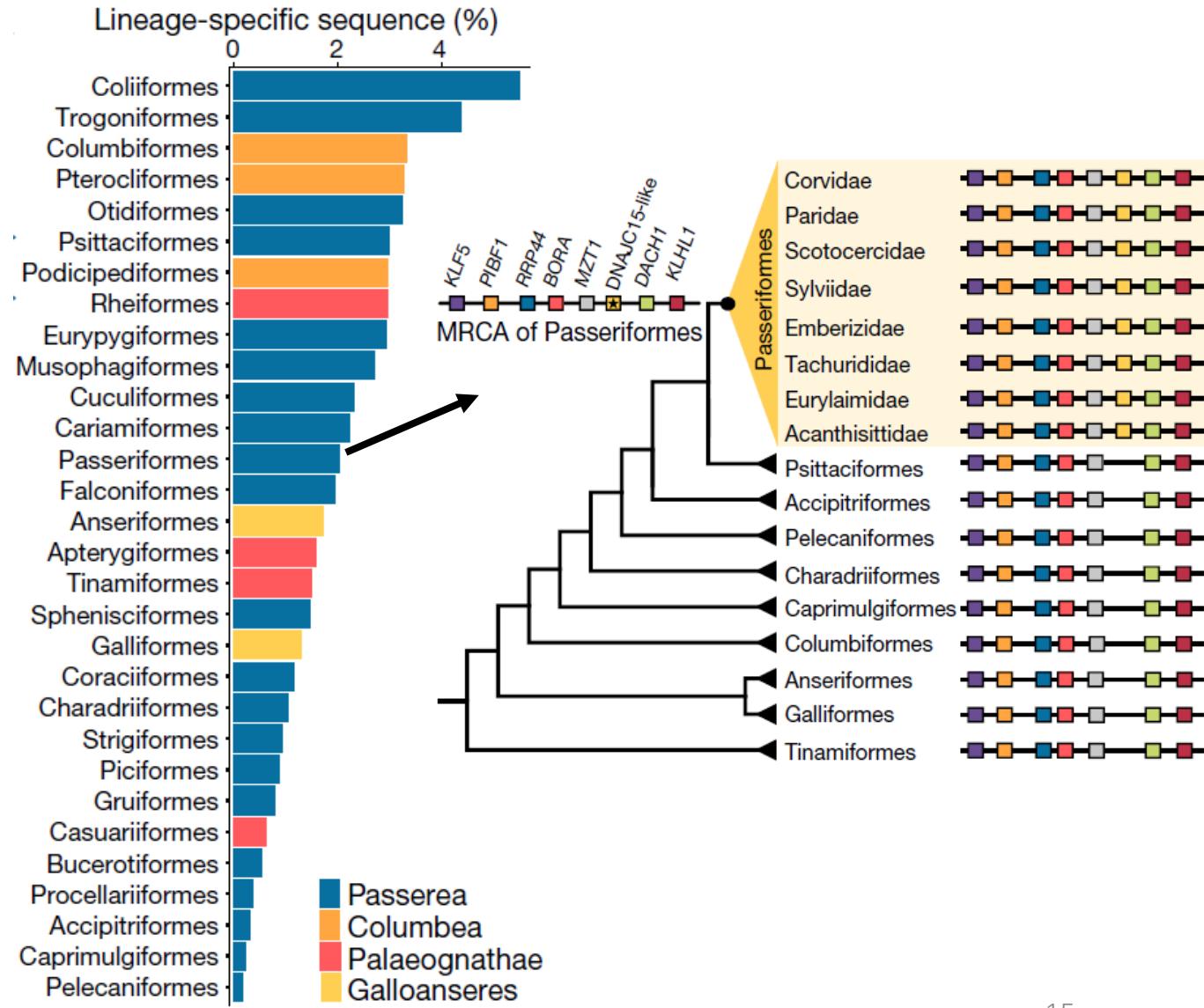
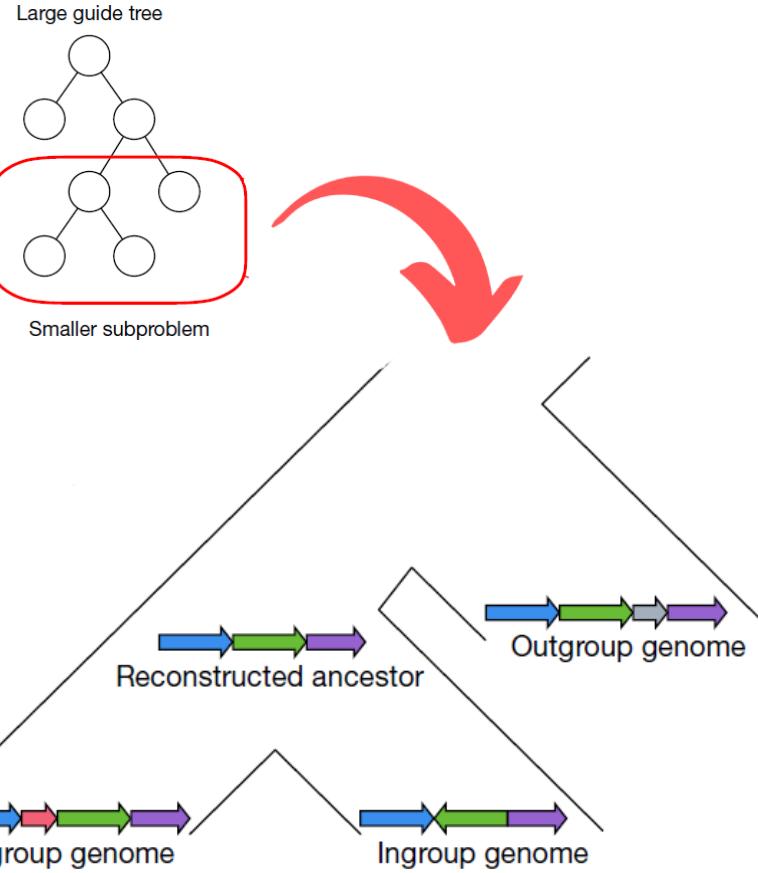
Aligned more complex rearrangements
(such as tandem duplications)

Cactus alignments cover more genomic regions



Massive lineage-specific sequences were identified

Genome dynamic evolution





Morphology

Physiology

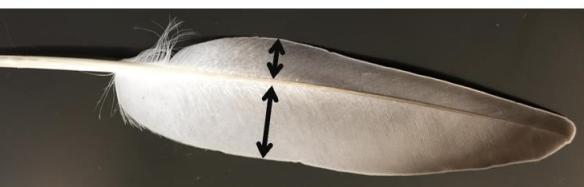
Behavior

Ecology

ASHCEs on macroevolution of bird-specific features



Flight feathers



Flight feathers are asymmetrically shaped feathers with long and stiff rachis, normally develop in wings and tails of birds

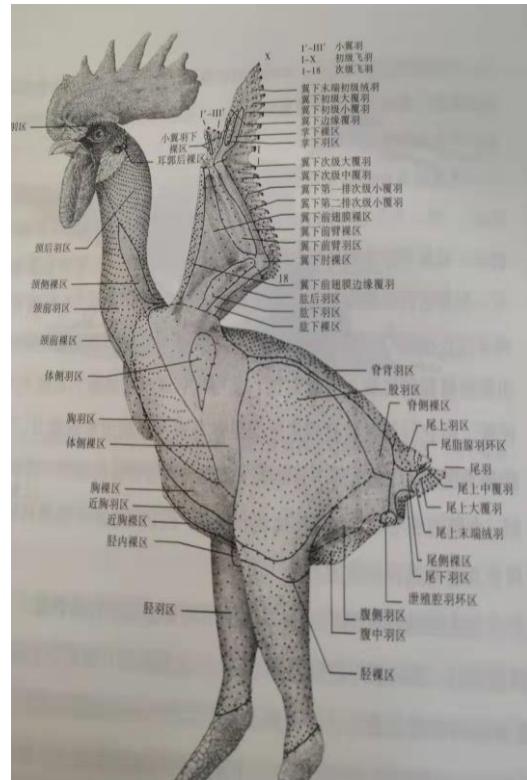


Fig. 1 Characteristic of birds: the flight feathers at wings and tail to help flying.

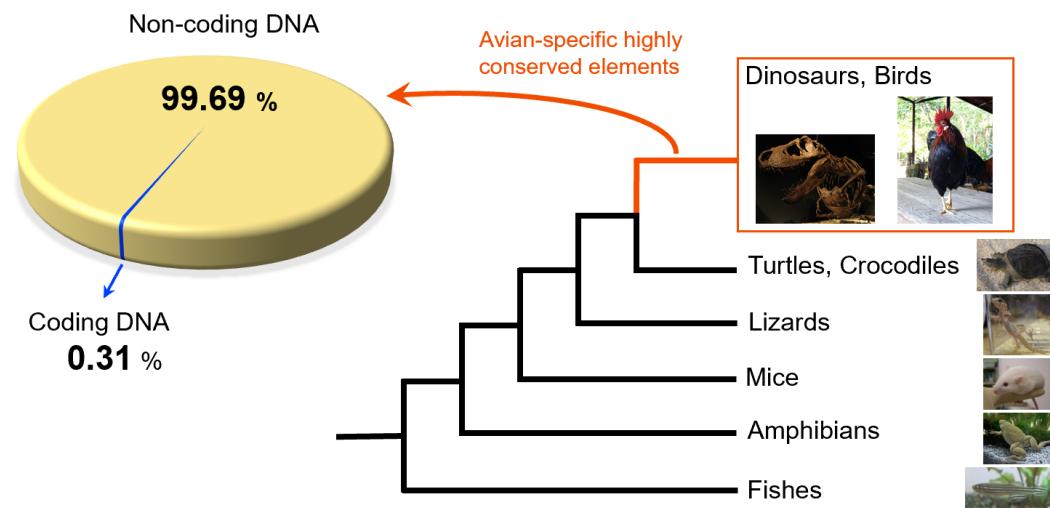


Fig. 2 There is almost no new coding gene in evolution of birds: by compared 48 avian genomes and 9 other animal genomes, avian specific conserved DNA sequences were almost all at non-coding genes (99.69%) .

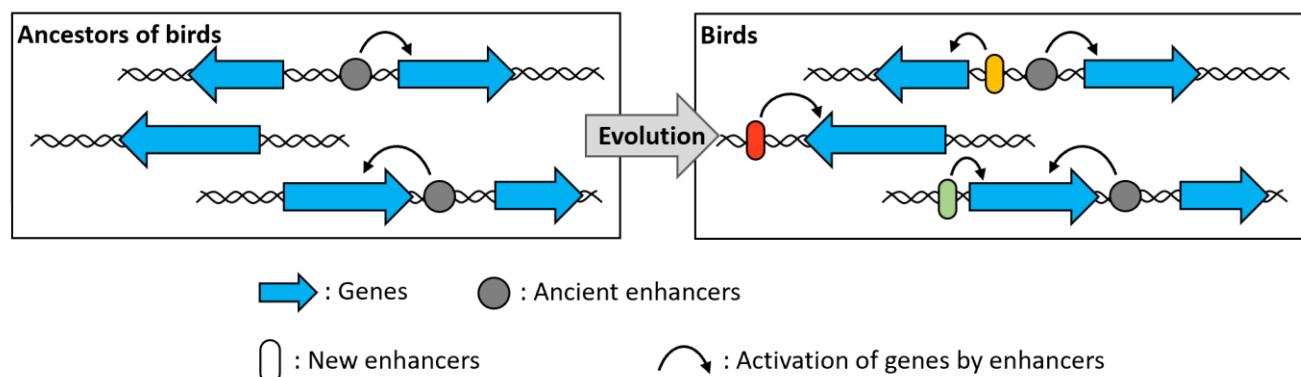


Fig. 3 Acquisition of new enhancer in avian evolution to influence the activation of genes: birds obtained the regulatory DNA sequences to control expression of genes, which called enhancer.

ASHCEs on macroevolution of bird-specific features

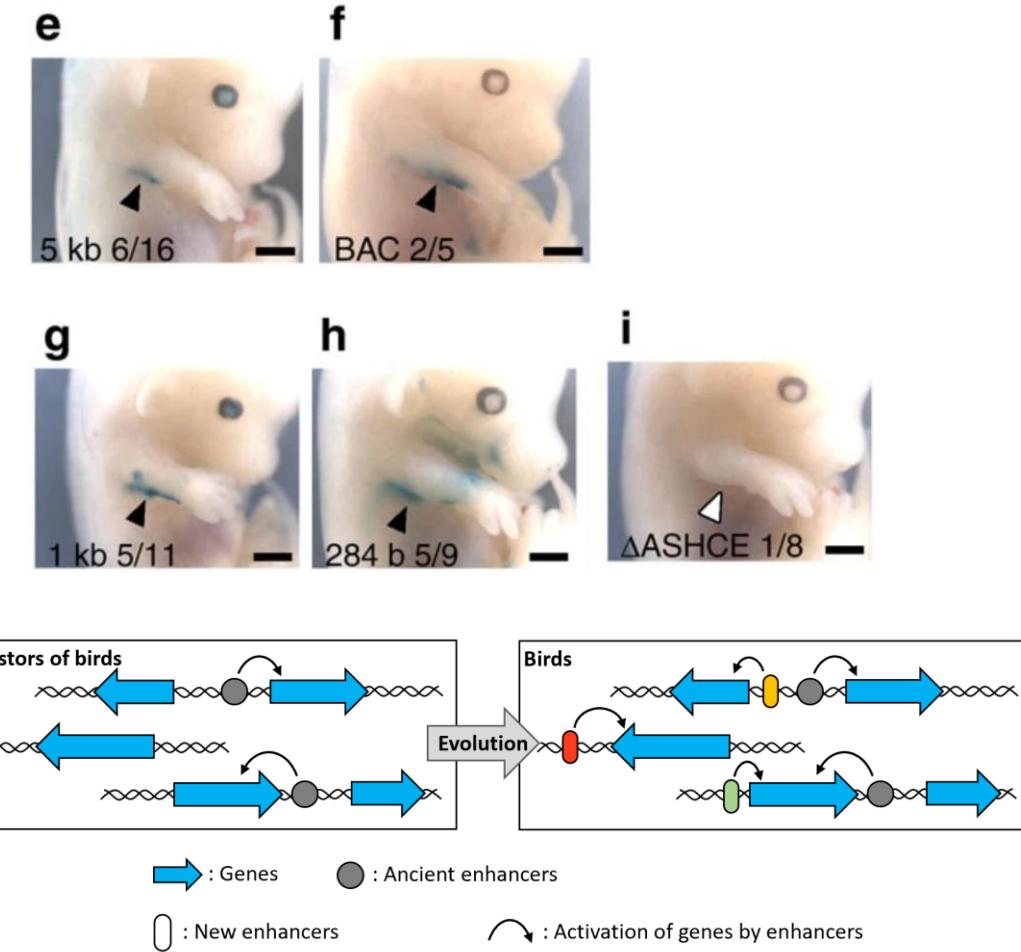
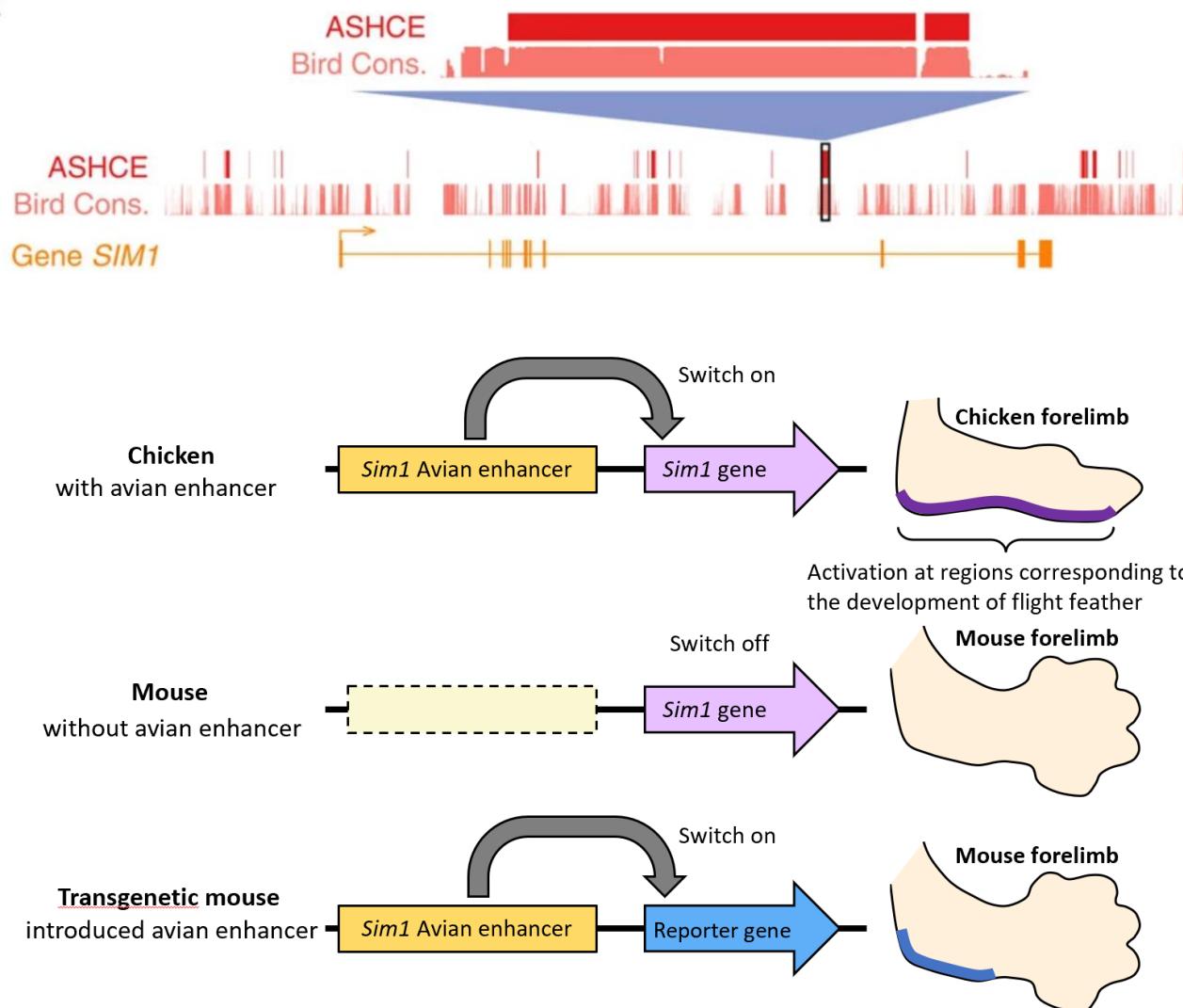
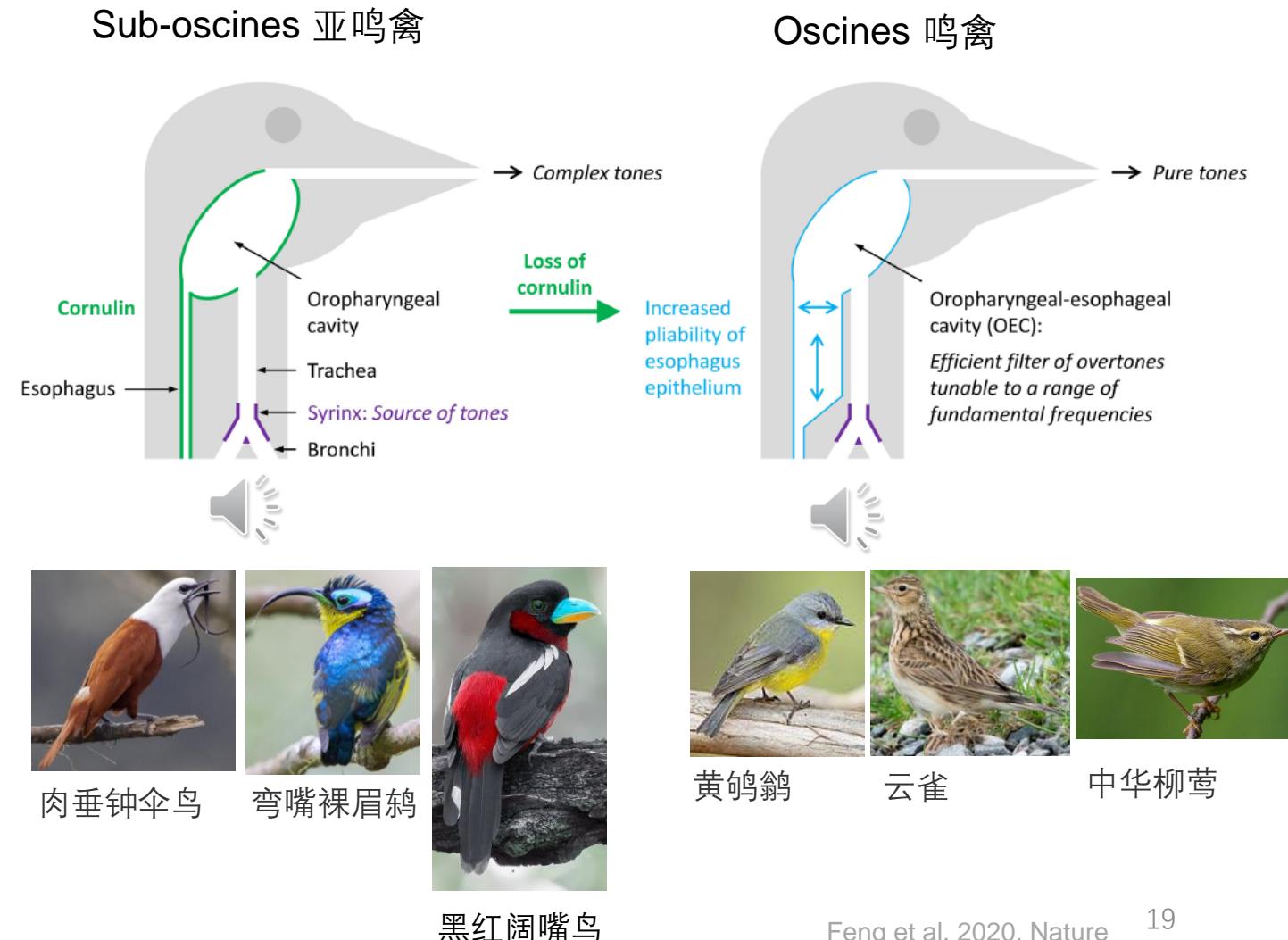
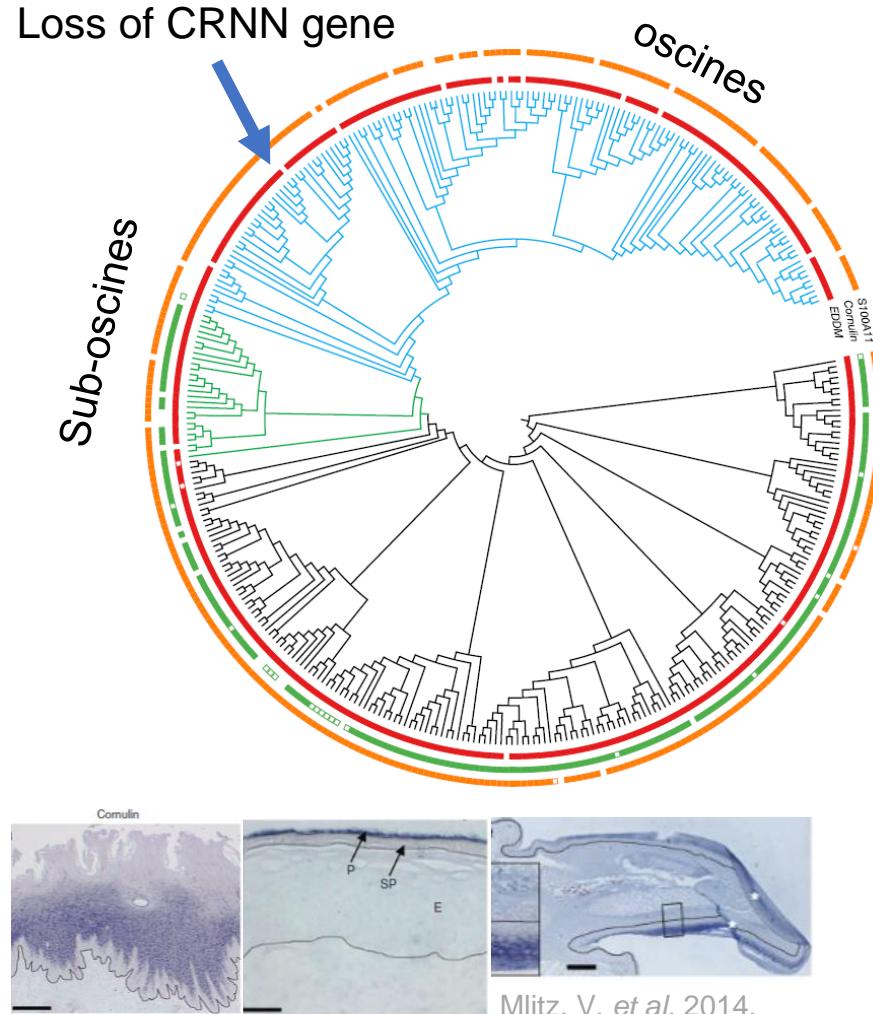


Fig. 3 Acquisition of new enhancer in avian evolution to influence the activation of genes: birds obtained the regulatory DNA sequences to control expression of genes, which called enhancer.

Pure-tone vocalizations of songbirds

- Cornulin (CRNN) was expressed in the esophageal epithelium, and its loss in songbirds changes the esophageal structure.



Acknowledgement



Guojie Zhang



Tom Gilbert



Erich Jarvis



Carsten Rahbek



Gary Graves



Fumin Lei



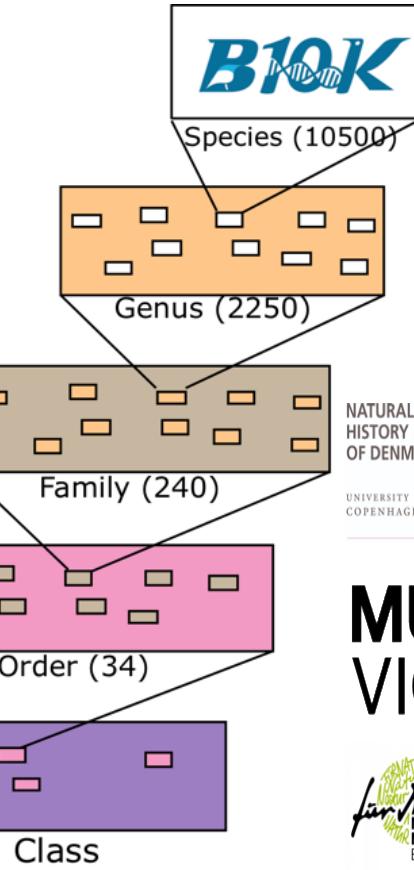
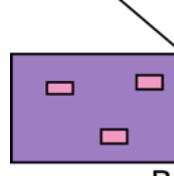
Josefin Stiller (josefin.stiller@bio.ku.dk)
Ph.D
Assistant Professor

Research Interesting:

- Phylogenomics and generation of biodiversity
- Phylogeography and historical biogeography
- Systematics and taxonomy



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BioK sample collection coordinator



+ 200 collaborators



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Thanks

