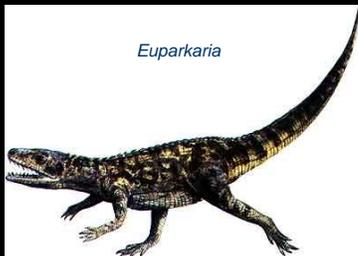


Origin and early evolution of birds

Birds evolved from reptilian ancestors of dinosaurs and crocodiles (Archosaurs) 250 - 300 million years ago



Reptile-bird shared characteristics

- One occipital condyle
- One middle ear bone (stapes)
- Similar ankle and jaw bone structure
- Scales (bird legs, feathers)
- Amniotic eggs, large yolk
- Nucleated red blood cells (erythrocytes)

The link between birds and reptiles

Archaeopteryx lithographica

135-155 MYA (Late Jurassic)

Shared characters with reptiles:

- Toothed jaws
- Long bony tail

Shared characters with birds:

- Feathers; wing feathers asymmetrical
- Bipedal



Geologic time scale

| Era | Period | Epoch | MYA | |
|--|------------|---------------------|---------|-----|
| Cenozoic (age of birds and mammals) | Quaternary | Recent | 0.1 | |
| | | Pleistocene | | |
| | Tertiary | Pliocene | 1.5-3.5 | |
| | | Miocene | 7 | |
| | | Oligocene | 26 | |
| | | Eocene | 37-38 | |
| | | Paleocene | 53-54 | |
| | | K/T boundary | | 65 |
| | | Cretaceous | Late | 100 |
| | | | Early | 135 |
| Late | 155 | | | |
| Jurassic | Middle | 170 | | |
| | Early | 180-190 | | |
| | Triassic | 230 | | |

Archaeopteryx?
Aves?

Modern birds (B) differ from Archaeopteryx (A) by:

1. Expanded braincase and fused skull bones
2. Fused carpels
3. Fused pelvic bones
4. Reduced and partially fused tail vertebrae (Pygostyle)
5. Keeled sternum
6. Rib cage strengthened by horizontal uncinate processes



Definitions

systematics – the study of evolutionary relationships among organisms.

phylogeny – evolutionary history or ancestry of a taxon.

monophyletic group – a group of organisms that share a common ancestor (clade).

cladistics – classification of organisms based on common ancestry.

cladogram – a branching diagram that shows phylogeny.

“**conservative**” characters that do not change easily in the course of ecological adaptation.

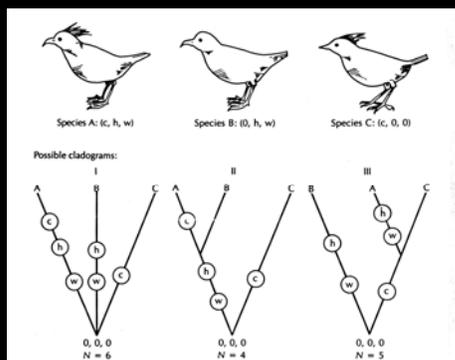
“**primitive**” refers to ancestral character states.

“**derived**” refers to advanced character states.

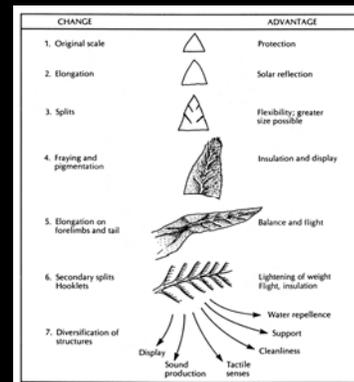
homology – characters shared by two (or more) taxa that can be traced phylogenetically to the immediate common ancestor.

convergence – similar adaptations (i.e., evolutionary solutions) observed in unrelated taxa.

Occam's razor and cladistics



Evolution of feathers

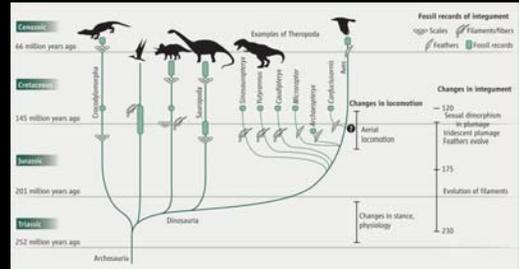


Feathers in amber



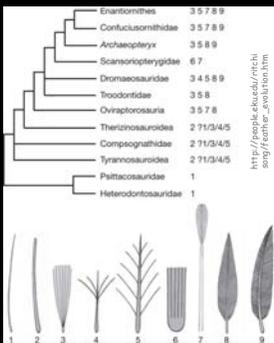
A Feathered Dinosaur Tail with Primitive Plumage Trapped in Mid-Cretaceous Amber
 Lida Xing, Ryan C. McKellar, Xing Xu, Gang Li, Ming Bai, W. Scott Persons, Tetsuto Miyashita, Michael J. Benton, Jianping Zhang, Alexander P. Wolfe, Qiru Yi, Kuowei Tseng, Hao Ran, Philip J. Currie
 Current Biology Volume 26, Issue 24, Pages 3352-3360 (December 2016)

Archosaurian body covering



The earliest preserved scales, filaments, or feathers are from the late Jurassic; the earliest birds with feathers are from the Paleocene, ~66 million years BP. Filamentous feather precursors may have originated nearly 100 million years before the origin of flight, but very few fossil deposits sample this period. Sexual dimorphism in plumage and color patterning in Late Jurassic and Early Cretaceous dinosaurs suggest that display functions played a key role in the early evolution of pinnate feathers (Clarke 2013).

Maniraptoran body covering



Feathers became more elaborate as birds evolved from dinosaurs

Several lineages of early birds went extinct by 66 Million years BP

Some Feathers were not developed for flight or even gliding
Scansoriopterygidae



Types of feathers found in Dinosaurs

Where did Archaeopteryx (and subsequent birds) come from?

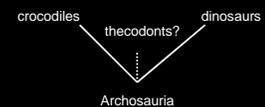
thecodonts?

Proposed by Heilmann (1926)

Possibility suggested by presence of lightly-built arboreal thecodonts with elongated scales in fossil record (Triassic).

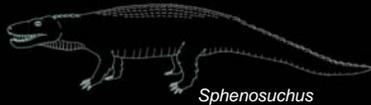


Longisquama



Where did *Archaeopteryx* (and subsequent birds) come from?

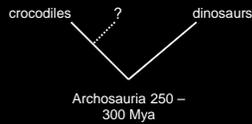
crocodilians?



Proposed by Walker (1972)

Most shared skeletal features also shared with basal Archosaurs.

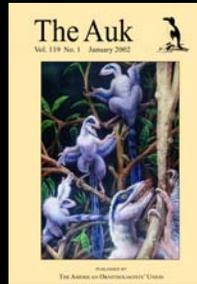
Hypothesis abandoned in recent years (except by Larry Martin!).



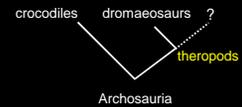
Archaeopteryx (and subsequent birds) likely came from Theropod Dinosaurs?

theropod dinosaurs?

Hypothesis dates to Huxley (1868); resurrected by Ostrom (1974)



Support building over past 35 years. Proponents (mostly paleontologists) claim evidence, based mostly on **cladistics** is conclusive.



So, was Huxley right?

Based on cladistics, it would seem so. Derived skeletal characters, from virtually the entire body, are shared by birds and theropods.

Latest evidence comes from modern feathers in a Dromaeosaur (Norell et al. 2002) and Microraptor (Xu et al. 2003)



Critics argue cladistics is fraught with problems and can't handle massive convergence.

"cladistic jihad!" (Allan Feduccia 1999)

Ever since *Archaeopteryx*

More recent fossils include:

1987 *Sinornis* (140 million years old)

1996 "Downy Dino" *Sinosauropteryx* (120 million years old)

2002 *Jeholornis* (early Cretaceous 135 million) and *Asparavus* (late Cretaceous 100 million)

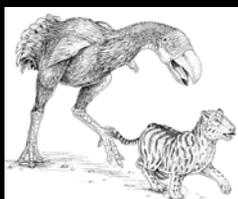
and old fossils reconsidered: *Hesperornis* and *Ichthyornis* from the late Cretaceous



from Marsh (1880)

The rise of modern birds

- Modern bird orders diverged from one another in early Tertiary (~ 60 Mya)
- Many modern genera present by the end of the Tertiary (5-10 Mya)



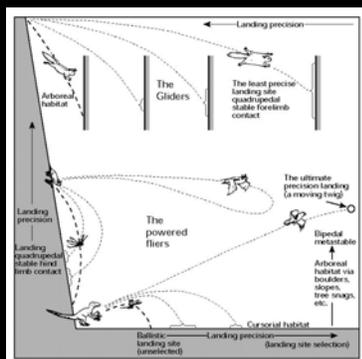
Diatryma

The Origin of Birds



Evolution of flight

1. Arboreal hypothesis (top-down): elongated wing structures (protowings) to parachute and glide
2. Cursorial hypothesis (bottom-up): used protowings for acceleration and leaping to catch flying insects



from Padian and Chiappe (1998)

2001 Microraptor Is the four-winged dino a missing link?

The four-winged Dinosaur



Note: Est. 400,000 species of dinosaurs, only 1,100 described. Is detection bias a problem?

Today:
10,000 -20,00 species of birds
4,000 species of mammals....

THIS IS STILL THE AGE OF DINOSAURS!!!



<http://www.smbc-comics.com/index.php?id=3095>

Systematics of extant birds

1. Phylogeny construction based on morphological characters
2. Molecular techniques
 1. Protein/allozyme analysis
 2. DNA-DNA hybridization
 3. mtDNA cytochrome *b* gene
 4. Nuclear DNA sequencing

Comparisons of multiple techniques are the most useful. Behavior, ecology, biogeography are also important.



Taxonomic Classification

Downy Woodpecker

| | |
|---------|------------------|
| Class | Aves |
| Order | Piciformes |
| Family | Picidae |
| Genus | <i>Picoides</i> |
| Species | <i>pubescens</i> |

Modern Birds are Diverse and Abundant

How many individuals? Gill says 300 billion

How many species? 10 – 20,000

| Scale | Species | Families | Orders |
|----------------|---------|----------|--------|
| World wide | ~10,000 | 187 | 29 |
| North America | ~2,000 | 105 | 22 |
| North Carolina | ~450 | 62 | 22 |

Barrowclough GF, Cracraft J, Klicka J, Zink RM (2016) How Many Kinds of Birds Are There and Why Does It Matter? PLoS ONE 11(11): e0166307. <https://doi.org/10.1371/journal.pone.0166307>