The Origin of Birds

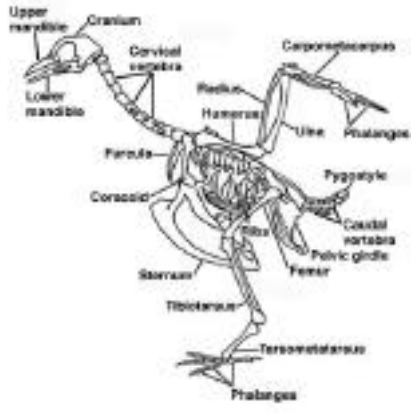
Technical name for birds is **Aves**, and "avian" means "of or concerning birds".

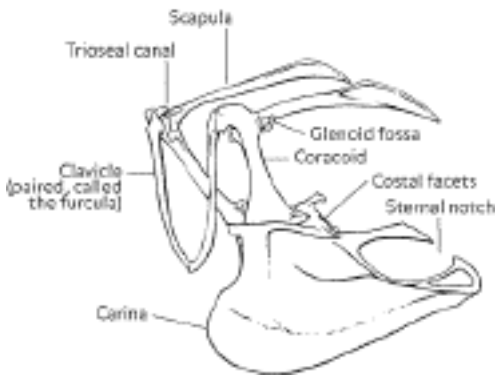
Birds have many unusual synapomorphies among modern animals: [Synapomorphies (shared derived characters), representing new specializations evolved in the most recent common ancestor of the ingroup]

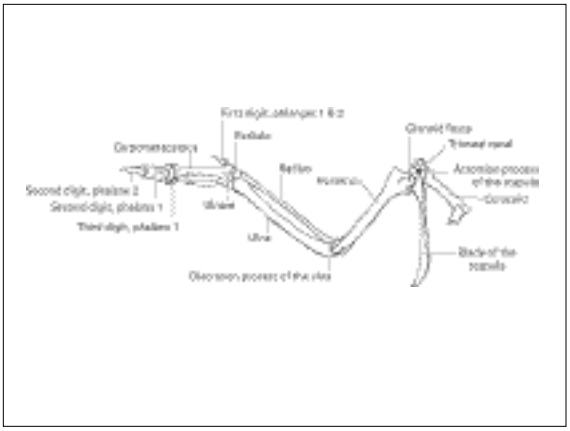
- Feathers
- Warm-blooded (also in mammals)
- Specialized lungs & air-sacs
- Hollow bones
- Toothless beaks
- Large brain

- Cervicals very different from dorsals, allowing neck to fold into "S"-shape
- Synsacrum (sacrum fused to pelves; pelvic bones fused together)
- Proximal caudals very mobile
- **Pygostyle** (distal caudals all fused together)
- **Furcula** - (the wishbone)
- Forelimb very long, has become wing
- Carpometacarpus (semilunate carpal block fused to metacarpals; all metacarpals fused together)
- Three fingers, but digits all reduced so no unguals

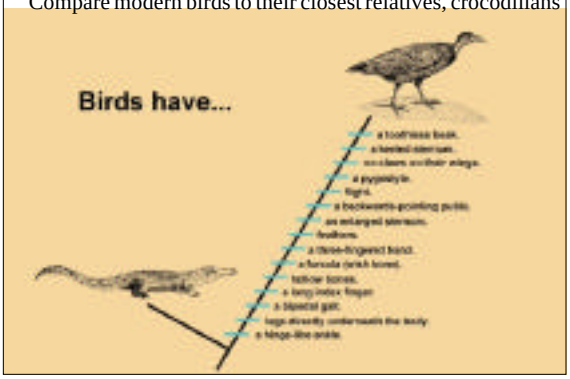
- Backwards-pointing pubis
- Fibula reduced to proximal splint
- Astragalus & calcaneum fused to tibia
- Hinge-like ankle joint
- Tarsometatarsus (distal tarsals fused to metatarsals; all metatarsals fused together)
- Main pedal digits II-IV
- Pedal digit I reversed, placed at bottom of tarsometatarsus





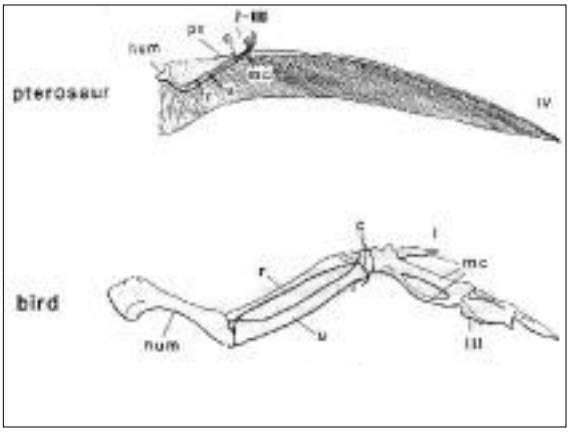


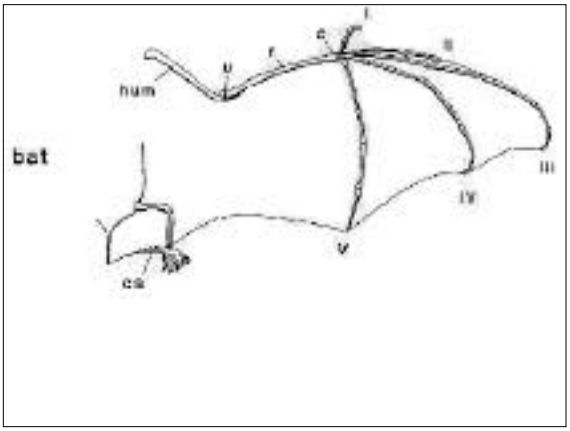
Compare modern birds to their closest relatives, crocodilians



- Difficult to find relatives using only modern animals (turtles have modified necks and toothless beaks, but otherwise very
- different; bats fly and are warm-blooded, but are clearly mammals; etc.)

- With discovery of fossils, other potential relations: pterosaurs had big brains, “S”-shaped neck, hinge-like foot, but wings are VERY different.





- In 1859, Darwin published the Origin; some used birds as a counter-example against evolution, as there were apparently known transitional forms between birds and other vertebrates. In 1860, a feather (identical to modern birds' feathers) was found in the Solnhofen Lithographic Limestone of Bavaria, Germany: a Late Jurassic formation. The following year, the skeleton of this feather-bearer was found.

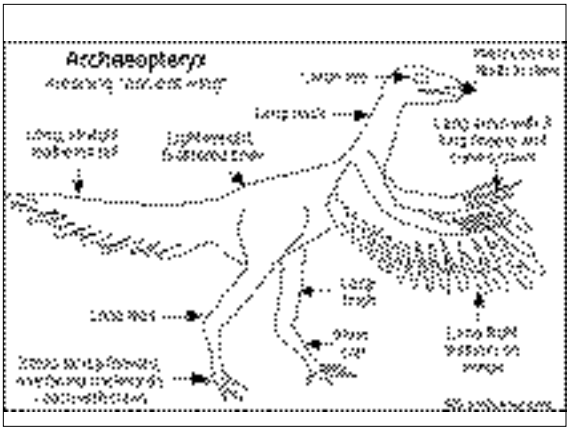
- This creature was named ***Archaeopteryx lithographica***: ancient wing of the Lithographic limestone.

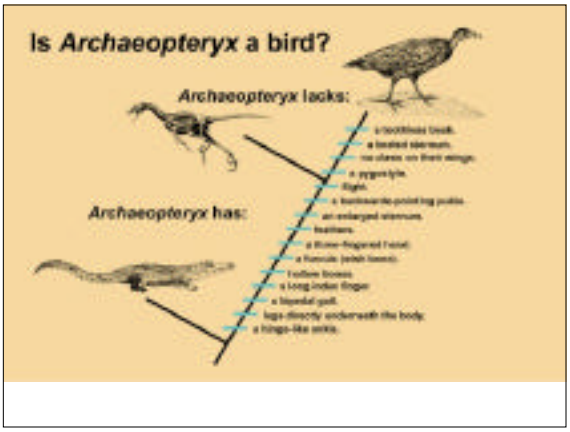
Like modern birds, it had:

- Feathered wings and a feathered tail
- Backwards-pointing pubis
- Backwards-pointing pedal digit I, located at the bottom of the metatarsus

BUT, it was very primitive compared to other birds in that it had:

- Individual distal caudals instead of a pygostyle
- Individual carpals and metacarpals with digits and unguals rather than a fused carpometacarpus
- Some evidence of teeth near the damaged skull: maybe from Archaeopteryx, maybe from something else





- Many saw Archaeopteryx as transitional between "normal" reptiles and birds. This specimen was bought by the British Museum (Owen's place of work). "The London Specimen"
- A second, and much better, specimen was found in 1877: this one was bought by the Humbolt Museum in Berlin. This specimen showed that the skull DID have teeth! "The Berlin Specimen"
- (During the 20th Century, five more Archaeopteryx skeletons have been found: all from the Solnhofen Limestone).

Archaeopteryx

the Solnhofen specimen 1960's

the London Specimen 1861

the Berlin Specimen 1877

With the discovery of these primitive bird specimens, could now better compare birds with potential ancestors:

- Thomas Huxley (Darwin's protégé) and O. C. Marsh suggested birds might be dinosaur descendants (as they shared many features). Huxley showed that bird ancestors were clearly archosaurs, since Archaeopteryx had an antorbital fenestra (among other features).
- During late 19th Century, the dinosaurian origin of birds was the best option.

- During the early 20th Century, a new hypothesis was suggested. In 1910, discovery of *Euparkeria* (a very primitive archosaur about the size of a cat). Its discover suggested it might have been "…very near the ancestor of the Dinosaurs, Pterodacyles (sic), Birds and Crocodiles".
- This idea was amplified by artist and natural historian Gerhard Heilmann. Heilmann examined lots of Mesozoic archosaurs. He considered coelurosaurian dinosaurs to have the most shared features with birds, but thought that they didn't have furculae or clavicles (and therefore didn't have anything that could evolve into bird clavicles).

Euparkeria

- He settled instead on *Euparkeria*, suggesting that it was sufficiently primitive to be a bird ancestor. Book The Origin of Birds published in 1927 in English (earlier Dutch version not as influential). Became THE main hypothesis by far from the 1920s until the 1970s/1980s.
- (Heilmann also championed a particular theory of the origin of avian flight: from quadrupedal ground dweller to quadrupedal tree climber to semiquadrupedal glider to bipedal flier).

- In 1970, John Ostrom was examining a supposed pterosaur specimen in the Tyler Museum in Haarlem, the Netherlands.
- Recognized it was really an Archaeopteryx (had actually been found in 1855, long before the better specimens), but also recognized that the manus was almost identical in every detail to that of Deinonychus!

Ostrom documented many features found in Archaeopteryx also found in various theropods, most especially coelurosaurs, most especially Deinonychus:

- Backwards pointing pubis
- Semilunate carpal block
- Three-fingered manus with digit II the longest, and metacarpal III bowed
- Elongate forelimbs
- Functionally three-toed foot
- Reduced pedal digit I
- Etc.

- Revised the Huxley/Marsh hypothesis, recognized that birds arose among the coelurosaurian theropod saurischian dinosaurs.
- Predicted that if an Archaeopteryx were found without feather impressions, it would be considered a coelurosaur: prediction came true in 1970, when a specimen (thought since 1955 to be a Compsognathus) turned out be an Archaeopteryx.

- Ostrom also revised an earlier idea that flight arose from fully terrestrial bipeds rather than going through a tree-dwelling gliding stage; noted that birds show no sign of using their hindlimbs in flight, whereas almost all gliders do.
- In 1980s and 1990s cladistic work helped establish the relationships of birds WITHIN the dinosaurs. In mid-to-late 1990s, discovery of other coelurosaurian dinosaurs with feathers!!

- Under cladistics, birds are the descendants of dinosaurs. As such, they are descendants of the most recent common ancestor of Megalosaurus and Iguanodon.

Therefore:

- Birds (Aves) are a type of dinosaur!

- In other words, Archaeopteryx and later birds are

  eumaniraptoran maniraptoran coelurosaurian avetheropod tetanurine eutheropod theropod saurischian dinosaurian dinosauriform ornithodiran archosaurs.

Avialae (the taxon comprised of Archaeopteryx and more advanced birds) share the following synapomorphies:

- Flight (probably)
- Number of caudals 25 or fewer
- Pedal digit I reversed and at bottom of metatarsus

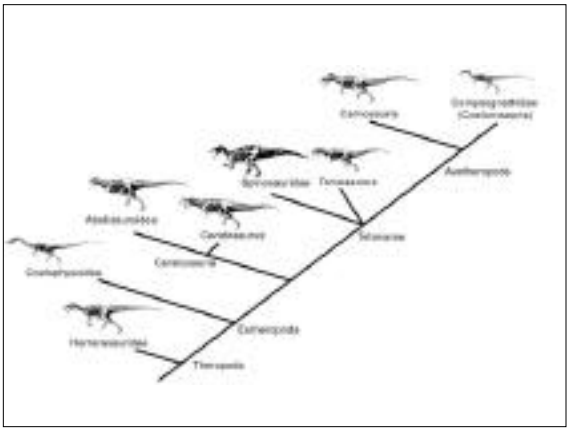
Many features that characterize modern birds evolved long after Archaeopteryx. These include:

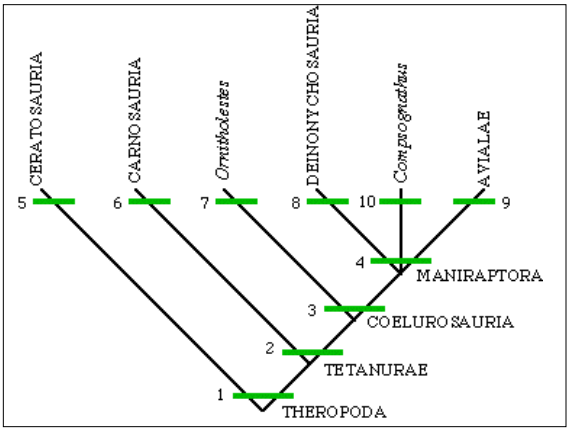
- Loss of teeth (occurs more than once in bird history)
- Synsacrum
- Pygostyle
- Carpometacarpus
- Tarsometatarsus

- All these features worked out by skeletal relationships. New discovery of feathered coelurosaurs leads to new interpretation of these "avian" features.
- This means that feathers are NOT an evolutionary novelty (diagnostic feature) of birds !

- Two species of dinosaur have recently been found in northeast China which possess feathers (Qiang et al. 1998). *Protoarchaeopteryx robusta* and *Caudipteryx zoui* show regiges, rectrices and plumulaceous feather inpressions. Further, they are not birds, lacking the more advanced diagnostic characteristics.
- This groups *Protoarchaeopteryx* and *Caudipteryx* with maniraptoran coelurosaurs rather than birds.

- Coelurosauria seems be characterized by feathers, and Maniraptora by vaned feathers.
- So, tyrannosaurids and ornithomimosaurs were most likely feathered (or at least descendants of feathered ancestors)!!





Since feathers are found in non-avian, non-flying dinosaurs, feathers must have evolved for something other than flight.

Possibilities include:

- Insulation
- Warmth for brooding eggs
- Display
- Combination of these

Flight origins:

Two traditional models are:

"Trees down" (arboreal hypothesis):

ancestors of birds were tree-dwellers, birds went through gliding stage

"Ground up" (cursorial hypothesis):

no arboreal (tree dwelling) phase, nor gliding stage

"Trees down" (arboreal hypothesis):

ancestors of birds were tree-dwellers, birds went through gliding stage

"Ground up" (cursorial hypothesis):

no arboreal (tree dwelling) phase, nor gliding stage

Given a bipedal cursorial (running) ancestor of a flying lineage, flight must have proceeded from the ground into the air, assuming that the ancestor did not normally live in trees, or if there were no trees around

A quadrupedal ancestor would have problems evolving flight from the ground up; it would have to be able to be bipedal in order to use its wings at all! A cursorial bipedal animal would have its arms free to do with them as it pleased while running, and its running speed would allow it to achieve the minimum speed necessary for liftoff.

Why did flight evolve?

Several Main Hypotheses:

(1) To help escape from predators

(2) To help catch flying or speedy prey

(3) To help move from place to place (leaping or gliding)

(4) To free the hindlegs for use as weapons.

(5) To gain access to new food sources or an unoccupied niche

- Recent study on primitive modern birds suggests wings evolved first to aid young (and small adults) in running up sides of trees, cliffs, etc. Later modifications allowed true flight. If true, this behavior was probably present in all small maniraptorans (theropod dinosaurs), and not just birds.

During Cretaceous, a great burst of bird diversity, including:

- Perching feet
- Toothless beaks (convergent in different bird groups)
- Flightless birds
- Even flightless swimming birds!

Because of the cladistic position of Aves, we now know that Dinosauria is not extinct! (In fact, it outnumbers mammal species 2:1).

PROTOAVIS

Protoavis texensis, small individual. (From Chatterjee 1991, fig. 7; courtesy Royal Society, London)

the type specimen is probably a chimaera.