Now let's think about flight...

Feathers
Loss of teeth
Large brains, adv. sight
Carpometacarpus
Bipedal
Pygostyle
Pneumatic bones
Rigid skeleton
Furcula

All Theropods
Coelurosauria
Derived Theropods

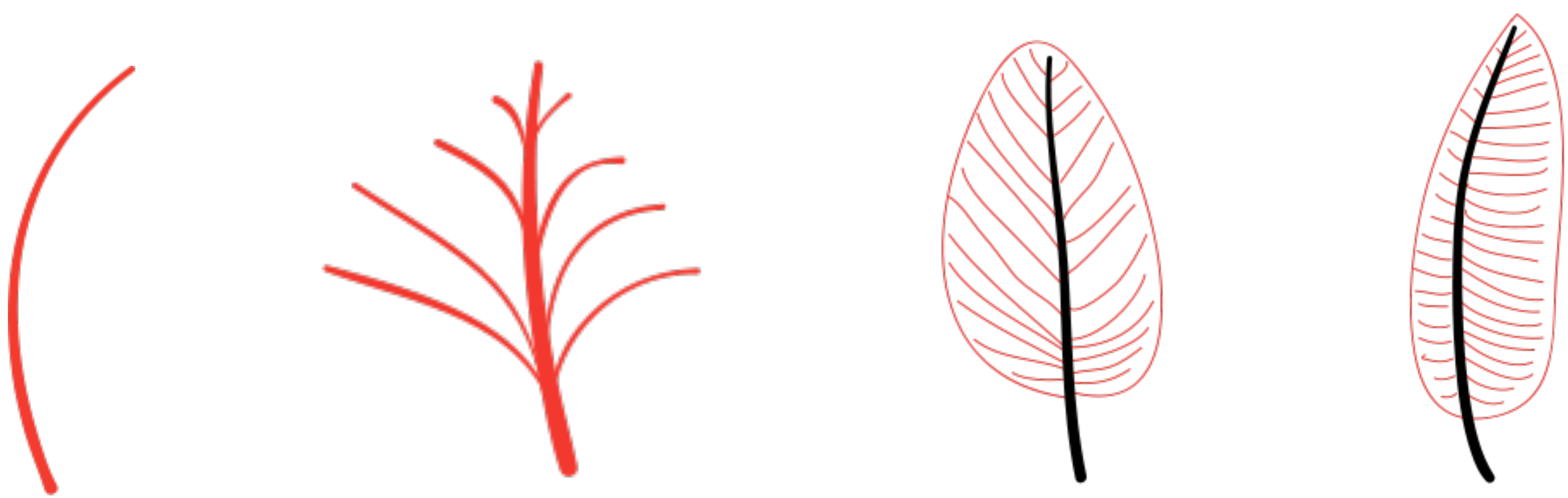
Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Embryological Evidence

Feather Development:

There are 4 stages of feather development controlled by a series of genes.

<u>Each stage is a developmental modification of the last!</u>



Formation of shaft

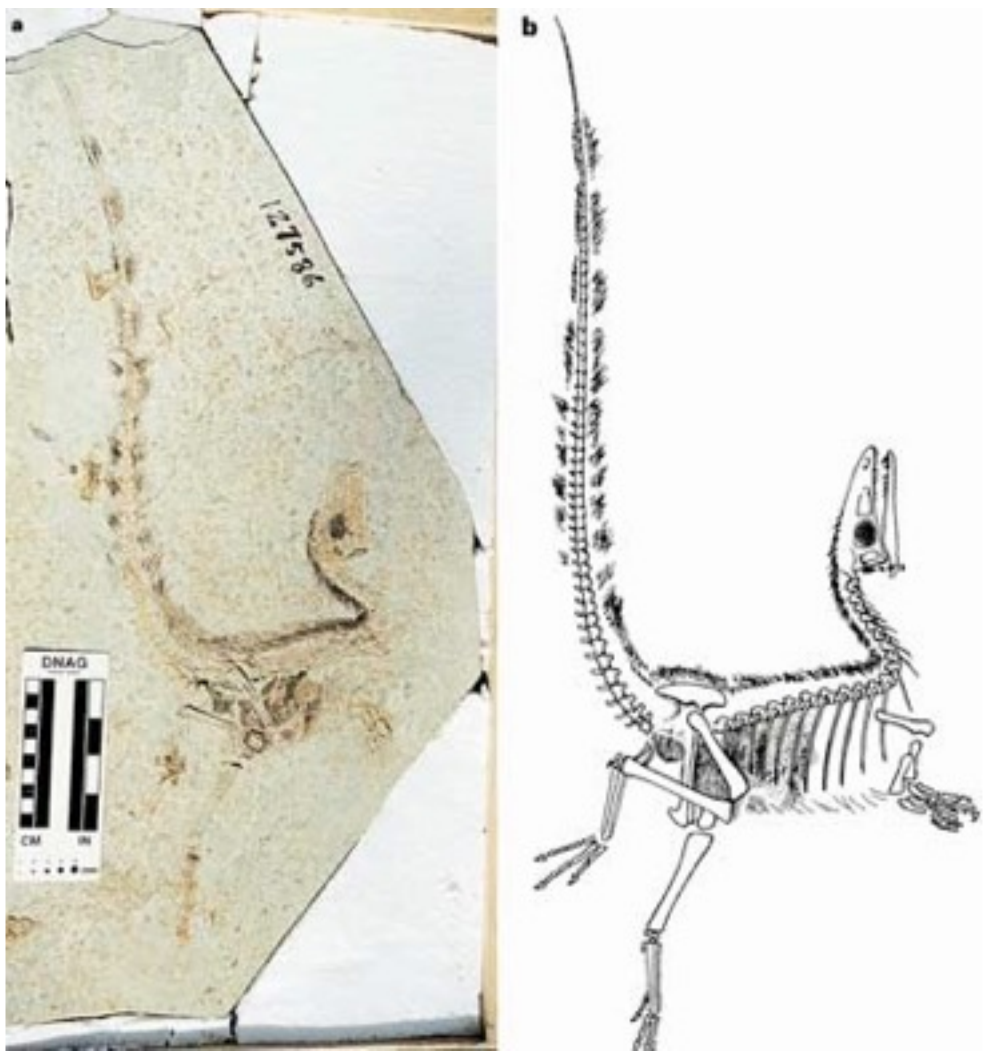
Formation of loosely connected, unhooked, barbs

Hooked barbs on a symmetrical vane

Hooked barbs on an asymmetrical vane

Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Paleontological Evidence



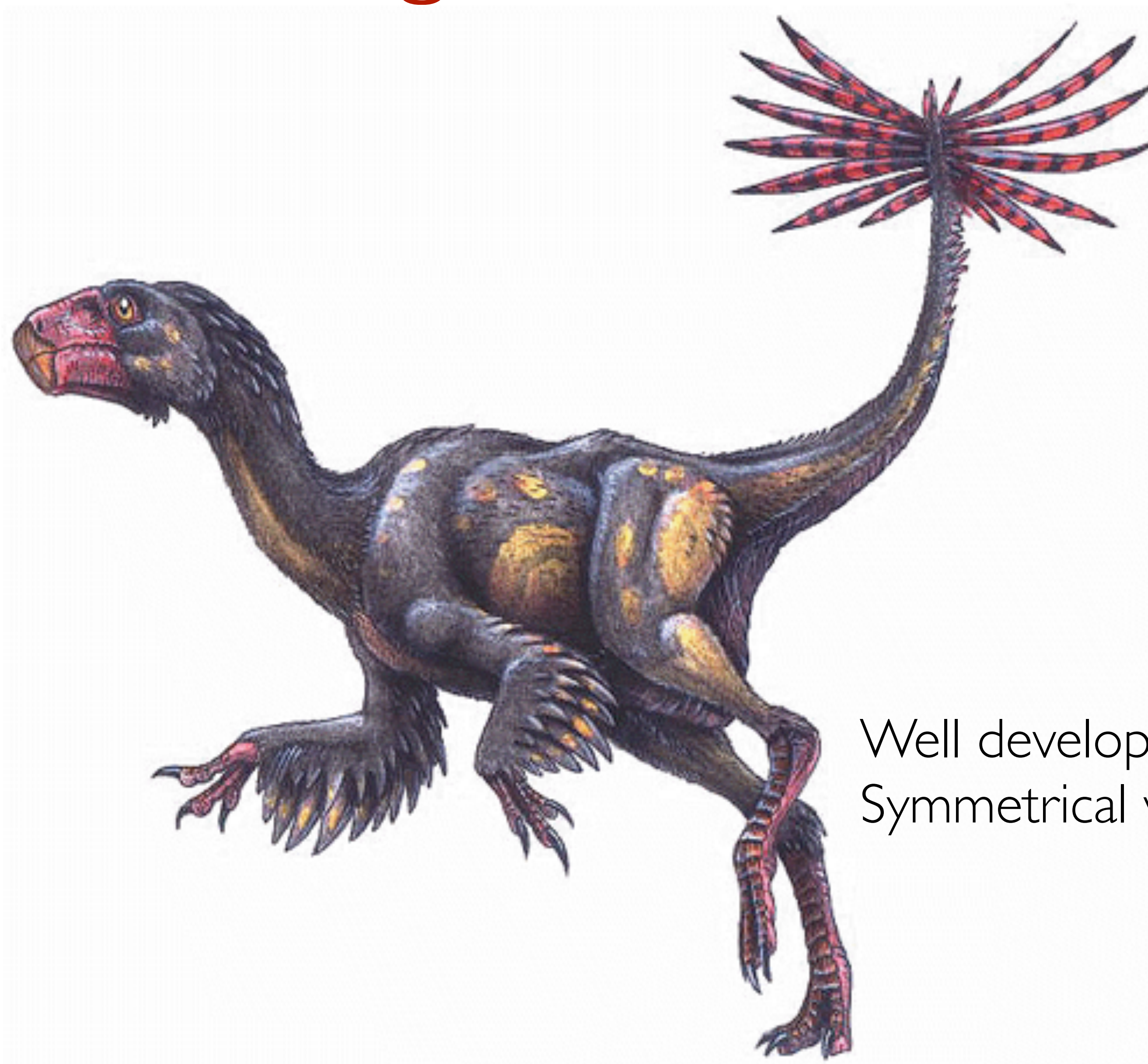
Covered in barbed filaments

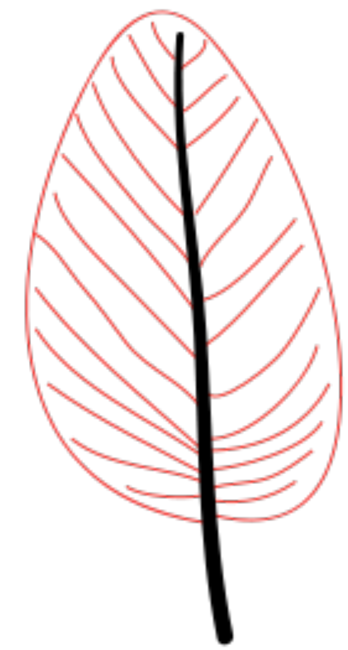
Sinosauropteryx:

small Coelurosaur; was not capable of flight

Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Paleontological Evidence





Well developed barbs & barbules
Symmetrical veins

Caudipteryx:
Oviraptorid

Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Paleontological Evidence

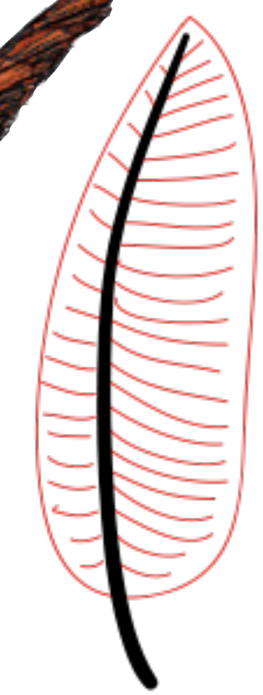
Covered in barbed filaments

Beipiaosaurus

Ostrich-sized Therizinosauroid

Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Paleontological Evidence



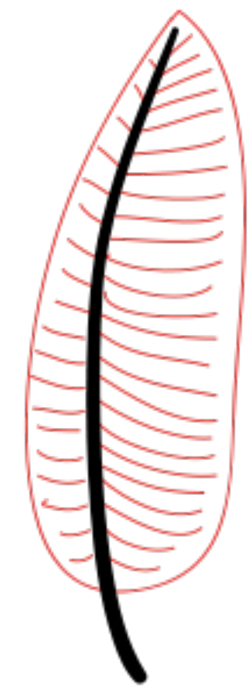
Bird-like Feathers

Sinornithosaurus

non-flying Deinonychosaur

Did feathers and pneumatic bones evolve for flight? Obviously not... evolved long before flight

Paleontological Evidence

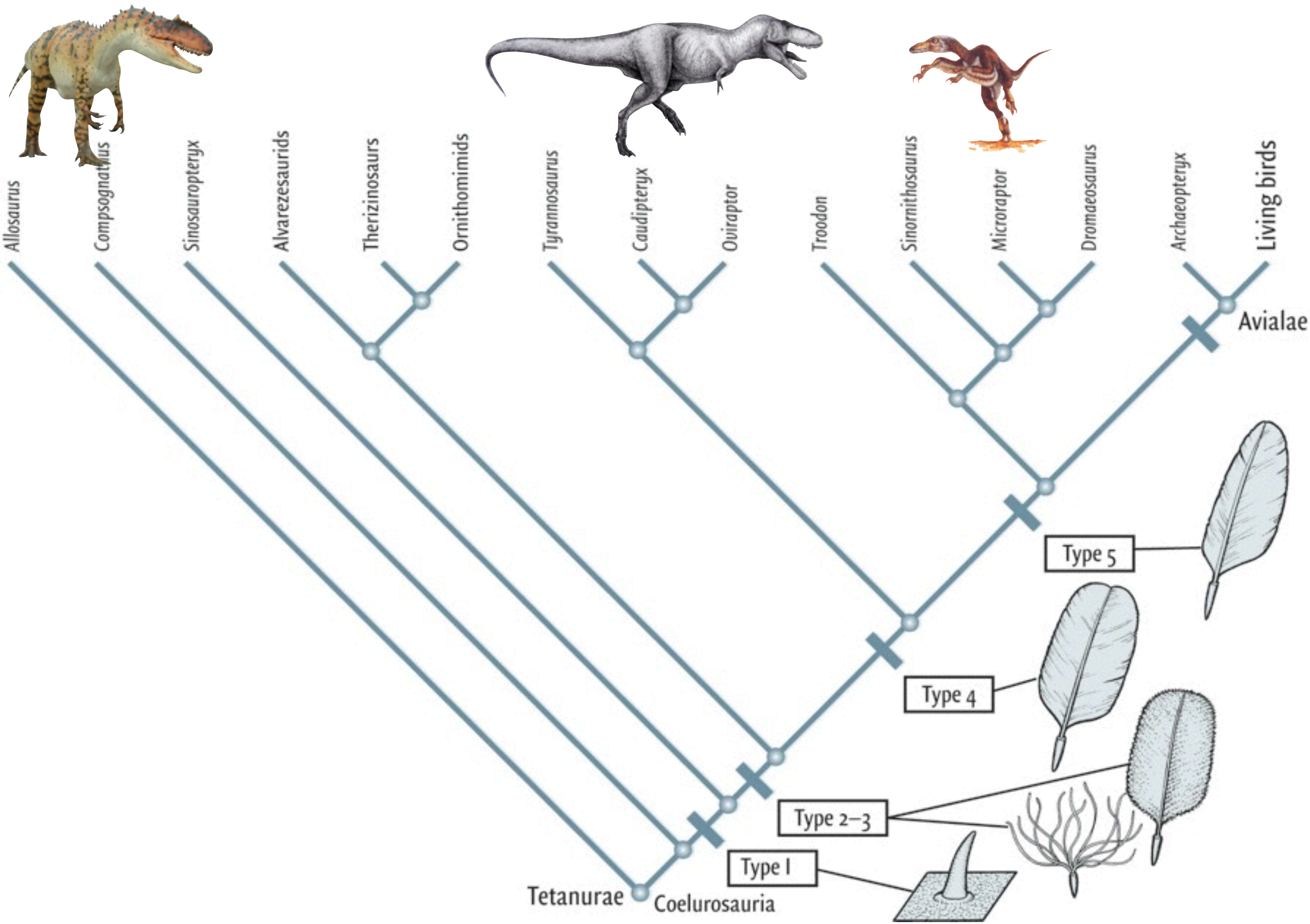


Bird-like Features

Microraptor

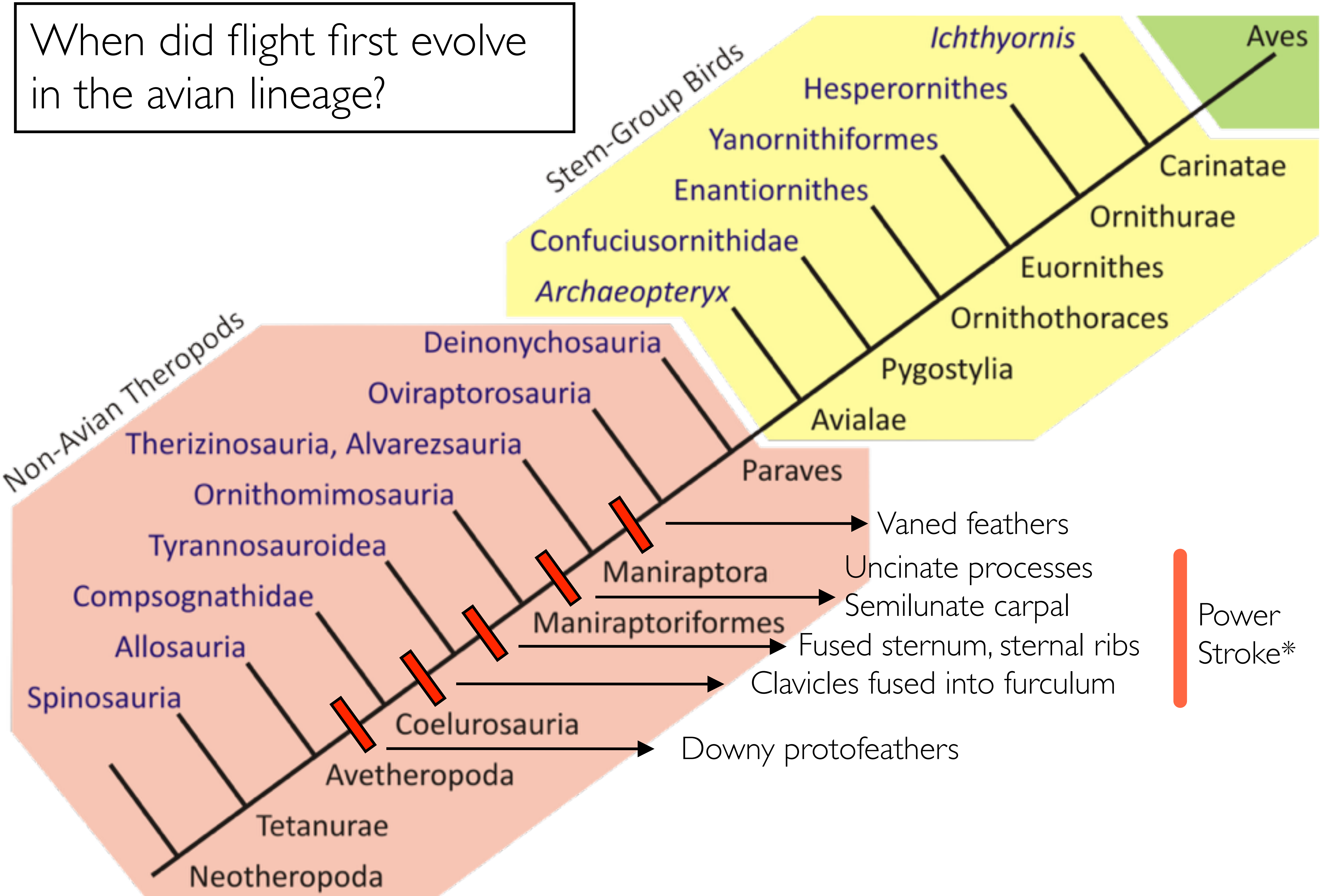
flying *Deinonychosaur*


BBC
Microraptor



Allosaurus
Compsognathus
Sinosauropteryx
Alvarezesaurids
Therizinosaurs
Ornithomimids
Tyrannosaurus
Caudipteryx
Oviraptor
Troodon
Sinornithosaurus
Microraptor
Dromaeosaurus
Archaeopteryx
Living birds
Avialae
Type 5
Type 4
Type 2–3
Type I
Tetanurae
Coelurosauria

When did flight first evolve in the avian lineage?

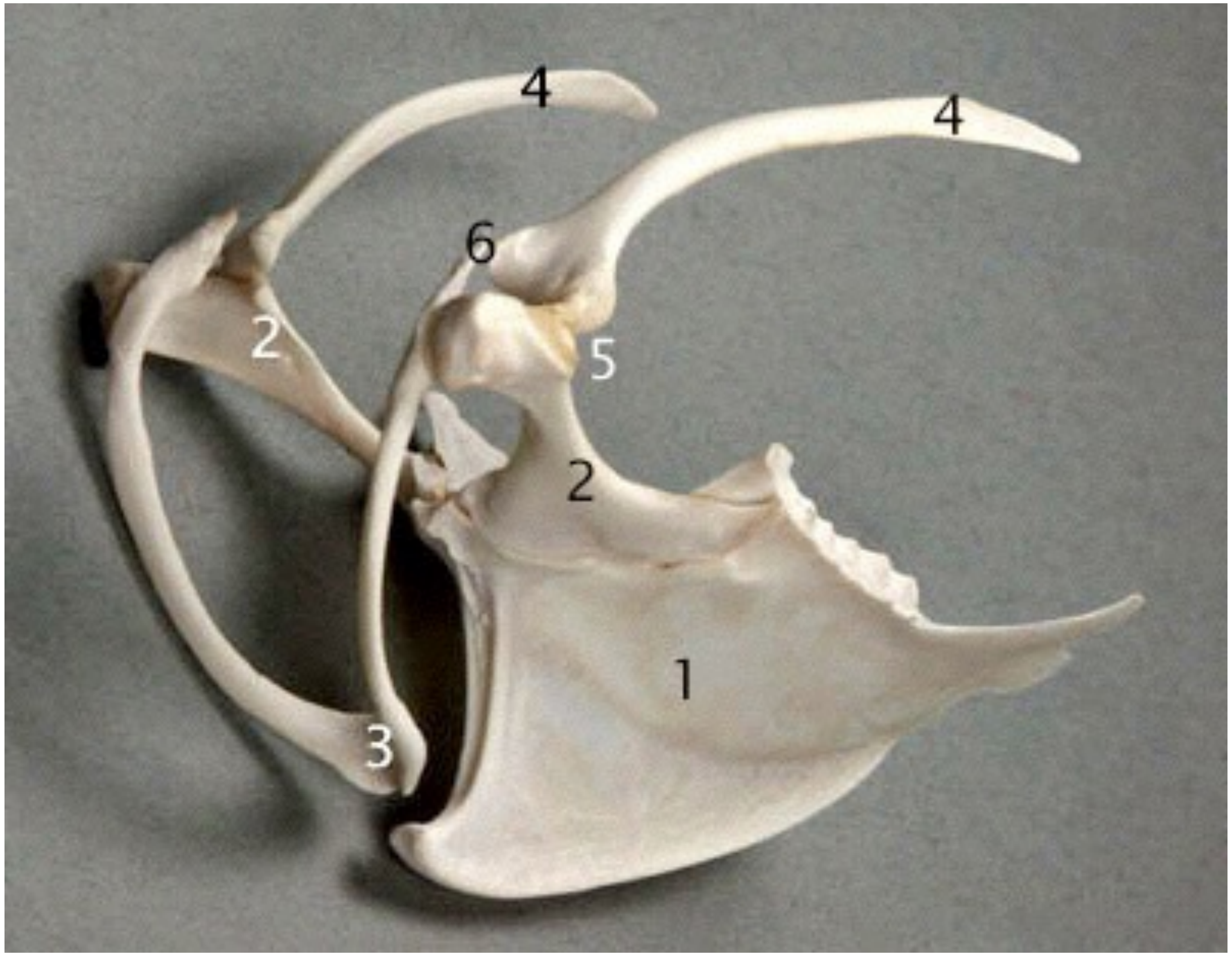


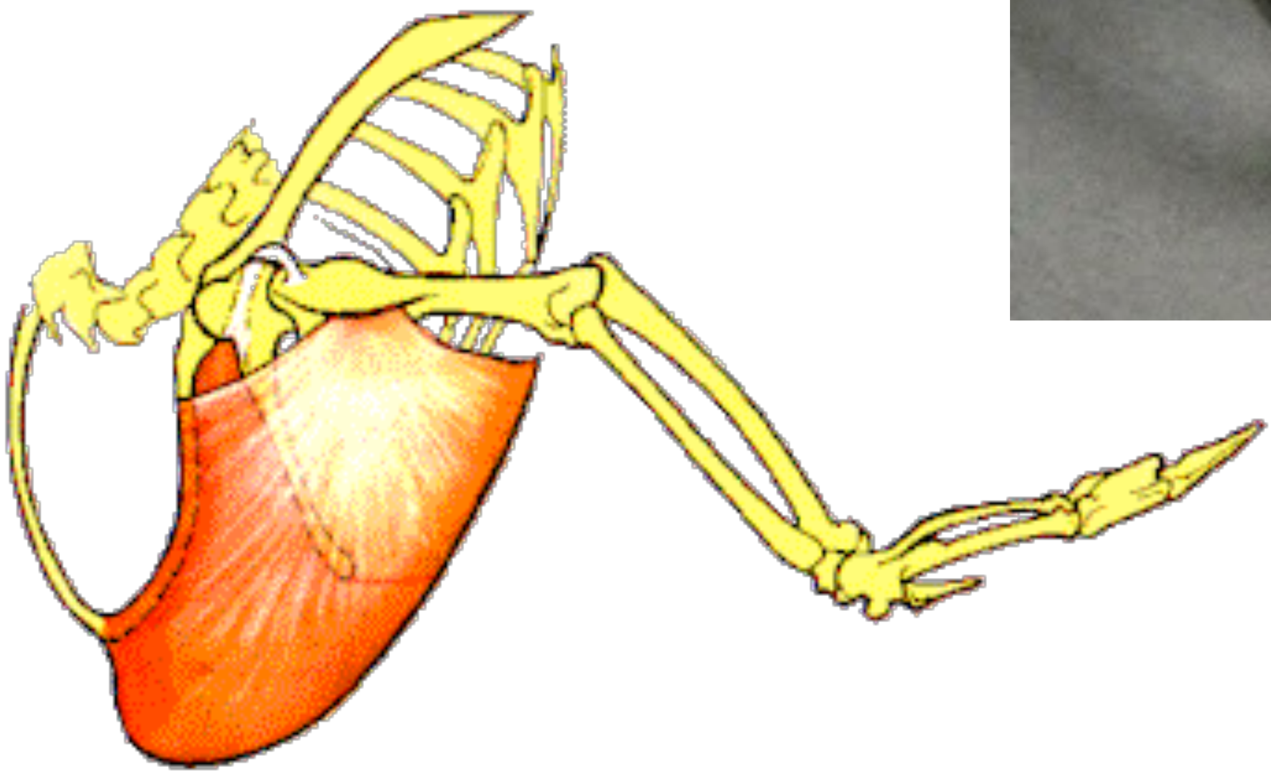
*Not necessarily for flight

Flight Muscle Attachment

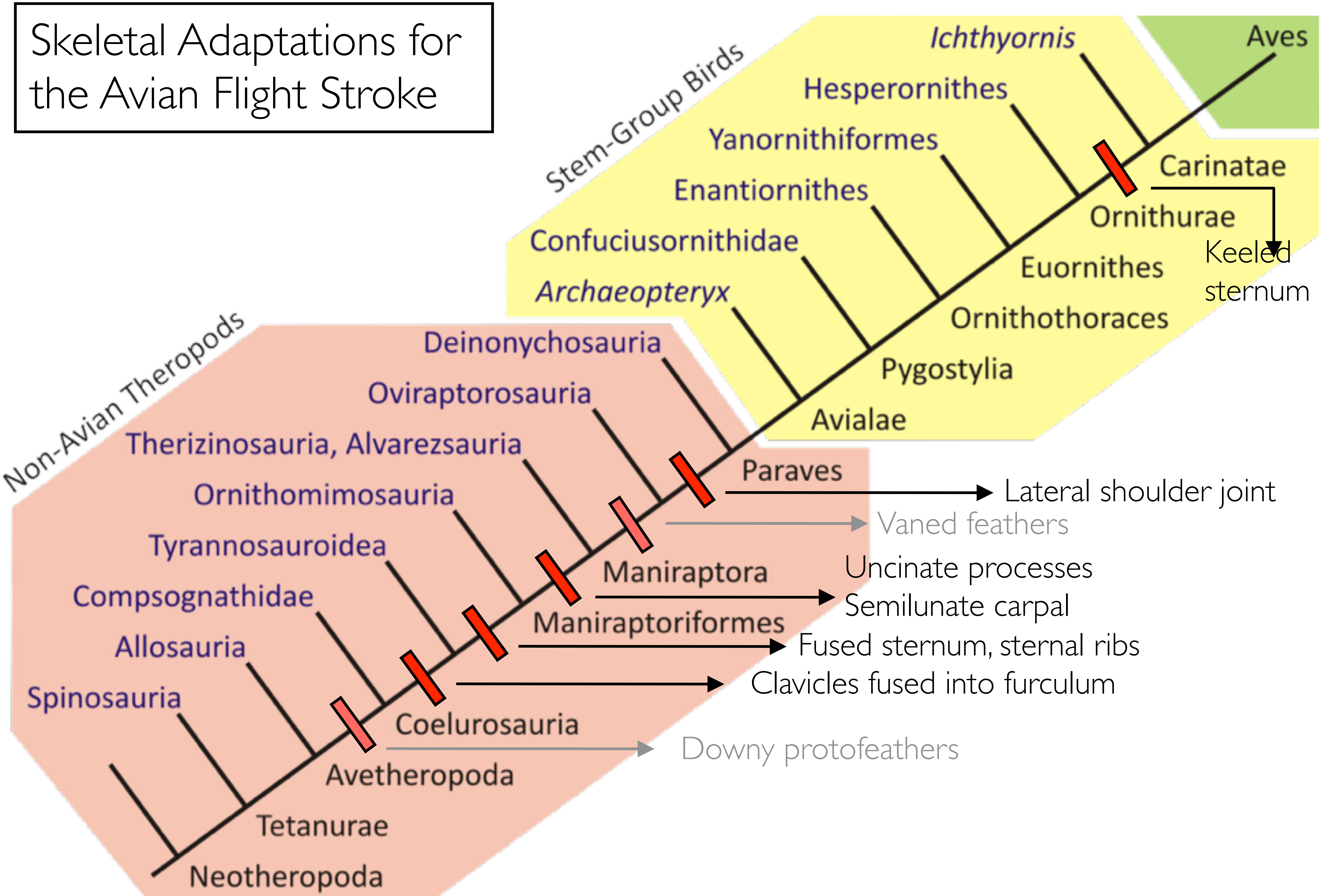
Flying birds have extremely large pectoral muscles (35% of body weight)

Keeled sternum provides large attachment site for maximum power



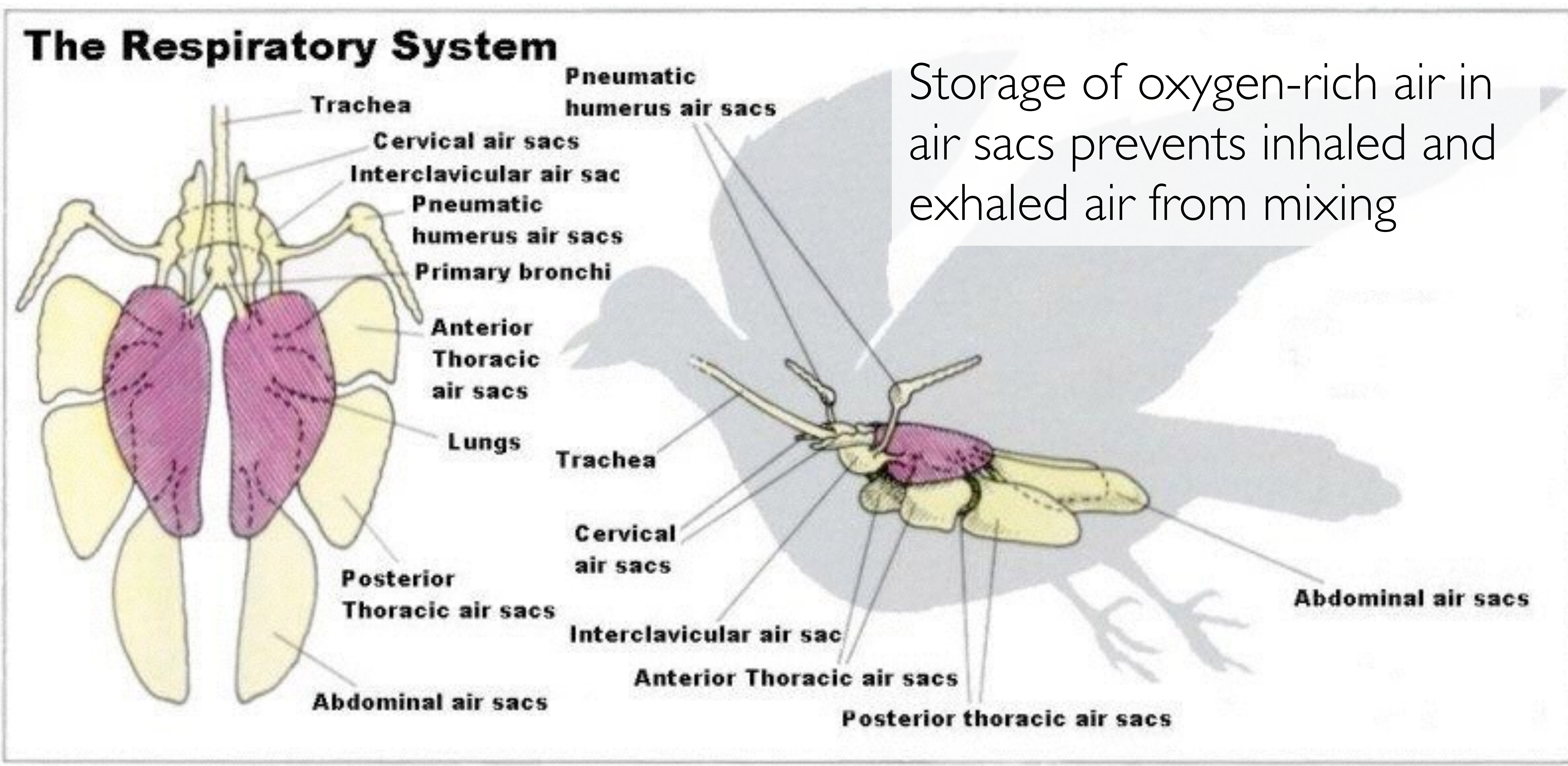


Skeletal Adaptations for the Avian Flight Stroke



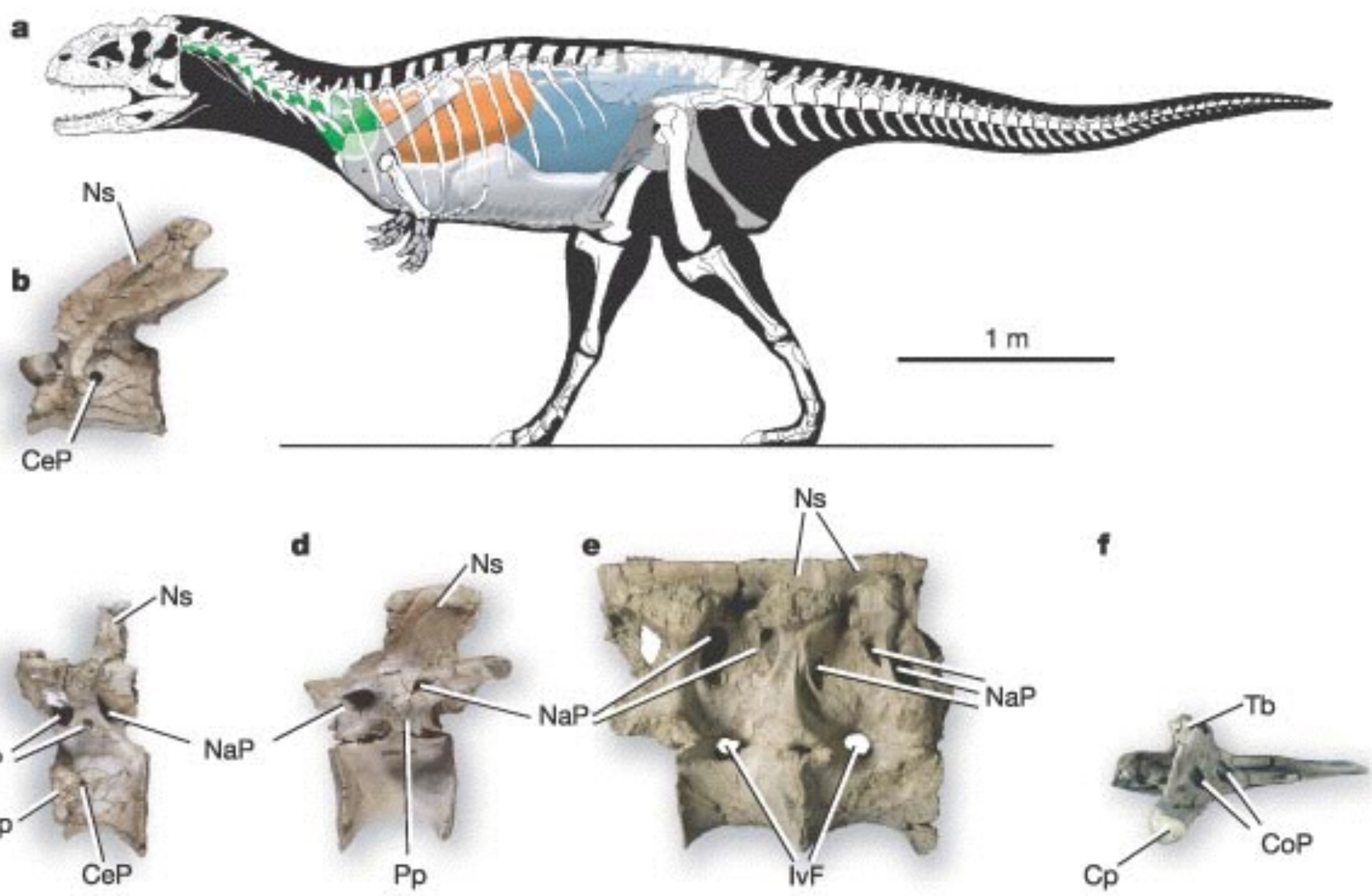
Avian Respiratory Adaptations

Flight takes a tremendous amount of energy, and birds have a unique flow-through lung to maximize oxygen uptake

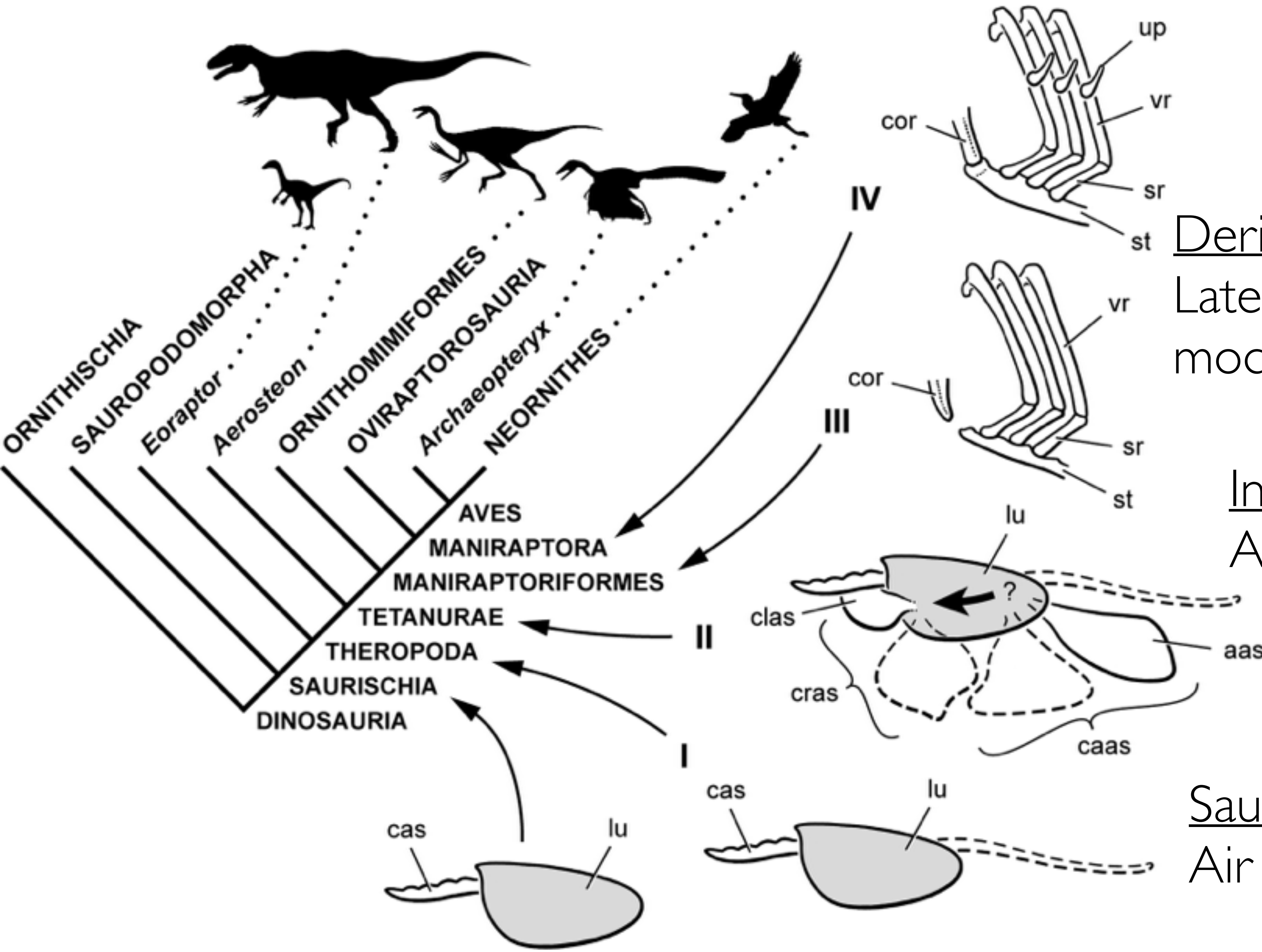


Storage of oxygen-rich air in air sacs prevents inhaled and exhaled air from mixing

Vertebral pneumaticity indicates presence of avian-like air sacs in theropod dinosaurs



Maniraptoran dinosaurs probably had a high avian metabolism (likely to power their active running lifestyle)

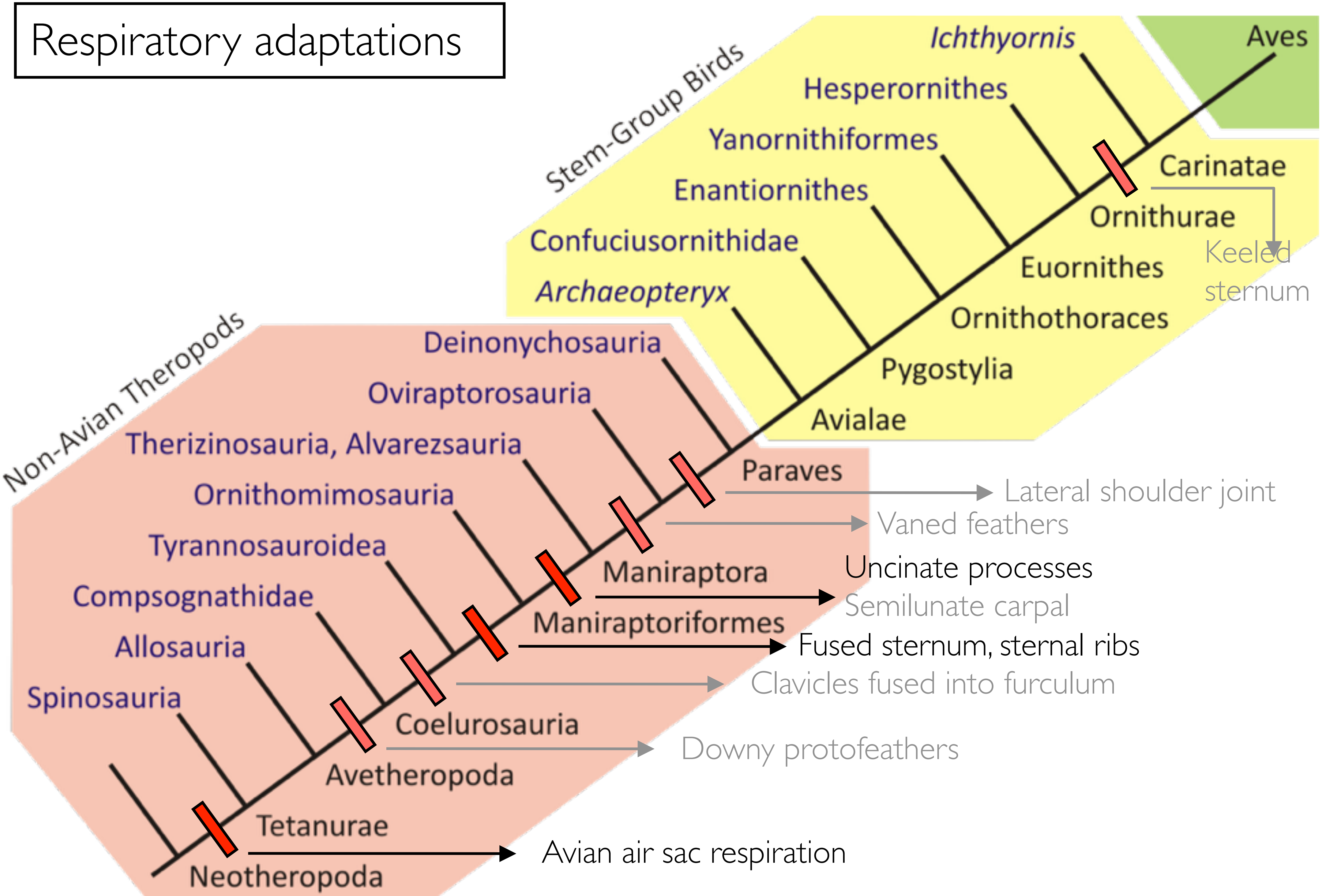


<u>Derived Theropods:</u>
Later rib cage modifications

<u>Int. Theropods:</u>
Auxiliary air sacs

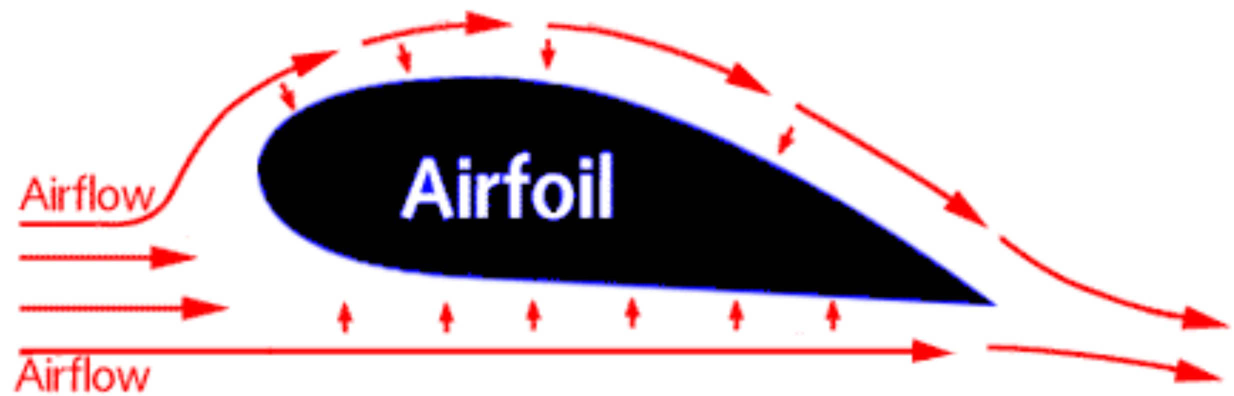
<u>Saurischia:</u>
Air sacs present

Respiratory adaptations



Adaptations for Low-Speed Flight

Bird wings are airfoils that generate lift proportional to the airspeed

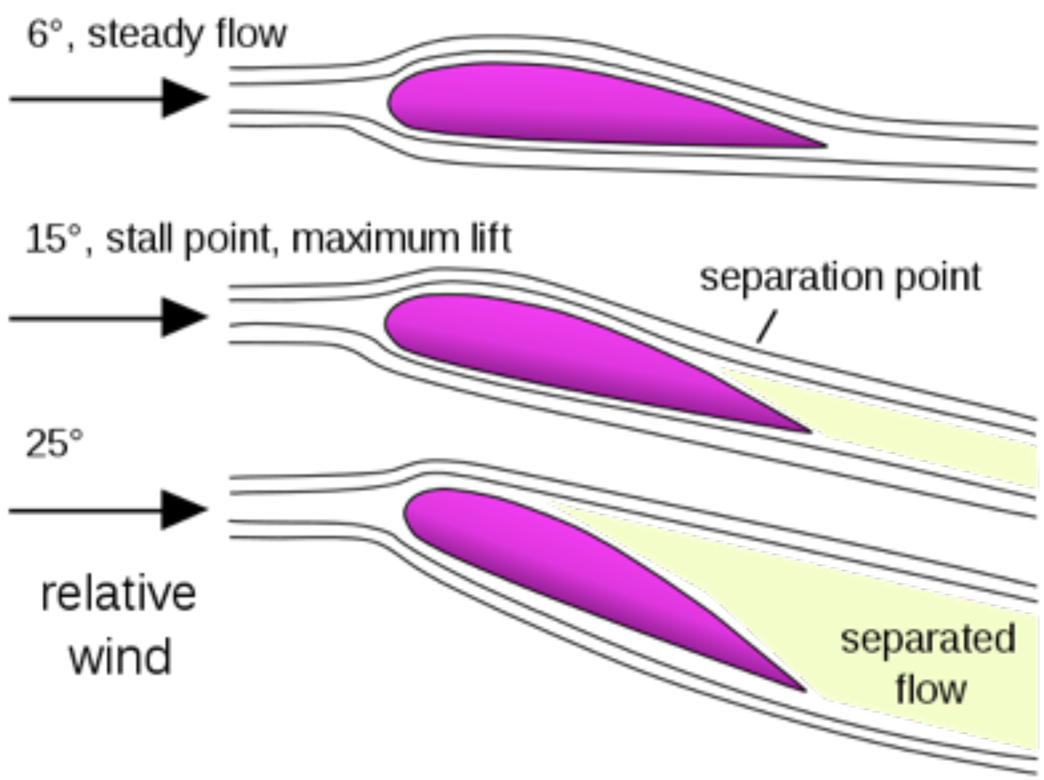


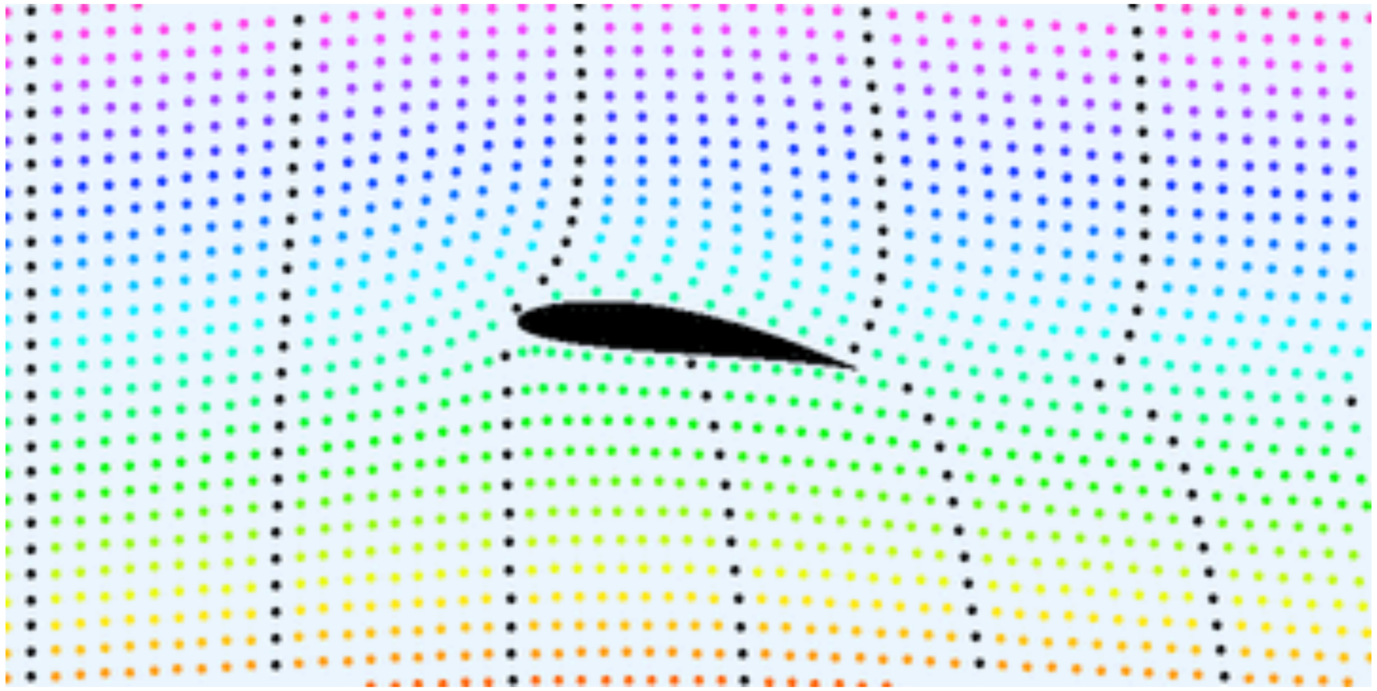
But birds also need to be able to generate lift at relatively low speeds for takeoff and landing

Lift is also a function of:

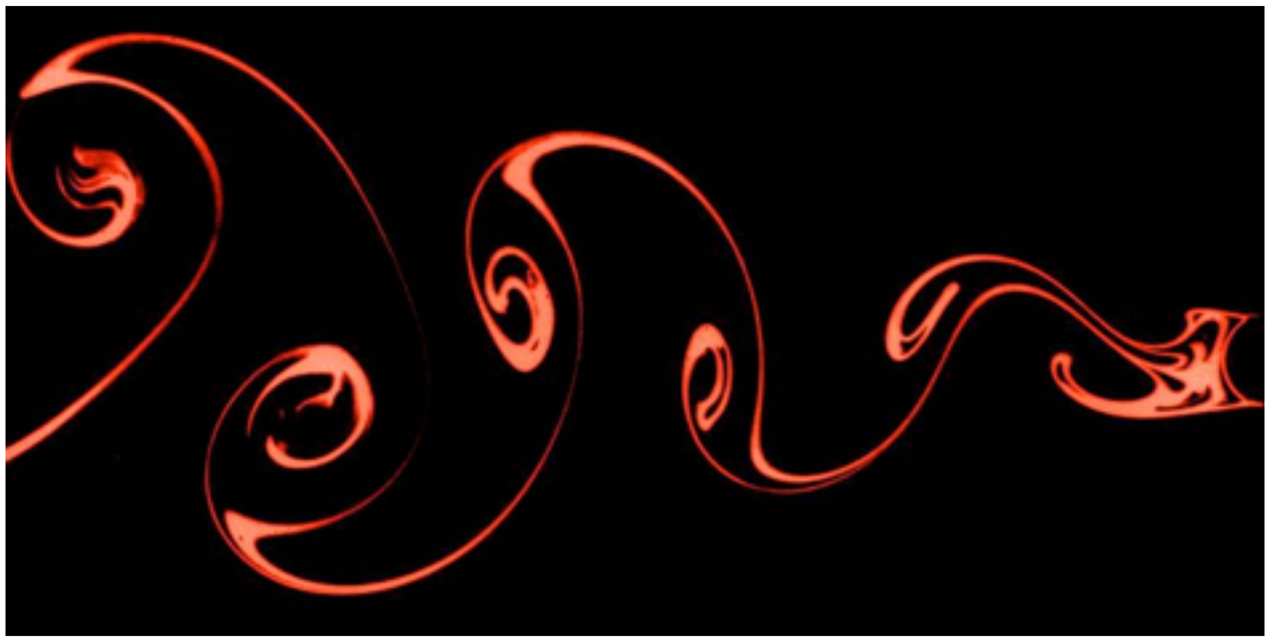
1) Wing area Difficult for bird to change
2) Wing curvature (camber) Difficult for bird to change
3) Angle of attack (tilt of the wing relative to the airflow)

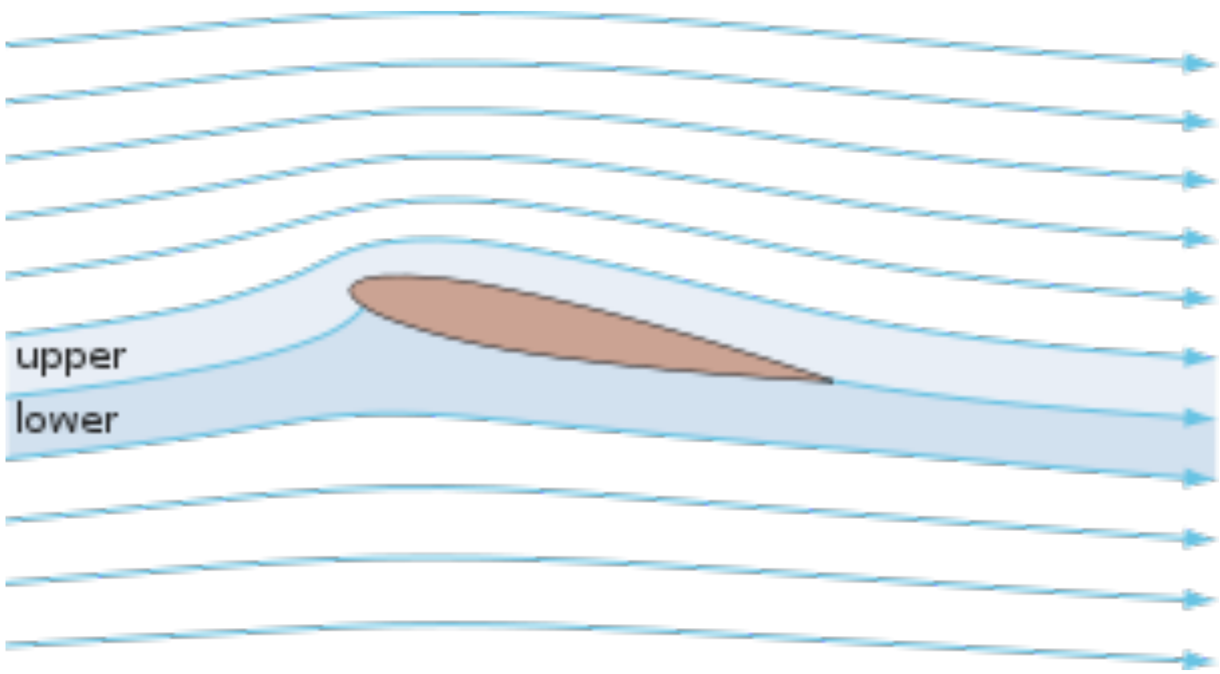
But increasing the angle of attack too much will lead to flow separation, creation of wing vortex, and stalling (abrupt loss of lift)





High velocity, low pressure;
Low velocity, high pressure





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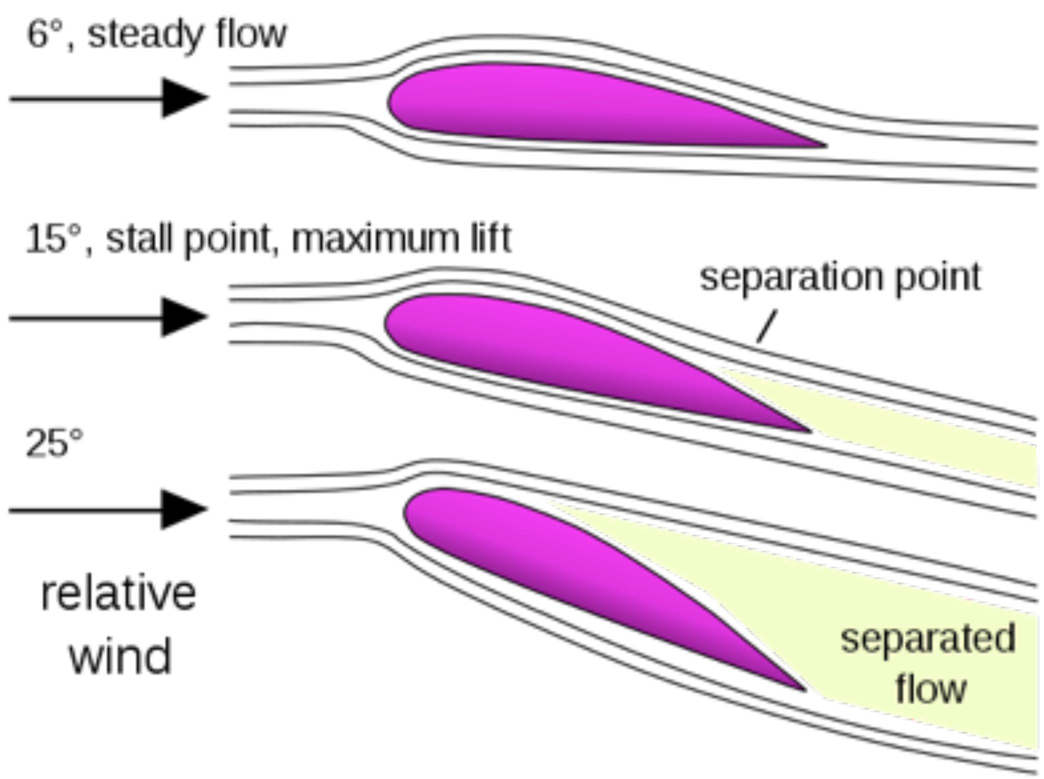

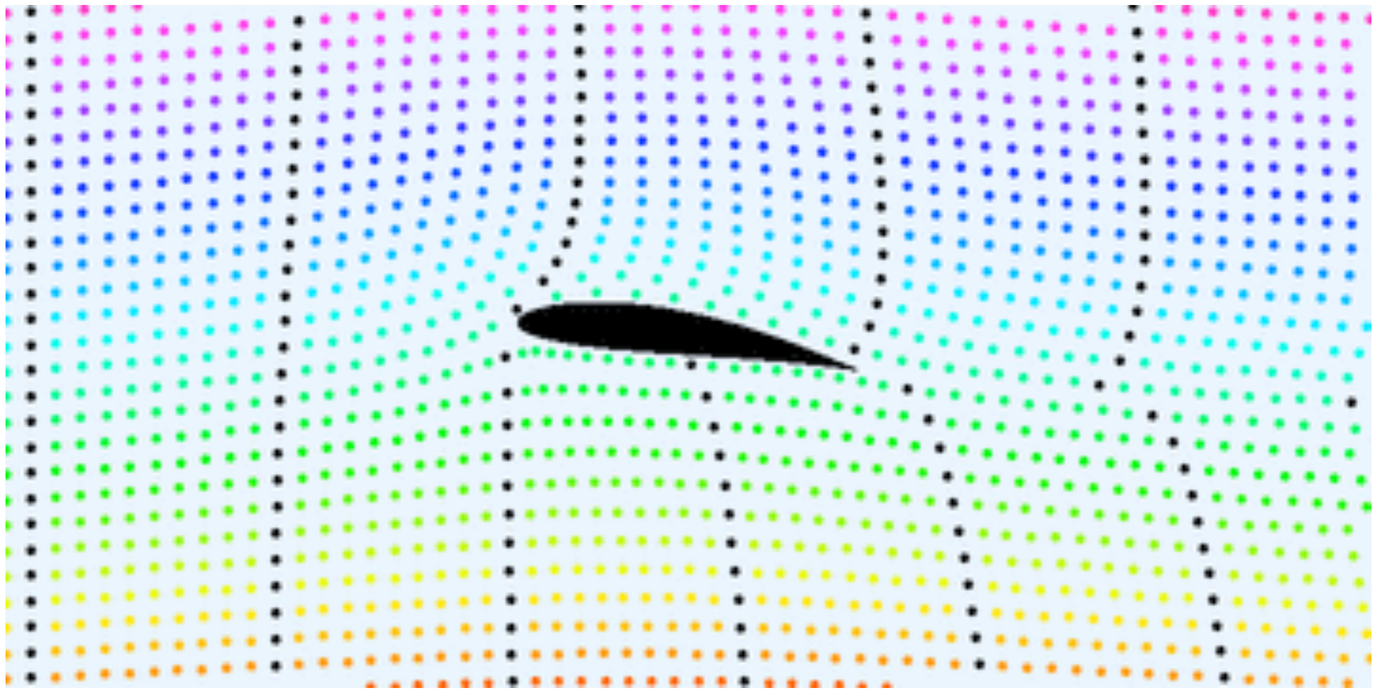

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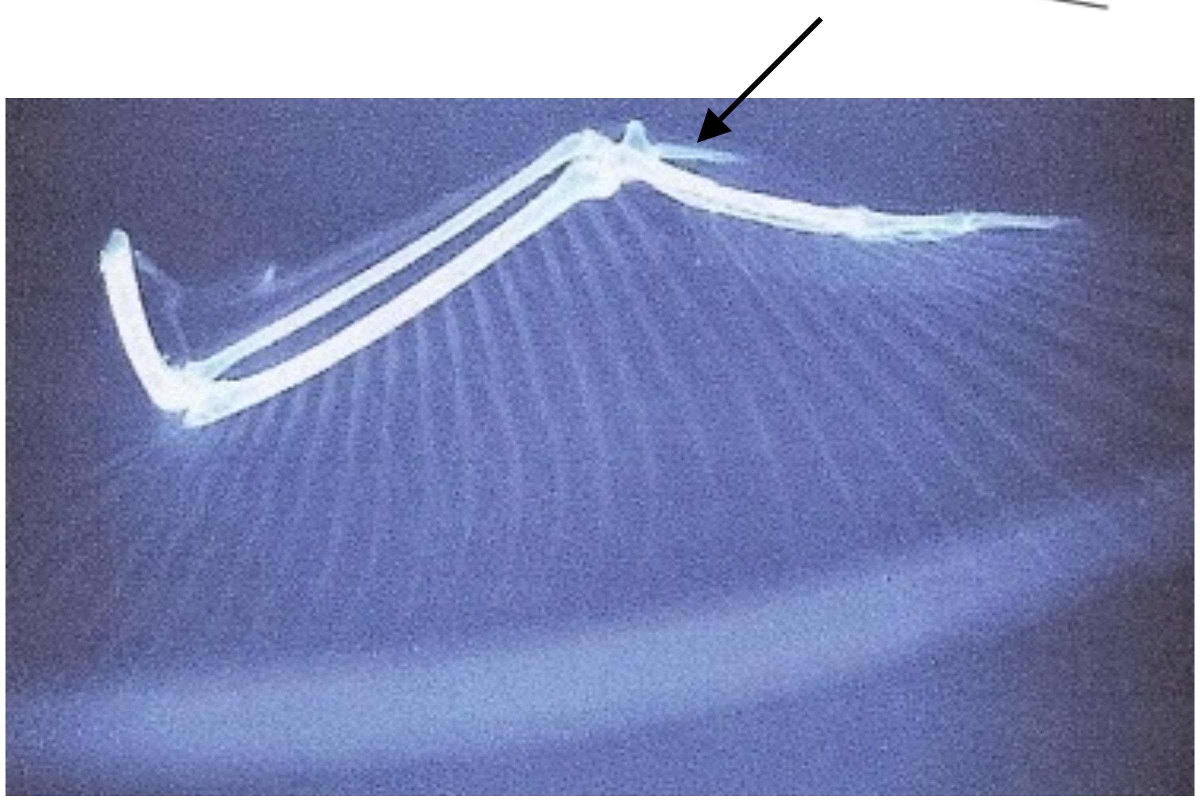
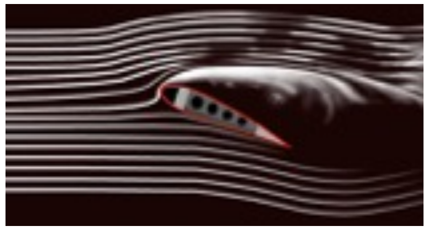


Finger modified to control winglet called an <u>alula</u>

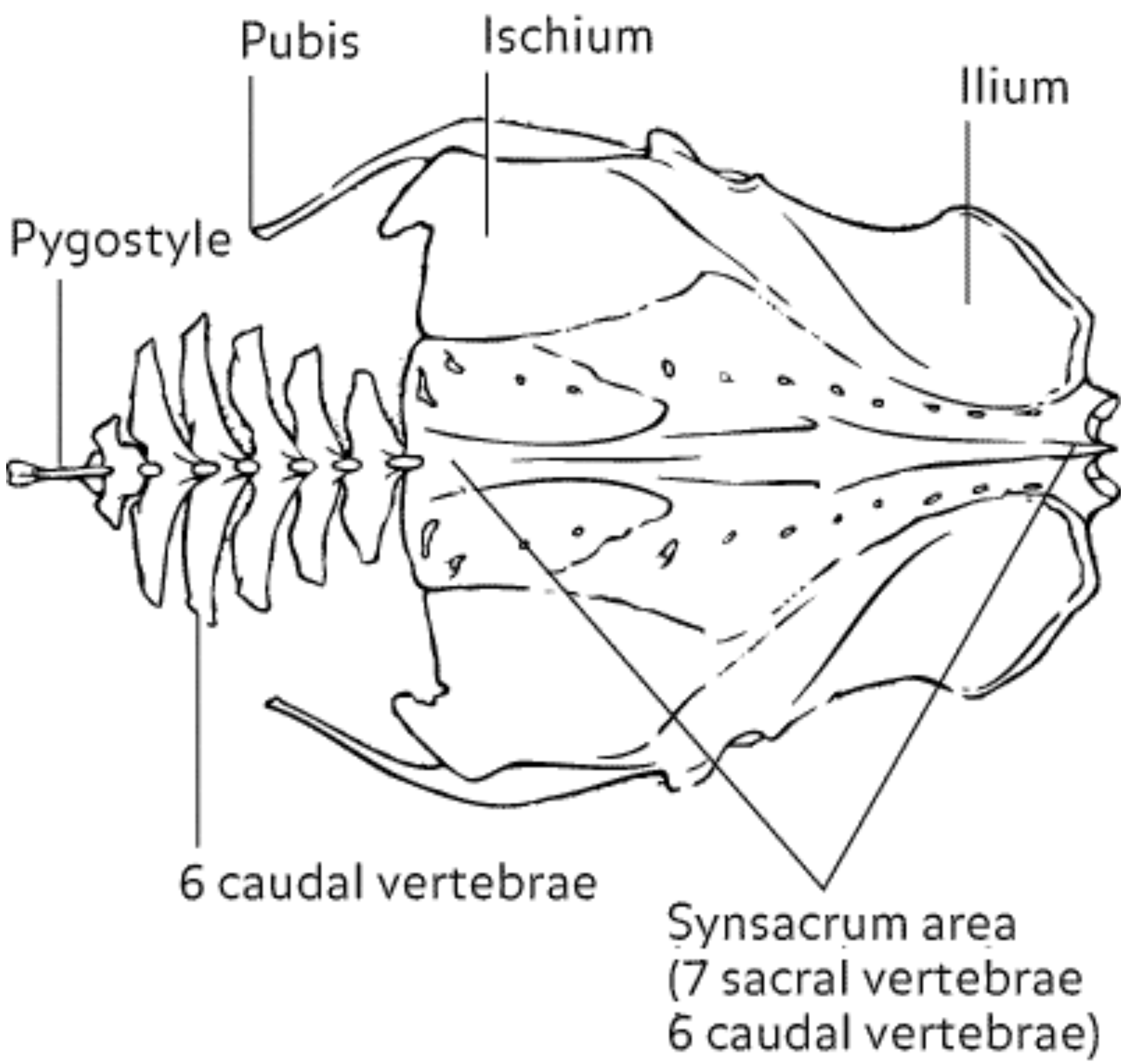
Channels airflow to prevent flow separation, enhancing low-speed flight



Evolution of Fan-Shaped Tails

Fusion of tail vertebrae into <u>pygostyle</u>

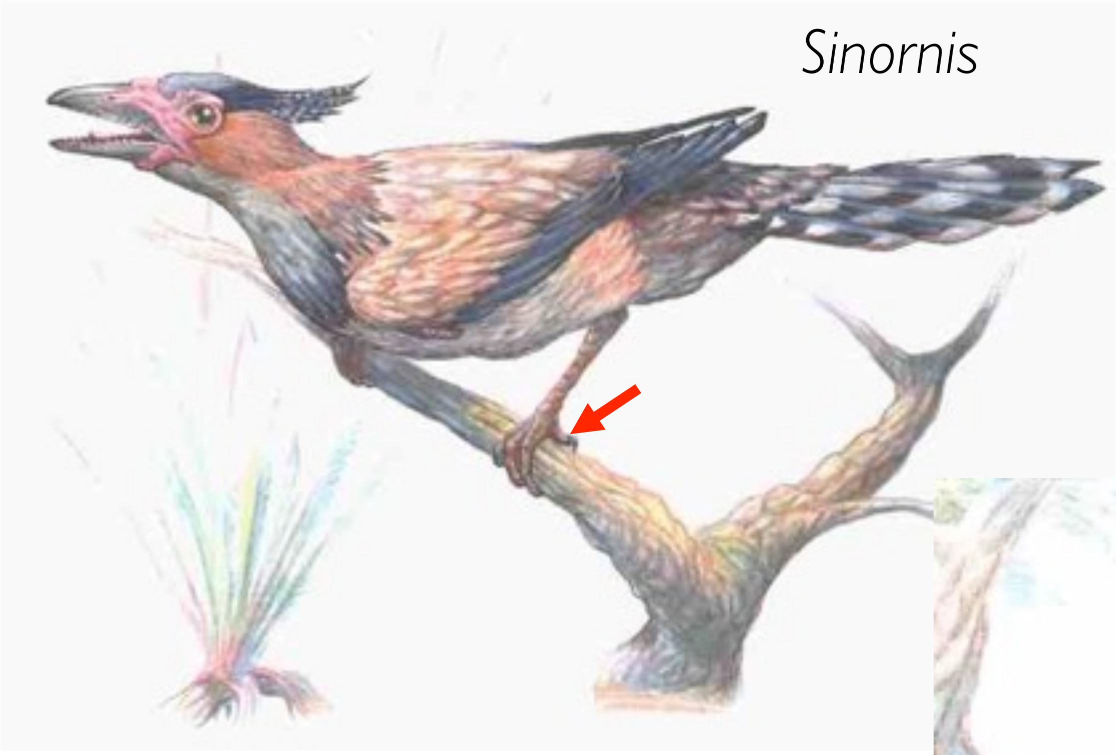
Allows fan shaped tail feathers, increasing wing area to increase lift at low speeds



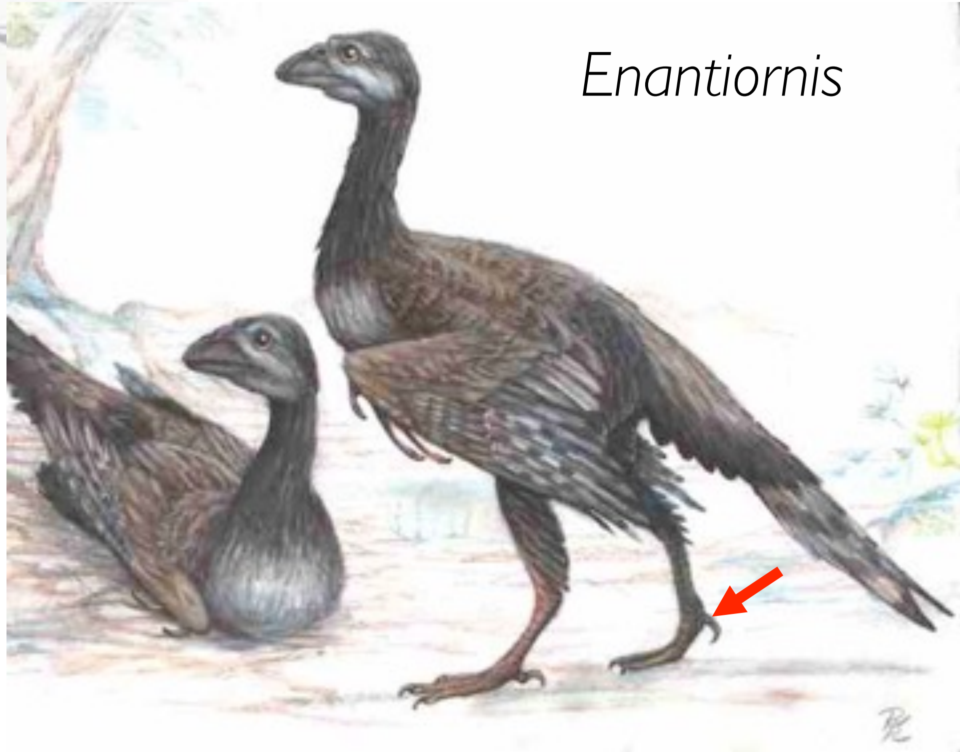
Perching Adaptations

Foot digit I is reversed in birds – the <u>hallux</u>

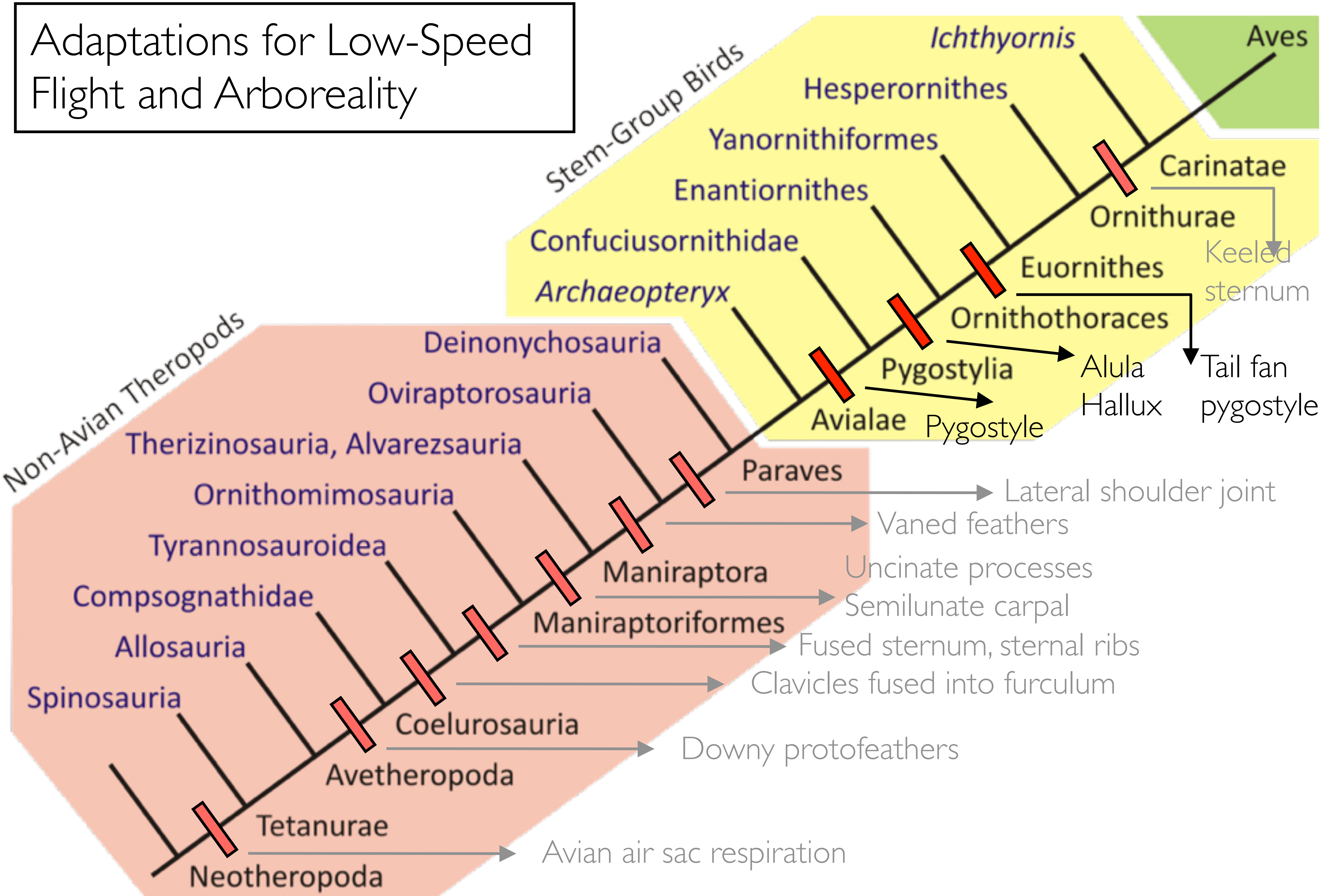
Allows grasping of branches while perching, an important adaptations for arboreal life



Cretaceous stem-group birds with reversed hallux



Adaptations for Low-Speed Flight and Arboreality



Evolution of Flight

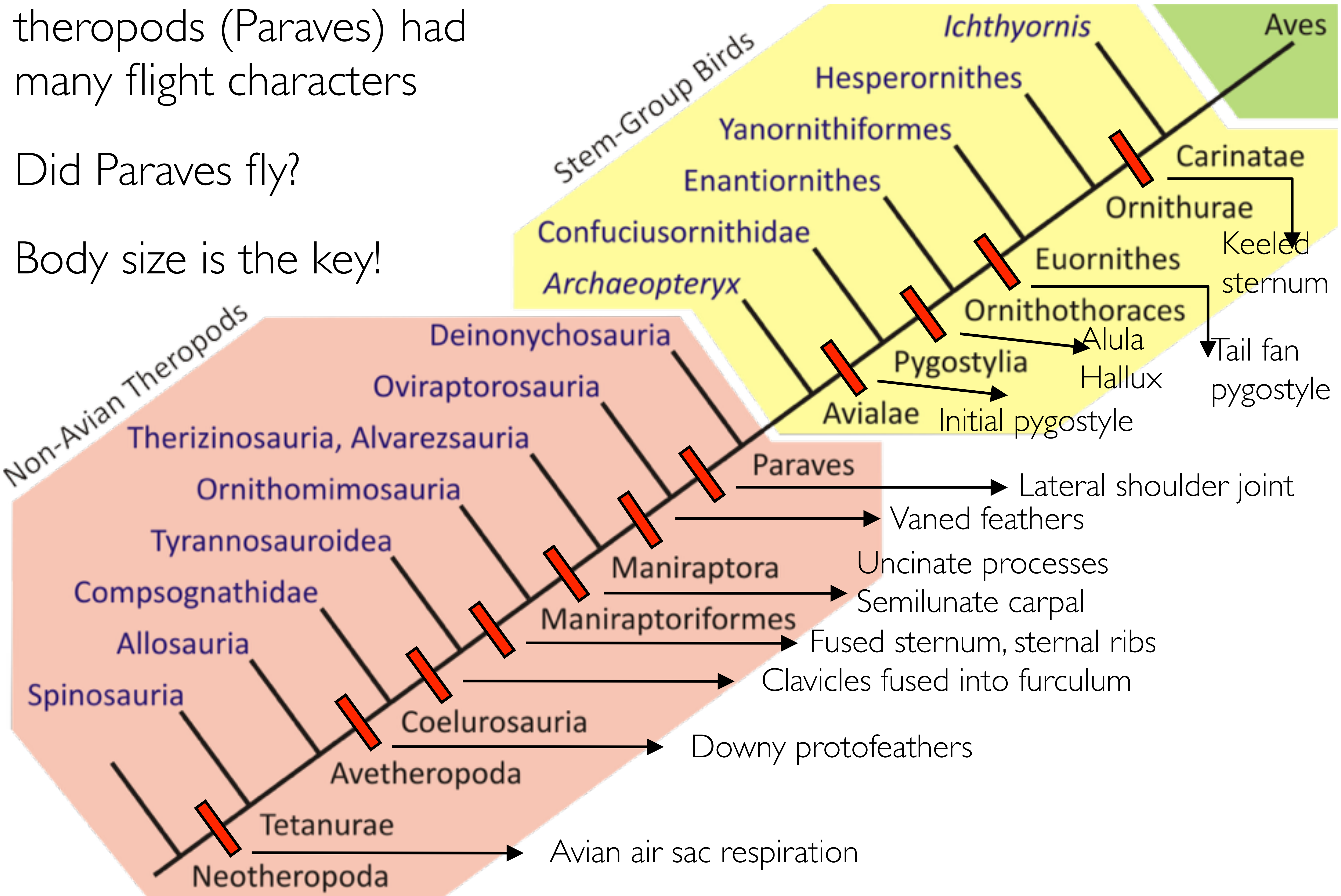
Did flight first evolve in the earliest birds (Avialae, *Archaeopteryx*) or could some theropods fly?

Did flight evolve from the ground-up (cursorial hypothesis) or from the trees-down (arboreal hypothesis)?

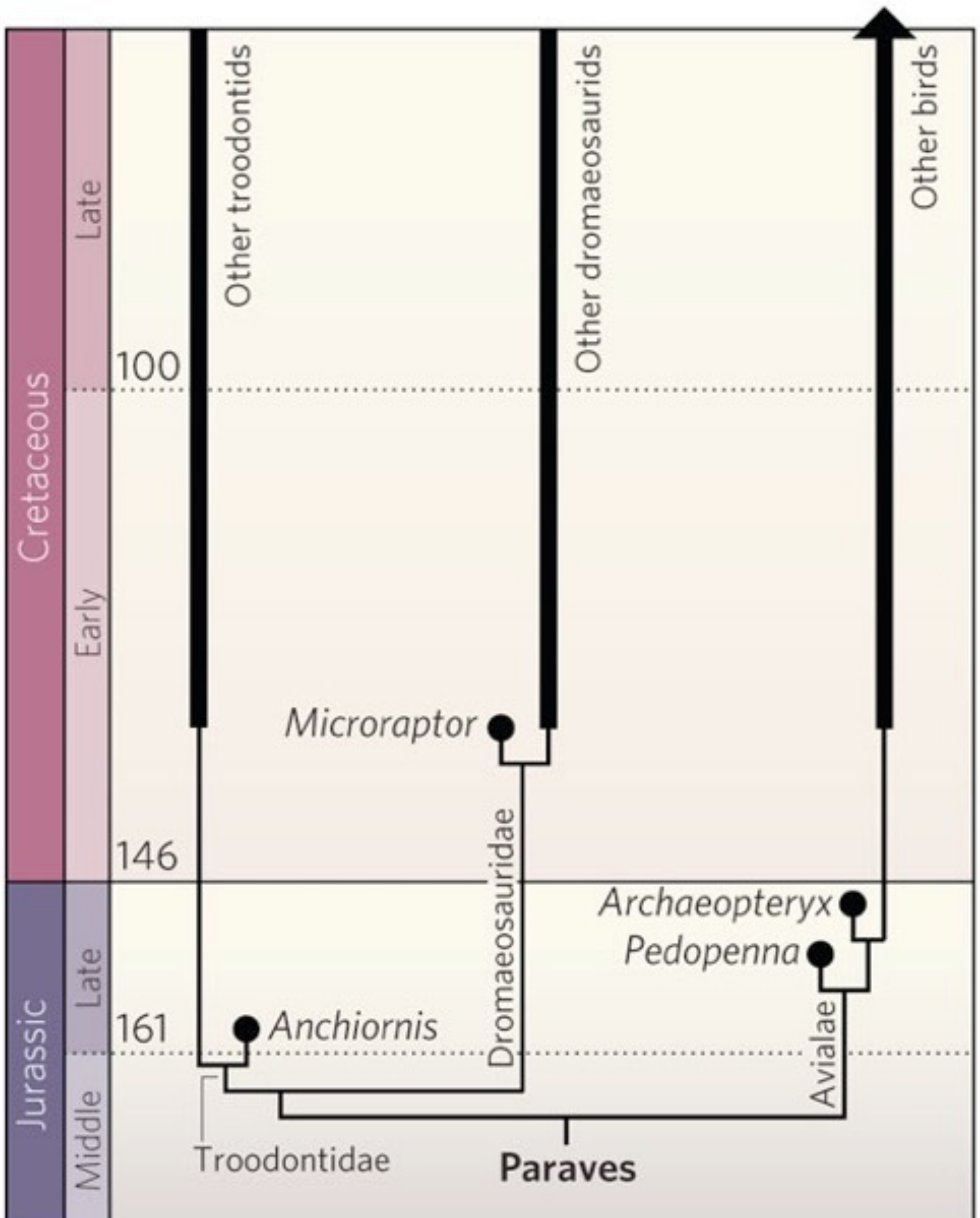
Advanced non-avian theropods (Paraves) had many flight characters

Did Paraves fly?

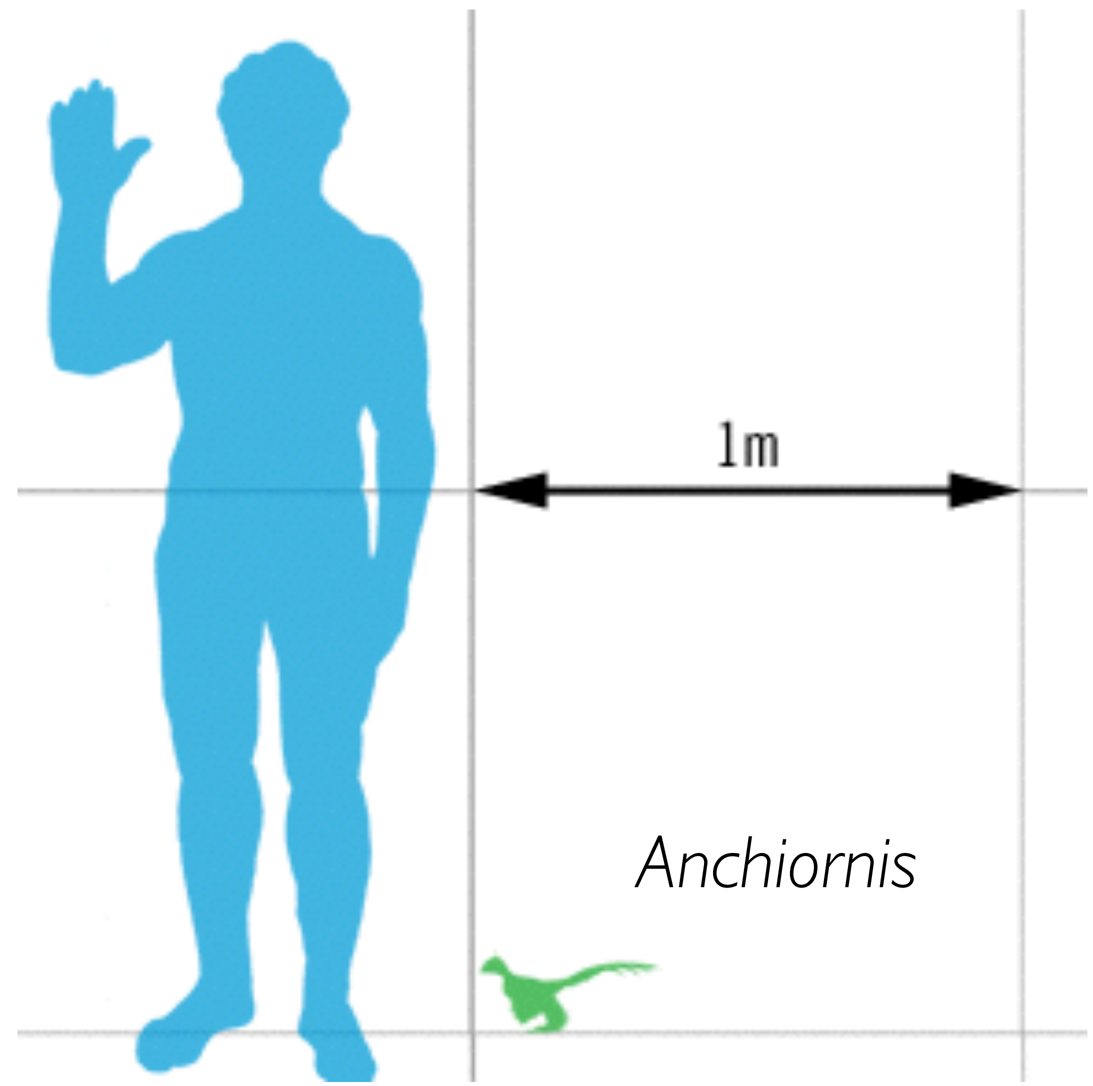
Body size is the key!



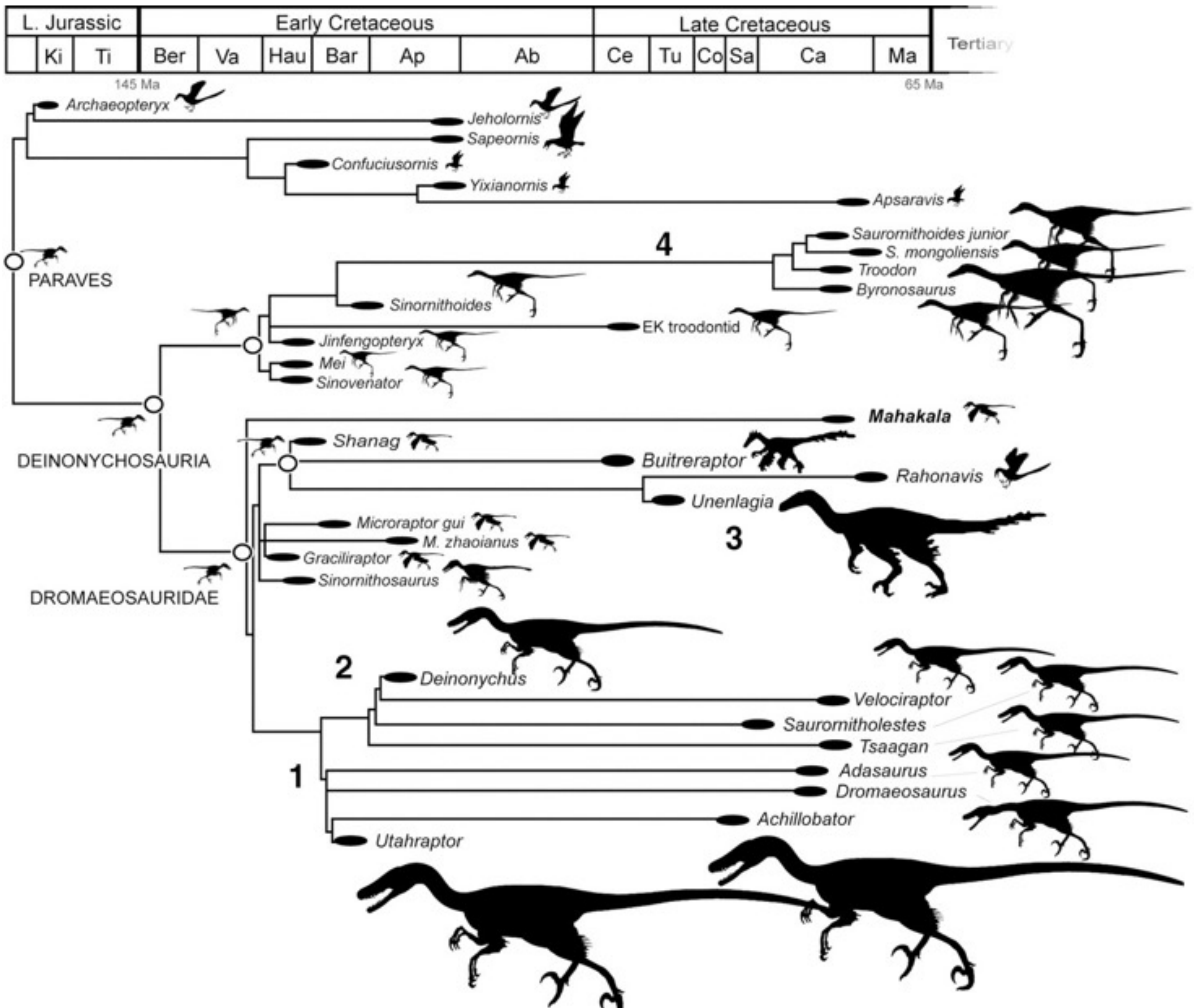
Body Size Reduction



Basal paravians were four-winged animals about the size of a crow



Large Cretaceous raptors were likely secondarily flightless – the ostriches of the Cretaceous!



Origins of Flight

Two primary hypotheses to explain origins of flight:

Cursorial Hypothesis: flight evolved from ground-dwelling, running ancestors (from the "ground up")

Theropod ancestors were fast runners with no arboreal adaptations

Gap may exist between max. running speed and takeoff velocity

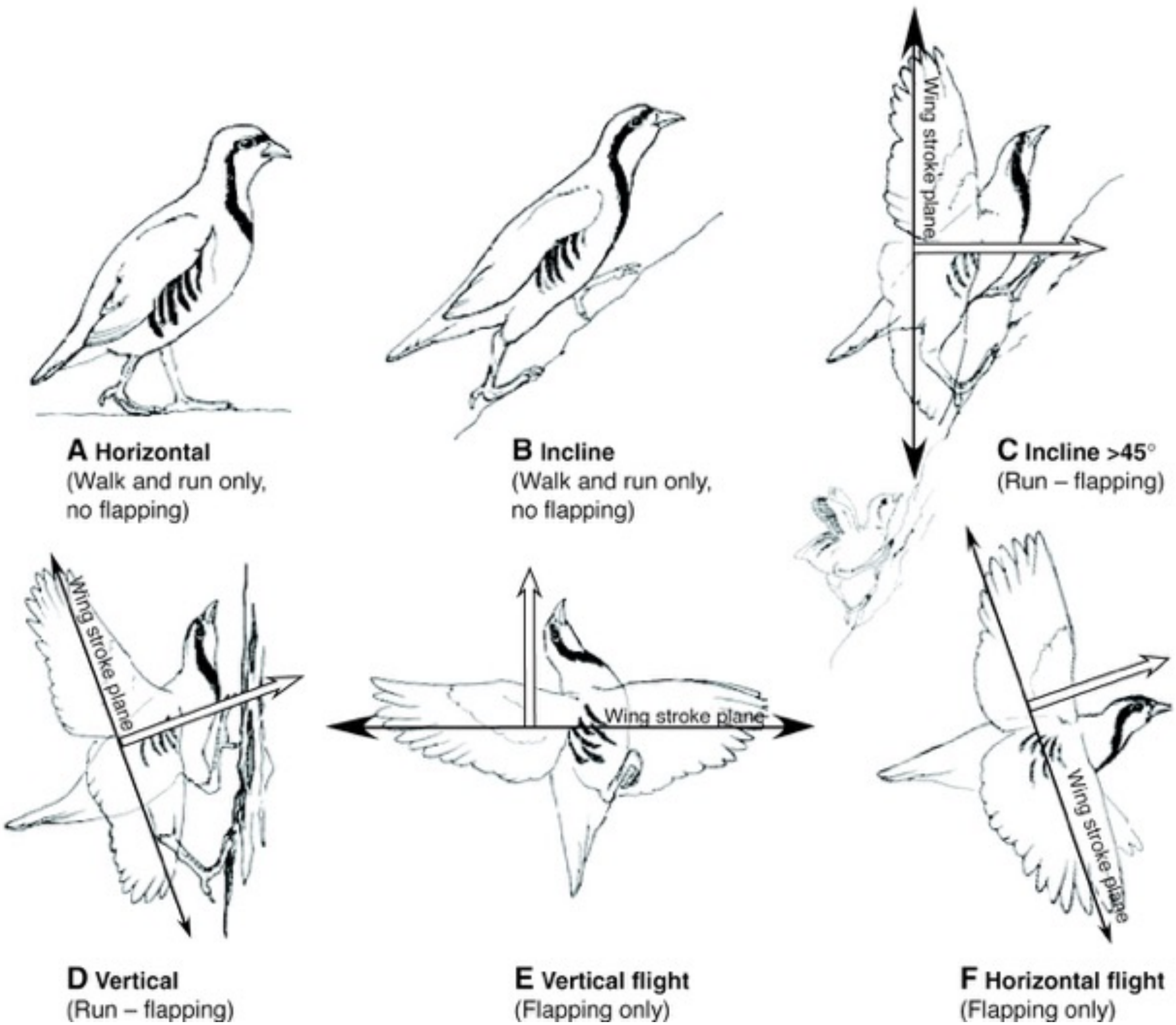
Arboreal Hypothesis: flight evolved through an intermediate gliding stage (from the "trees down")

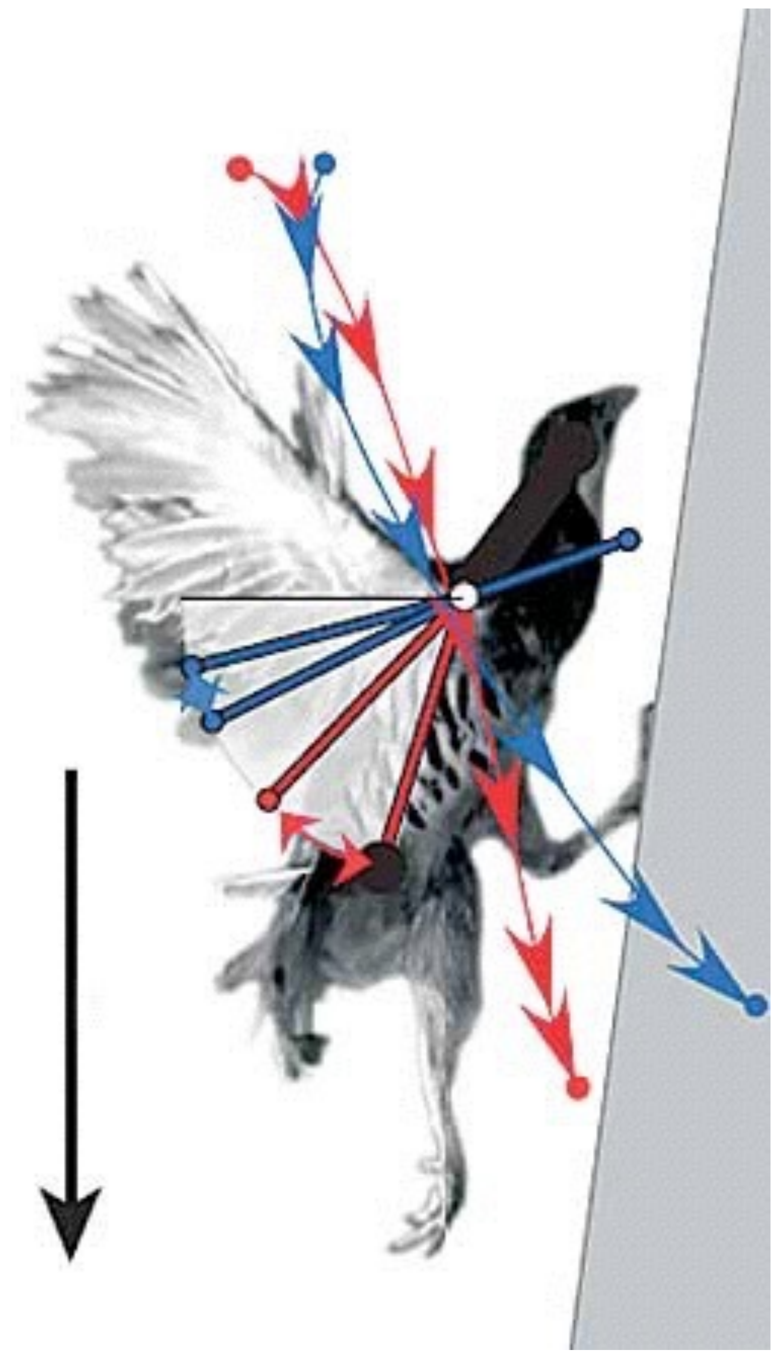
Gravity provides necessary potential energy for flight

Archeopteryx was an agile ground-dweller

Cursorial Hypothesis

Theropods may have flapped their wings to increase running speed or run up steep inclines: <u>Wing-Assisted Incline Running</u>



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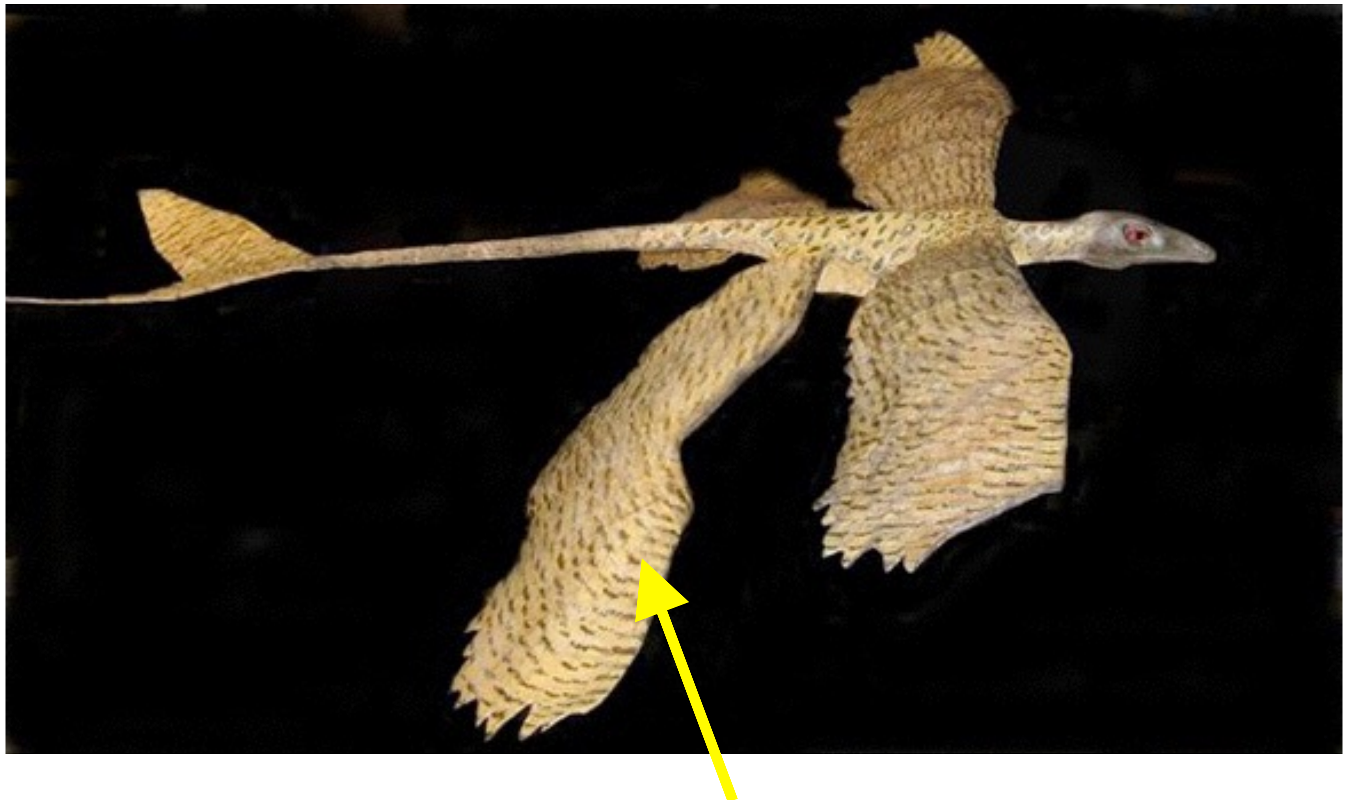
Arboreal Hypothesis

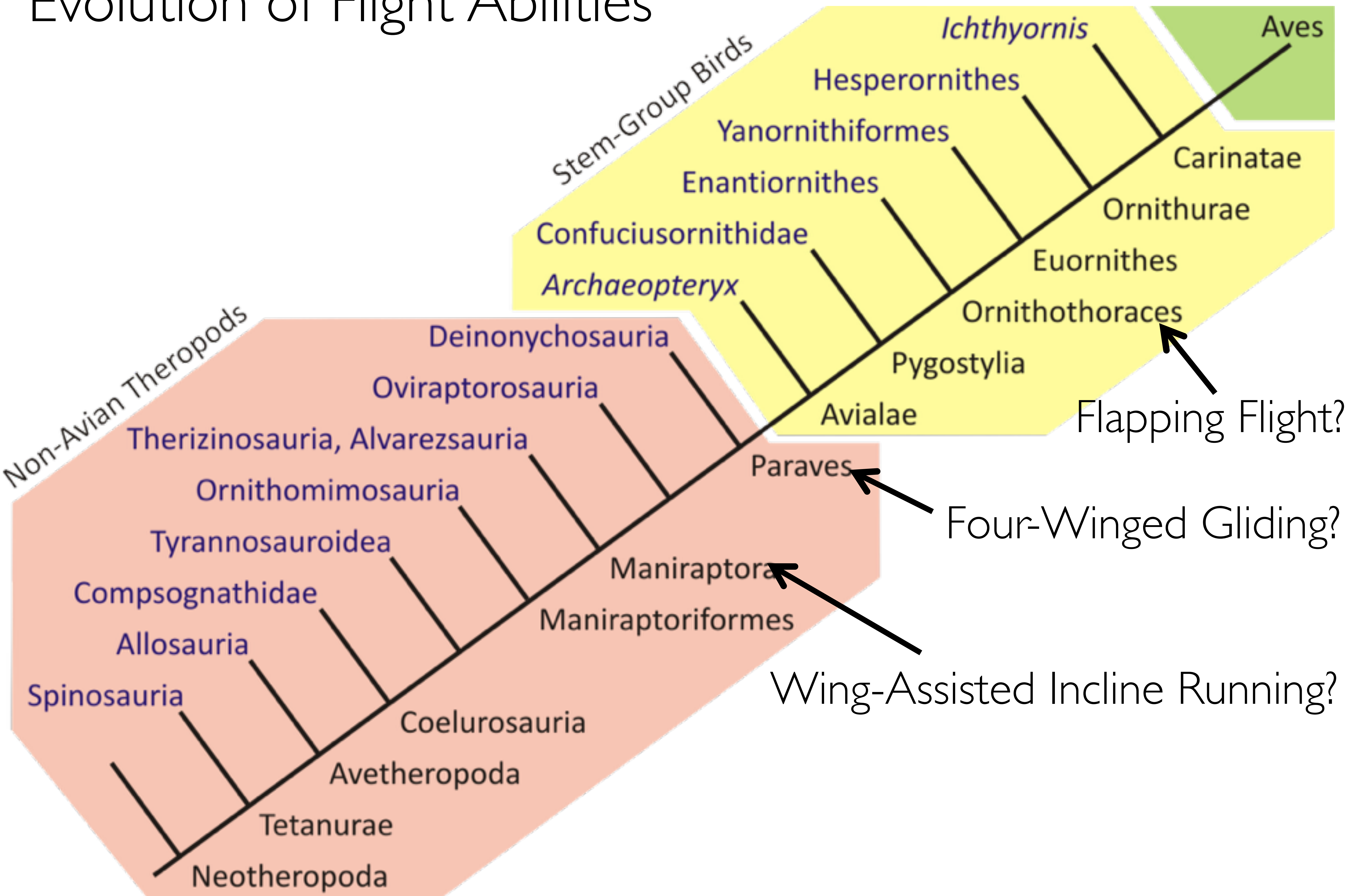
Earliest paravians (including birds) had four wings, with feathers on the arms and legs – may have glided from tree to tree



Paravians do not have any obvious arboreal adaptations, but then again neither do goats

It has been debated whether the hind legs could bend outward to provide a horizontal airfoil

Evolution of Flight Abilities

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Flight Laboratory

Bird Evolution Summary

- Birds are theropod dinosaurs, demonstrated by similarities in osteology, oology, integument, collagen structure, and behavior

- Feathers and arm flapping evolved **before** the animals were capable of powered flight

- Flight likely first evolved in paravian theropods (not in birds), but they were poor fliers

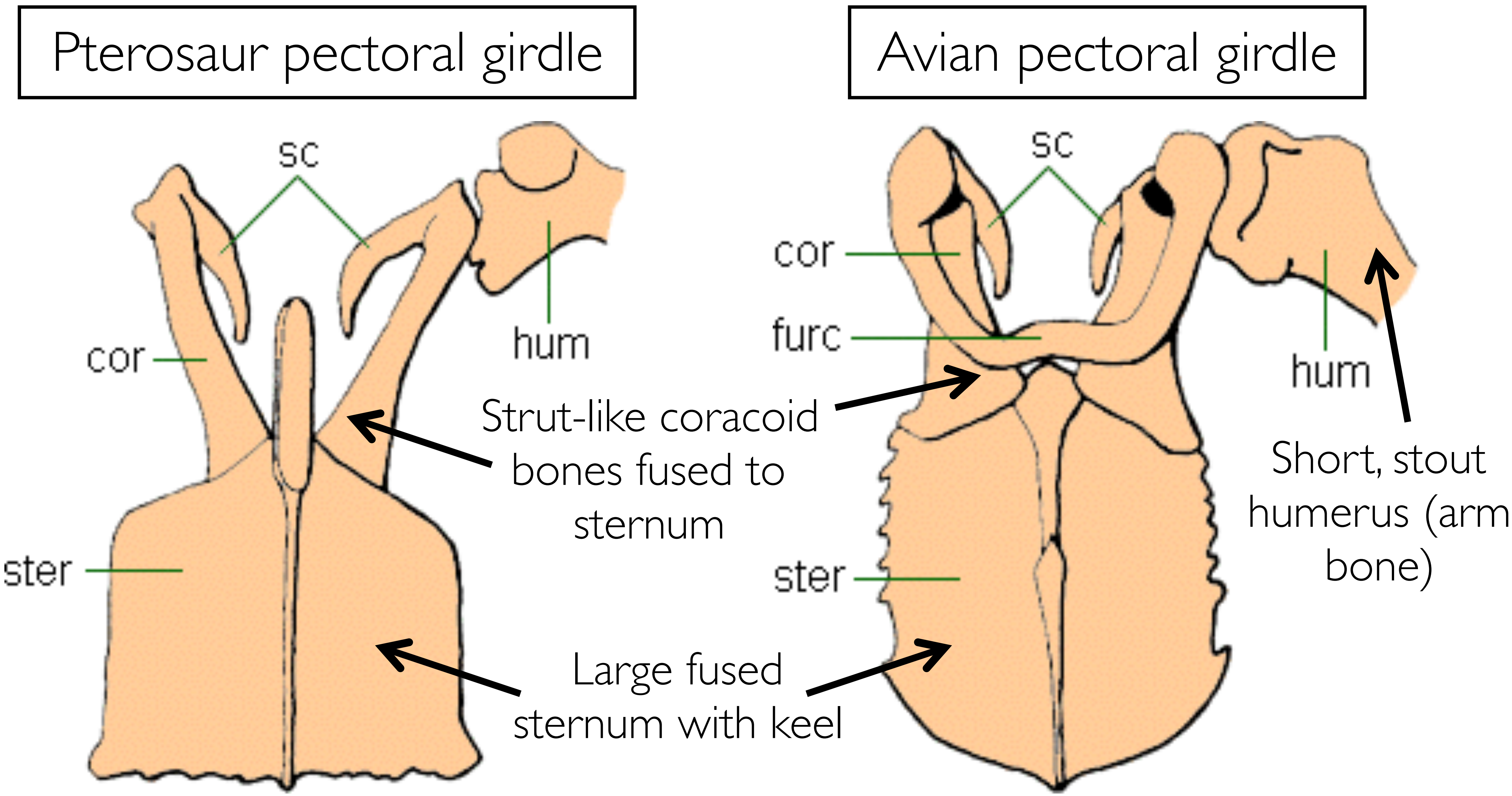
- Further acquisition of flight adaptations (pygostyle, sternum, alula) occurred during Mesozoic bird evolution

Convergent Flight Adaptations in Pterosaurs

Pterosaurs are flying archosaur reptiles (related to but not dinosaurs) that evolved in the Late Triassic

Pectoral Girdle Similarities

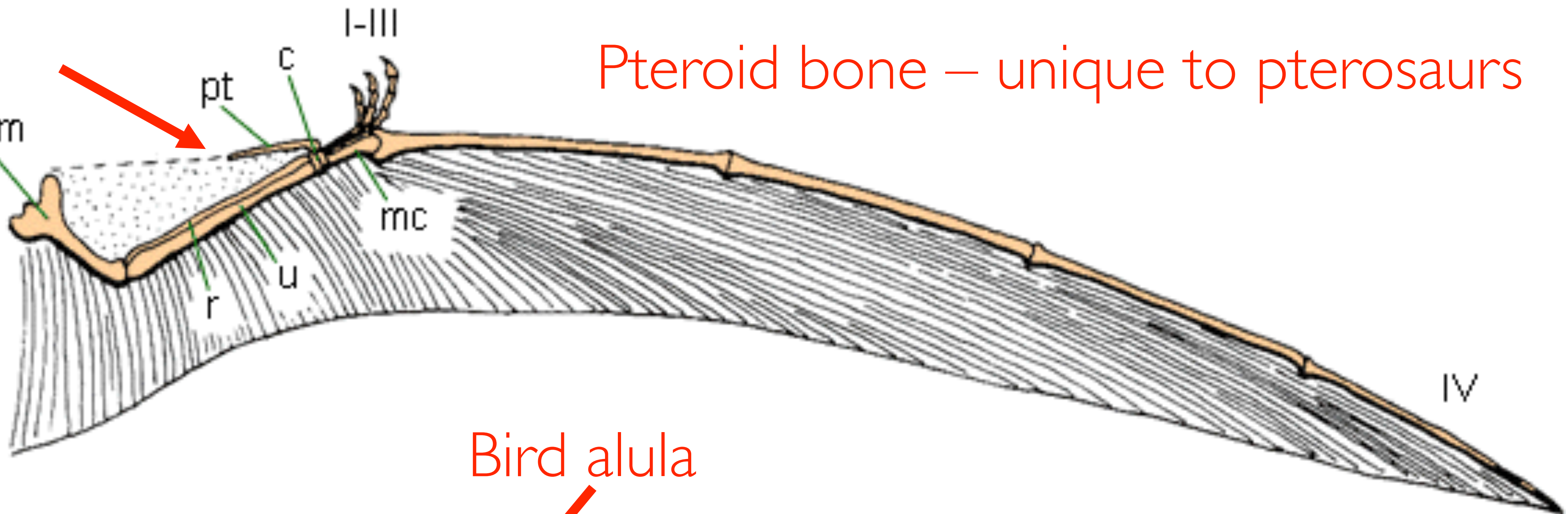
Pterosaurs independently evolved a pectoral girdle for supporting flight muscles



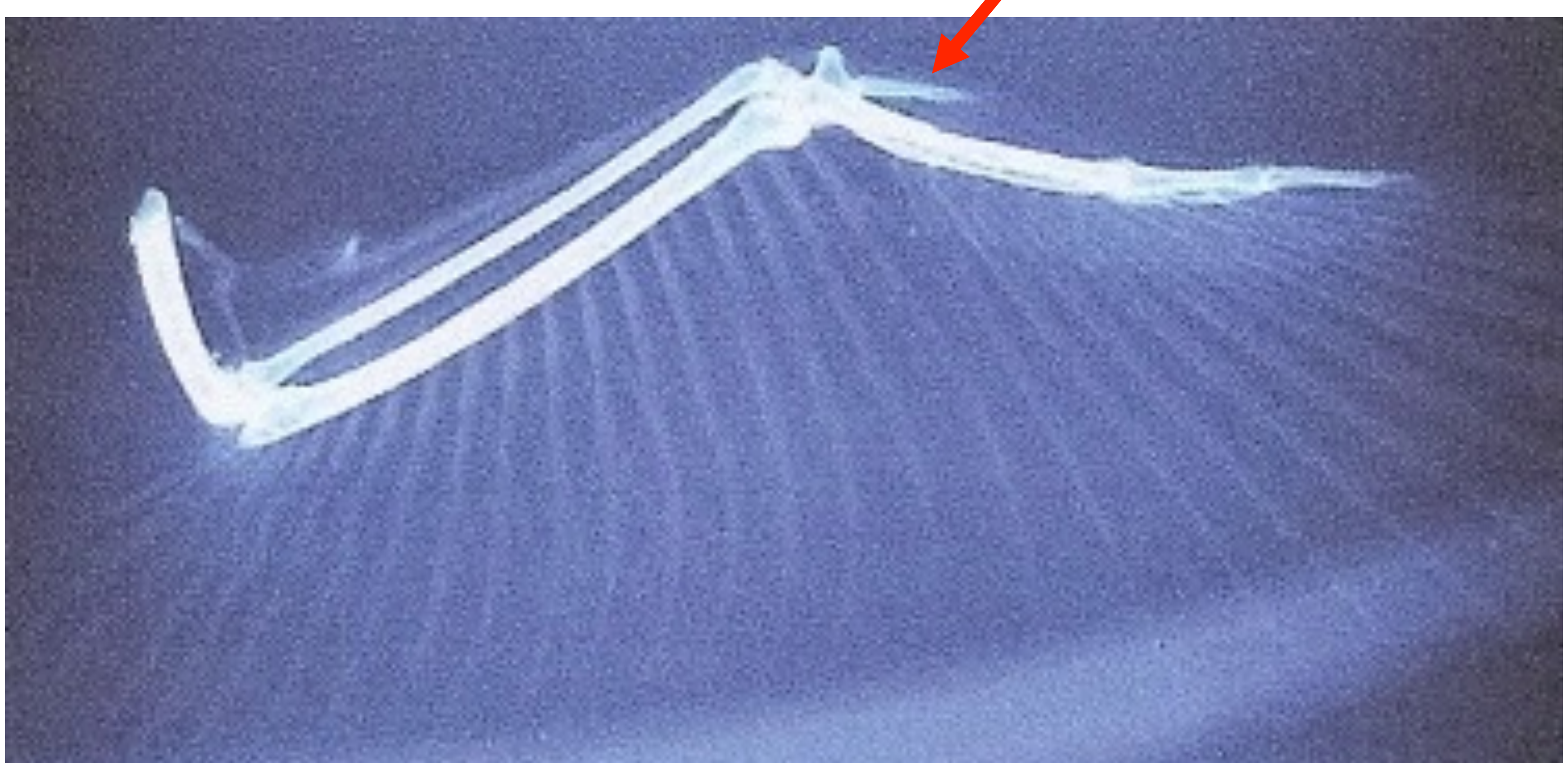
No feathers – instead use skin membrane stretched across hand

Wing surface primarily supported by extended finger digit IV

Pteroid bone – unique to pterosaurs



Bird alula

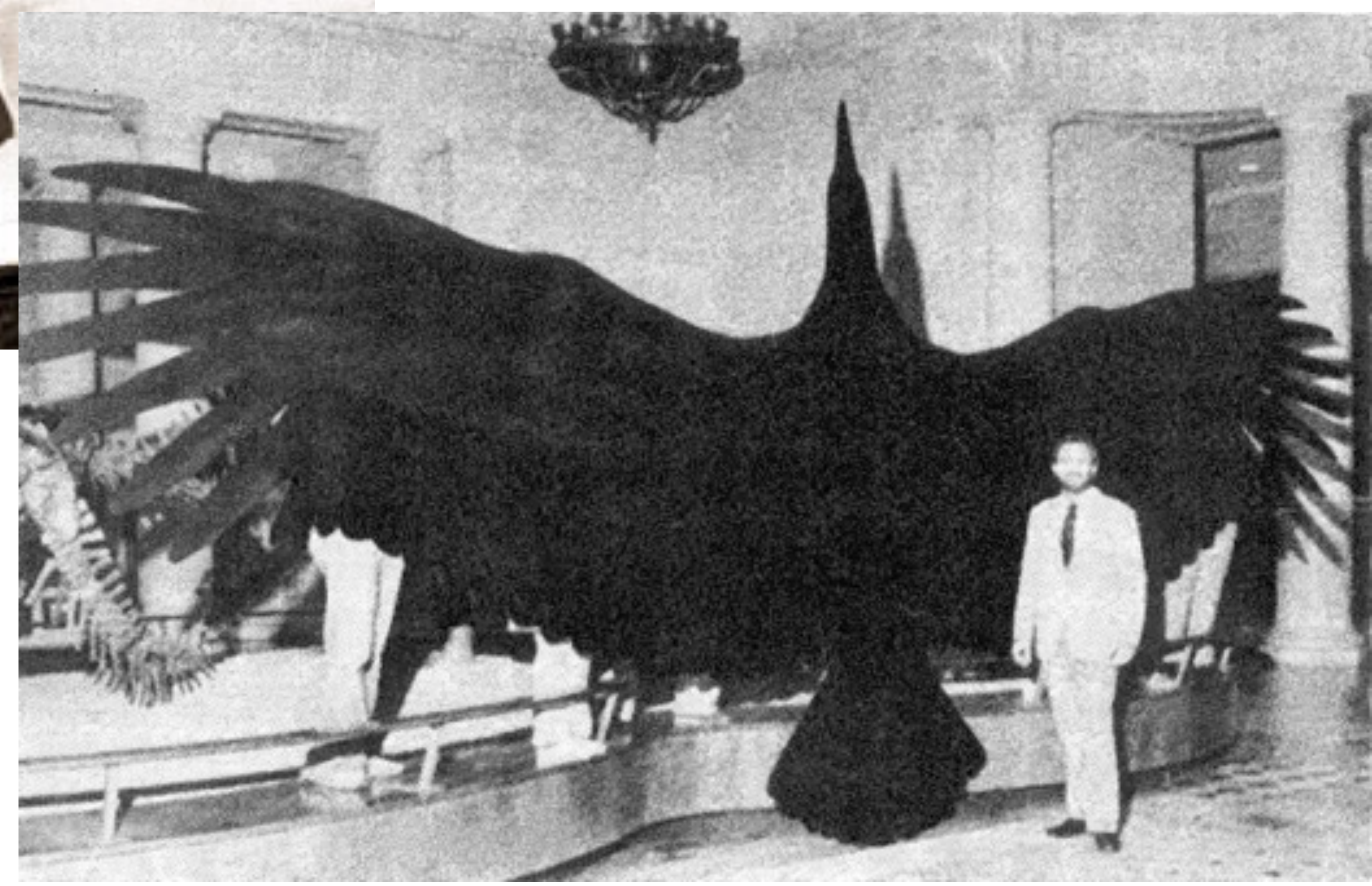


Bird wing: feathers

Wing surface primarily supported by ulna, wrist

Giant Flying Animals

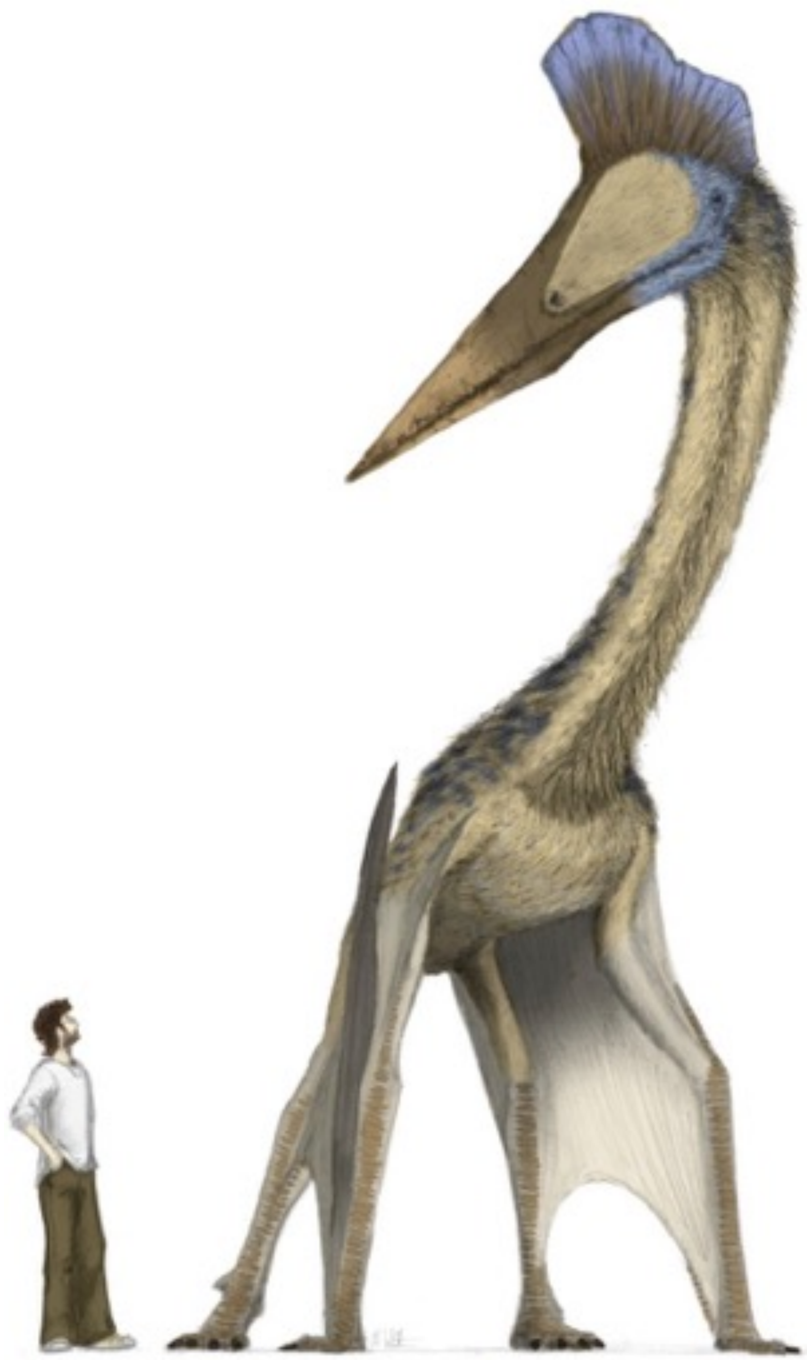
Largest pterosaur (*Quetzalcoatlus*, from the latest Cretaceous) had a 12 m wingspan and weighed 100 kg



Largest bird (*Argentavis*, Miocene) had 7 m wingspan and weighed 80 kg

Giant Pterosaurs

Largest pterosaurs were probably excellent gliders but would have had difficult reaching takeoff velocity



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- Flight likely first evolved in paravian theropods (not in birds), but they were poor fliers
- Further acquisition of flight adaptations (pygostyle, sternum, alula) occurred during Mesozoic bird evolution
- Flying pterosaur reptiles are not related to birds but display convergent evolution of many flight adaptations