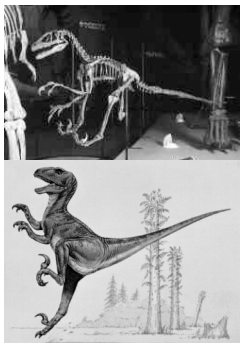
"Nothing in biology makes sense, except in the light of evolution."
Theodosius Dobzhansky

Archaeopteryx

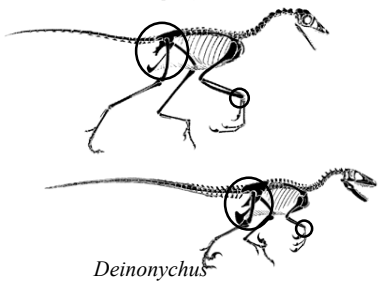
- 1861
  - German quarrymen find the remains of an angel
    - a small skeleton surrounded by the delicate impressions of feathers.
- *1868*
  - Many scientists examined *Archaeopteryx*
  - 150 MYA
  - If it wasn't for the feathers, you'd think it was a dinosaur.
  - Unlike modern birds,
    - Has a long bony tail
    - Clawed wings
    - Teeth

Archaeopteryx

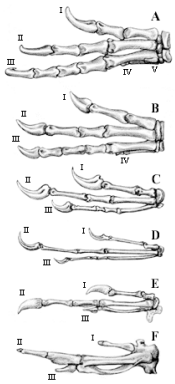
- *1968*
- John Ostrom discovers *Deinonychus*
  - 110 MYA
  - hips similar to *Archaeopteryx*
  - wrists similar to *Archaeopteryx*
- Conclusion
  - Raptors and birds are related
- Many scientists were skeptical
  - More proof that meat-eating dinosaurs really were the ancestors of birds.
- They wanted to see dinosaurs with feathers!



Archaeopteryx



Deinonychus



The semilunate carpal and its homologues are shaded red.

A. *Herrerasaurus* (based on Sereno, 1993). Note that all five digits are present, which of course is primitive for the Amniota. Digit V is shaded yellow and would be hidden on the other side of the manus from this view.

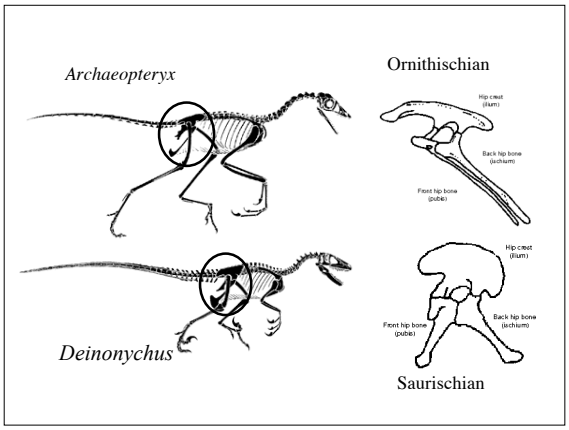
B. *Coelophysis* (based on Colbert, 1989). Note that digit V is gone.

C. *Deinonychus* (based on Ostrom, 1969). Note loss of both digits IV and IV - the tetanurine condition.

D. *Archaeopteryx* (based on Heilmann, 1927). Note very close correspondence in proportions and relative lengths of bones to *Deinonychus*.

E. Hoatzin embryo *Opisthocomus* (based on Heilmann, 1927). Note reduction of number of bones in digit III.

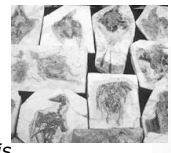
F. Hoatzin adult *Opisthocomus* (based on Heilmann, 1927). Most of the bones of the manus fuse up in the adult, including the emilunate carpal to the metacarpals.



Archaeopteryx vs. Bird

Comparison of reconstructed skeleton of *Archaeopteryx* (left) and a pigeon (right).
Homologous bones
- pale yellow, sternum (breastbone);
- orange, furcula = fused clavicles (wishbone);
- yellow, coracoids
- red, semilunate carpal
- yellow-green, digit I of manus
- green, digit II of manus
- blue, digit III of manus

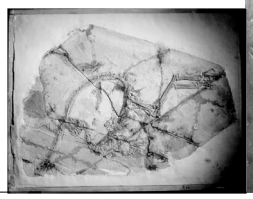
Ancestral features in *Archaeopteryx*
- Long tail
- Separate fingers of the manus,
- small sternum
- inherited virtually without modification by non-bird maniraptorans.

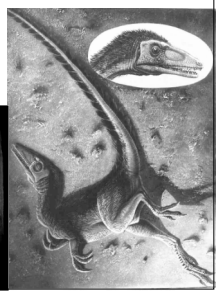


- *1995*
- *Confuciusornis*
  - 120 - 150 MYA
  - Slightly more advanced than *Archaeopteryx*
  - Discovered in large numbers.
  - Perching feet
  - Lost their long bony tail
  - Lost their toothed jaws
  - Retained clawed wings.

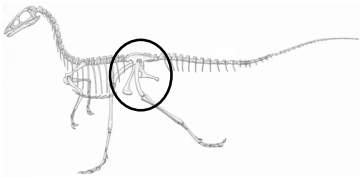
Sinosauropteryx

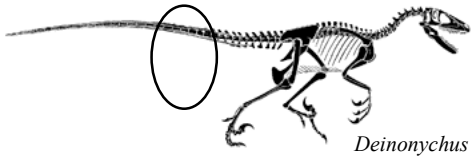
- *1996*
- *Sinosauropteryx*,
  - a small predatory dinosaur related to *Compsognathus*
  - 120 - 150 MYA
  - Had a fringe of what scientists call 'unbranched integumentary structures' or 'fluff', preserved along its backbone.
  - The fluff may be the most primitive type of feathery covering and would have insulated these small animals.
  - This is the most primitive dinosaur ever to be found with a feathery coat.





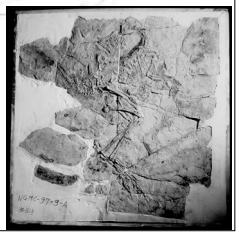
Compsognathus

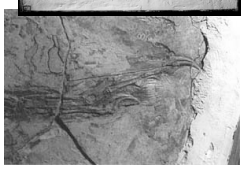




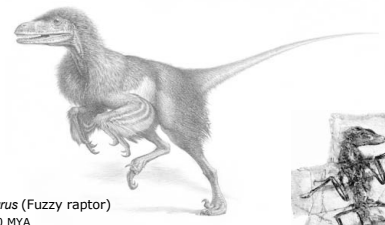
Deinonychus

- *1997*
- *Caudipteryx*
  - 120 - 150 MYA
  - Feathers similar to the body feathers of birds today.
  - Wrists similar to A*rchaeopteryx* –
  - Hands and arms had begun to lengthen for wings.





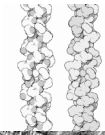
- *1997*
- *Protarchaeopteryx*
  - 120 - 150 MYA
  - Arms and hands designed to sweep forwards quickly after prey.
  - Wrists similar to *Archaeopteryx*
  - Hands and arms had begun to lengthen for wings.

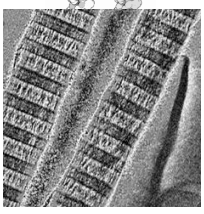


- *2001*
- *Sinornithosaurus* (Fuzzy raptor)
  - 120 - 140 MYA
  - Same family (dromaeosaurs) - as the predatory dinosaur *Deinonychus*
  - Two types of feathers
    - Ancestral downy feathers
    - Derived feathers on its front limbs
  - wrist joints are adapted so that they can perform a twisting down-stroke as in modern birds

The Collagen Connection

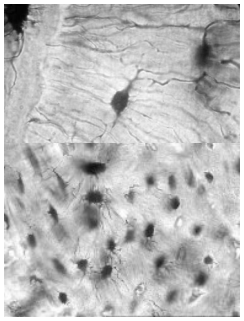
- Collagen fibers
  - Bind bone minerals together in much the same way that rebar binds concrete
  - In coelosaurs and birds
    - Layers are thicker and thin
    - Often they disappear completely before reforming.
  - This only occurs in bone that forms very rapidly, as it does in birds.
  - Mammals
    - Only at young ages or
    - Healing bone breaks,
      - I.e. times when bone growth rates are highest.
    - Most collagen bundles show a uniform pattern,
      - Little thickness variation from one part of a layer to another because the layers are growing more slowly.





The Canaliculi Connection

- Canaliculi
  - submicron-sized channels that connect bone cells and blood vessels within the bone to transport nutrients
- Coelurosaurs
  - Circuitous & meandering routes. Today that same pattern is found only among birds.
- Ornithischians
  - Regular pattern with very direct and parallel routes, a structure similar to that in modern mammals.
- Birds
  - Circuitous & meandering
- Mammals
  - Direct & parallel

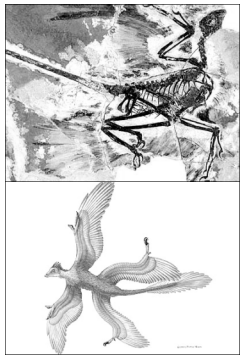


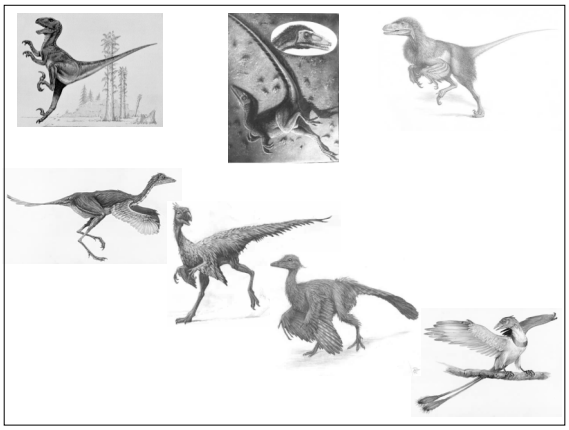
Protoavis Problem

- *Protoavis texensis*
- 1995
- 225 MYA
- It is earlier than Archaeopteryx or even dinosaurs,
  - Dinosaurs would not be ancestral to birds
    - Rather, crocodiles came in the fossil record in time to be the sister group of birds.
  - Most paleontologists question whether Protoavis is a bird, however.
- Characteristics
  - large braincase
    - but interpretation was based on very incomplete skull).
  - Large orbit
    - like birds, but based on incomplete parts
  - sclerotic ring
    - but glued together
  - furculum
    - wishbone, based on incomplete parts
  - Cervical and dorsal vertebrae have large vertebral canals
    - Both are avian characteristics
- With no feathers, but all bones, it is considered a small Triassic reptile of unknown affinity.

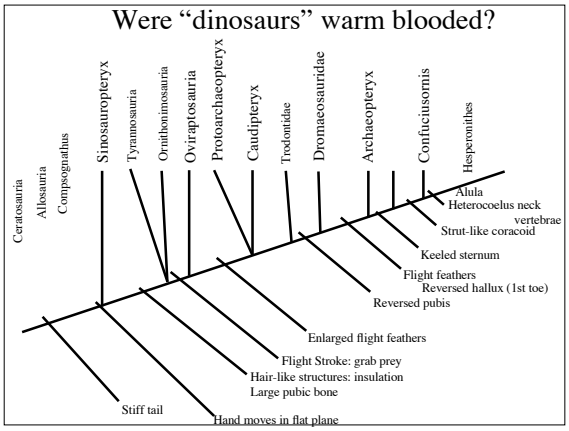
New Questions

- Microraptors
  - Sinovenator
  - 120 - 150 MYA
  - The body was covered by feathers around 25-30 mm long
  - The wing feathers were in a pattern similar to modern birds.
  - It is thought it used these limbs, along with a long feather-fringed tail, to glide from tree to tree, much as flying squirrels do.
  - The study suggests that the fore limb and leg feathers would enable the dinosaur to glide in a similar way to animals such as bats.
  - The authors conclude that these features suggest there was a stage between flightless dinosaurs and those that could fly.

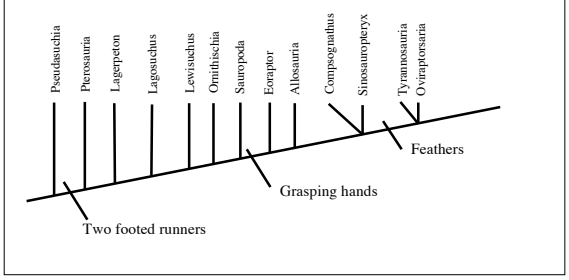




Were “dinosaurs” warm blooded?



Which came first, bipedality or flight?



Why and when did feathers arise?