EVOLUTION OF BIRDS

Fastovsky
Chapter 8

Is it a Dinosaur or Bird?

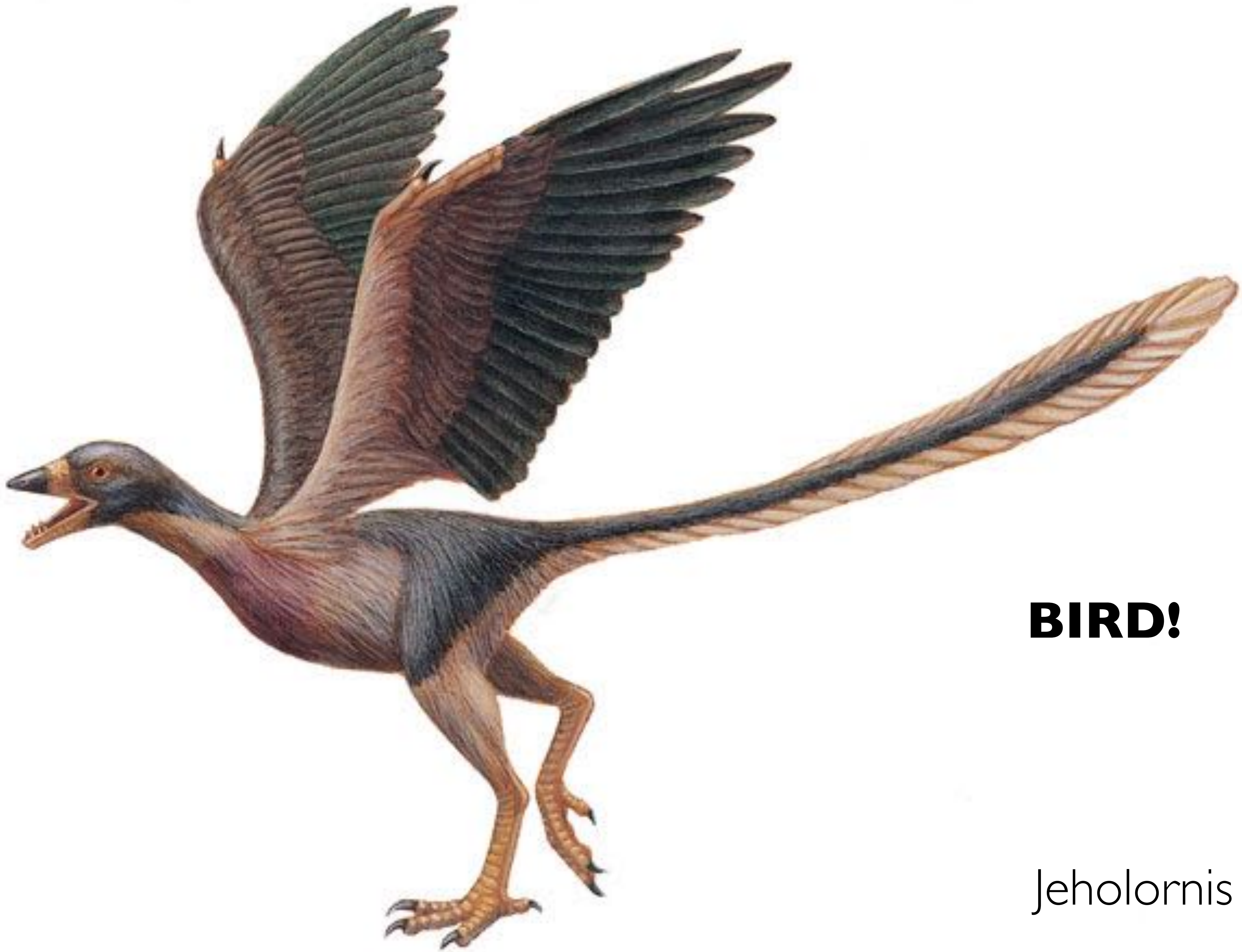
DINOSAUR!

Jinfengopteryx

Is it a Dinosaur or Bird?

DINOSAUR!
Microraptor

Is it a Dinosaur or Bird?



BIRD!

Jeholornis

Is it a Dinosaur or Bird?

DINOSAUR!

Mahakala

Is it a Dinosaur or Bird?

BIRD!

Archaeopteryx

Is it a Dinosaur or Bird?

DINOSAUR!

Rahonavis

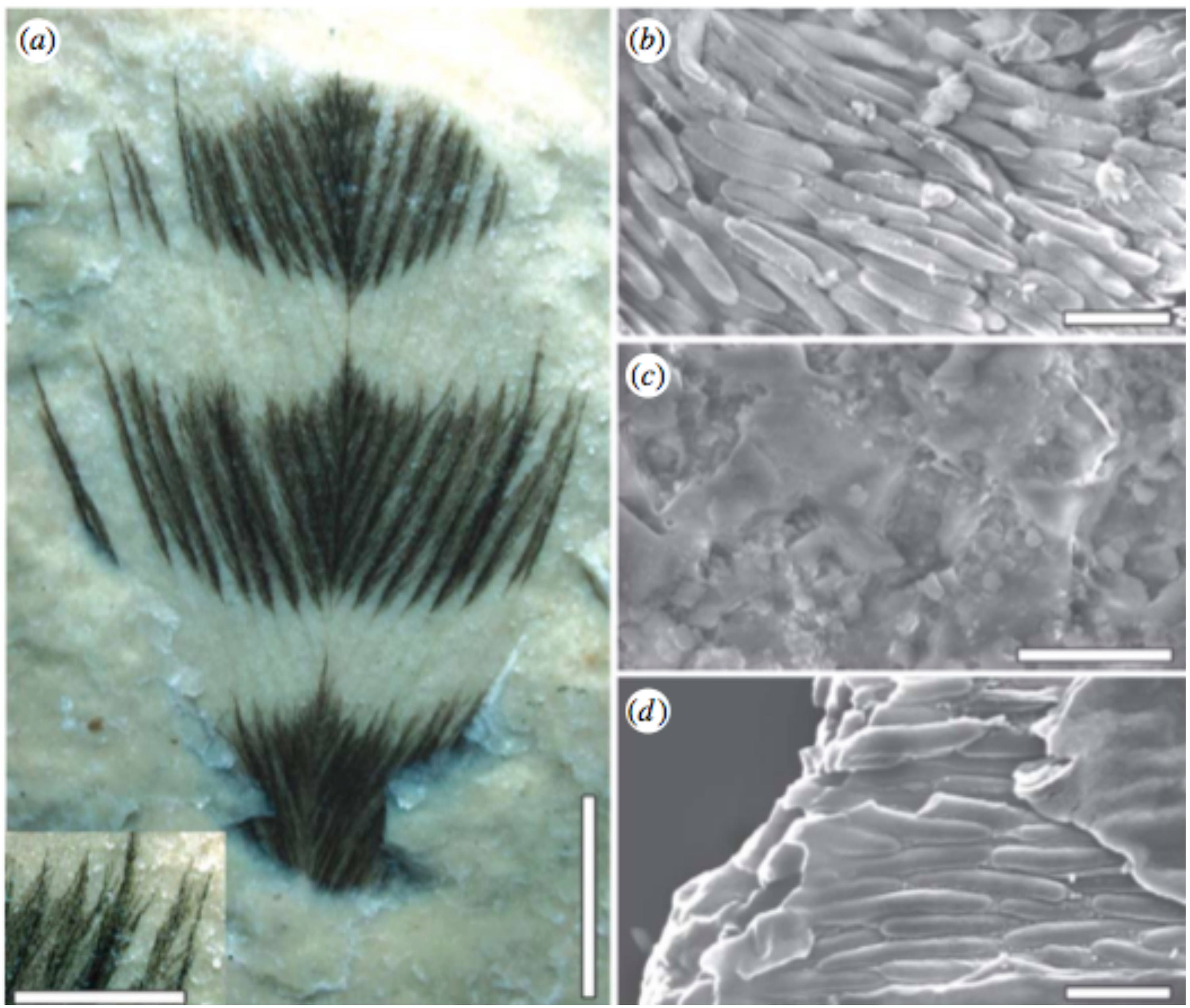
Is it a Dinosaur or Bird?

DINOSAUR!

Anchiornis

Dinosaur Color Patterns

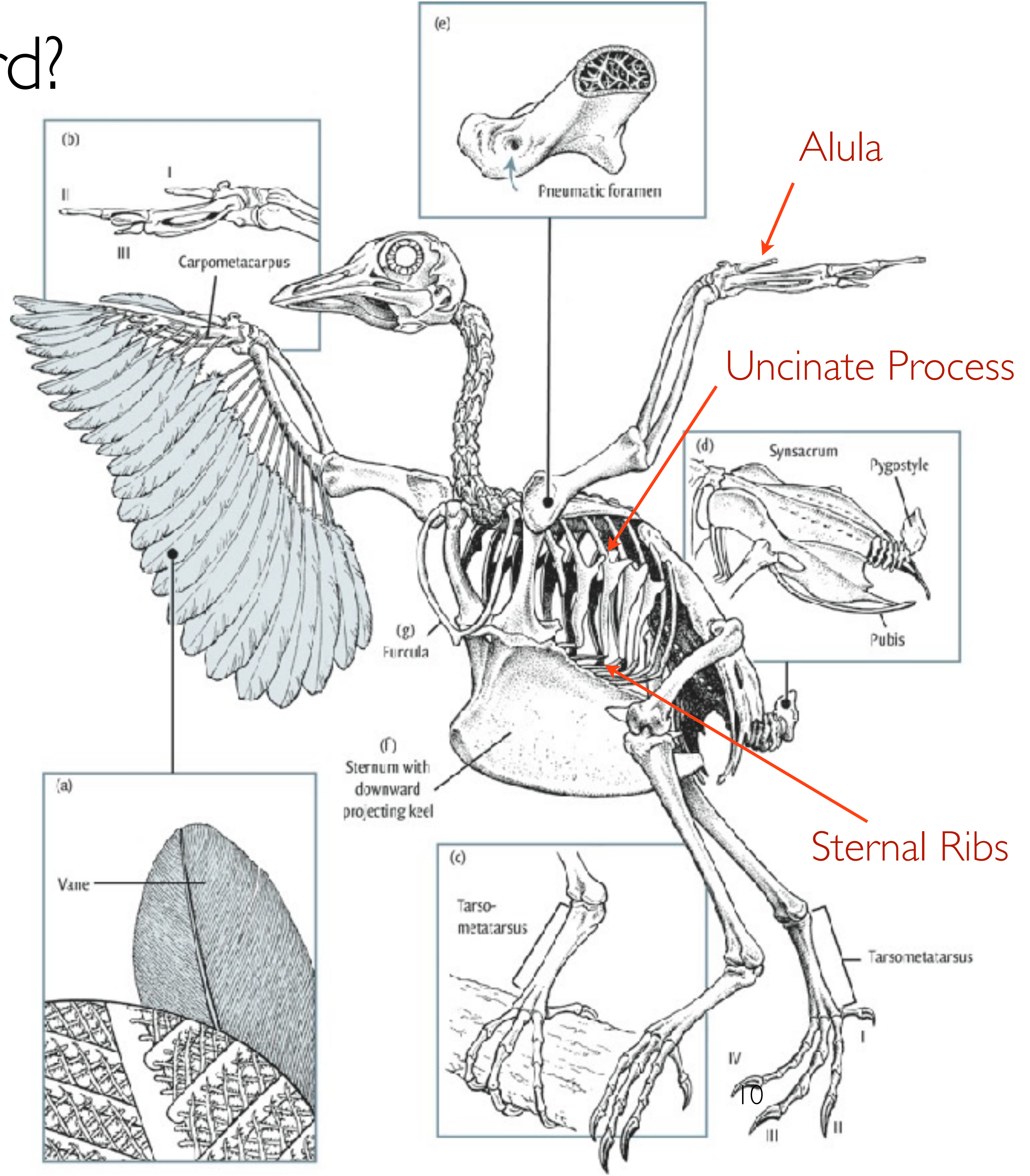
This is the actual coloration of the Jurassic dinosaur *Anchiornis*



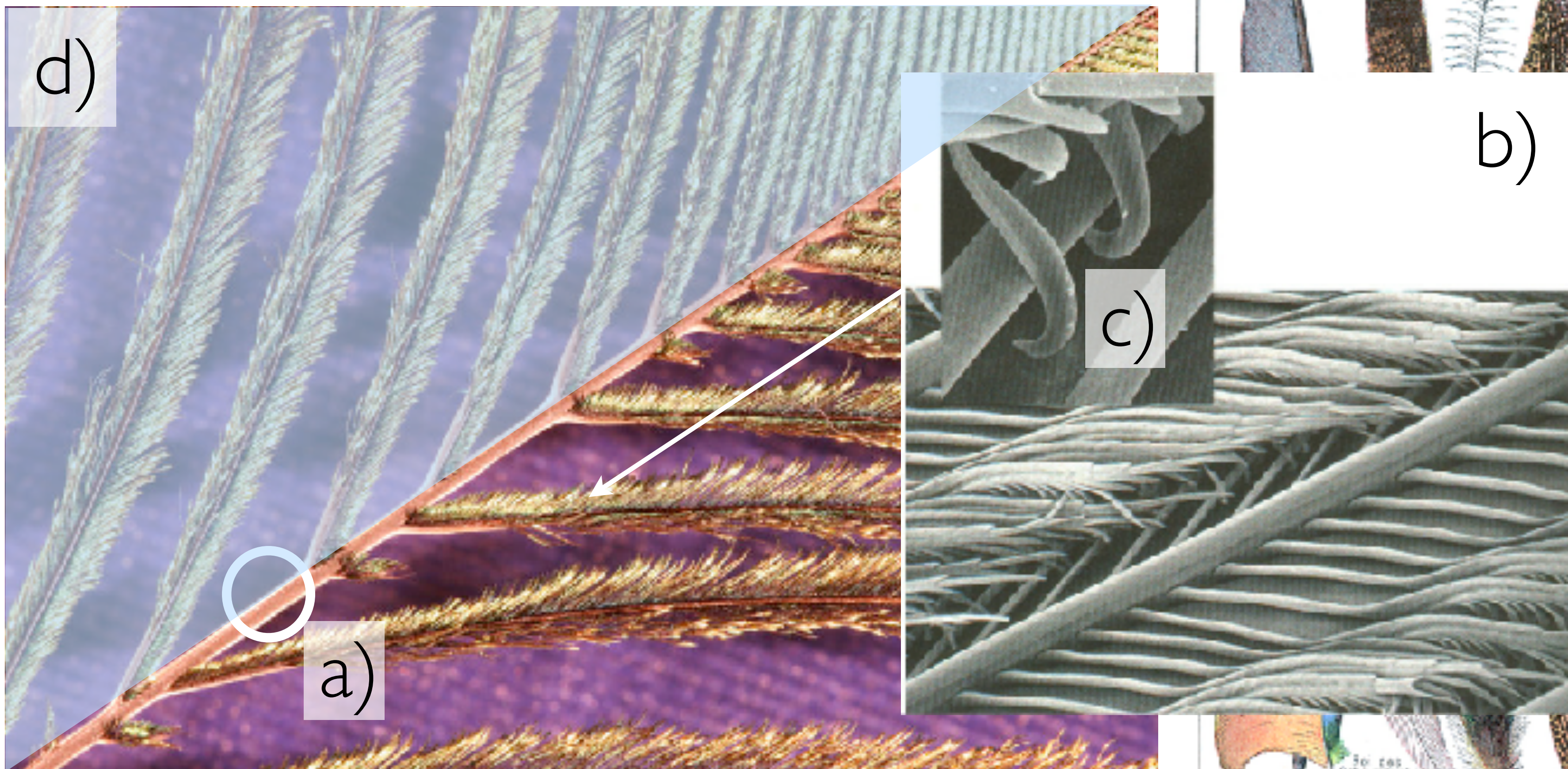
Distribution of two types of preserved pigment cells (melanosomes) allows actual color pattern to be determined

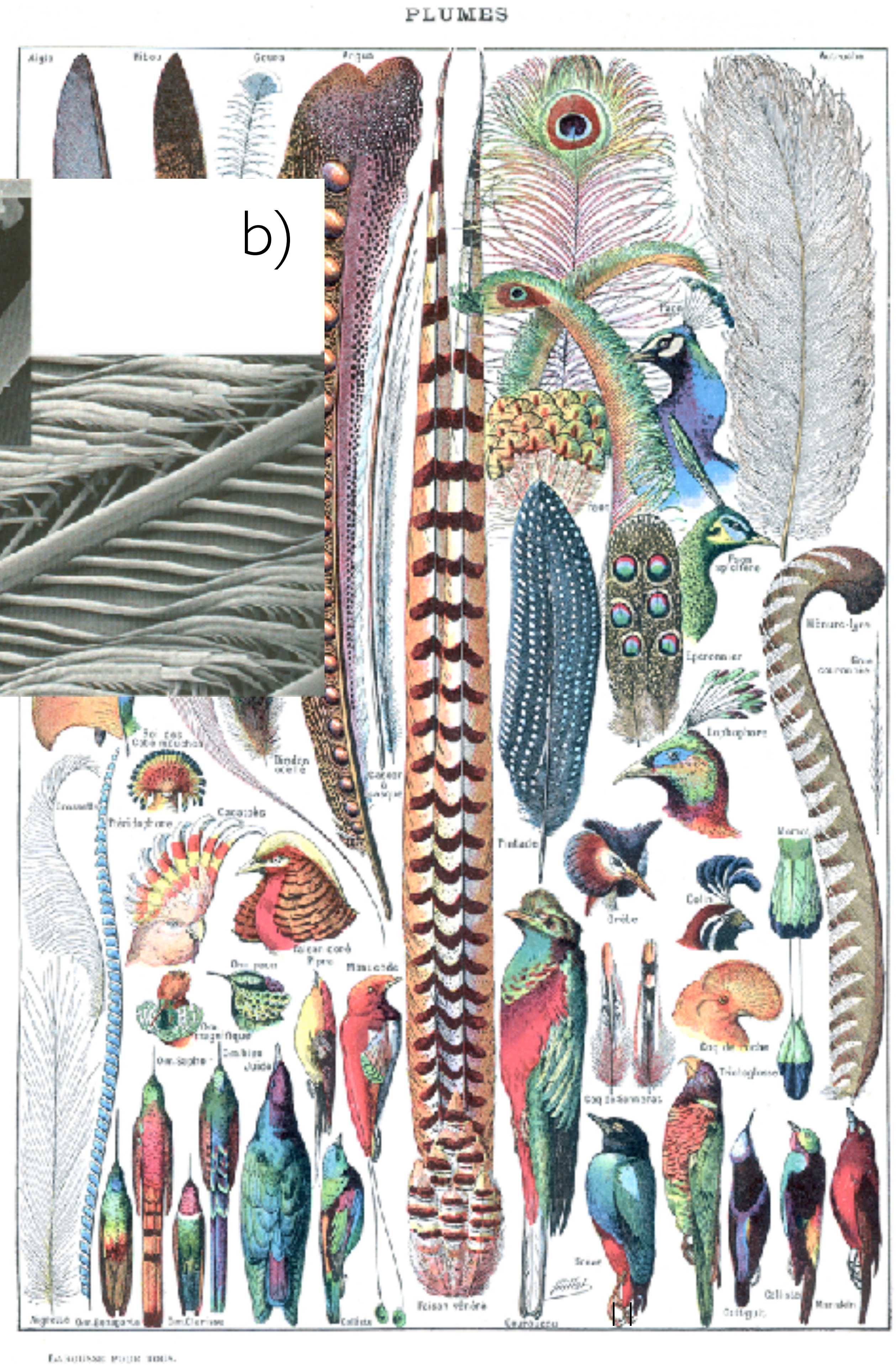
First, what is a bird?

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

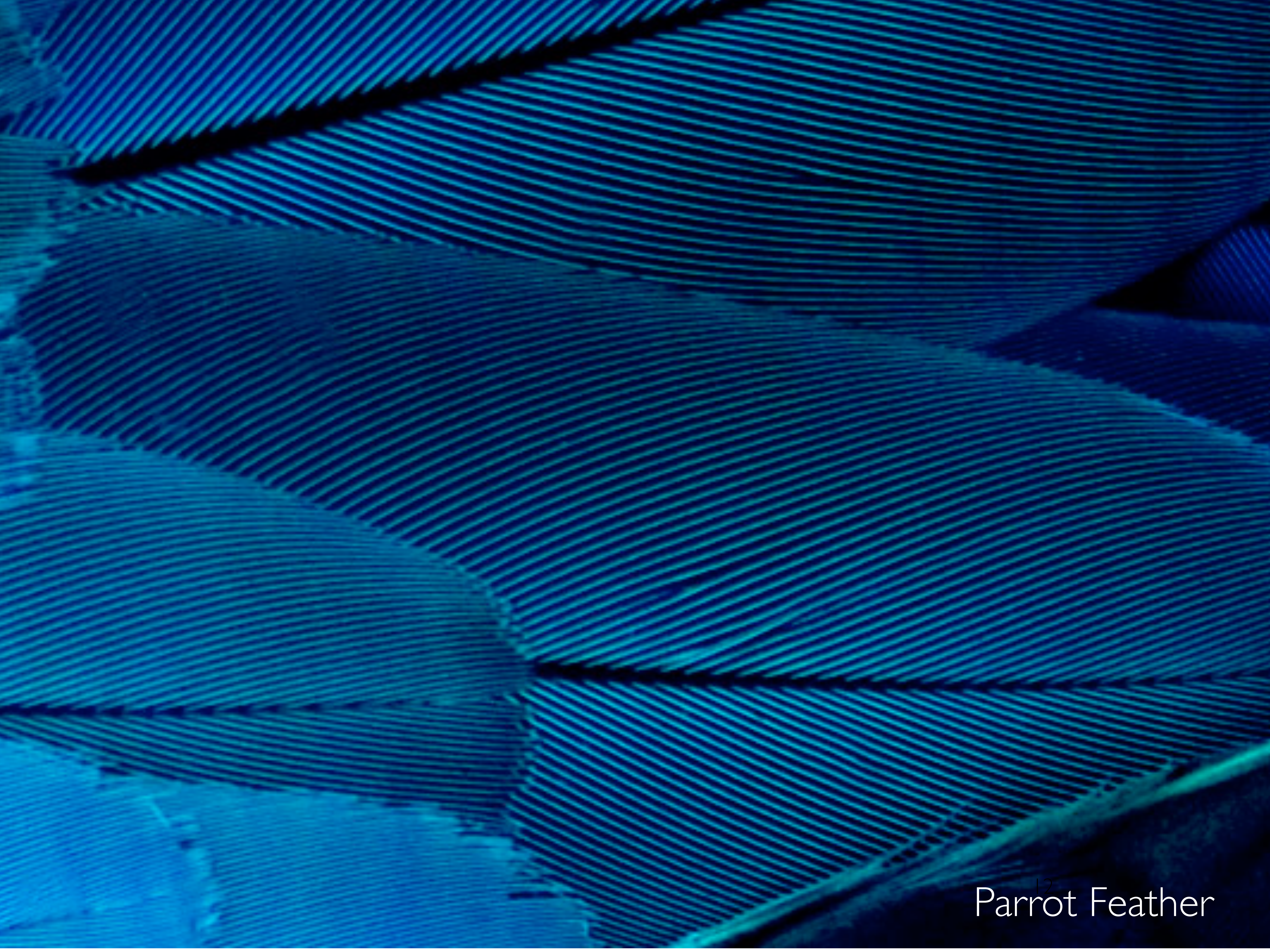


Feathers



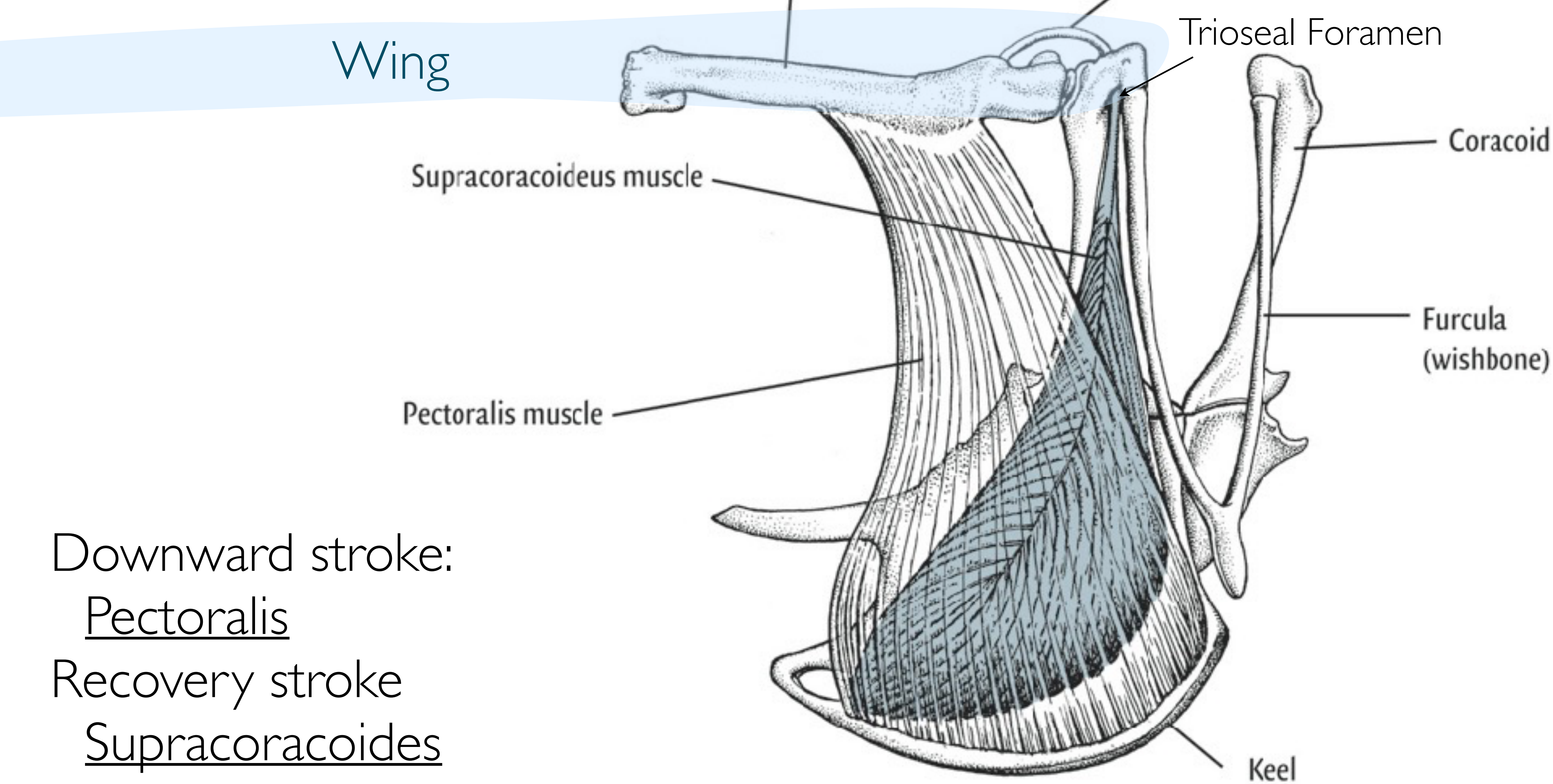


a) Central shaft
b) Barbs radiate from shaft
c) Barbs can be linked by Barbules
d) A sheath of linked barbs = Vane



Parrot Feather

Birds: Powered flight



Downward stroke:

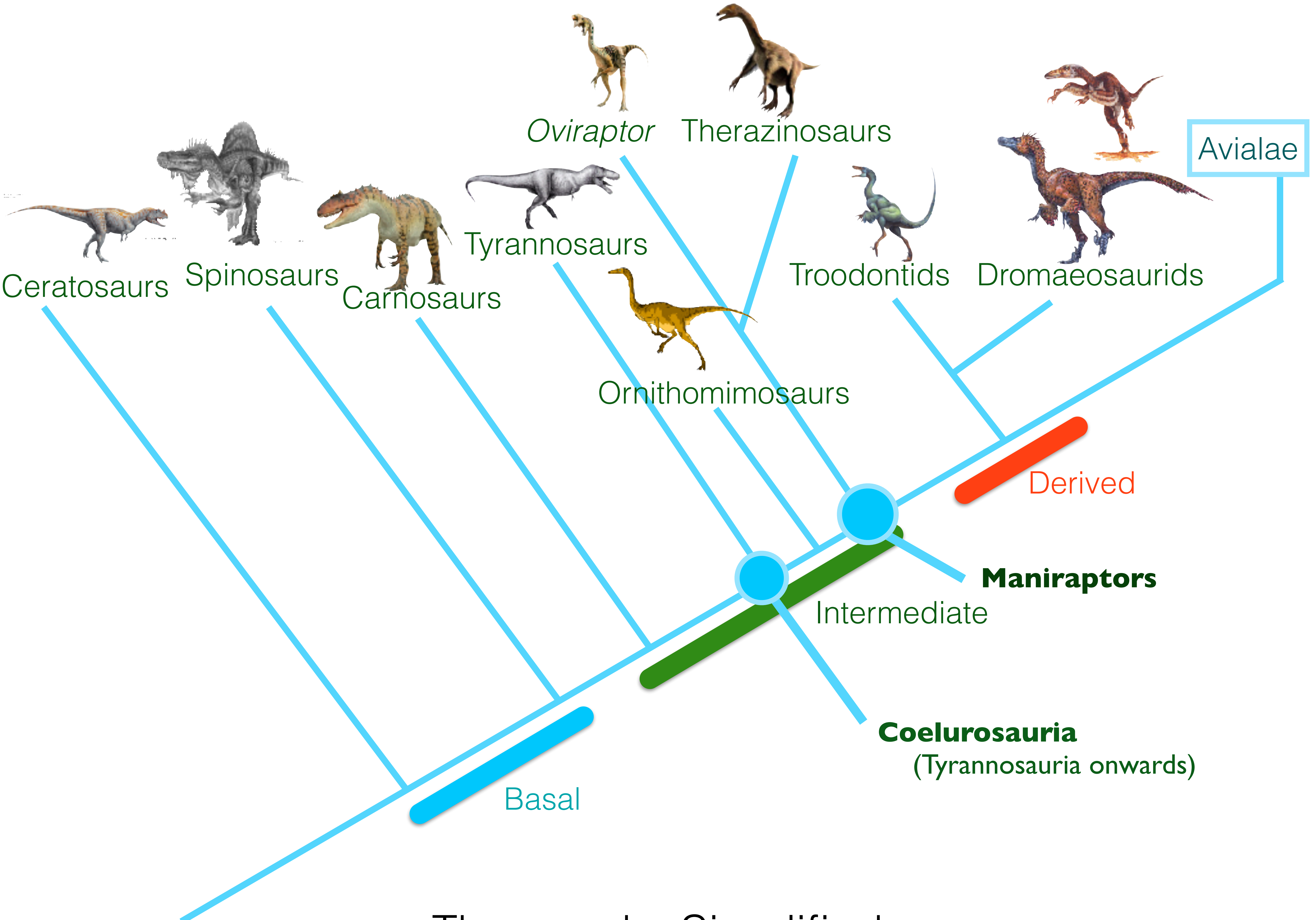
<u>Pectoralis</u>

Recovery stroke

<u>Supracoracoides</u>

Attached to to the keel; similar to Pectoralis... but how does it cause opposite motion?

Hooked via tendon through the TRIOSEAL FORAMEN... unique in Animal Kingdom



Theropods: Simplified

Now we know what birds are...
But which traits are unique?

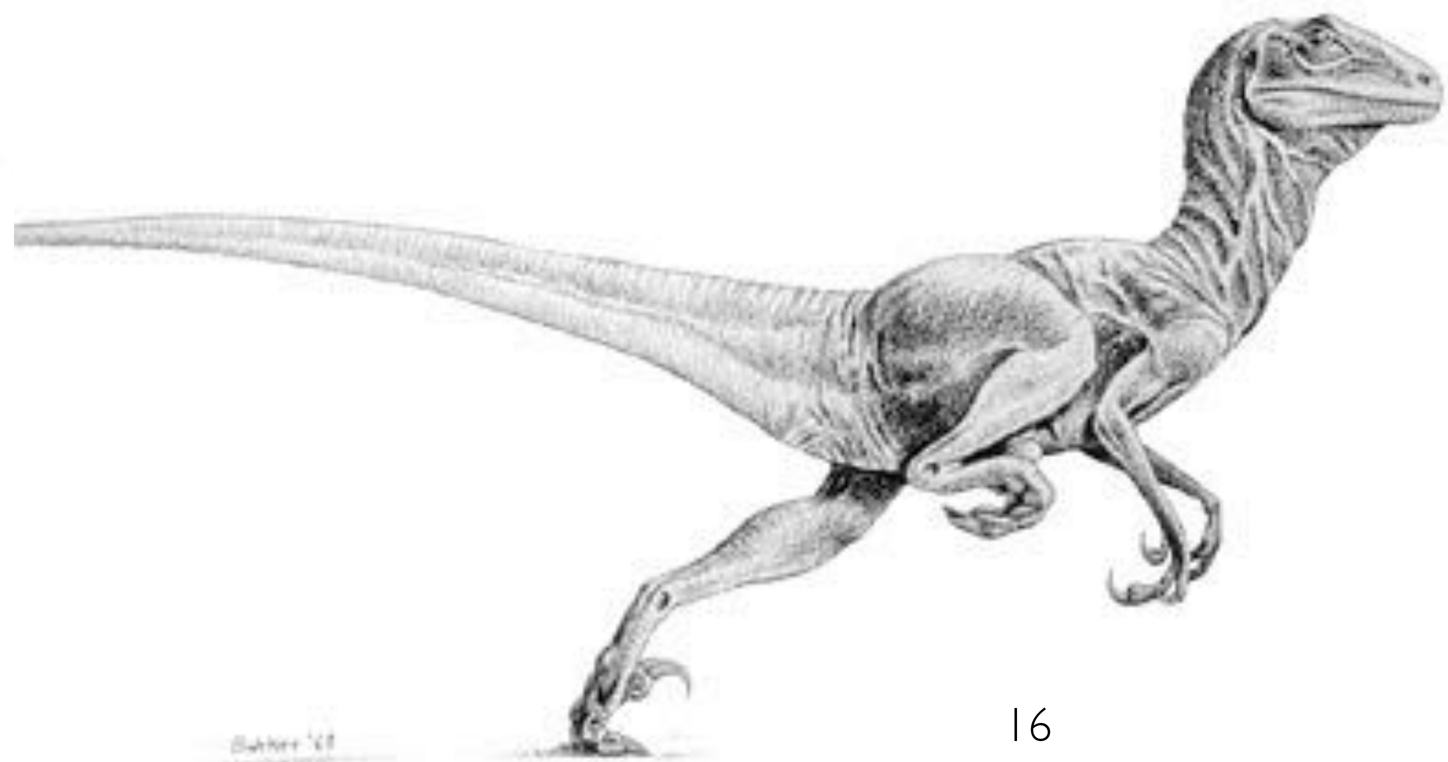
Feathers
Loss of teeth
Large brains, adv. sight
Carpometacarpus
Bipedal
Pygostyle
Pneumatic bones
Rigid skeleton
Furcula

All Theropods
Coelurosauria
Derived Theropods

Bird Ancestors

In the 1960s, paleontologist John Ostrom championed the idea that birds descended from <u>theropod</u> dinosaurs

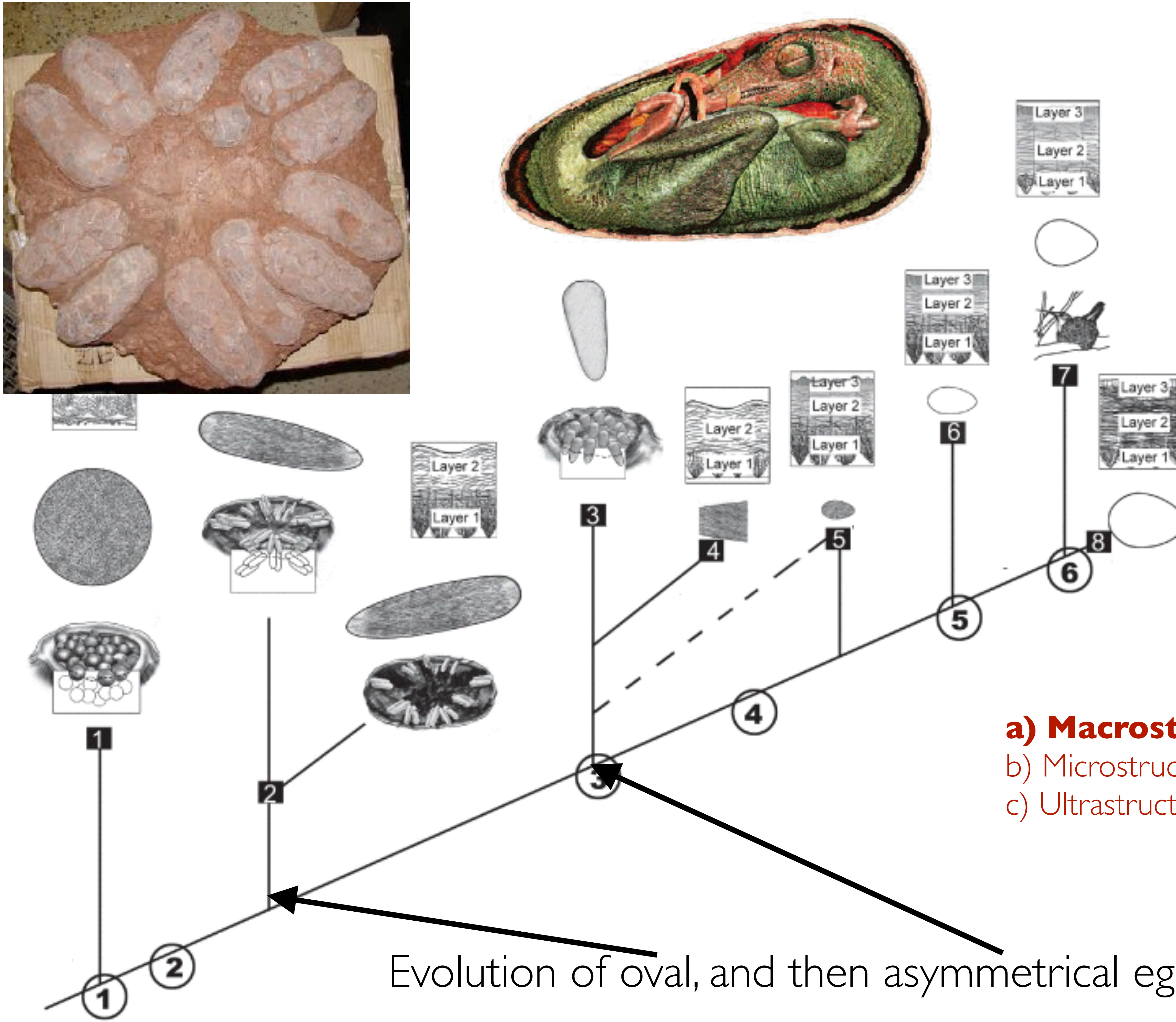
Deinonychus
(Dromaeosauridae)



Bird Ancestors

Evidence that theropod dinosaurs are the ancestors of birds comes from four major aspects of their biology

1. Oology (eggshell, nest, and egg-laying)
2. Behavior
3. Osteology (bone structure)
4. Integument (skin covering)
5. Molecular Evidence (Amino Acid sequences from T. rex)



a) Macrostructure

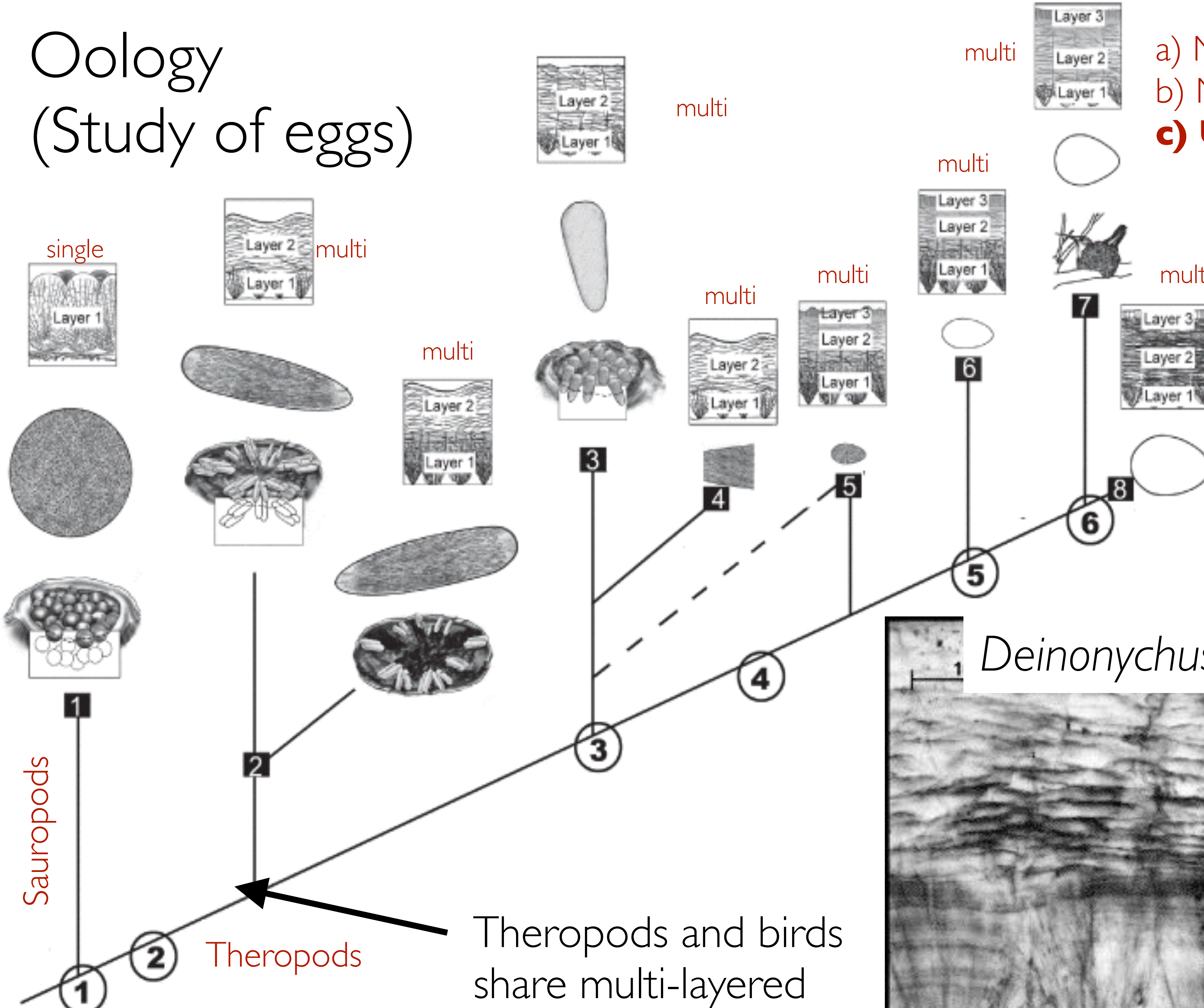
b) Microstructure

c) Ultrastructure

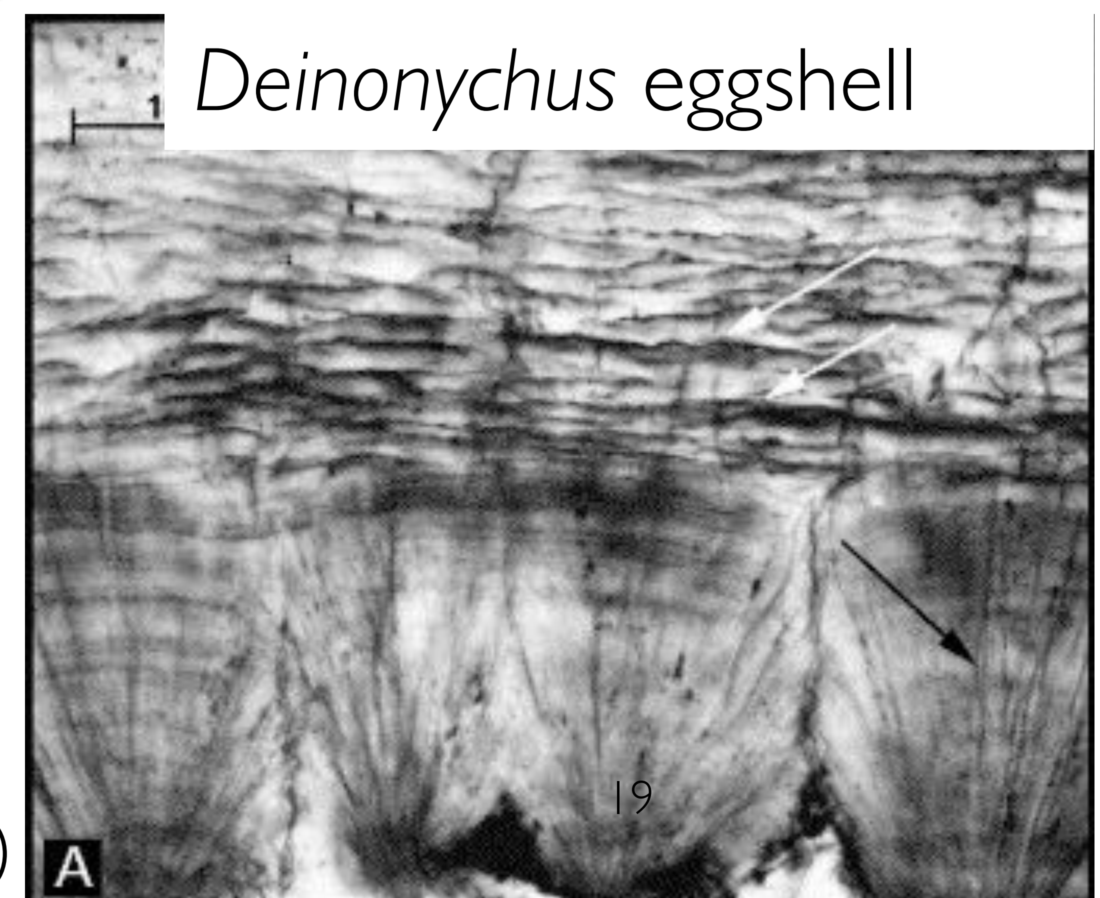
Evolution of oval, and then asymmetrical eggs

Oology
(Study of eggs)

a) Macrostructure
b) Microstructure
c) Ultrastructure



Theropods and birds share multi-layered eggshell structure (prismatic and laminar)



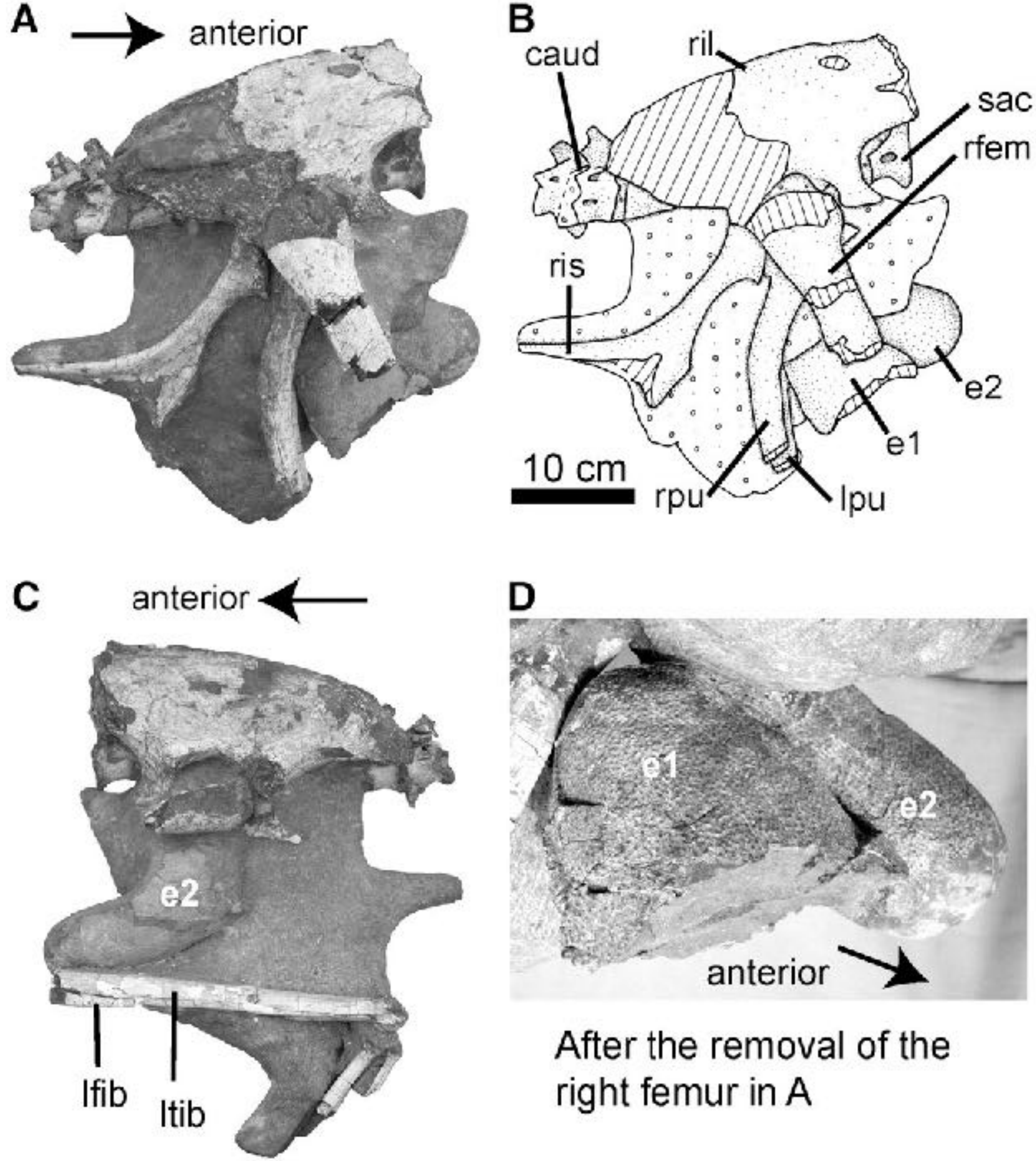
Deinonychus eggshell

Autochronous Ovideposition

Crocodiles, sauropods, and ornithischians laid all eggs at once

Theropods and birds laid two (or one) eggs at a time

Asymmetrical eggs in advanced non-avian theropods may indicate single functional oviduct



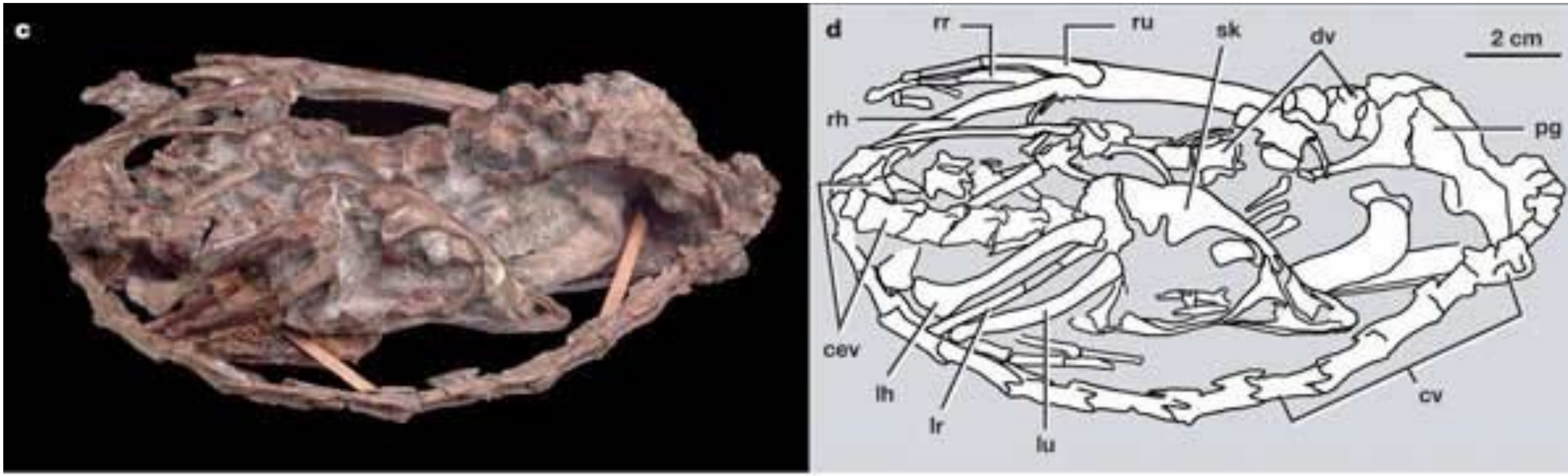
After the removal of the right femur in A

Theropods actively brooded their egg clutch, like birds

Crocodiles and sauropods have minimal parental care and buried eggs in pile of sand/leaves

Behavior – Sleeping Position

Troodontid *Mei long*



Furculum ("Wishbone")

Formed by fusion of clavicles, gradually changed from boomerang shape to wishbone shape

In birds, acts as strut or spring to resist compressional forces during flight stroke

Tyrannosaurus

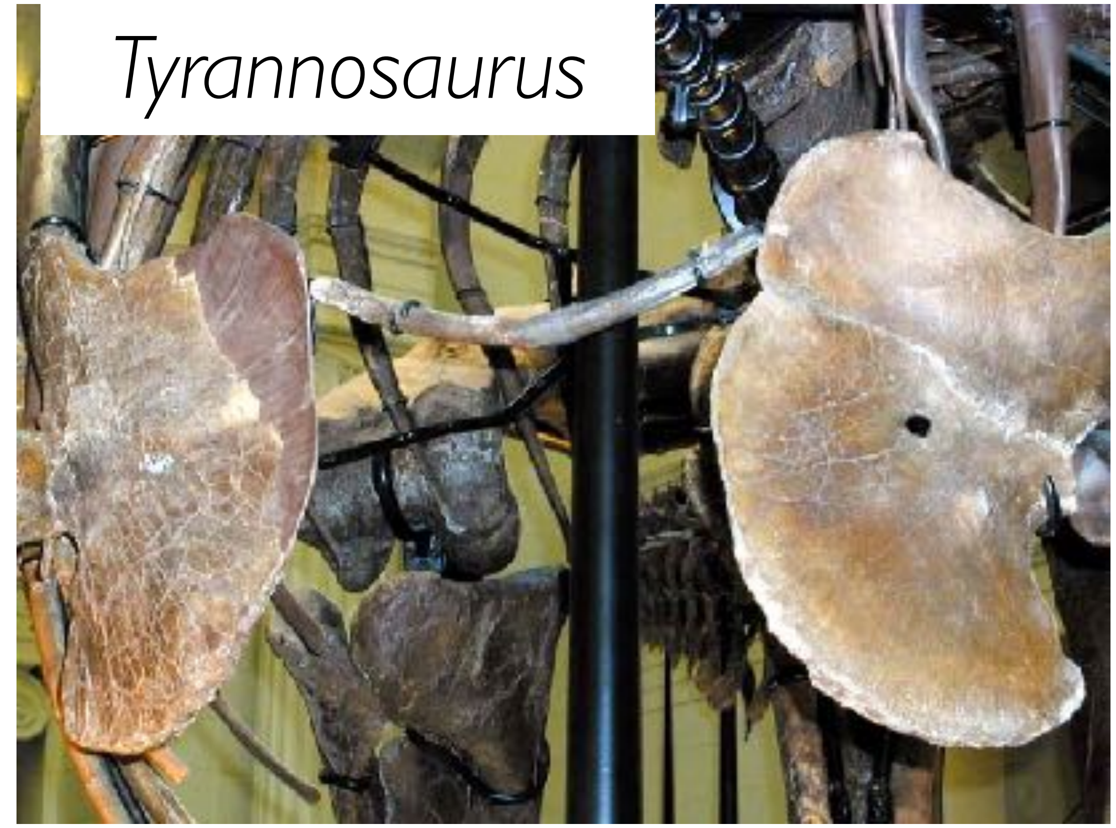
Archaeopteryx

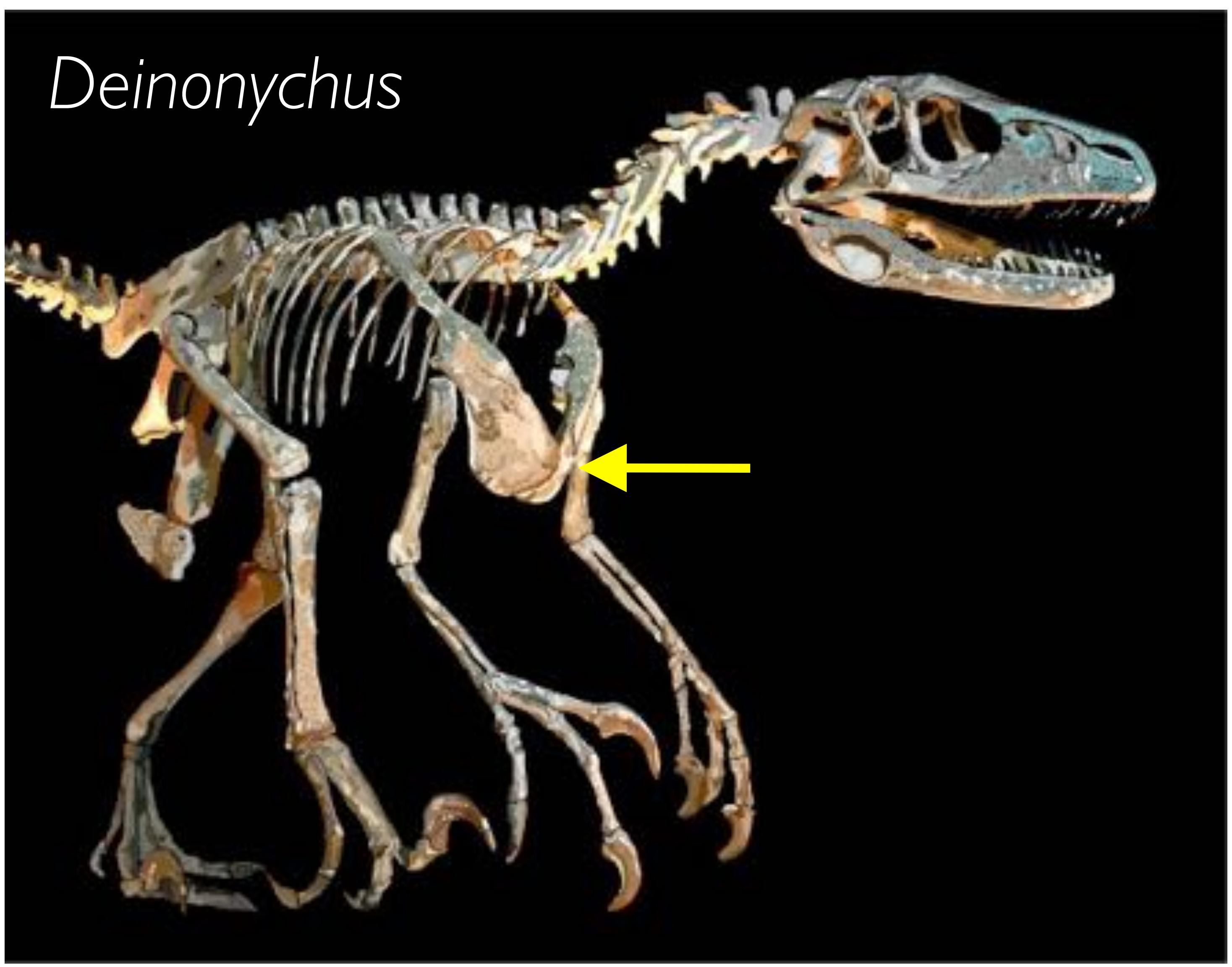
Turkey

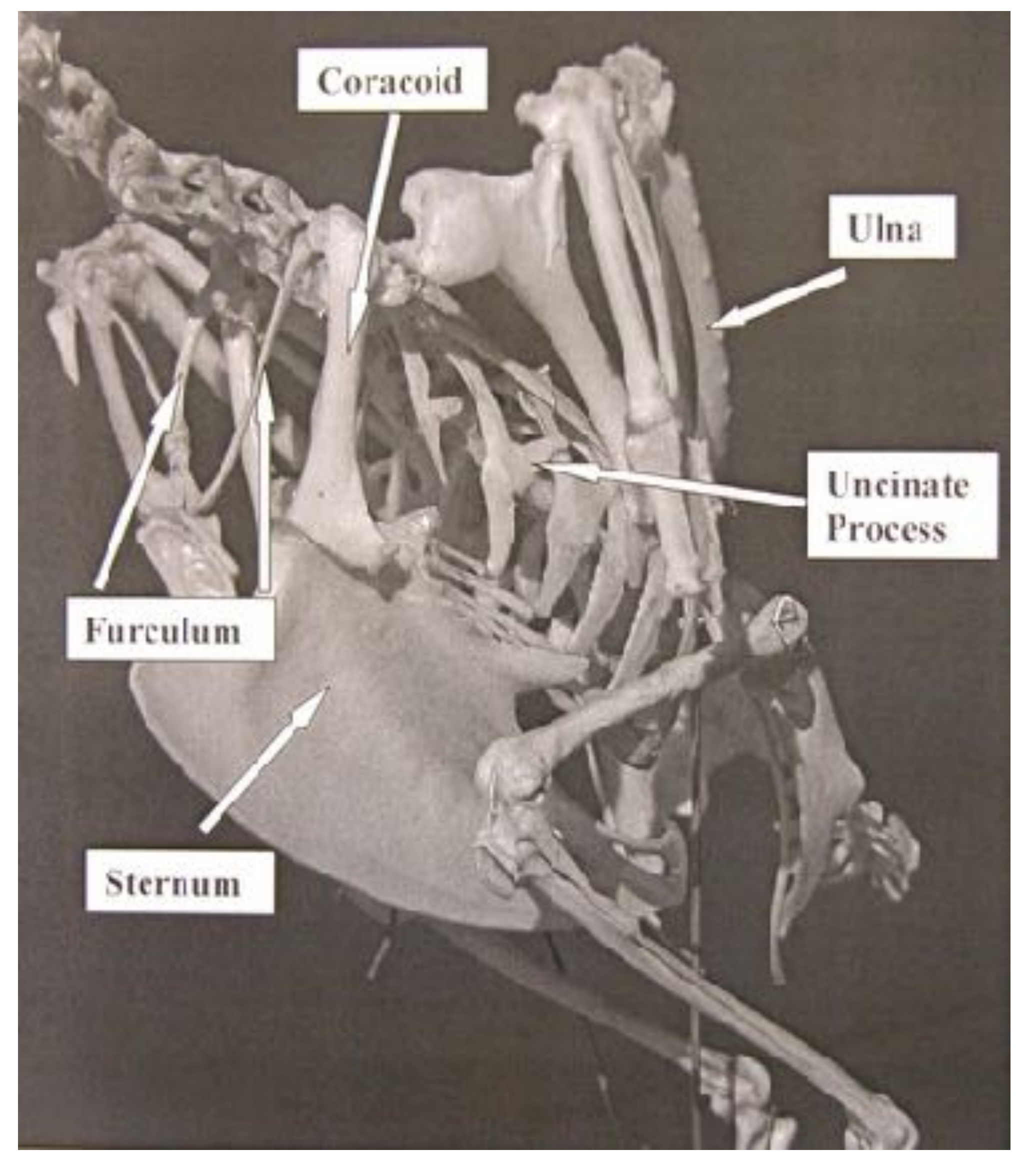
Fused Sternum

Pectoral girdle fused into large sternum in later theropods and birds

In birds, provides large attachment surface for flight muscles

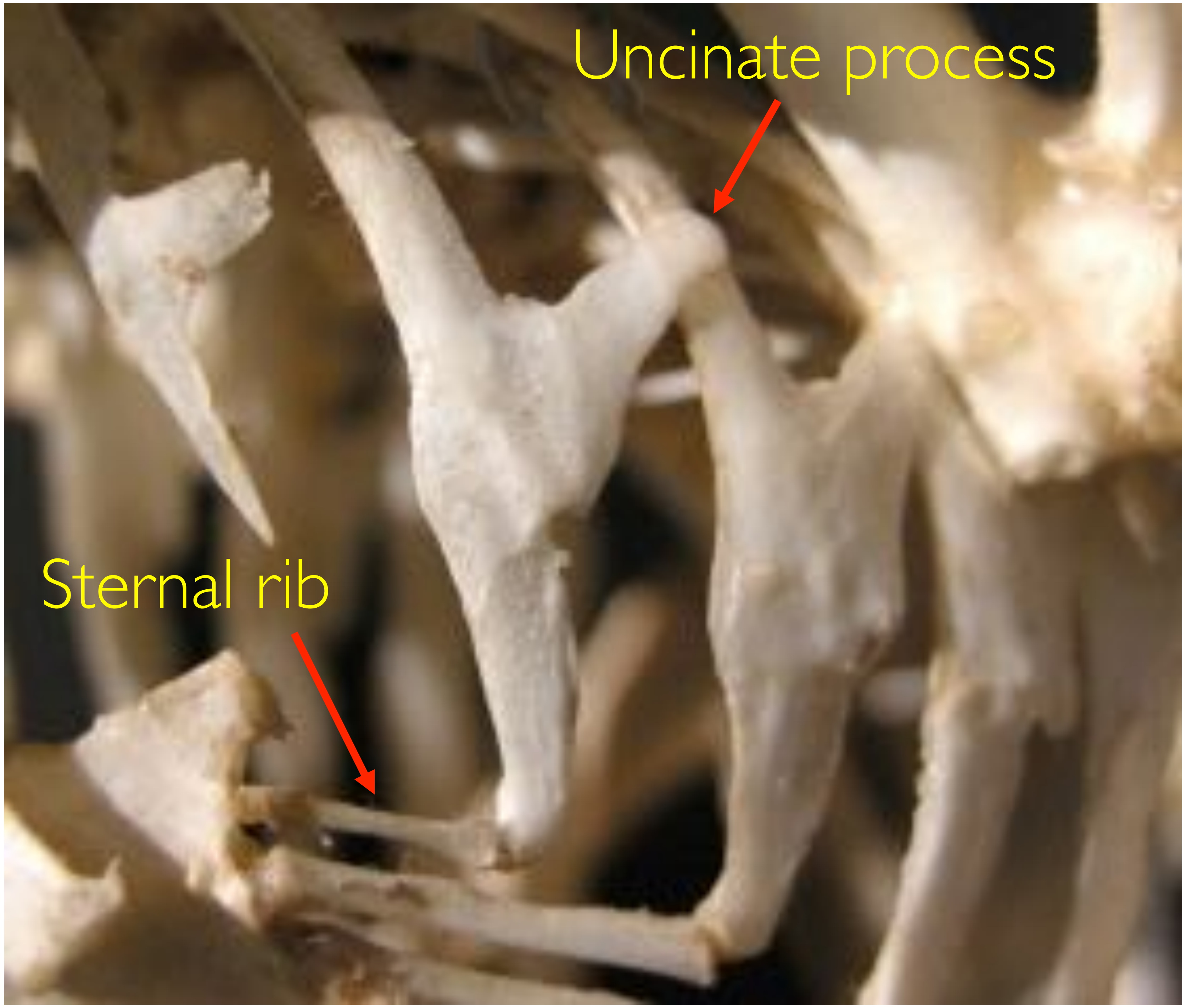






Ventral Ribs

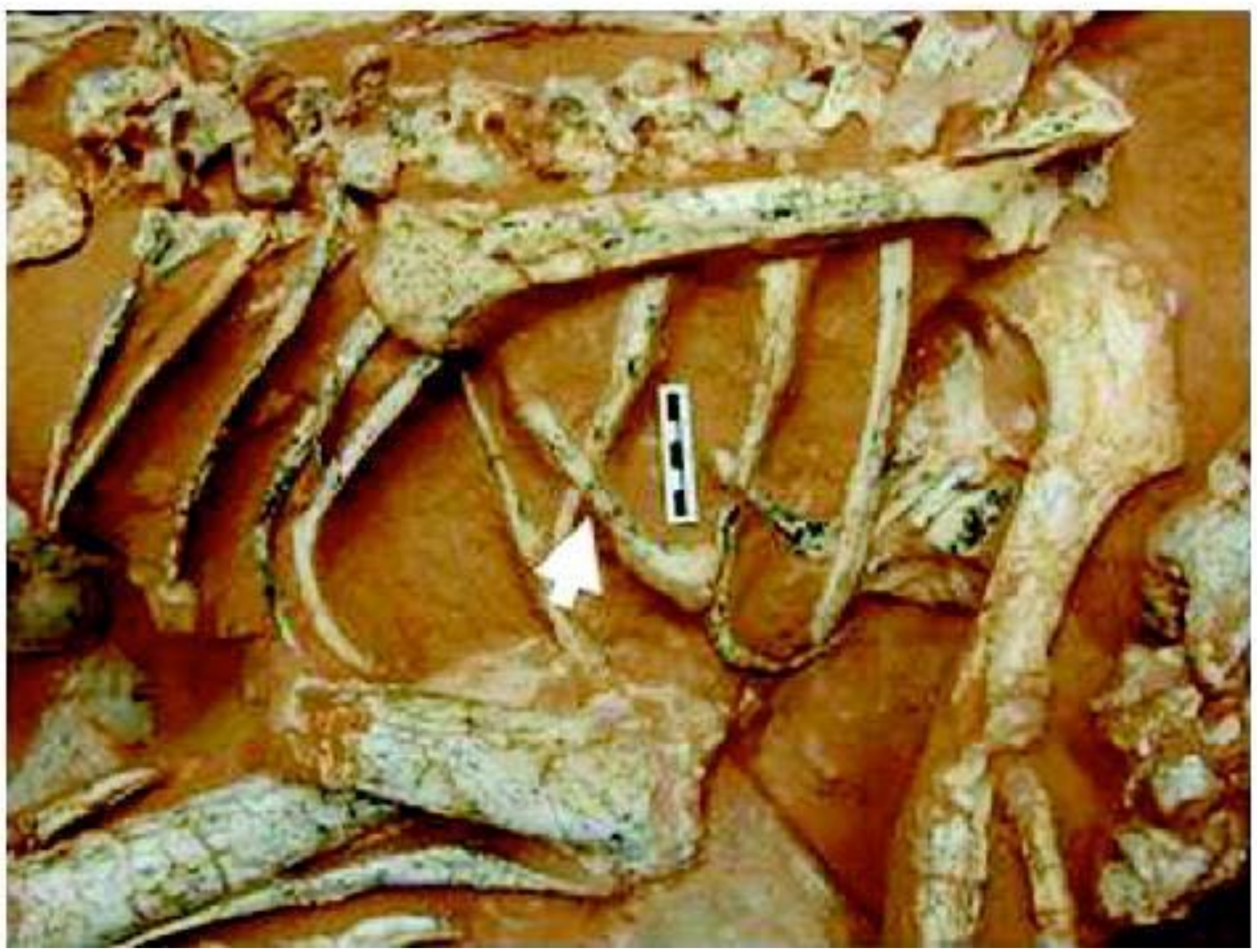
Theropods and birds have bony <u>sternal ribs</u> and <u>uncinate processes</u> connecting ribs



Uncinate Processes

In birds, prevent ribcage from being crushed during powerful flight stroke

An integral part of theropod and bird respiratory system

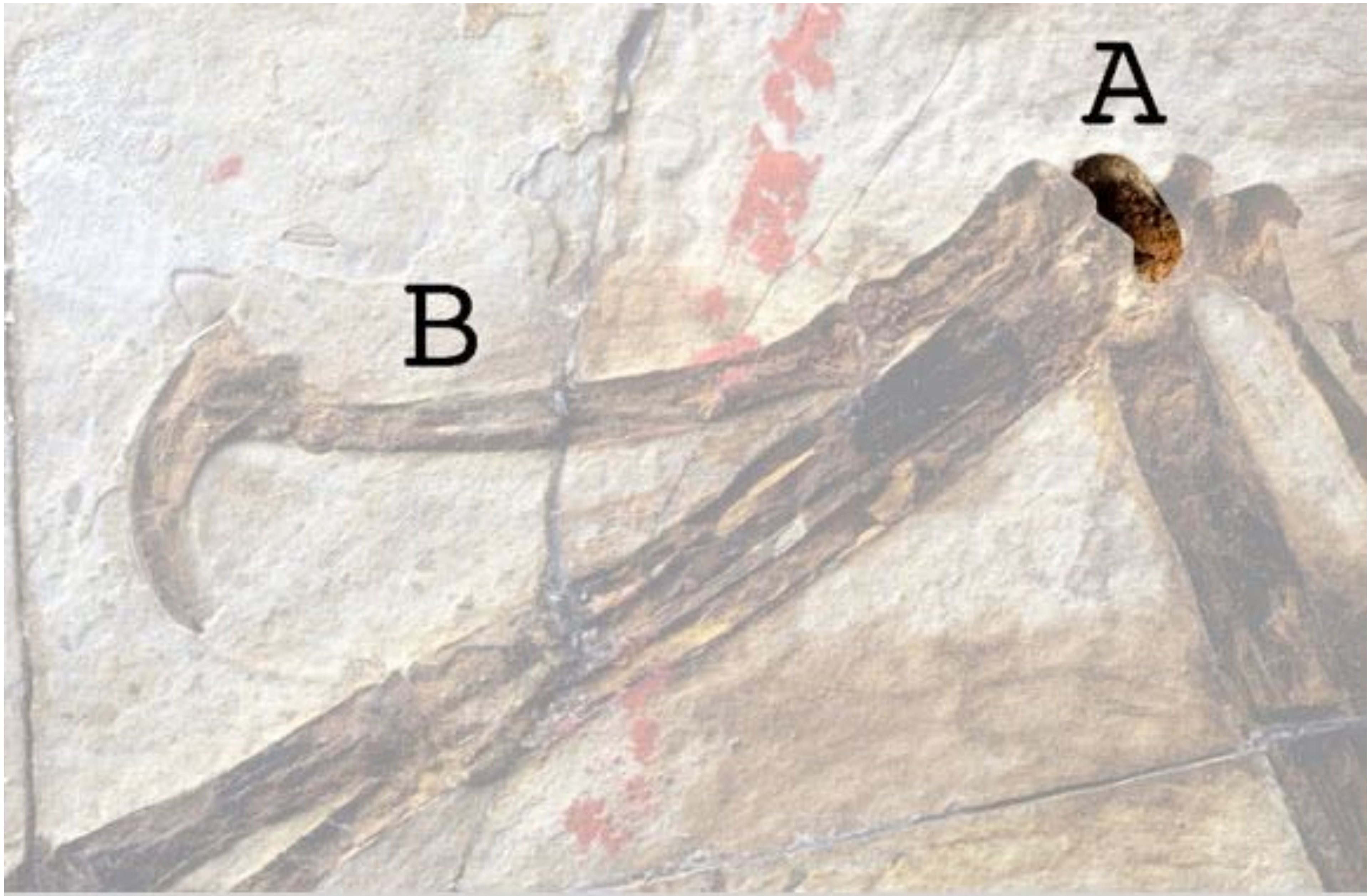


(e)

Semilunate Carpal

Half-moon shaped wrist bone first found in advanced theropods

Important for wing folding during avian flight stroke



A. Semilunate wrist bone **B.** First finger

Integument – Feathers

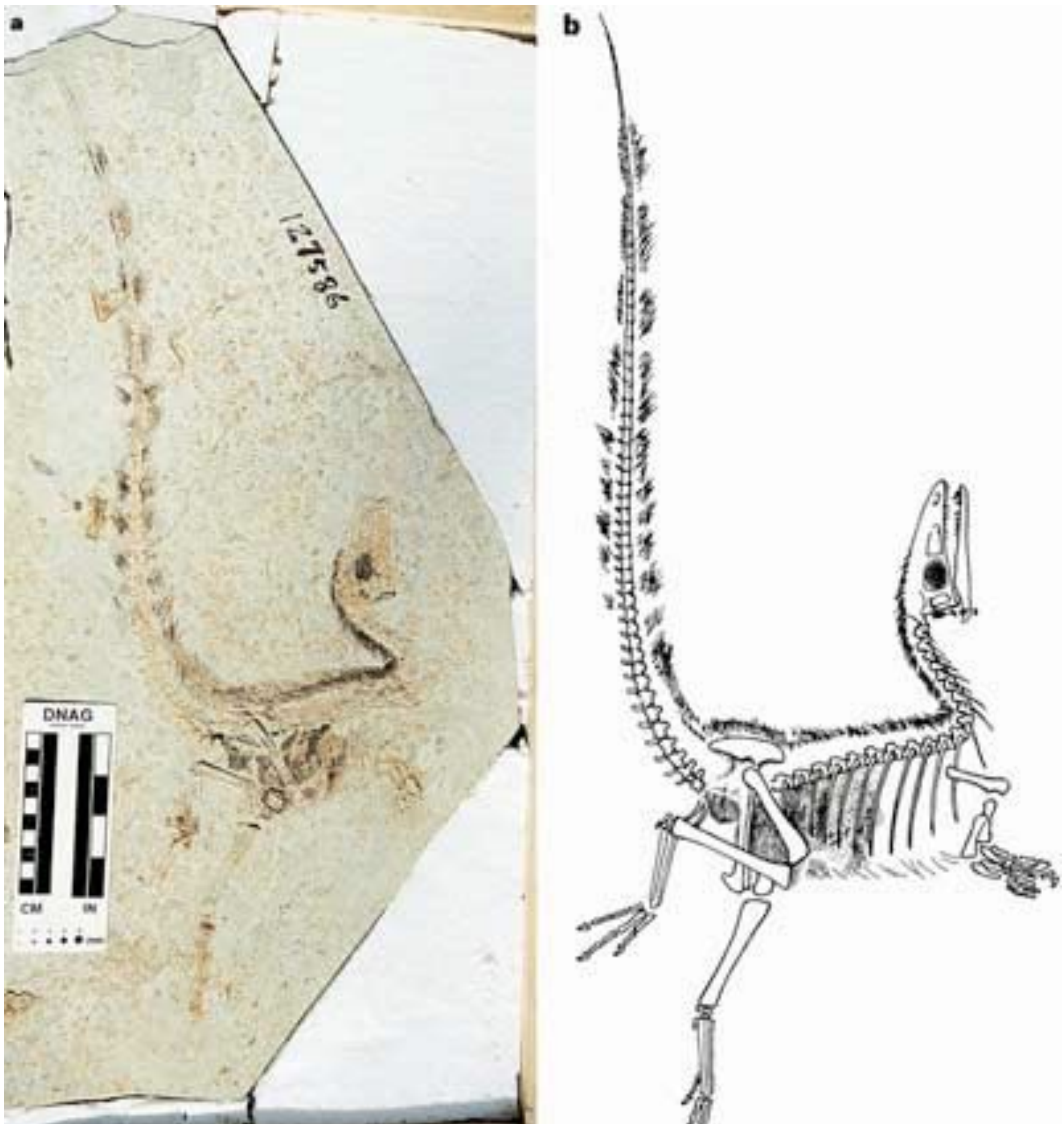
Animals with feather MUST be endothermic.

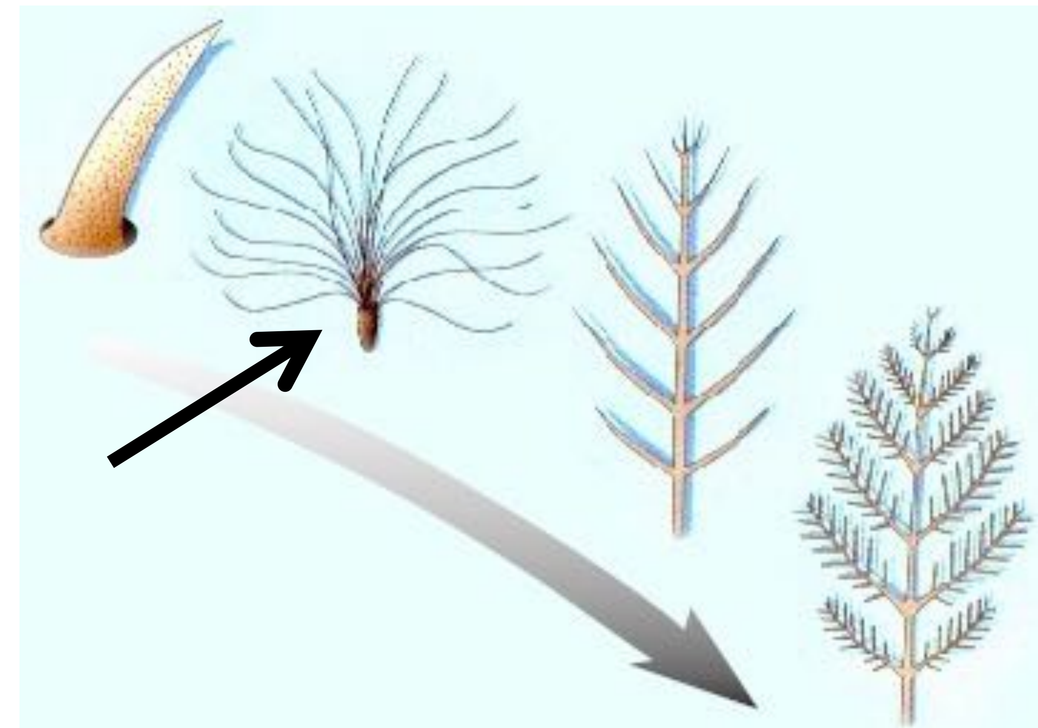
Logic: If you require external heat, why would you insulate yourself?

No ectothermic animals have insulation

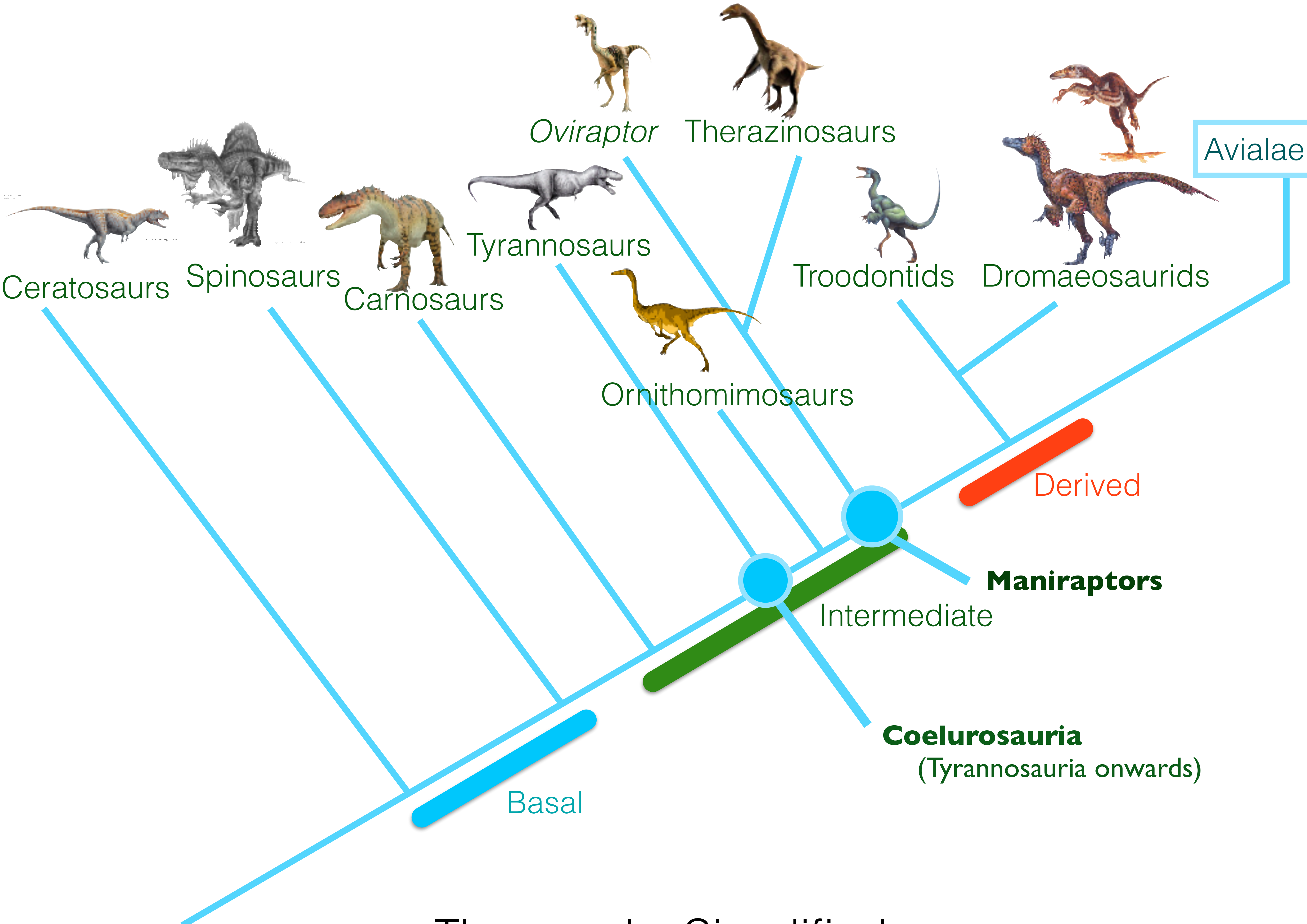
Integument – Feathers

Feathers first evolved in non-avian theropods





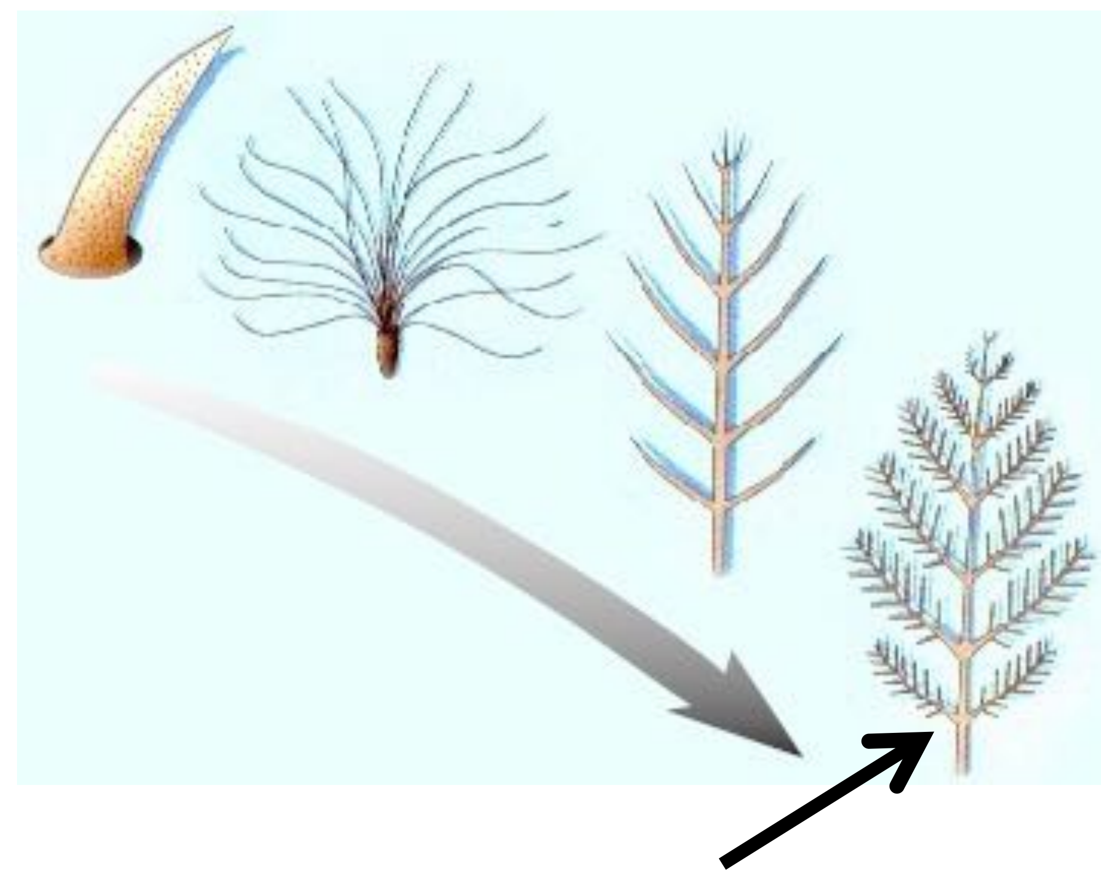
Downy (plumulaceous) feathers in coelurosaurians like *Sinosauropteryx* and tyrannosaurs

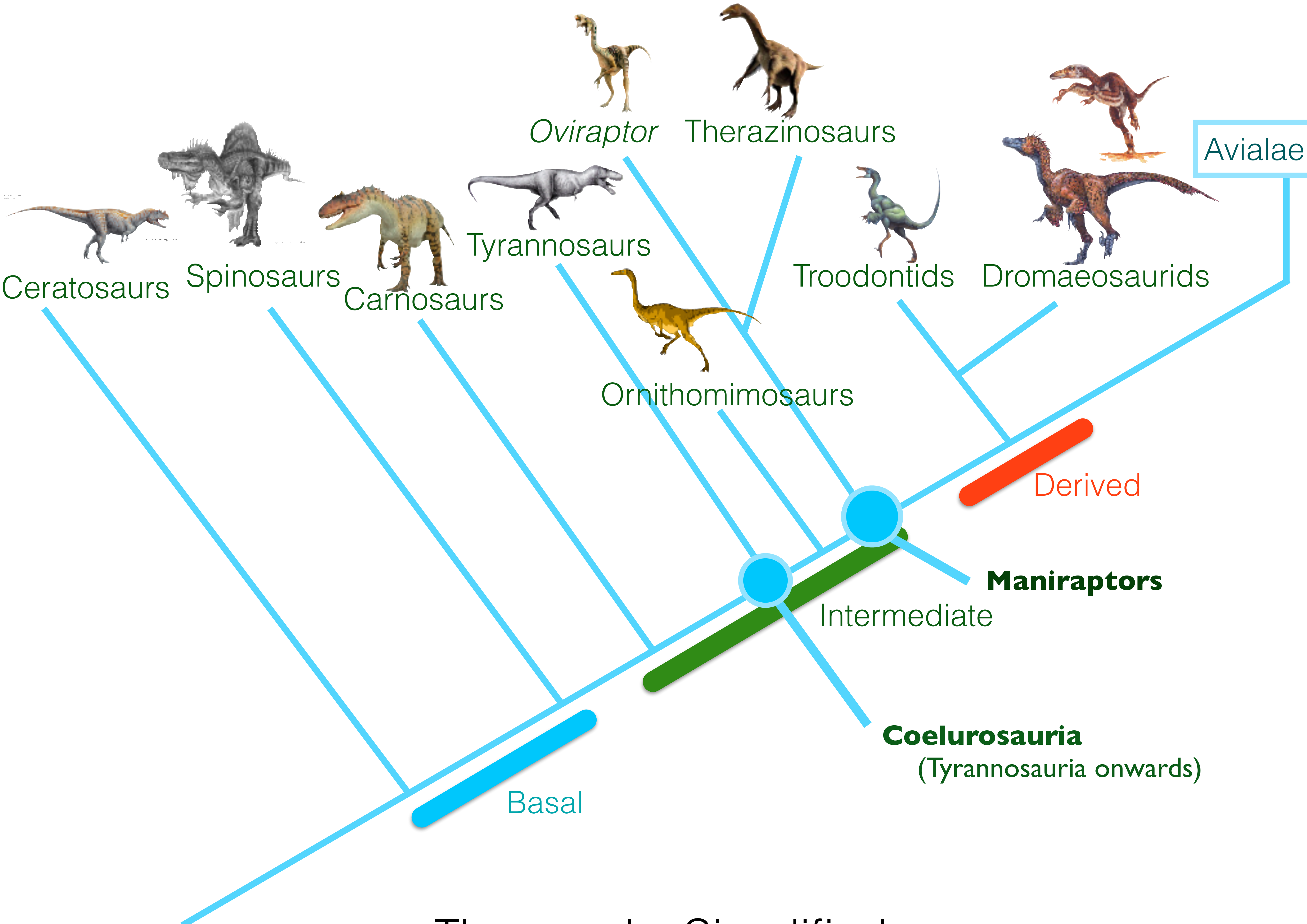


Theropods: Simplified

Integument – Feathers

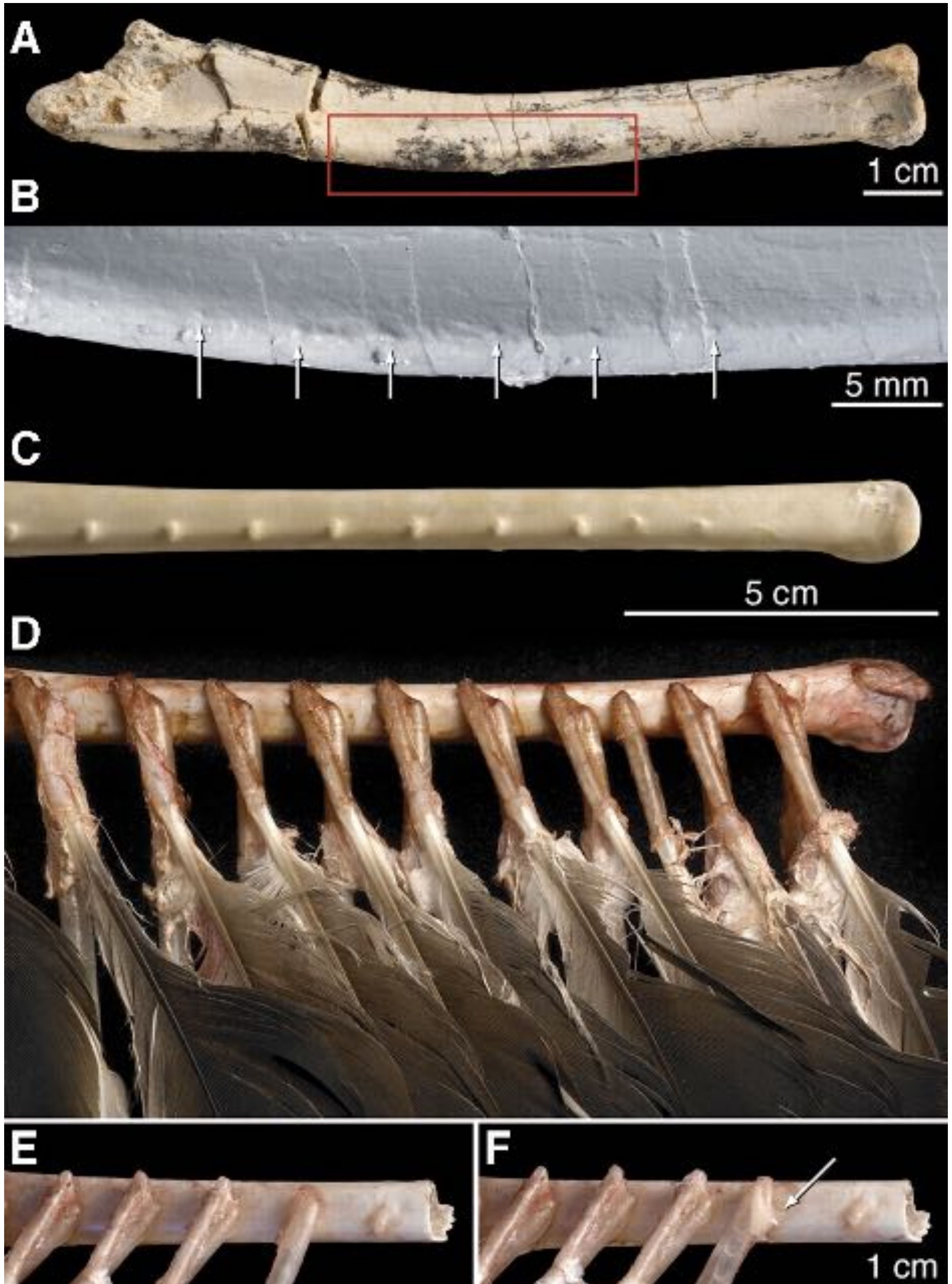
Vaned (pennaceous) feathers in maniraptorans (oviraptorids, troodontids, dromaeosaurs) like *Microraptor*





Theropods: Simplified

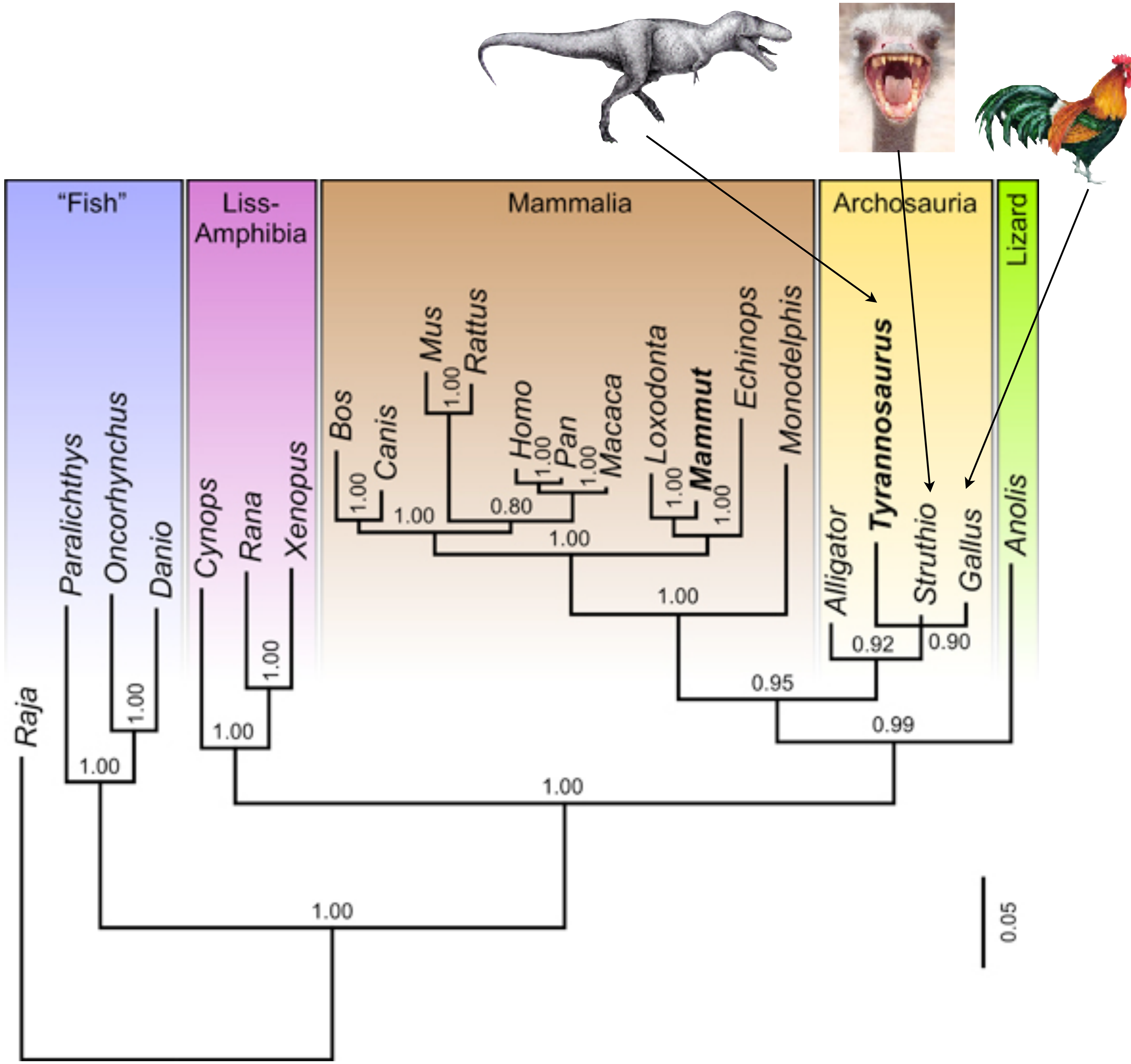
Integument – Feathers

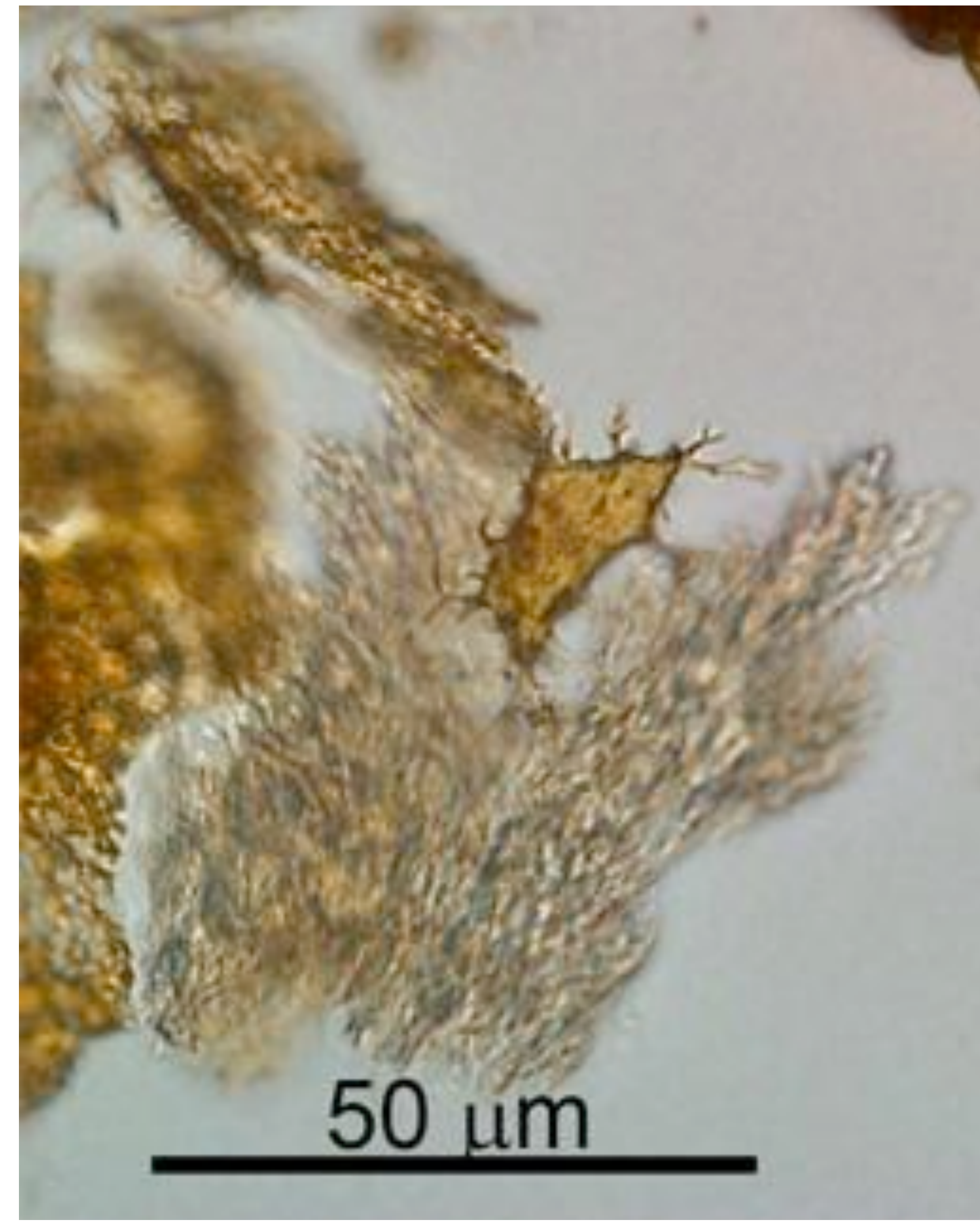


Even theropods such as *Velociraptor* had feathers

Quill knobs on ulna (lower arm bone) indicate attachment sites for large vaned feathers

Molecular Evidence: Amino Acid Sequences





Collagen: a protein coded by a sequence of amino acids

Compare collagen amino acid sequences across many different lifeforms and group by similarity!

Dinosaurs... tastes like chicken...

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

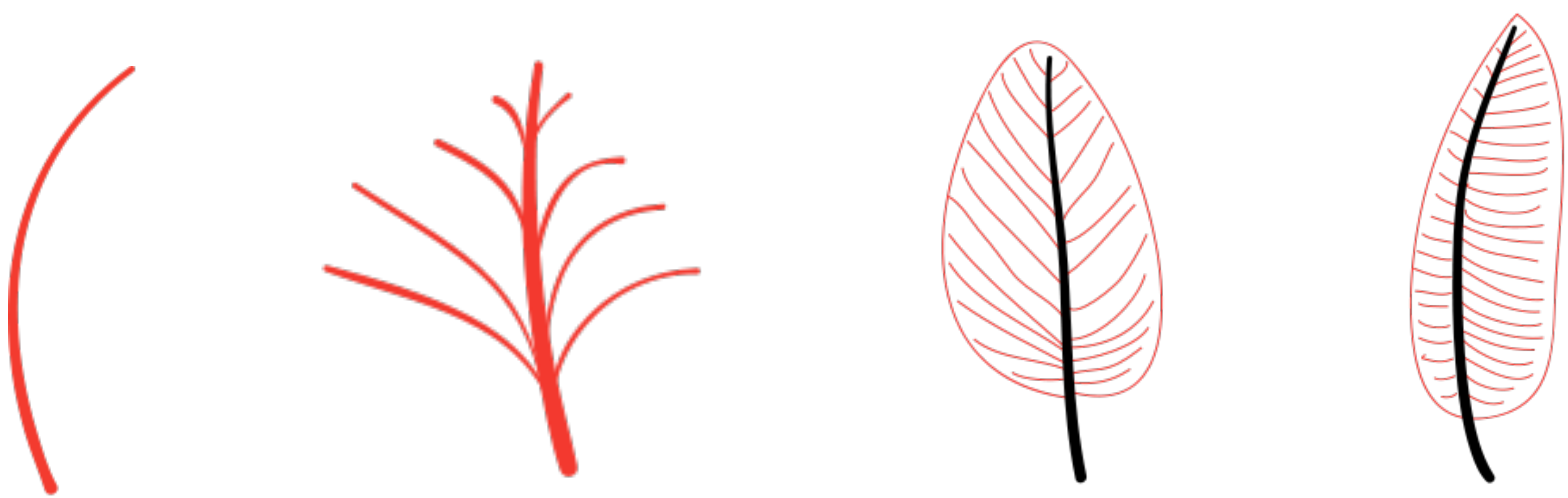
Did feathers and pneumatic bones evolve for flight? Obviously not… evolved long before flight

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

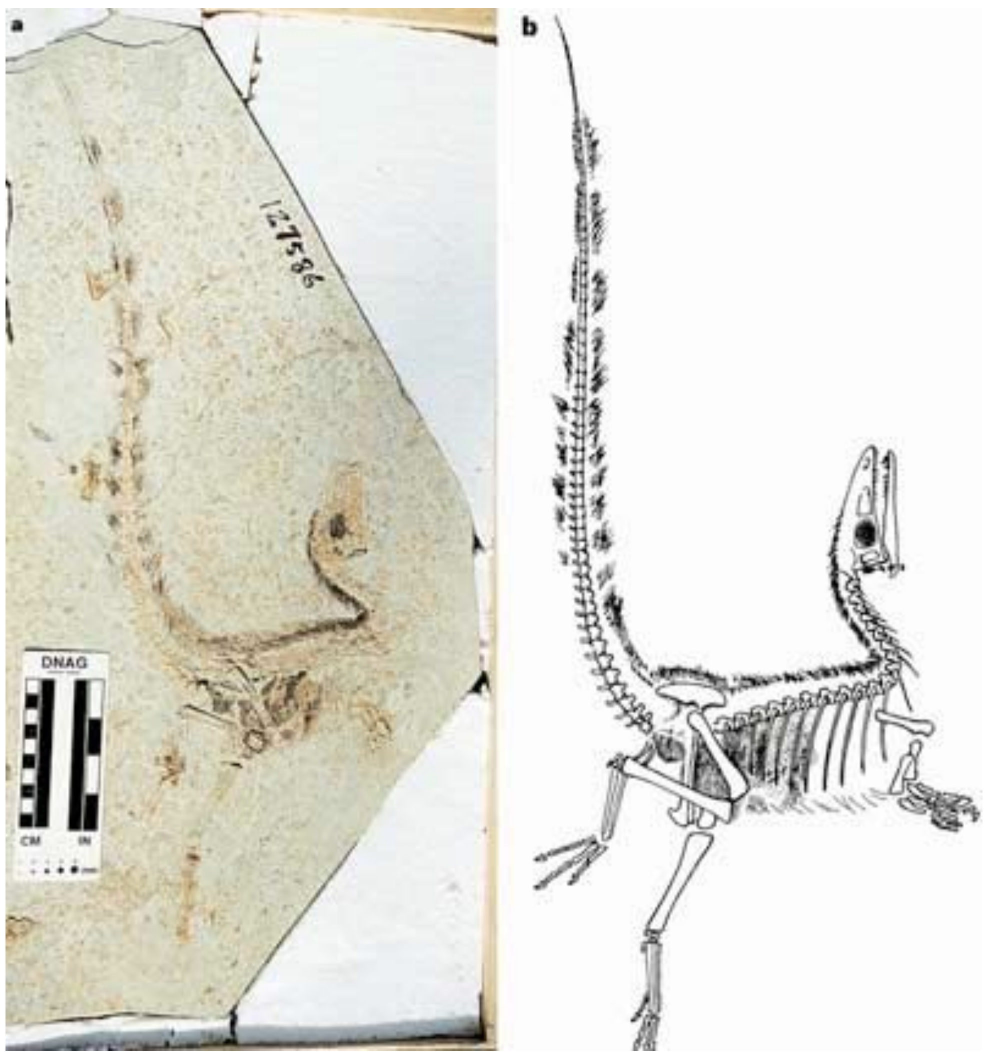
Formation of loosely connected, unhooked, barbs

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



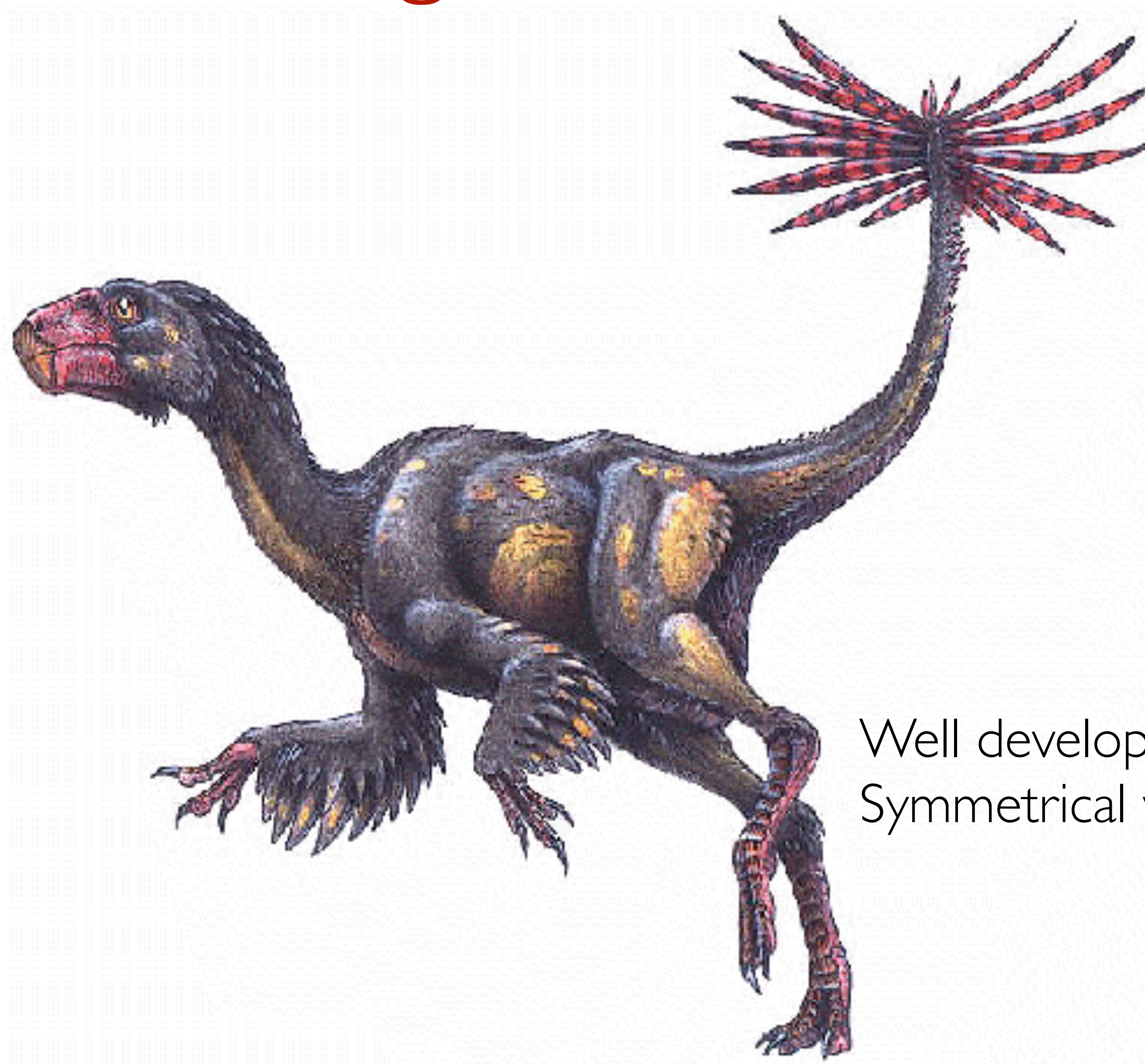
Covered in barbed filaments

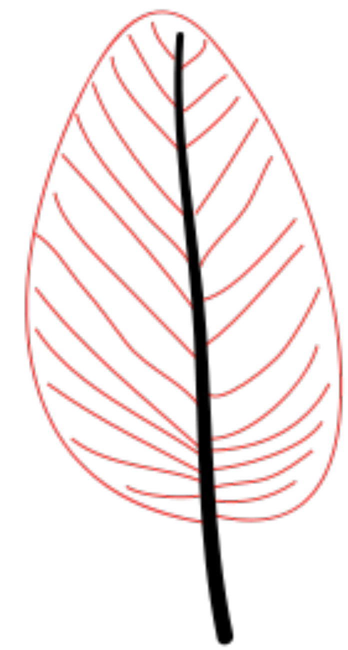
Sinosauropteryx:

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

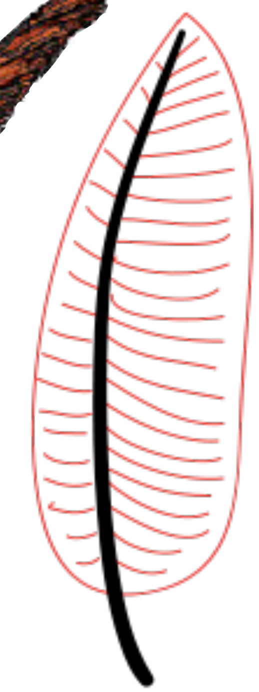
Covered in barbed filaments

Beipiaosaurus

Ostrich-sized Therizinosauroid

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

Paleontological Evidence



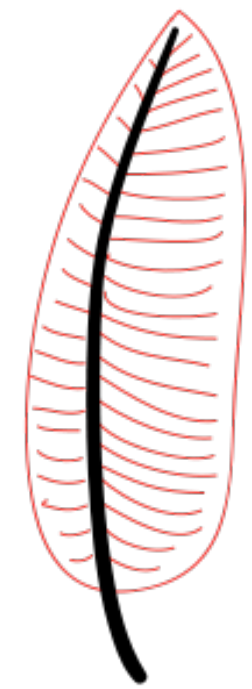
Bird-like Feathers

Sinornithosaurus

non-flying Deinonychosaur

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

Paleontological Evidence

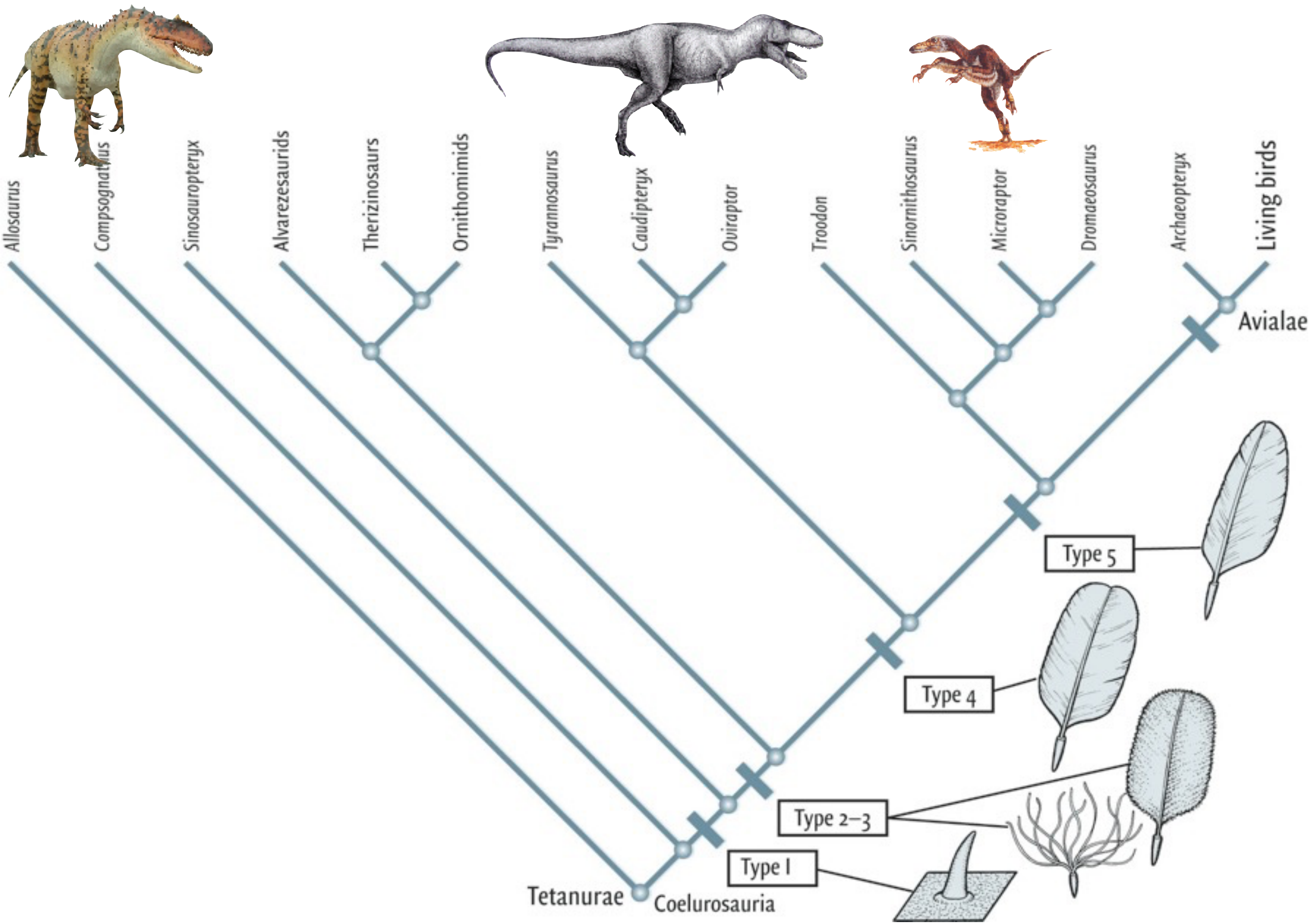


Bird-like Feathers

Microraptor

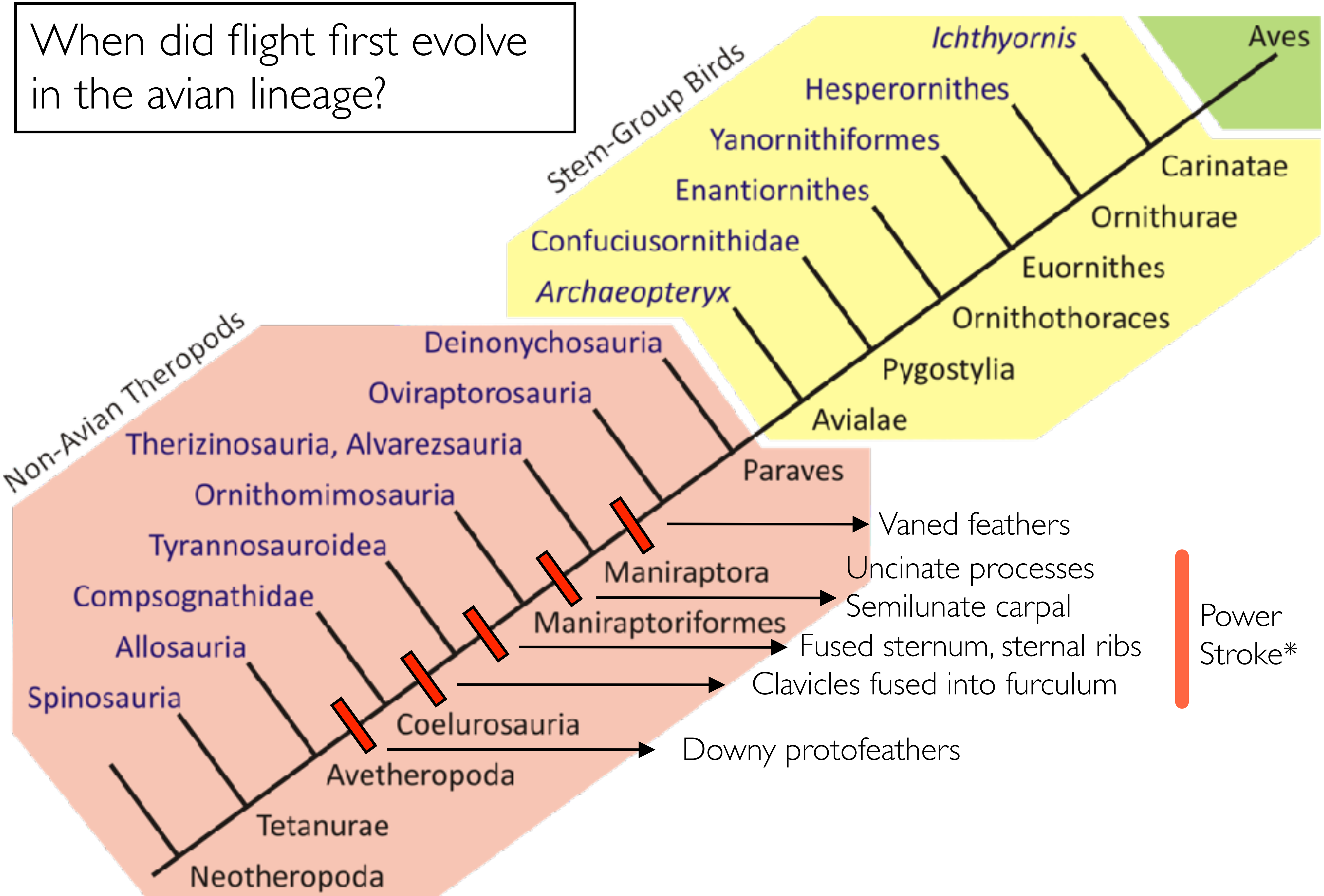
flying *Deinonychosaur*


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?

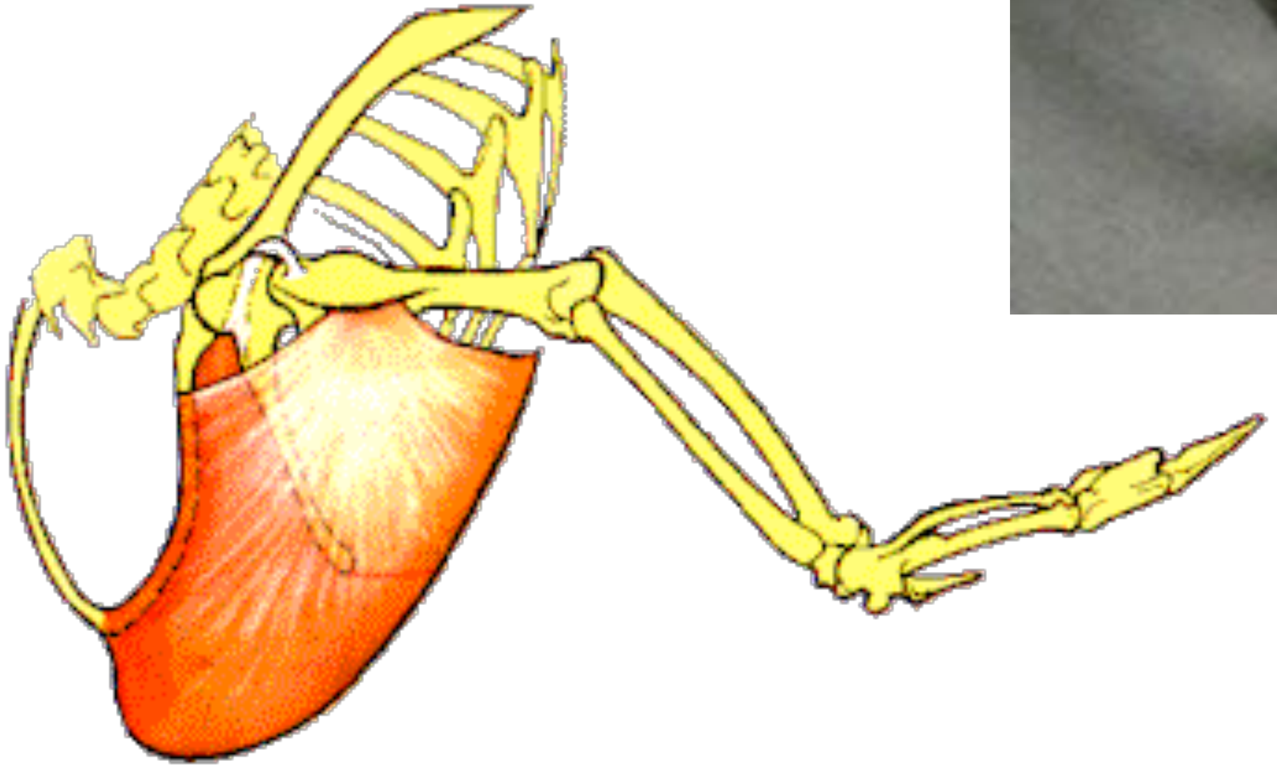


*Not necessarily for flight

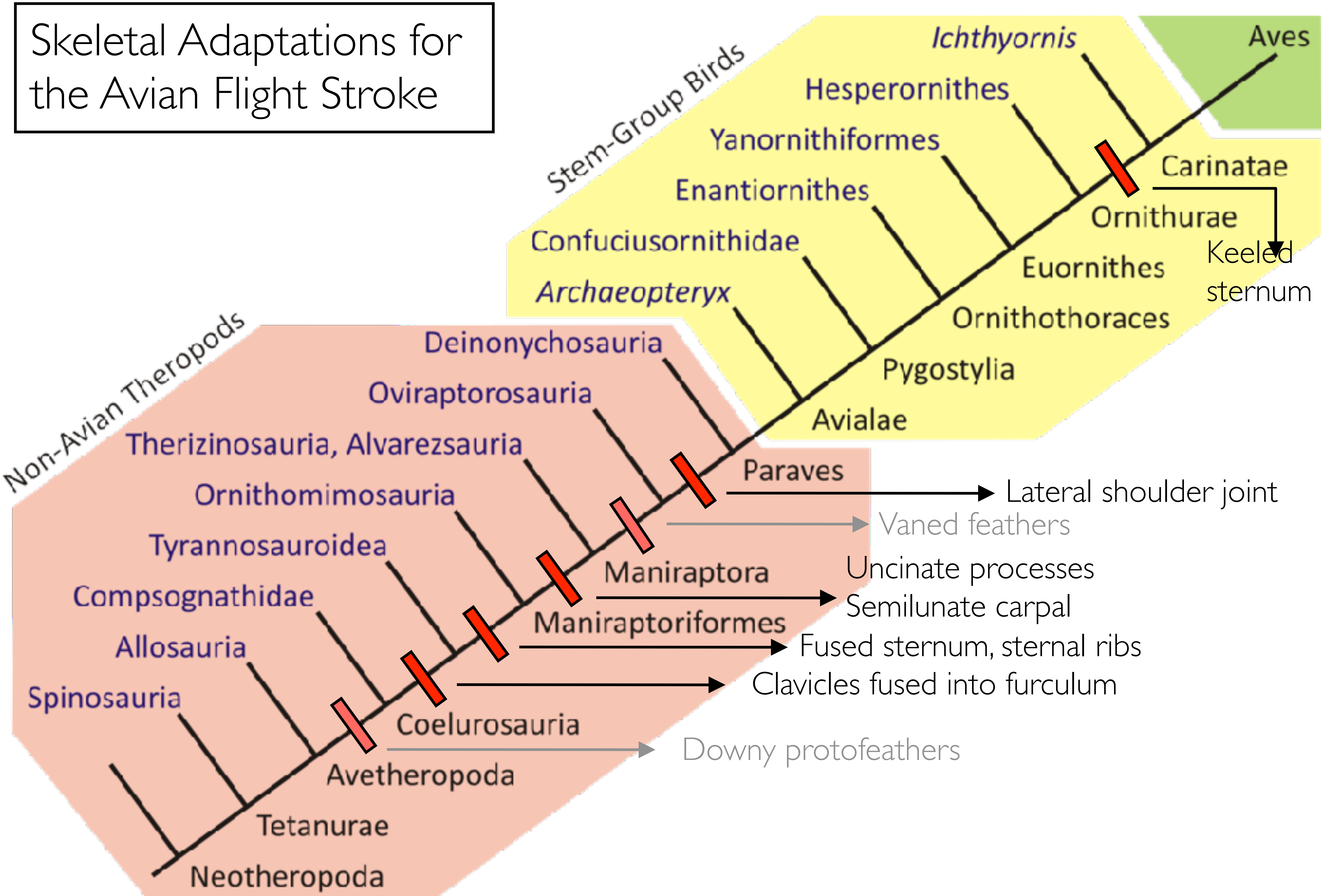
Flight Muscle Attachment

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

Keeled sternum provides large attachment site for maximum power

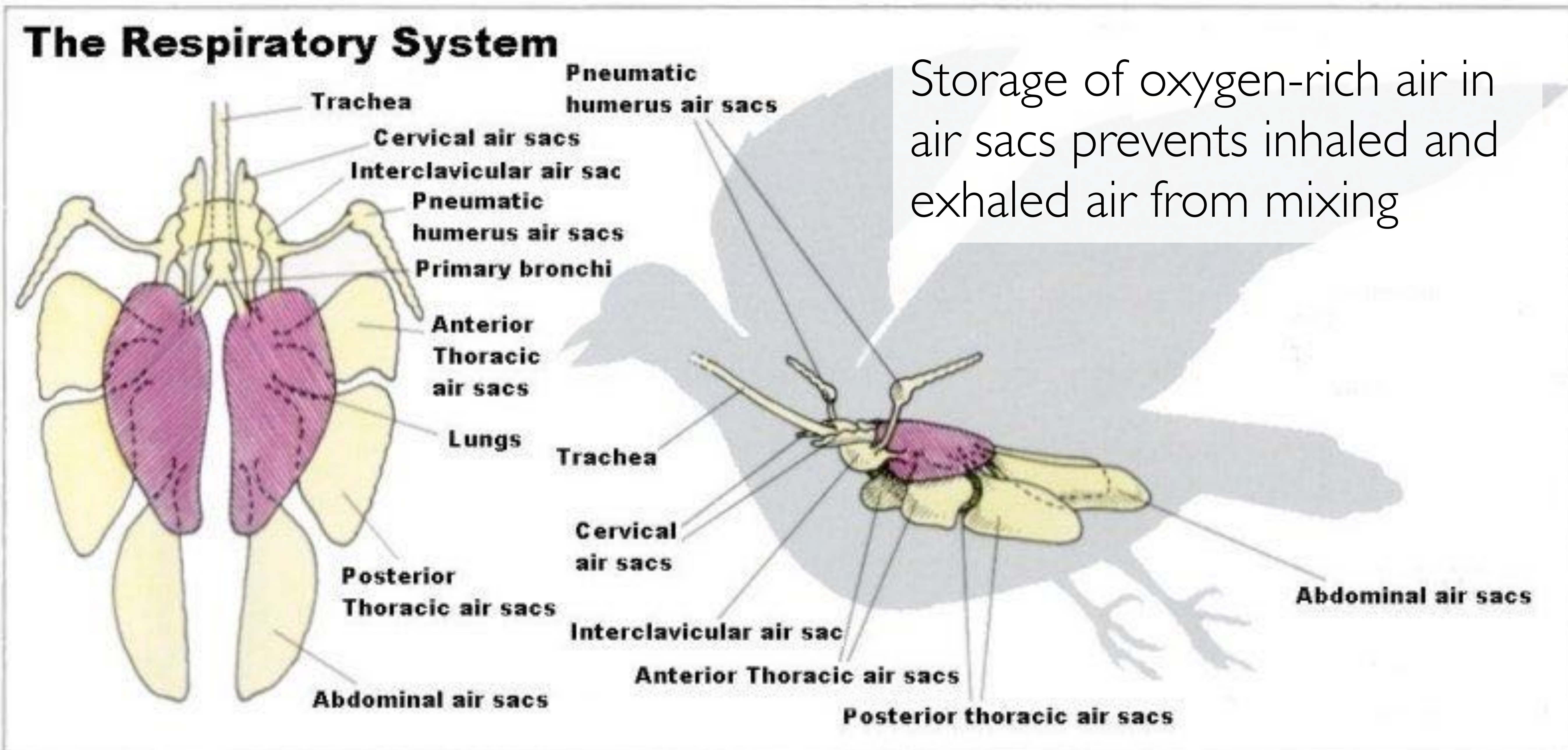


Skeletal Adaptations for the Avian Flight Stroke



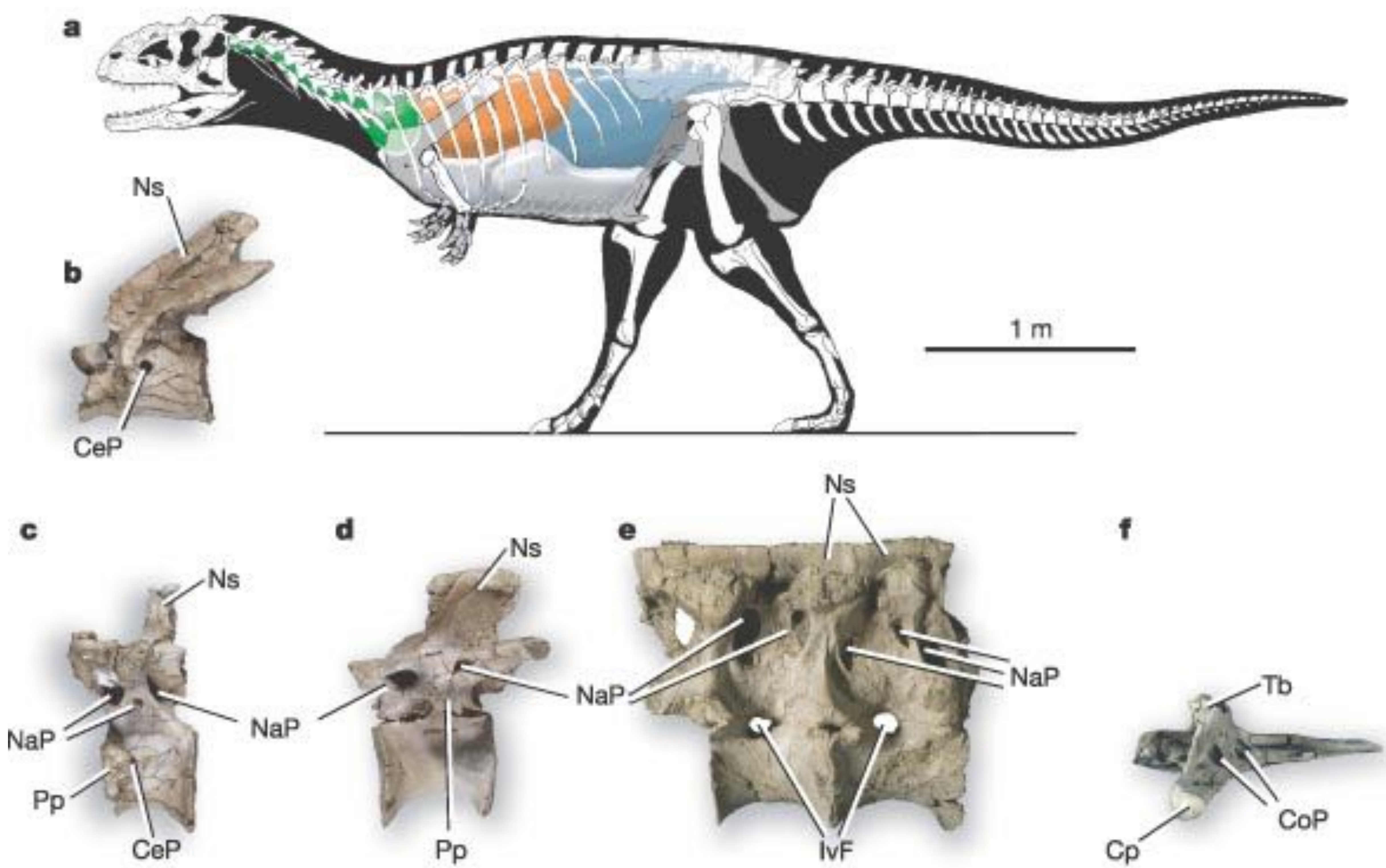
Avian Respiratory Adaptations

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

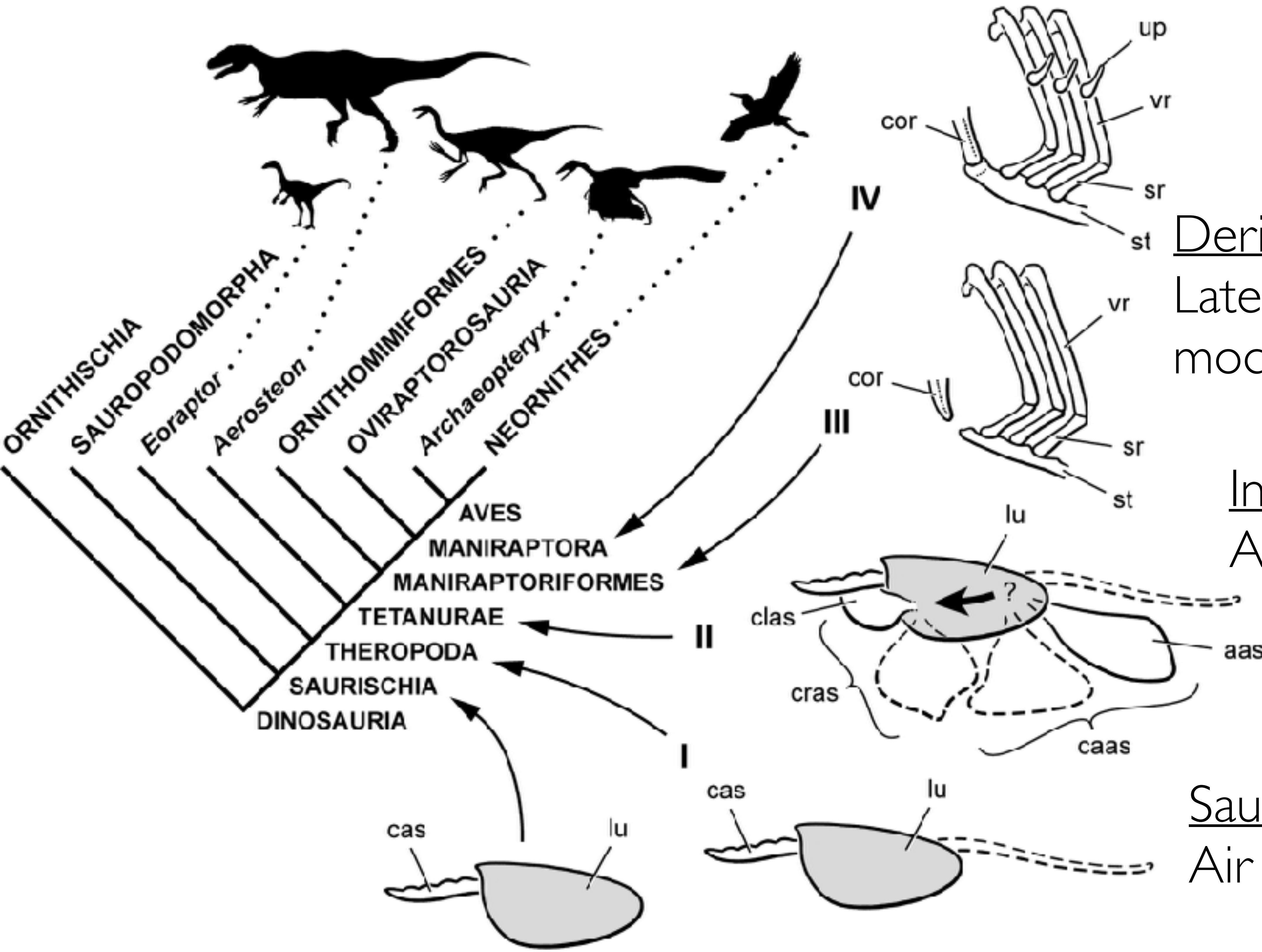


Storage of oxygen-rich air in air sacs prevents inhaled and exhaled air from mixing

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)

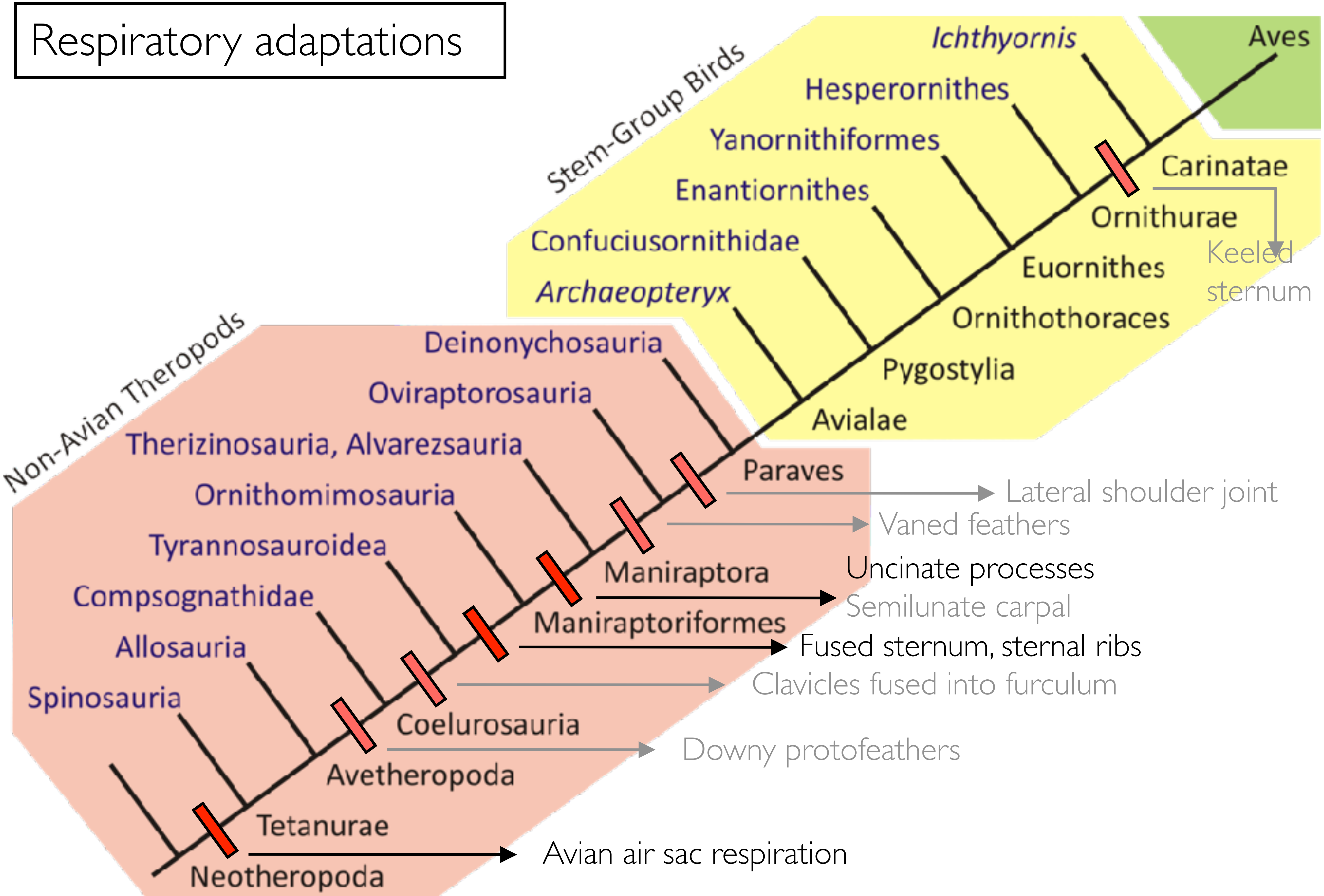


<u>Derived Theropods:</u>
Later rib cage modifications

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

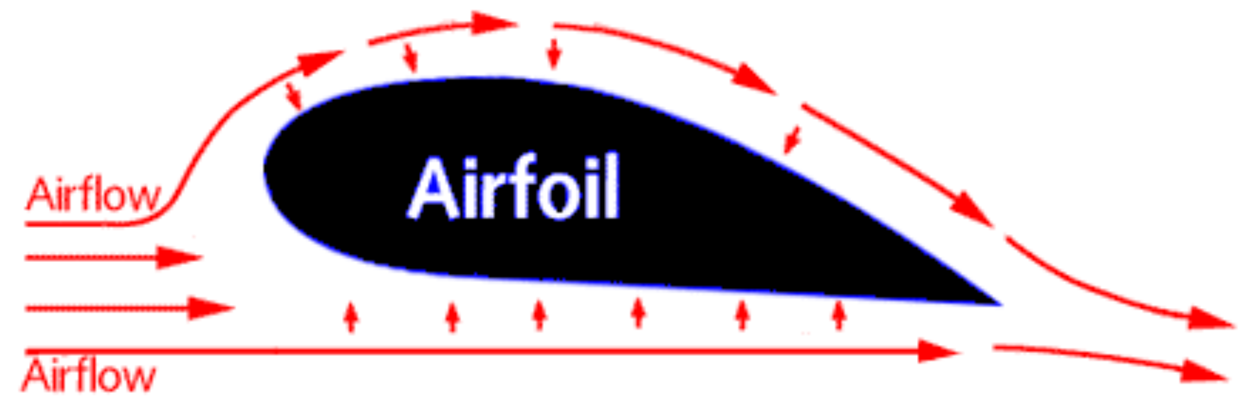
<u>Saurischia:</u>
Air sacs present

Respiratory adaptations



Adaptations for Low-Speed Flight

Bird wings are airfoils that generate lift proportional to the airspeed

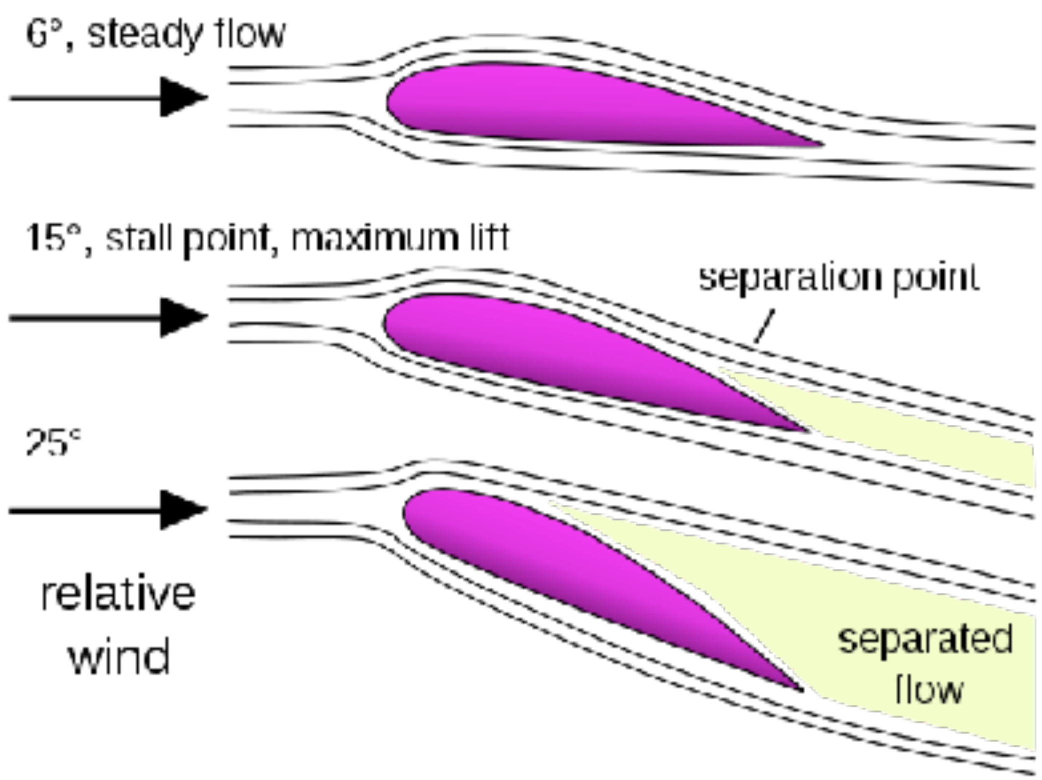


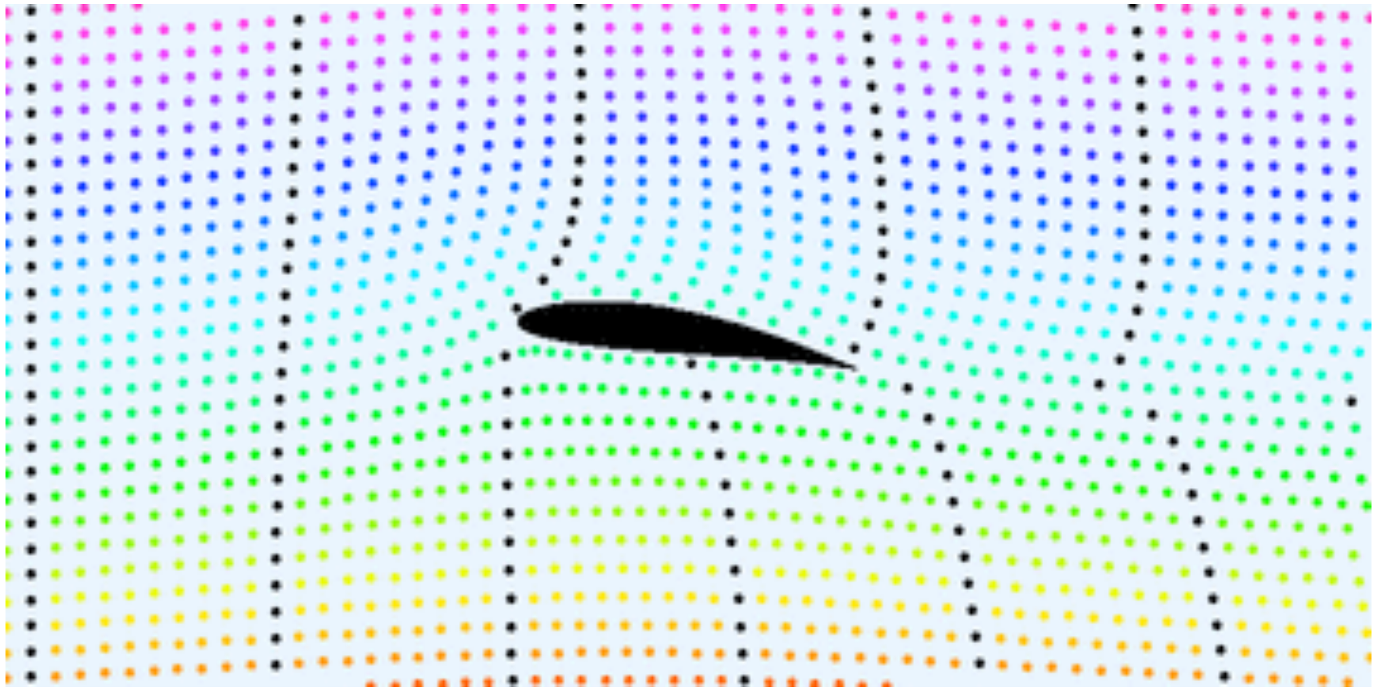
But birds also need to be able to generate lift at relatively low speeds for takeoff and landing

Lift is also a function of:

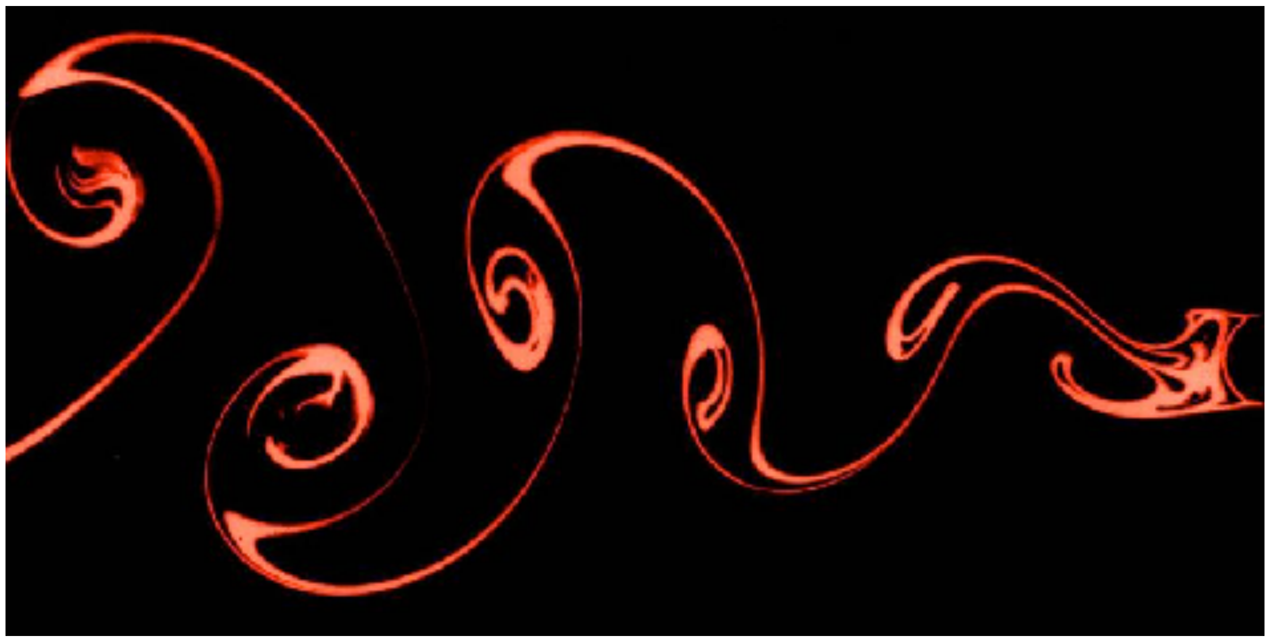
1) Wing area — Difficult for bird to change
2) Wing curvature (camber) — Difficult for bird to change
3) Angle of attack (tilt of the wing relative to the airflow)

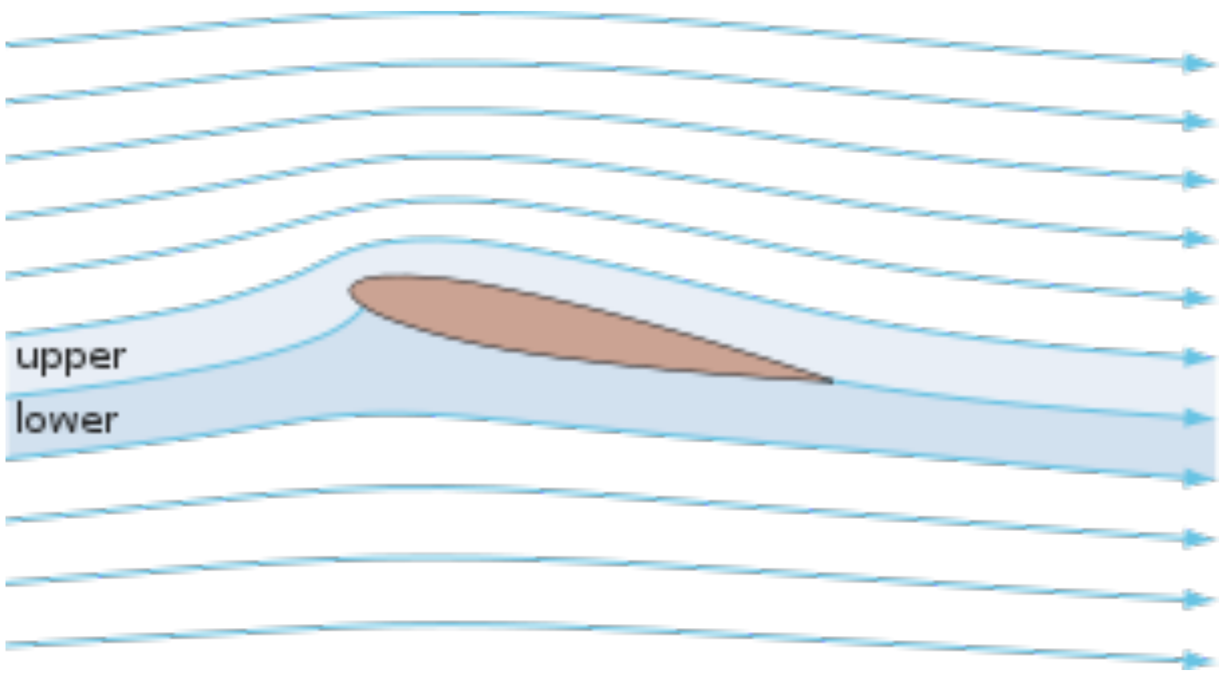
But increasing the angle of attack too much will lead to flow separation, creation of wing vortex, and stalling (abrupt loss of lift)



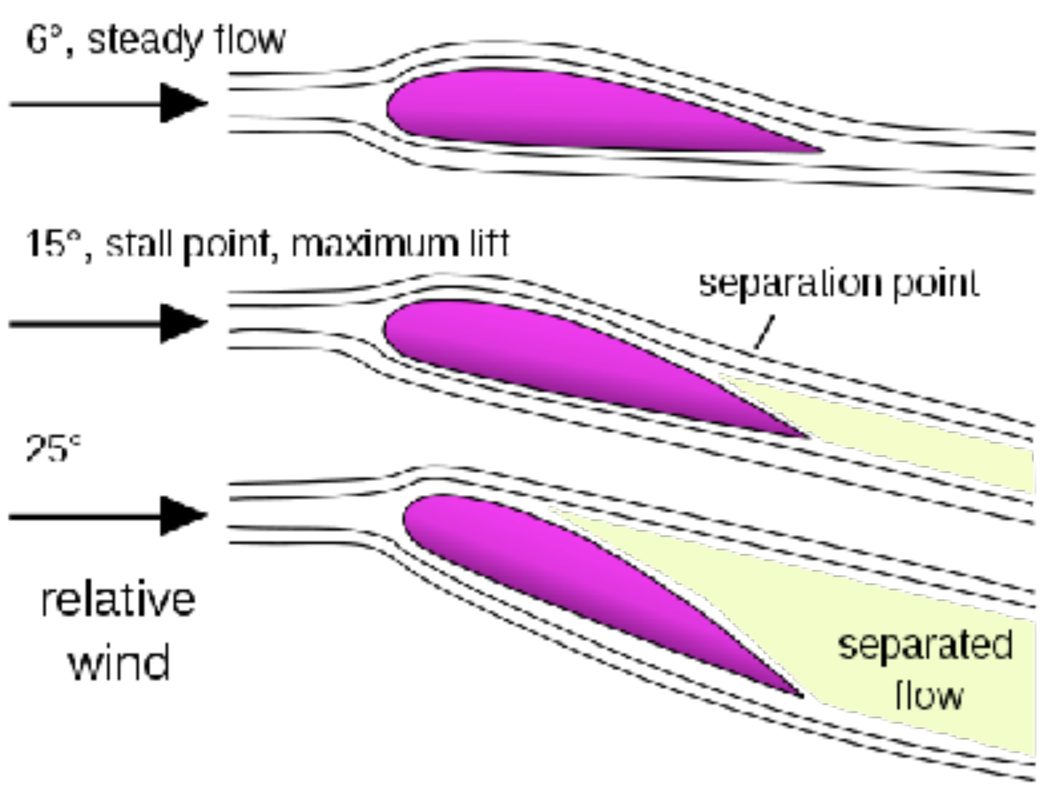


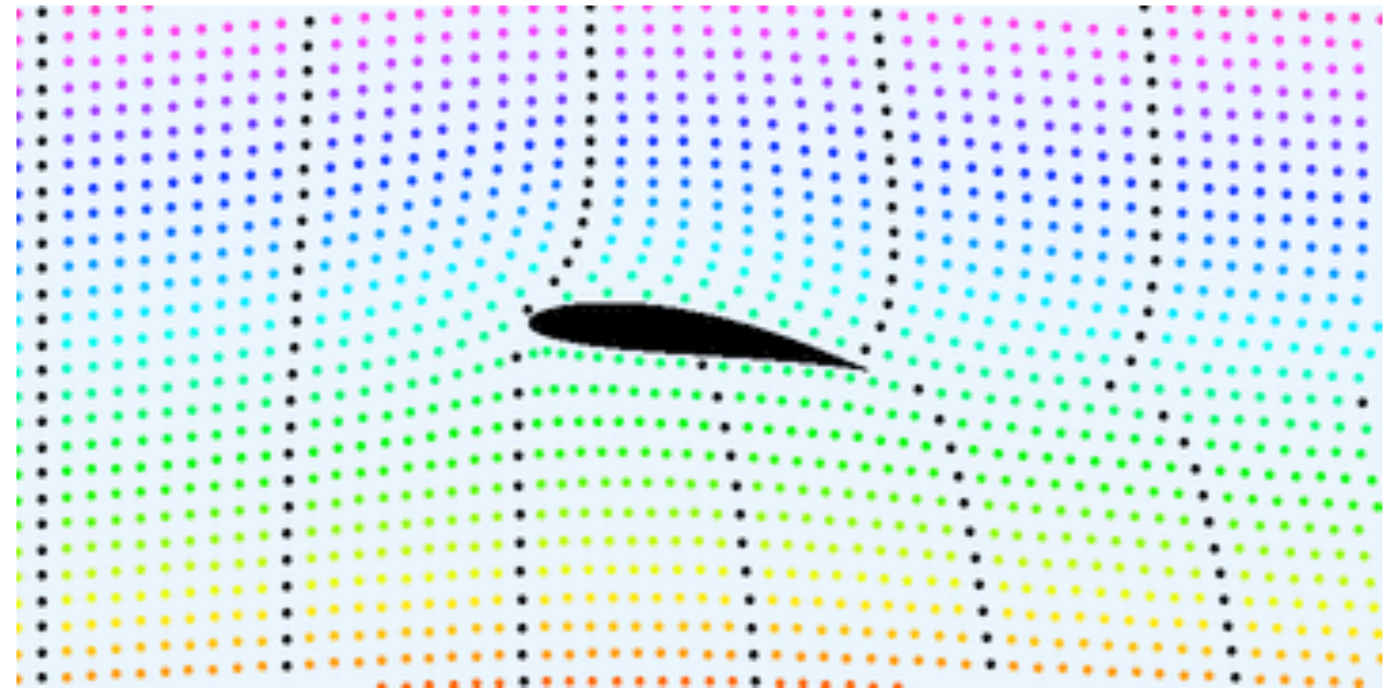
High velocity, low pressure;
Low velocity, high pressure



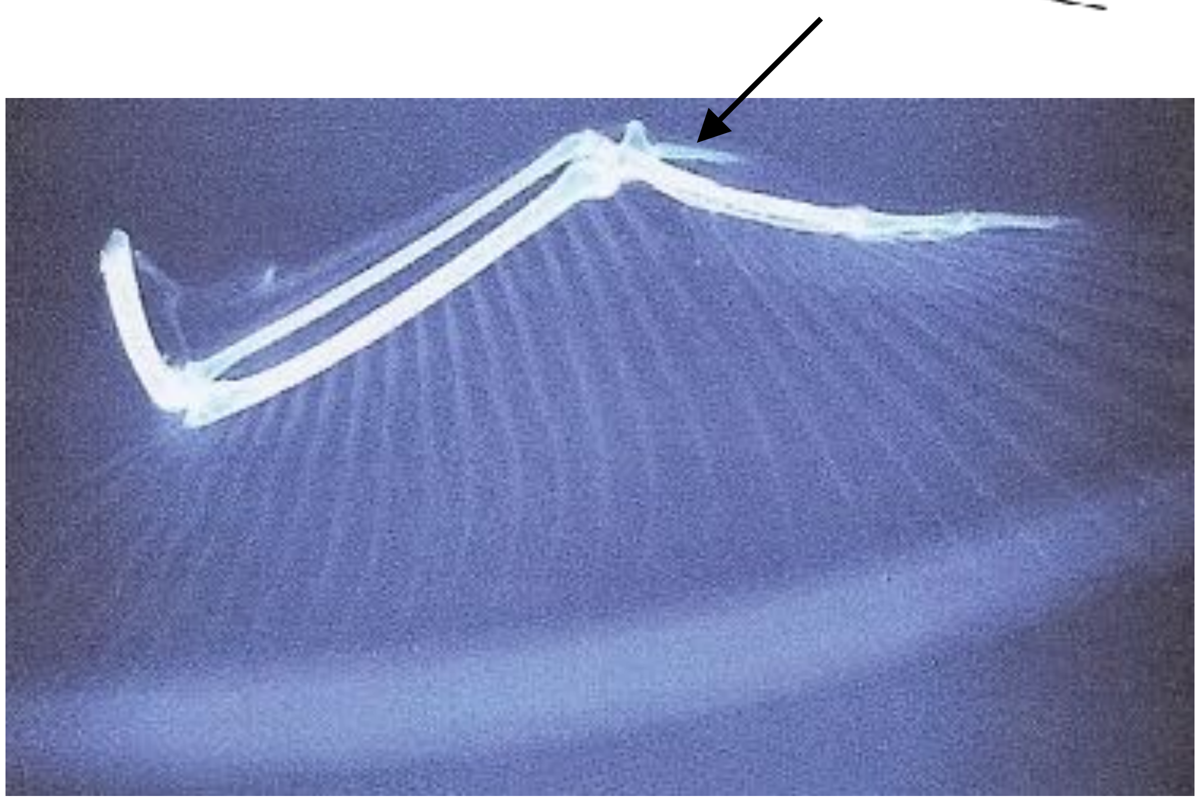


But increasing the angle of attack too much will lead to flow separation, creation of wing vortex, and stalling (abrupt loss of lift)





High velocity, low pressure;
Low velocity, high pressure



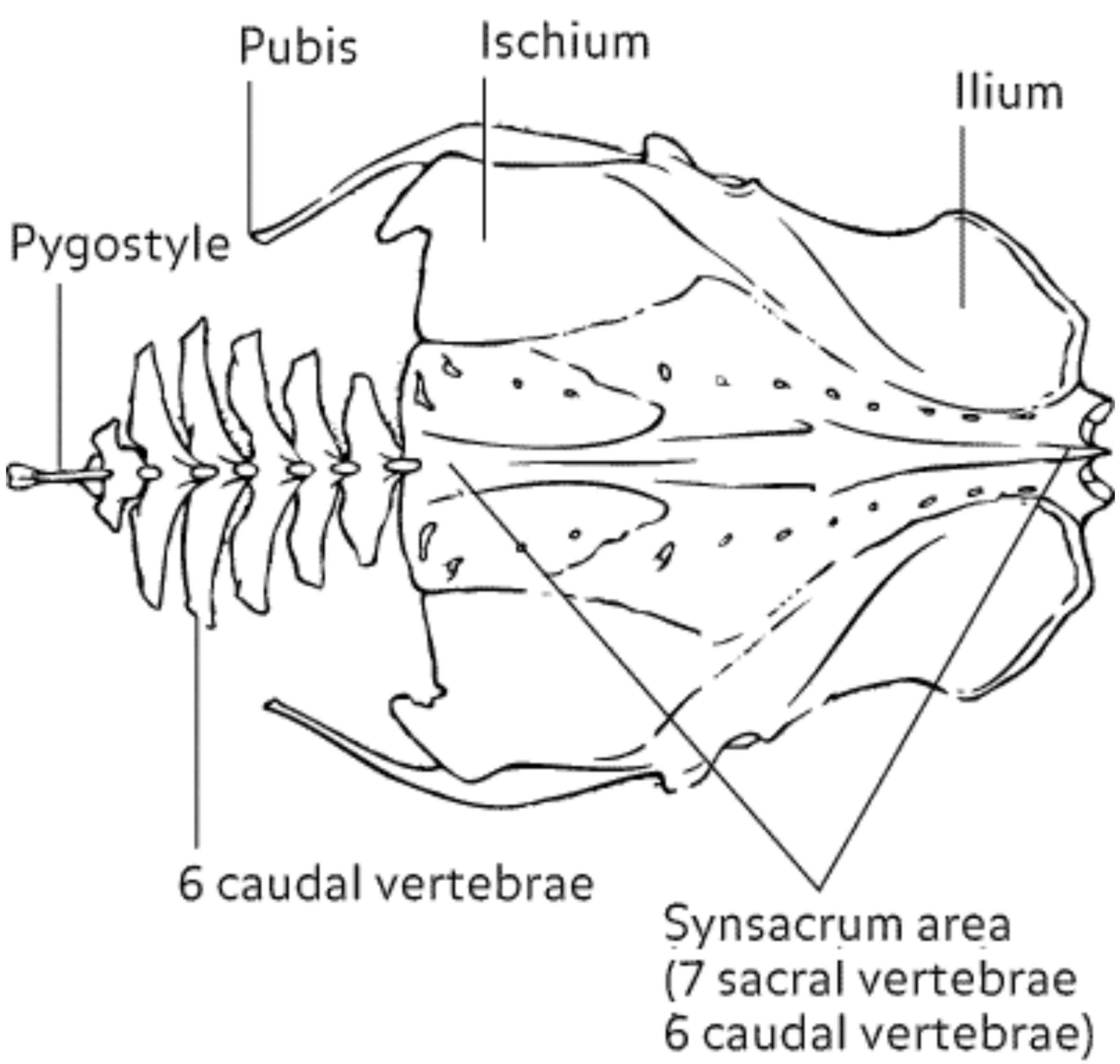
Finger modified to control winglet called an <u>alula</u>

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

Evolution of Fan-Shaped Tails

Fusion of tail vertebrae into pygostyle

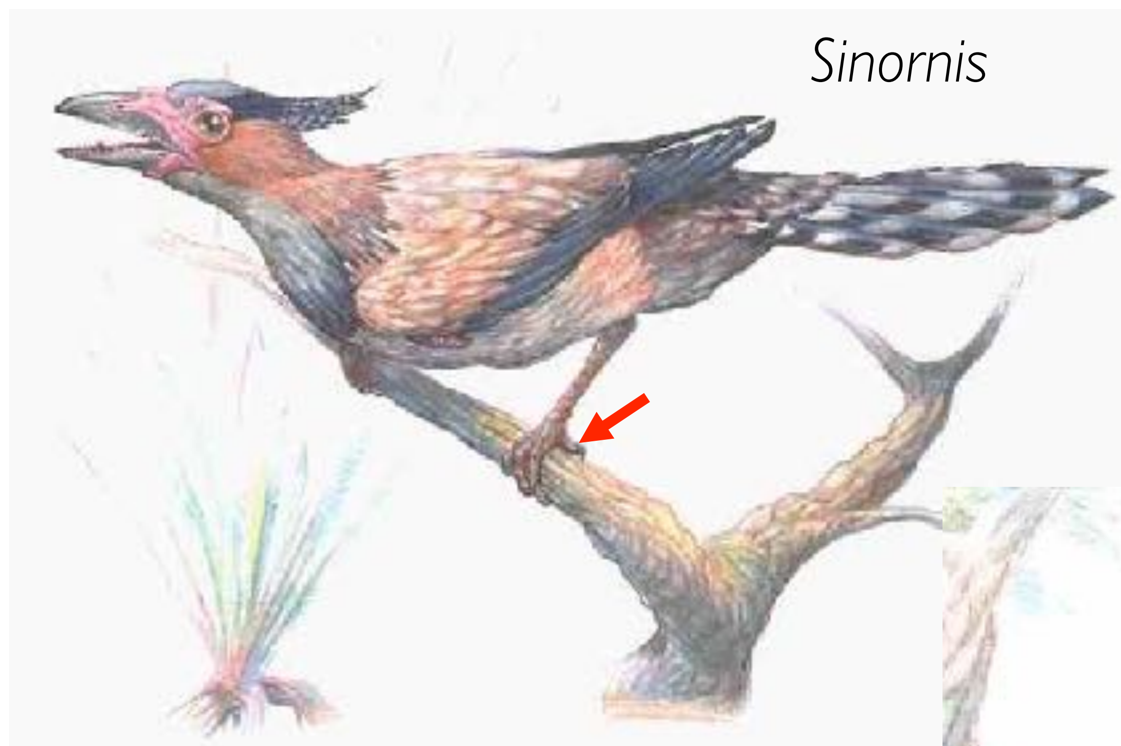
Allows fan shaped tail feathers, increasing wing area to increase lift at low speeds

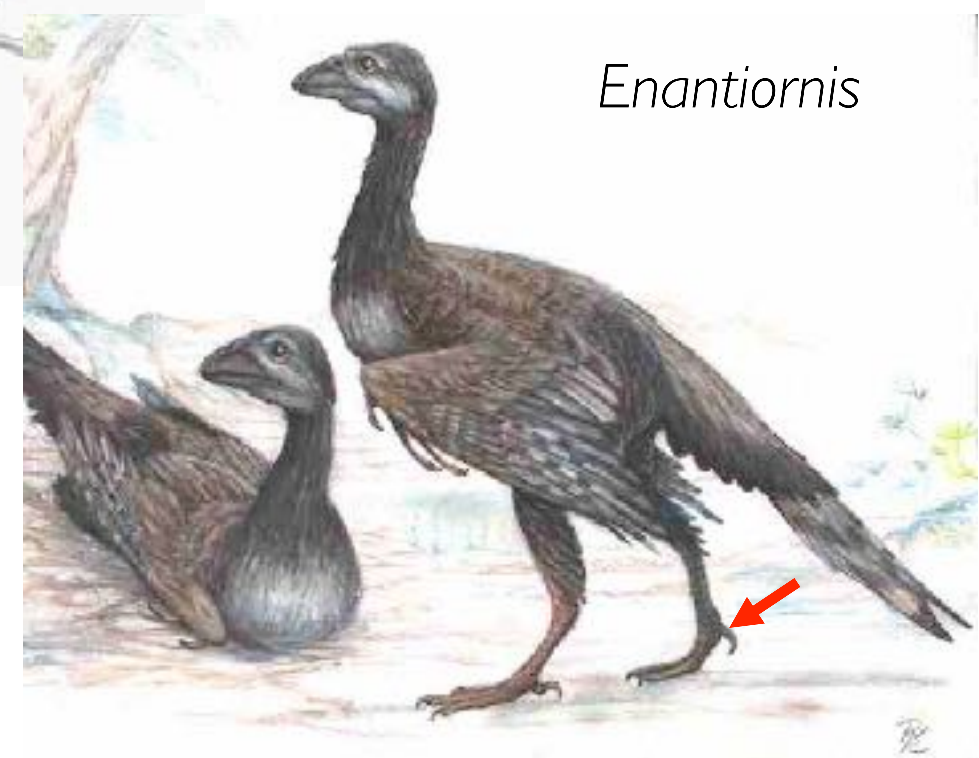


Perching Adaptations

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

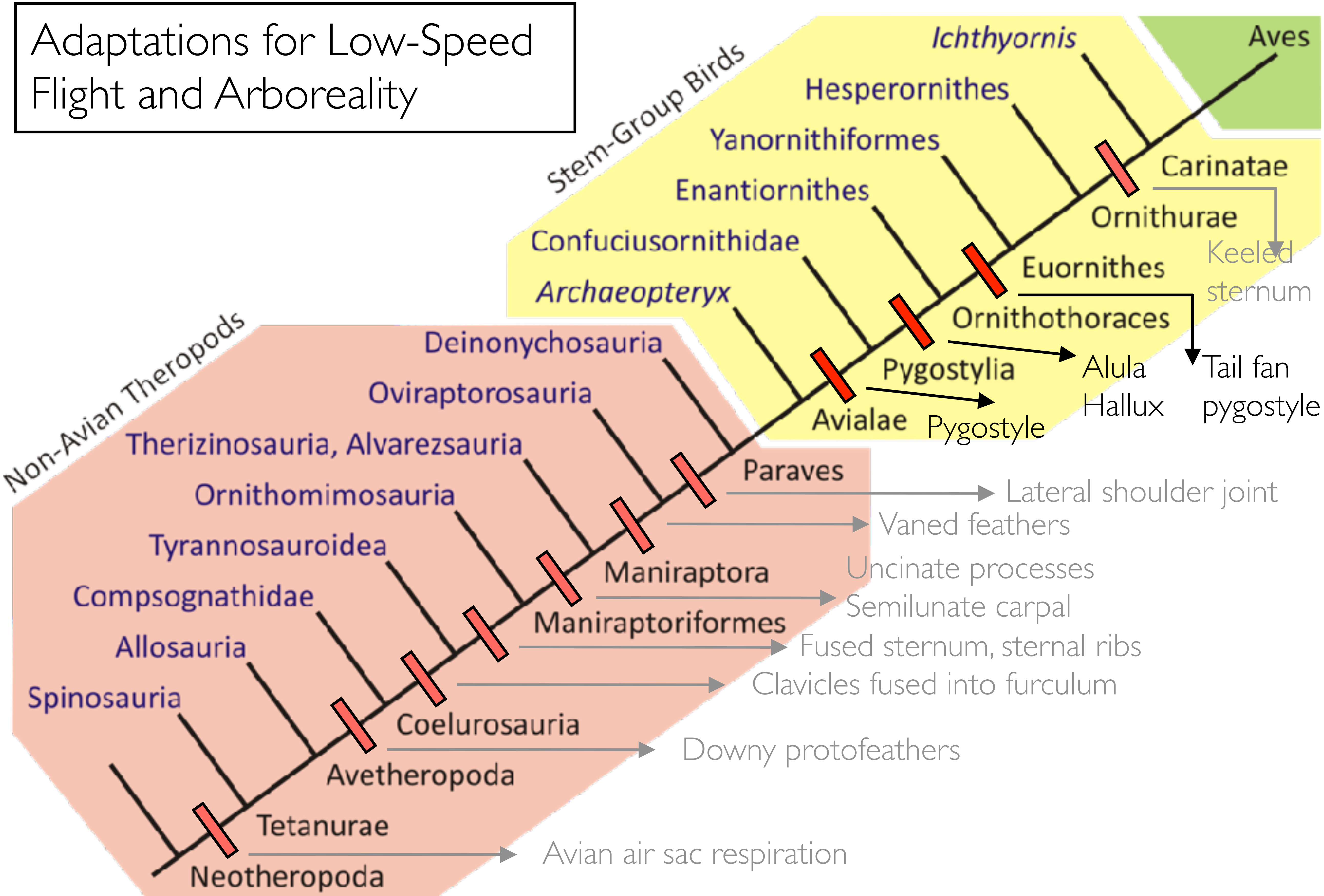
Allows grasping of branches while perching, an important adaptations for arboreal life





Cretaceous stem-group birds with reversed hallux

Adaptations for Low-Speed Flight and Arboreality



Evolution of Flight

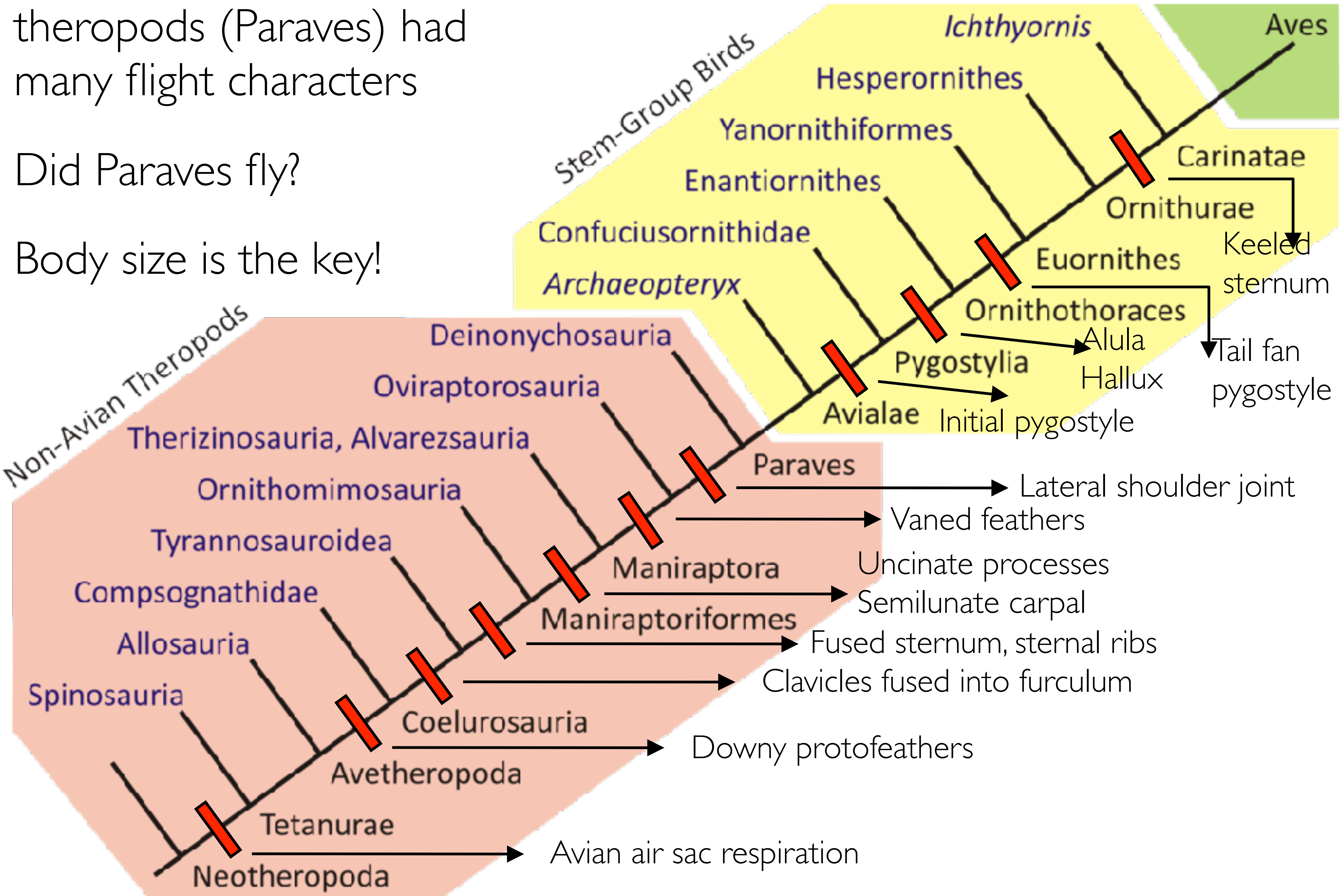
Did flight first evolve in the earliest birds (Avialae, *Archaeopteryx)* or could some theropods fly?

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

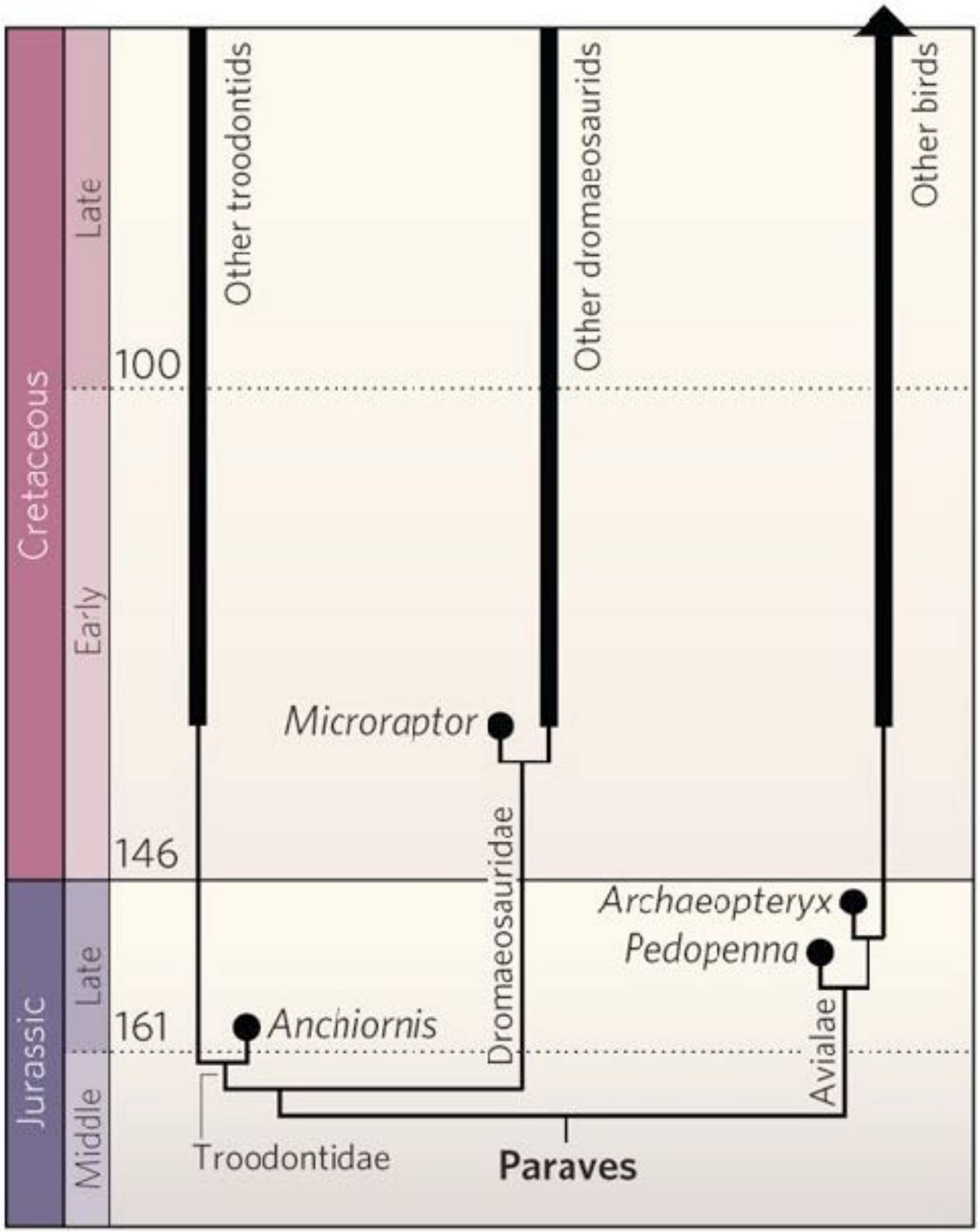
Advanced non-avian theropods (Paraves) had many flight characters

Did Paraves fly?

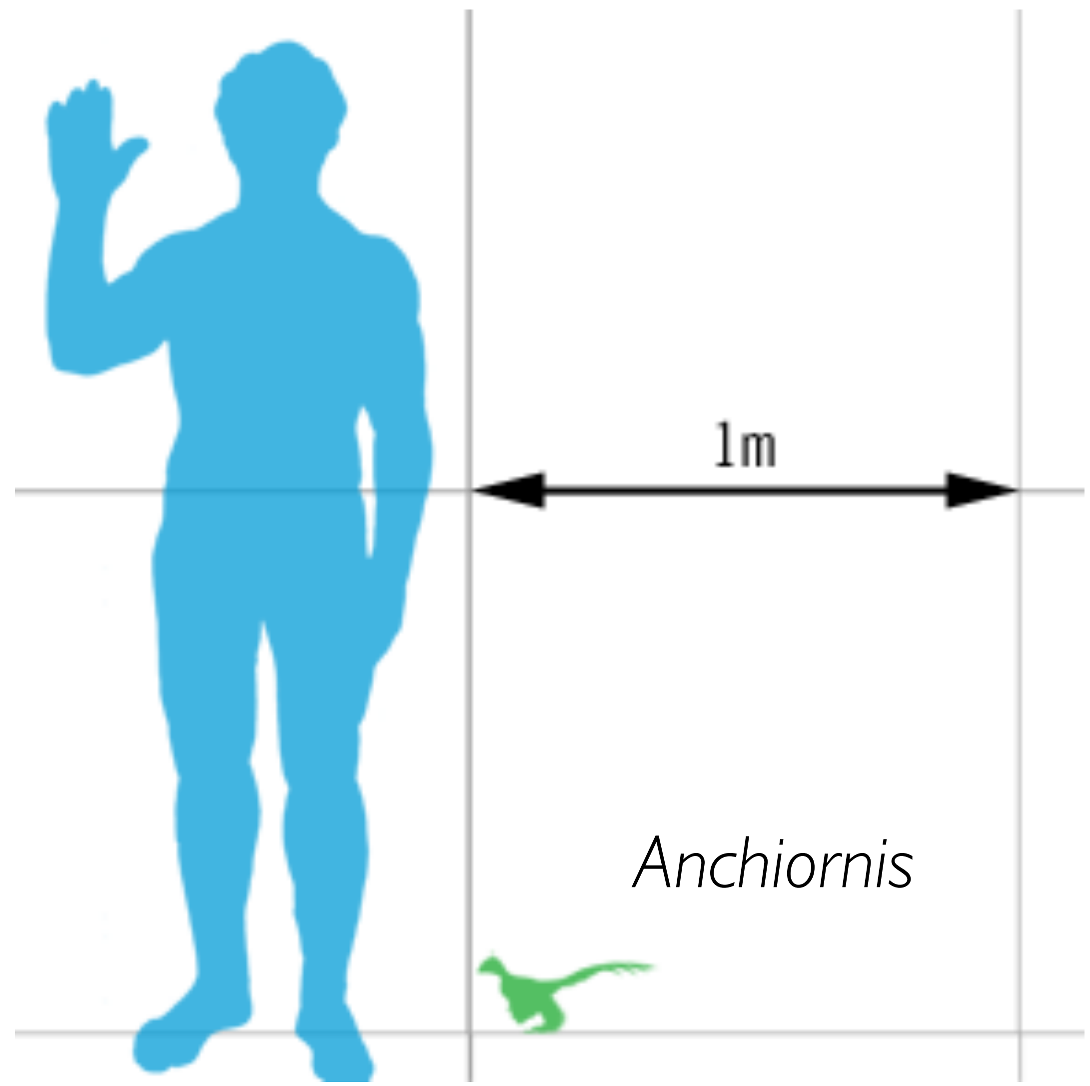
Body size is the key!



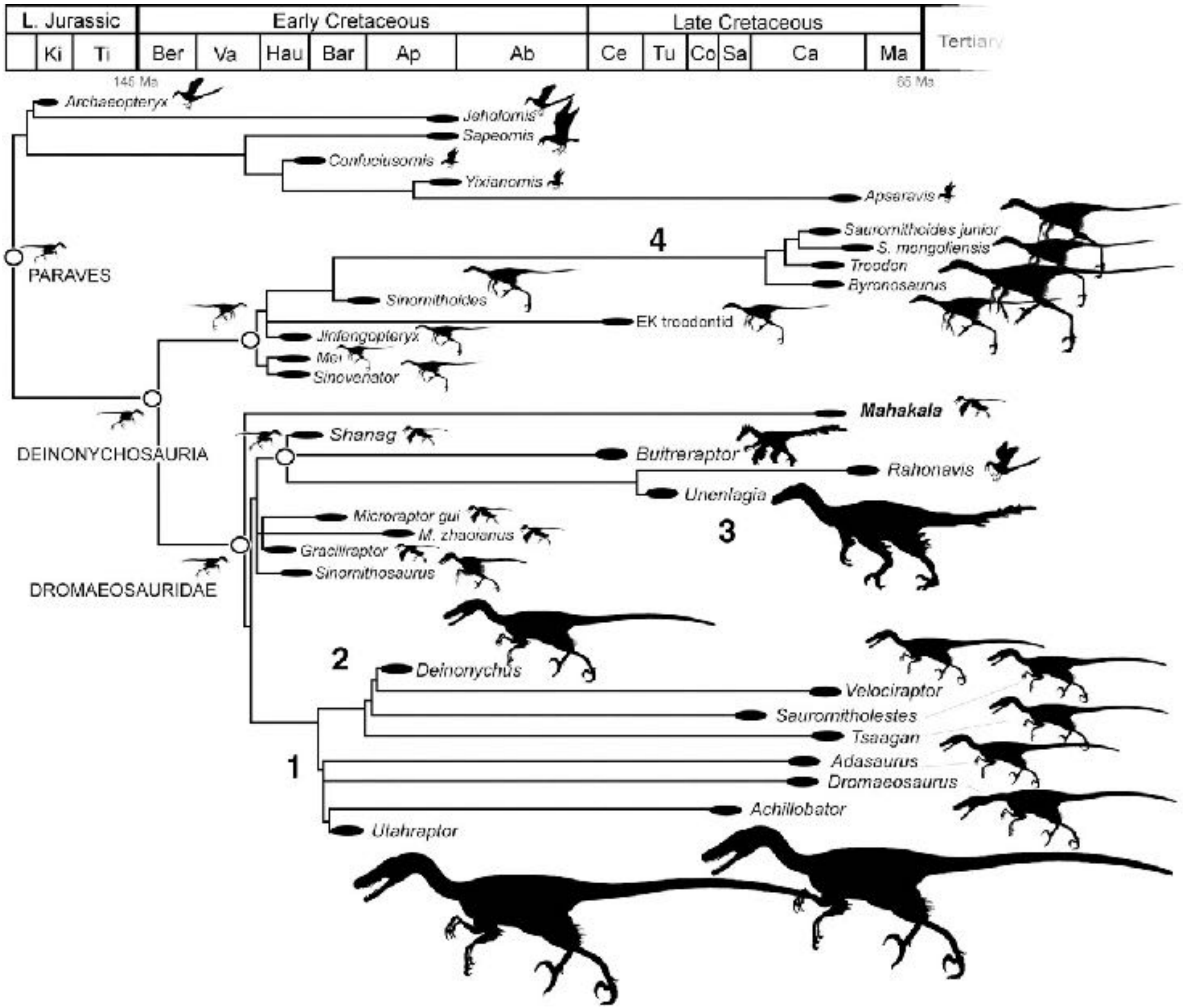
Body Size Reduction



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

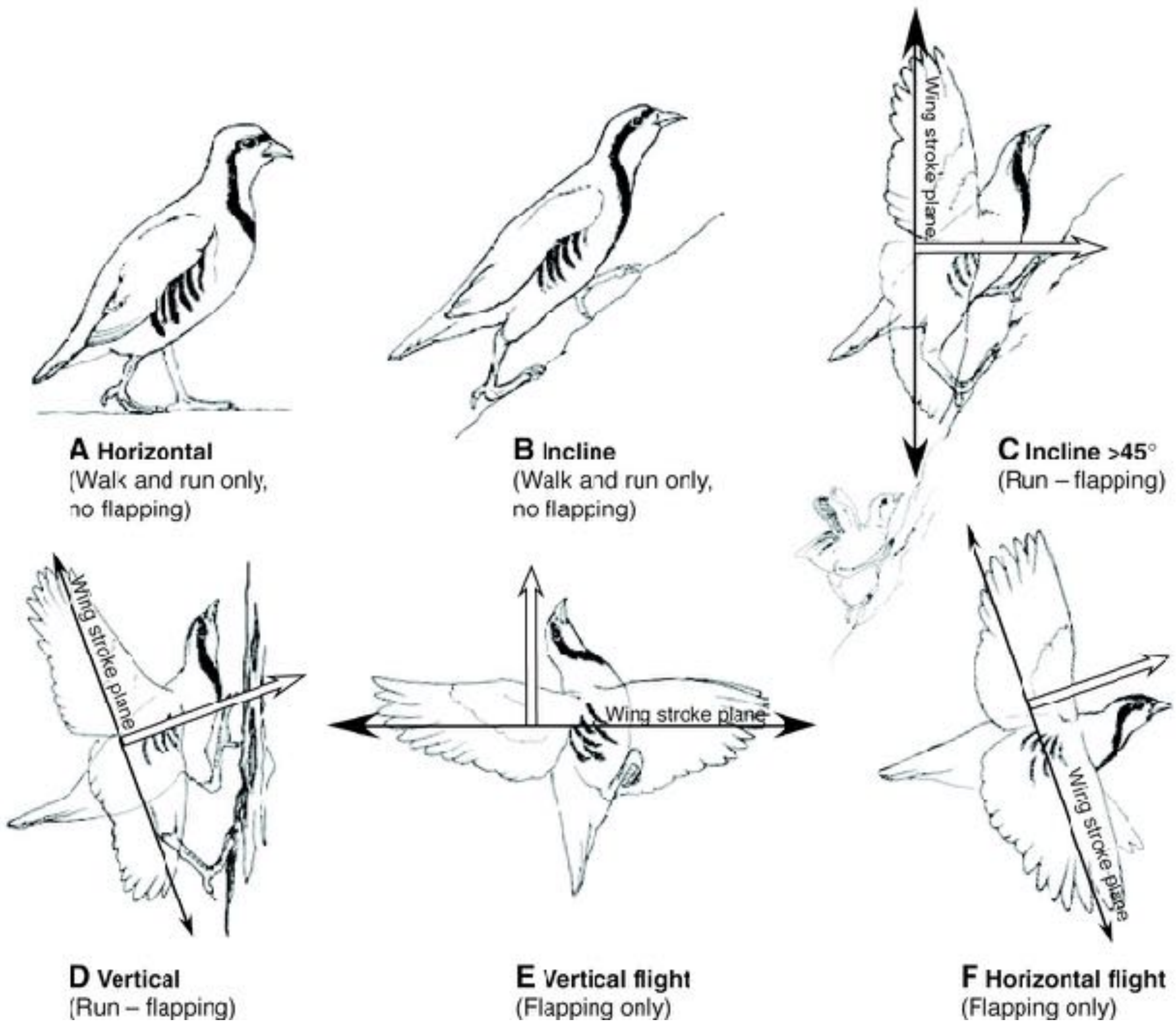
Arboreal Hypothesis: flight evolved through an intermediate gliding stage (from the "trees down")

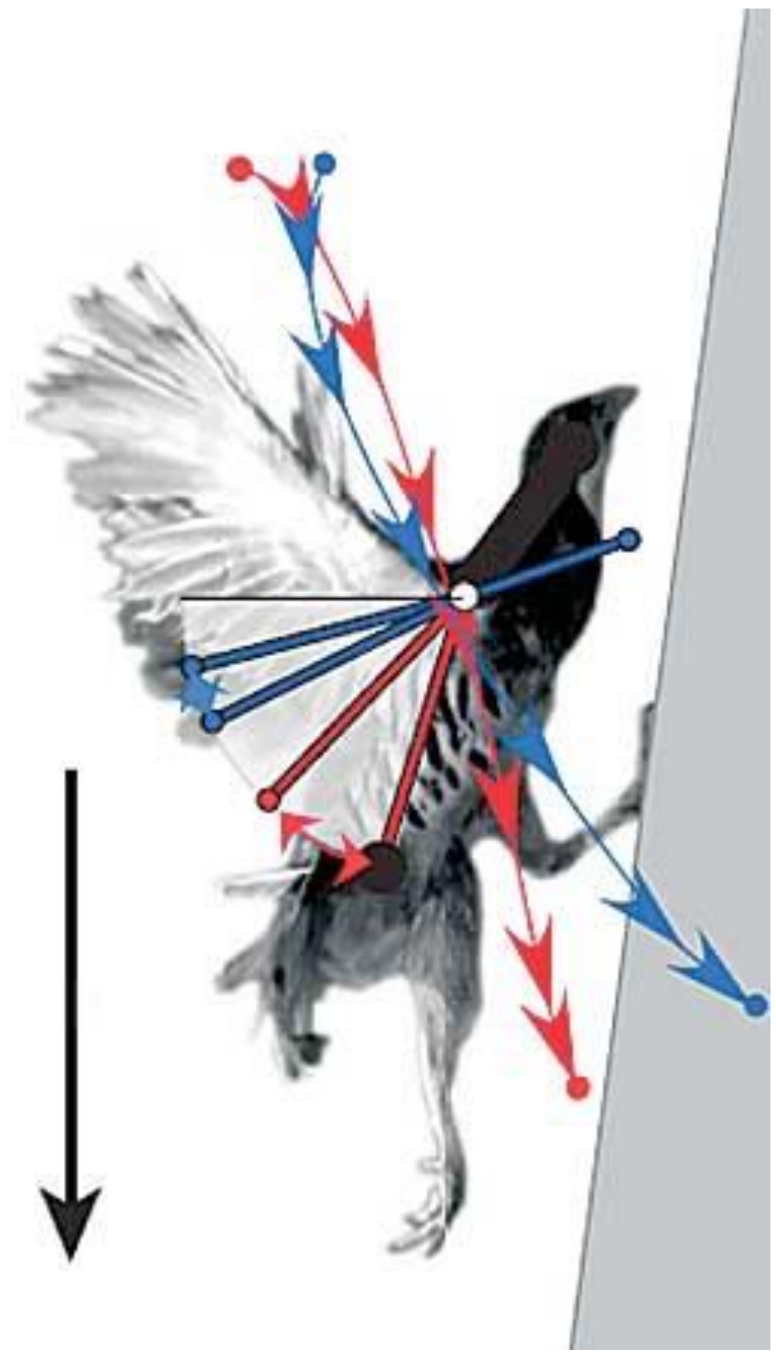
Gravity provides necessary potential energy for flight

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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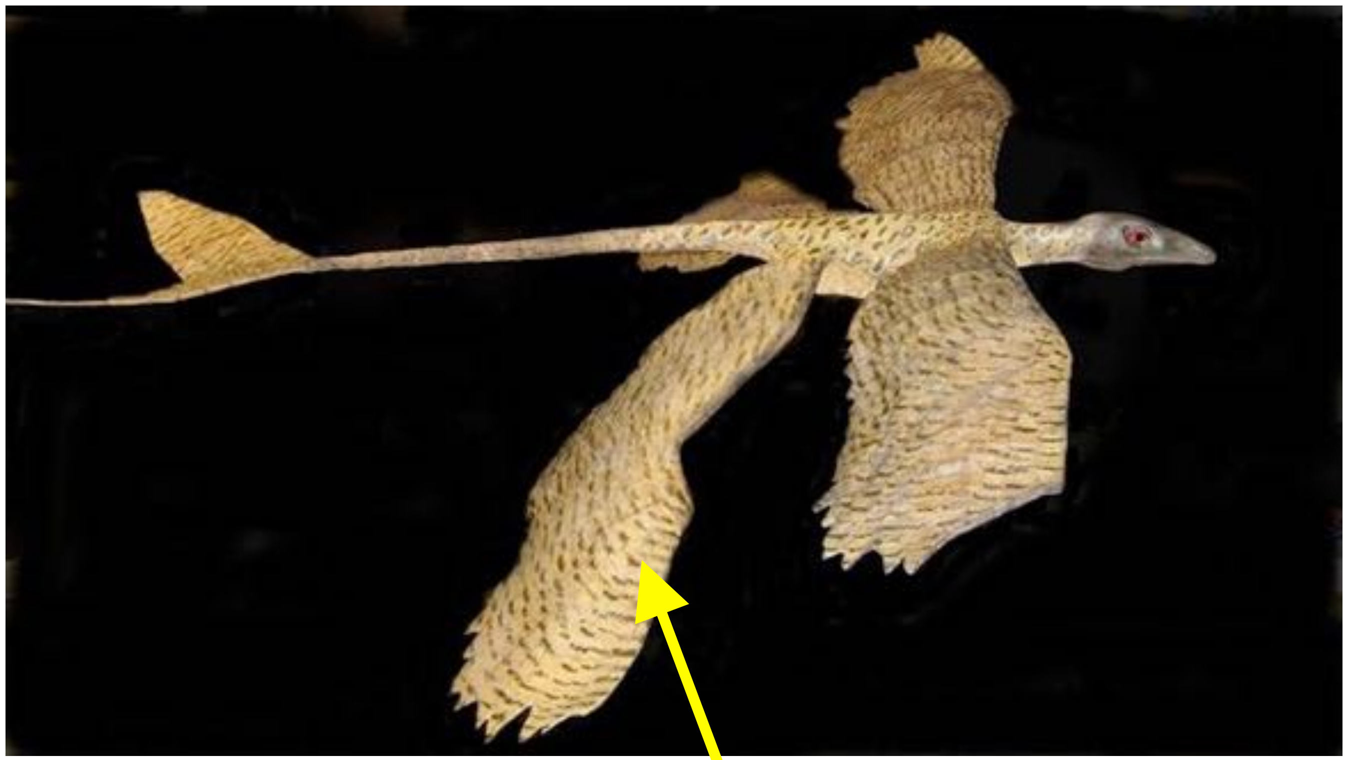
Arboreal Hypothesis

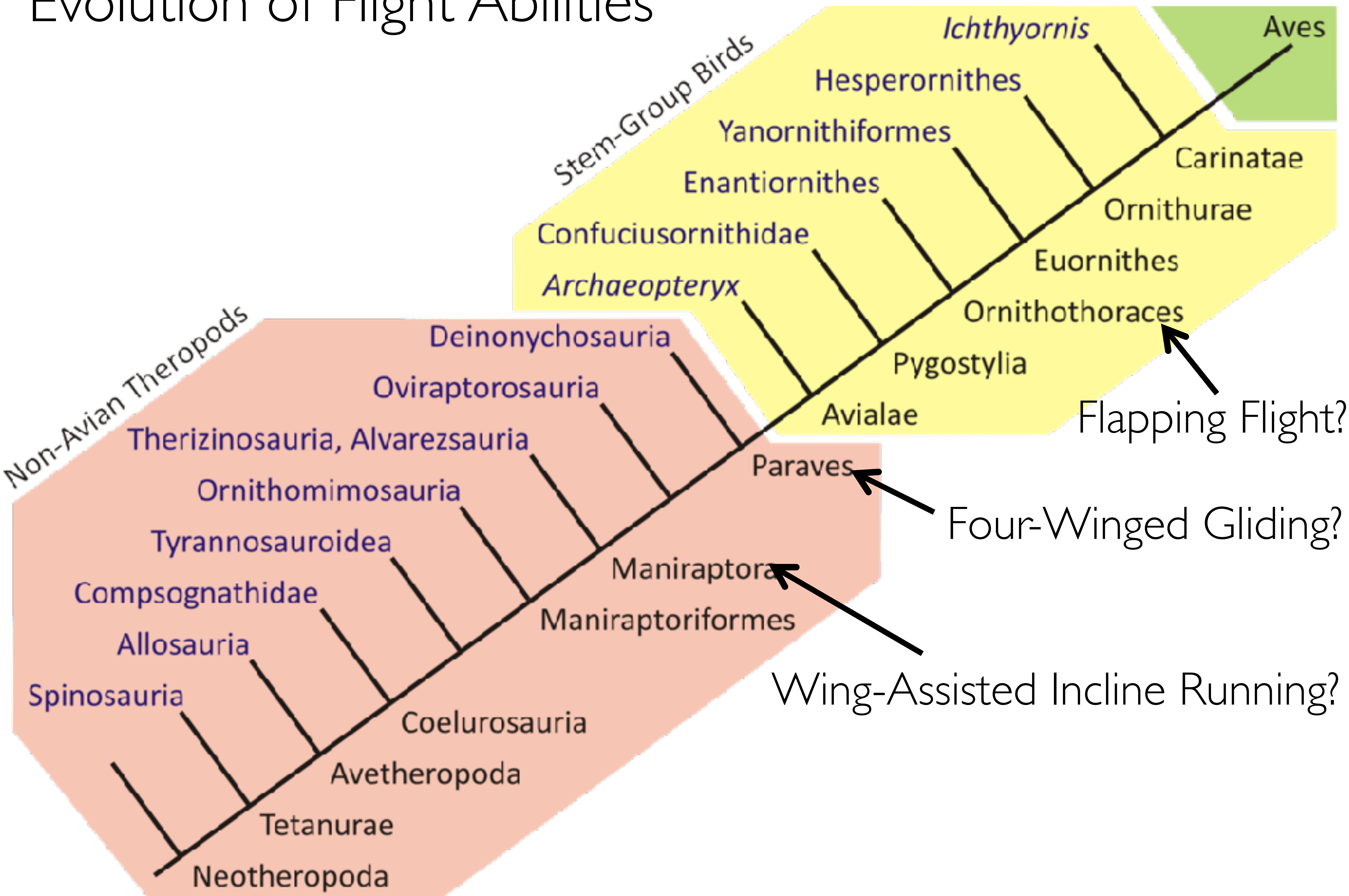
Earliest paravians (including birds) had four wings, with feathers on the arms and legs – may have glided from tree to tree



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

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

Evolution of Flight Abilities

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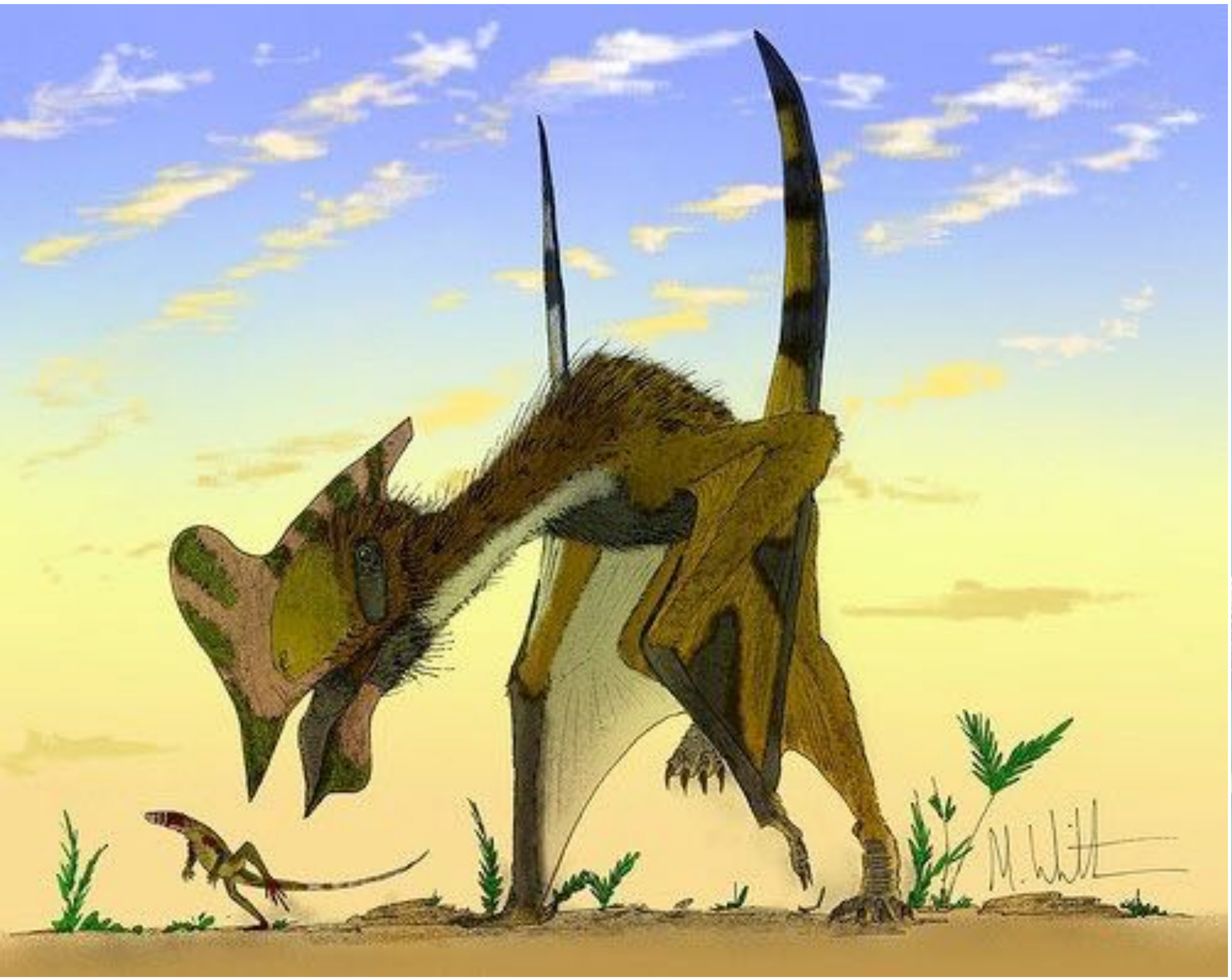
Bird Evolution Summary

- 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

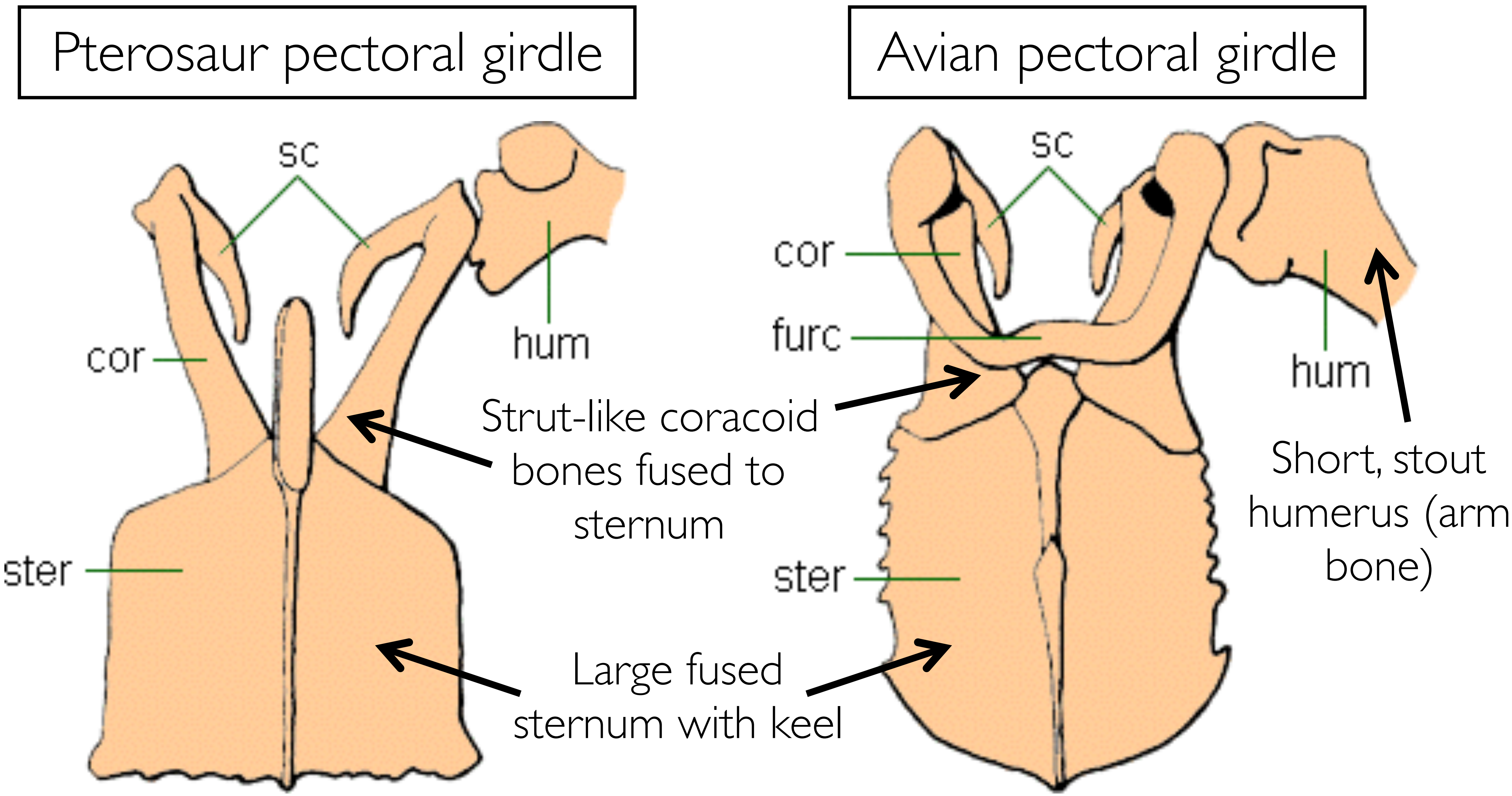
Convergent Flight Adaptations in Pterosaurs

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



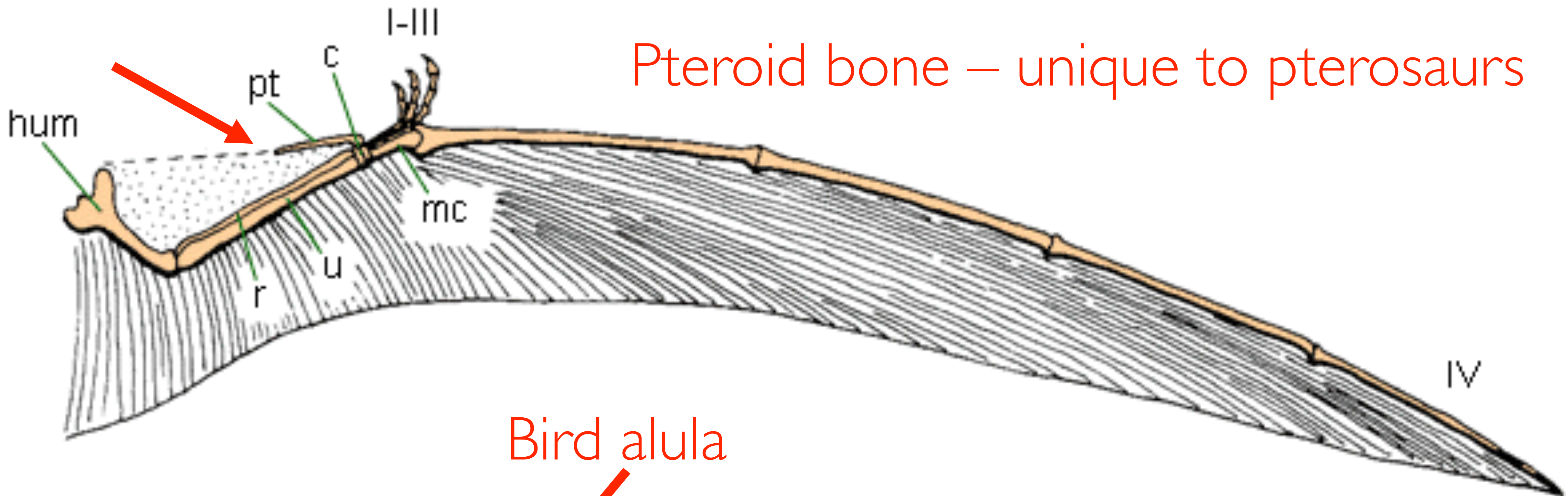
Pectoral Girdle Similarities

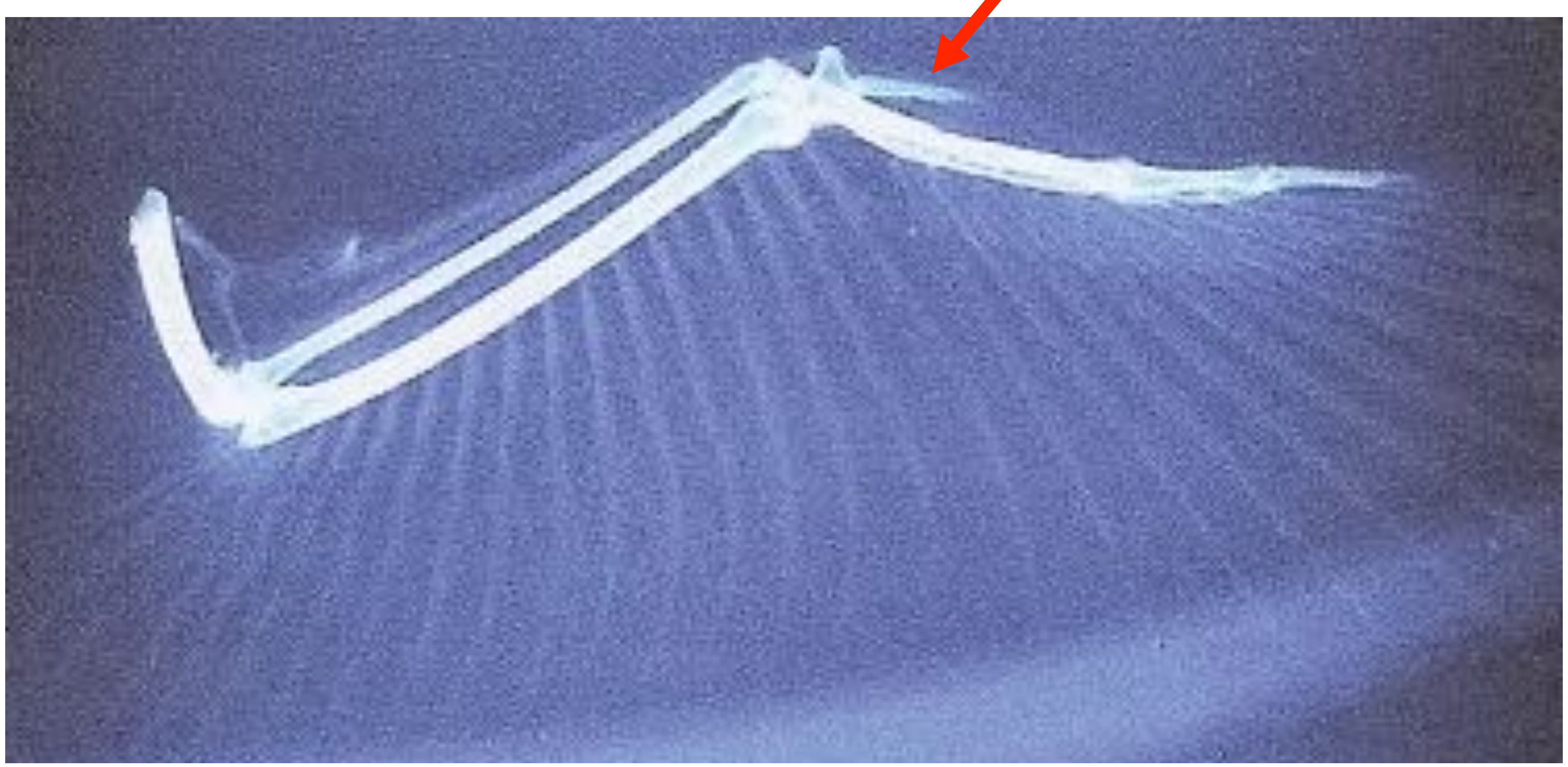
Pterosaurs independently evolved a pectoral girdle for supporting flight muscles



No feathers – instead use skin membrane stretched across hand

Wing surface primarily supported by extended finger digit IV





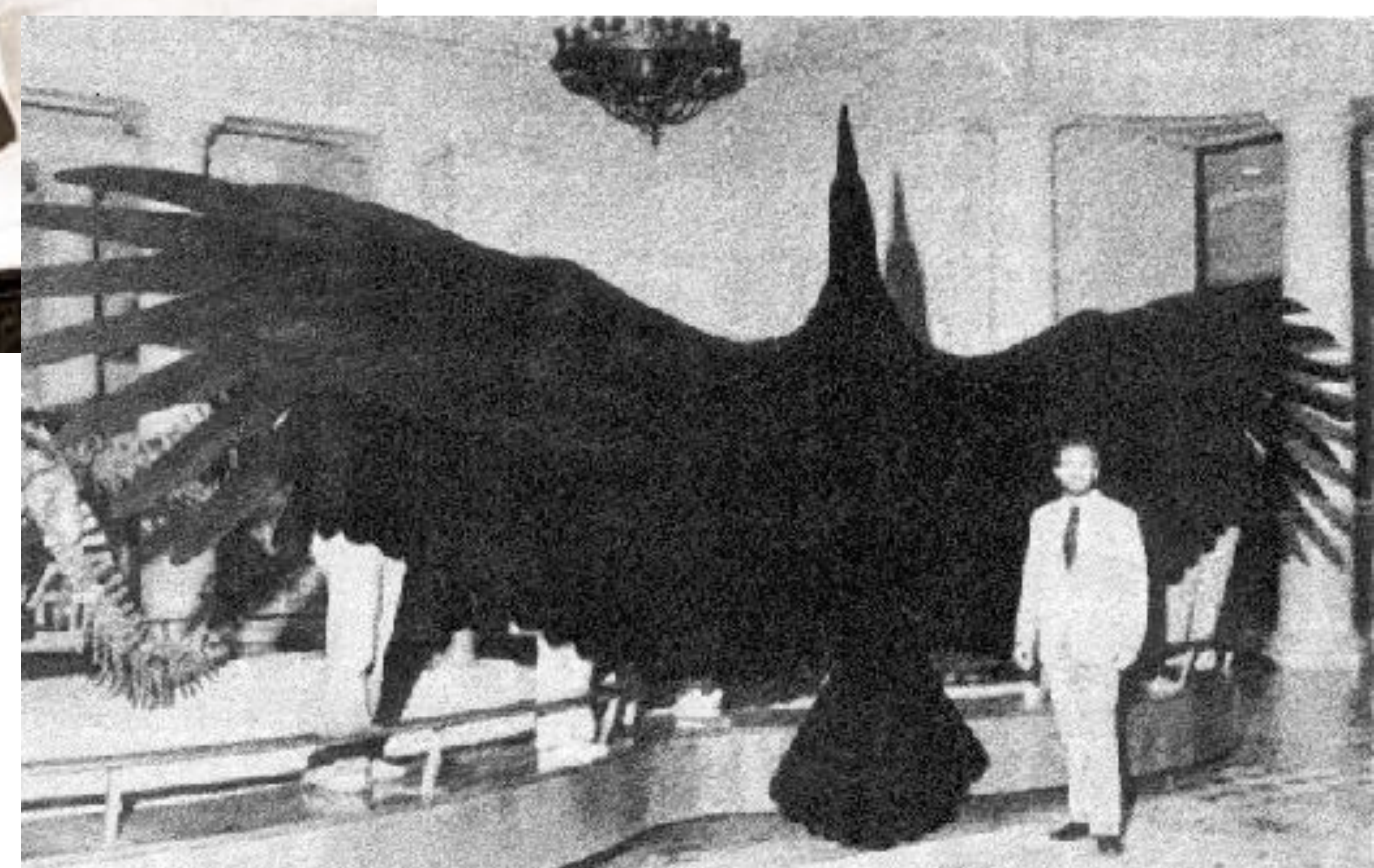
Bird wing: feathers

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

Bird Evolution Summary

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- 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