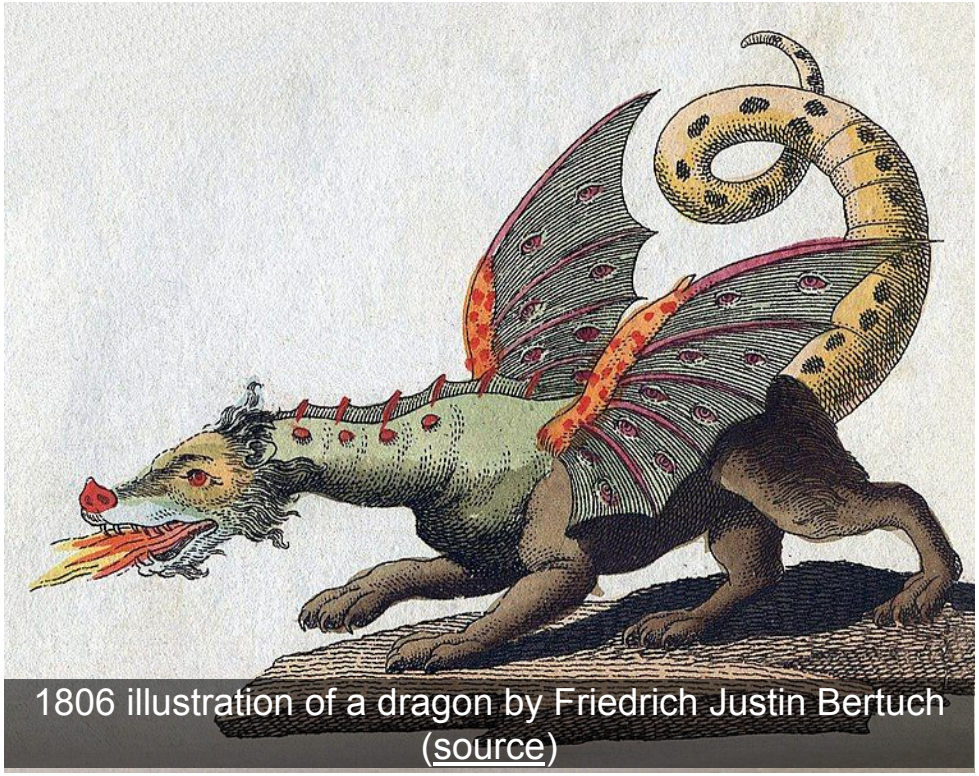
Lecture 7: Morphology
(Why do dinosaurs look the way they do?)

Skeleton of *Triceratops* (source)

Why don’t dinosaurs look different?

- People have imagined many dinosaur-like animals
- Even the most fantastical reconstructions challenge us to imagine what could be...

A “dinosaur” toy with two heads (source)



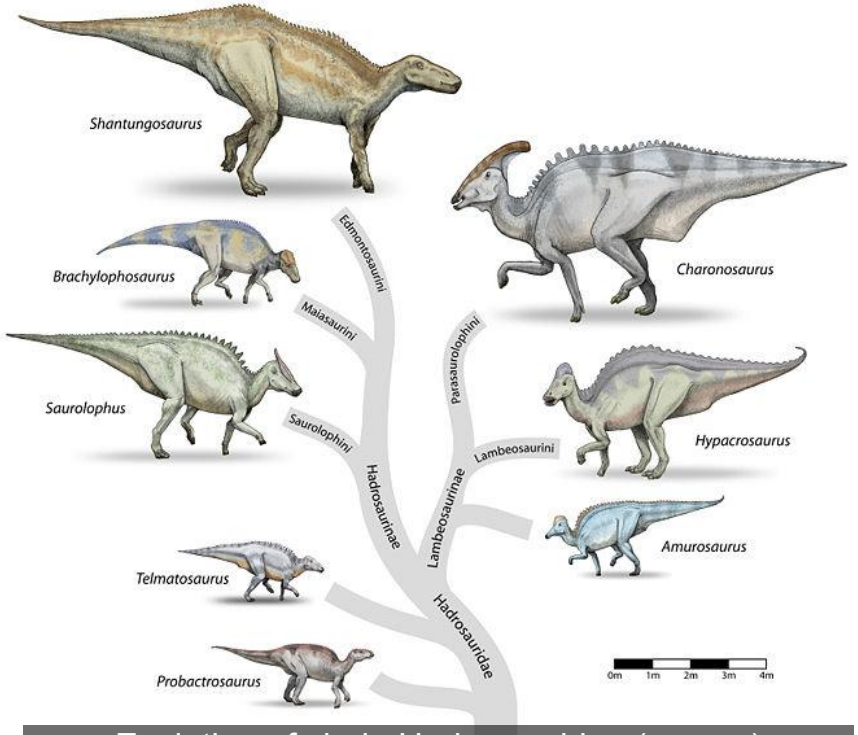
1806 illustration of a dragon by Friedrich Justin Bertuch (source)

Dinosaurs were living organisms, and obeyed the same laws as organisms today (uniformitarianism)

- Dinosaurs needed to:
  - Obtain energy from their environment
  - Remove waste from their bodies
  - Withstand physical forces (e.g. gravity)

At ~164,000 tons, the dinosaur-like Godzilla exceeds the theoretical weight limit of land vertebrates (ref; image source)

Dinosaurs were living organisms, and obeyed the same laws as organisms today (uniformitarianism)

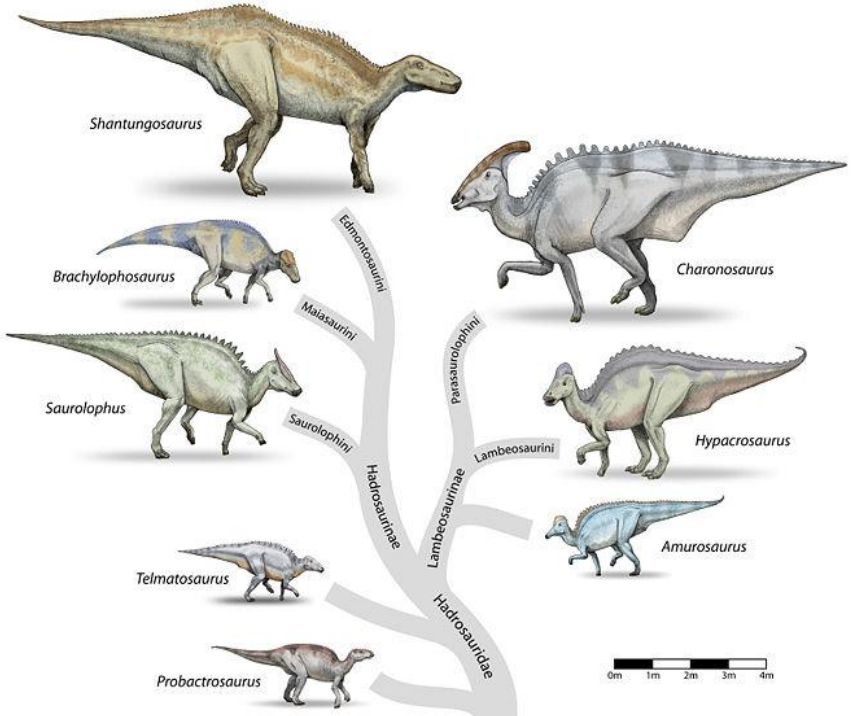


Evolution of clade Hadrosauridae (source)

- Dinosaurs dealt with these constraints the same as other living, through **descent with modification** (a.k.a. Darwinian evolution)
- Let's unpack what this means

Darwin, Charles. *On the origin of species by means of natural selection, or, the preservation of favoured races in the struggle for life*. J. Murray, 1859.

Descent with modification

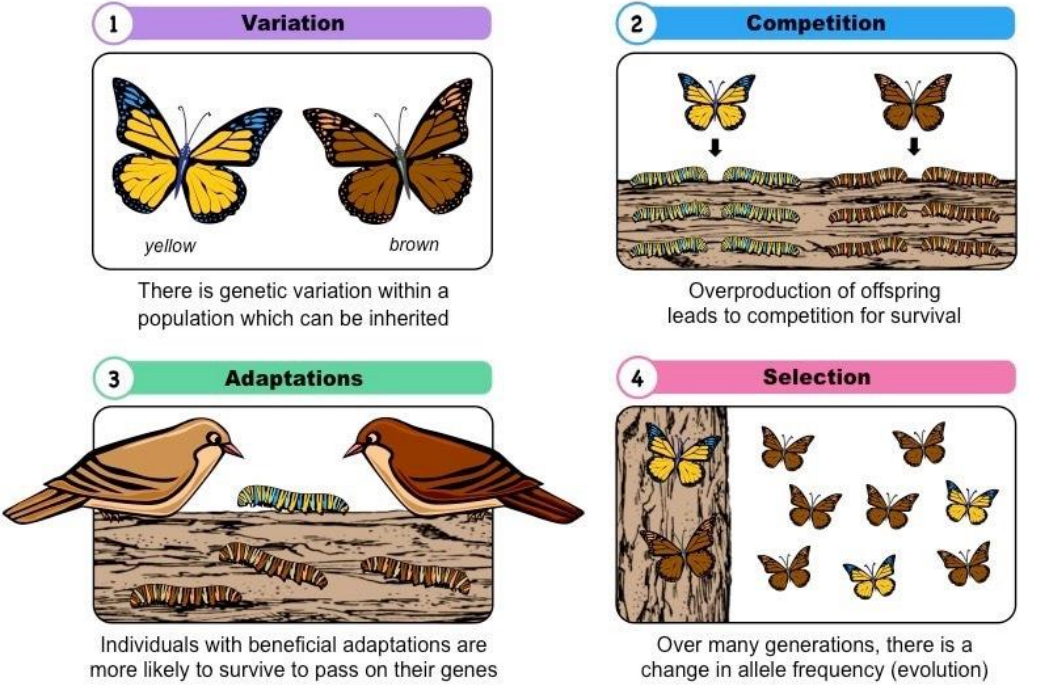


Evolution of clade Hadrosauridae (source)

- Every living thing (past and present) had one or more parents

- The scientific **theory of common descent** states that all living things are connected through a series of common ancestors

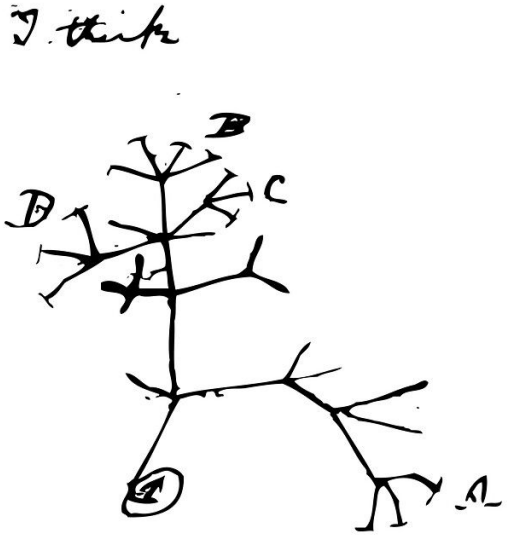
Populations give rise to new species through natural selection



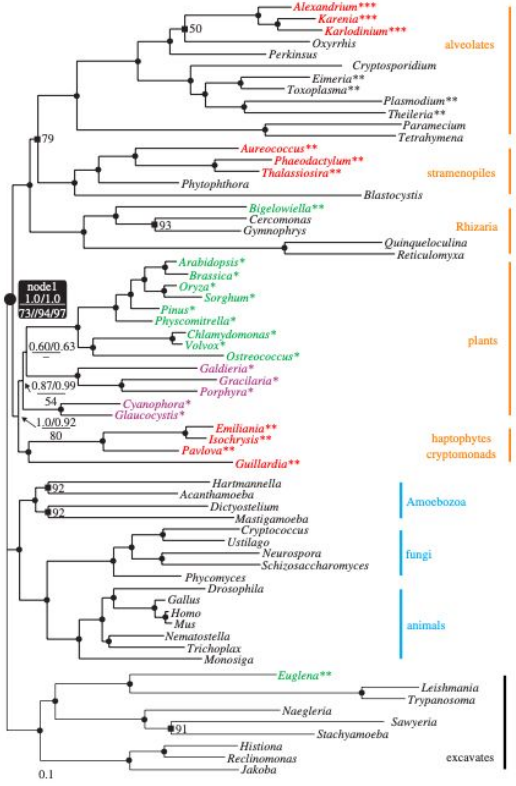
Cartoon overview of natural selection (source)

- The scientific law of **natural selection** shows how populations become better adapted to their environment by the preservation of favorable traits

Populations give rise to new species through natural selection



Burki, Fabien; Shalchian-Tabrizi, Kamran & Pawlowski, Jan (2008), "Phylogenomics reveals a new 'megagroup' including most photosynthetic eukaryotes", Biology Letters, 4 (4): 366–369,

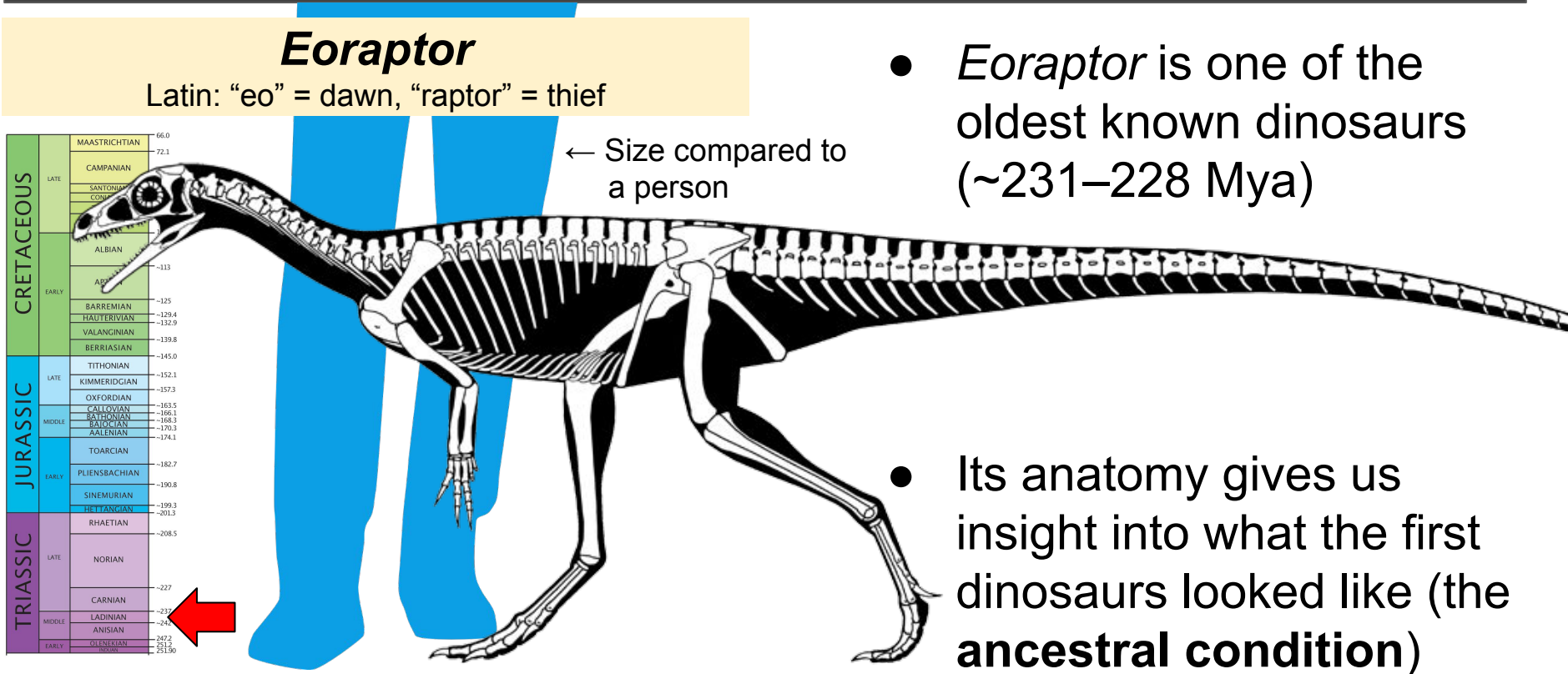


- Over time this creates differences between populations as they adapt to their local environment
- With enough time populations no longer reproduce with each other (they become biological species)

The dinosaur bodyplan

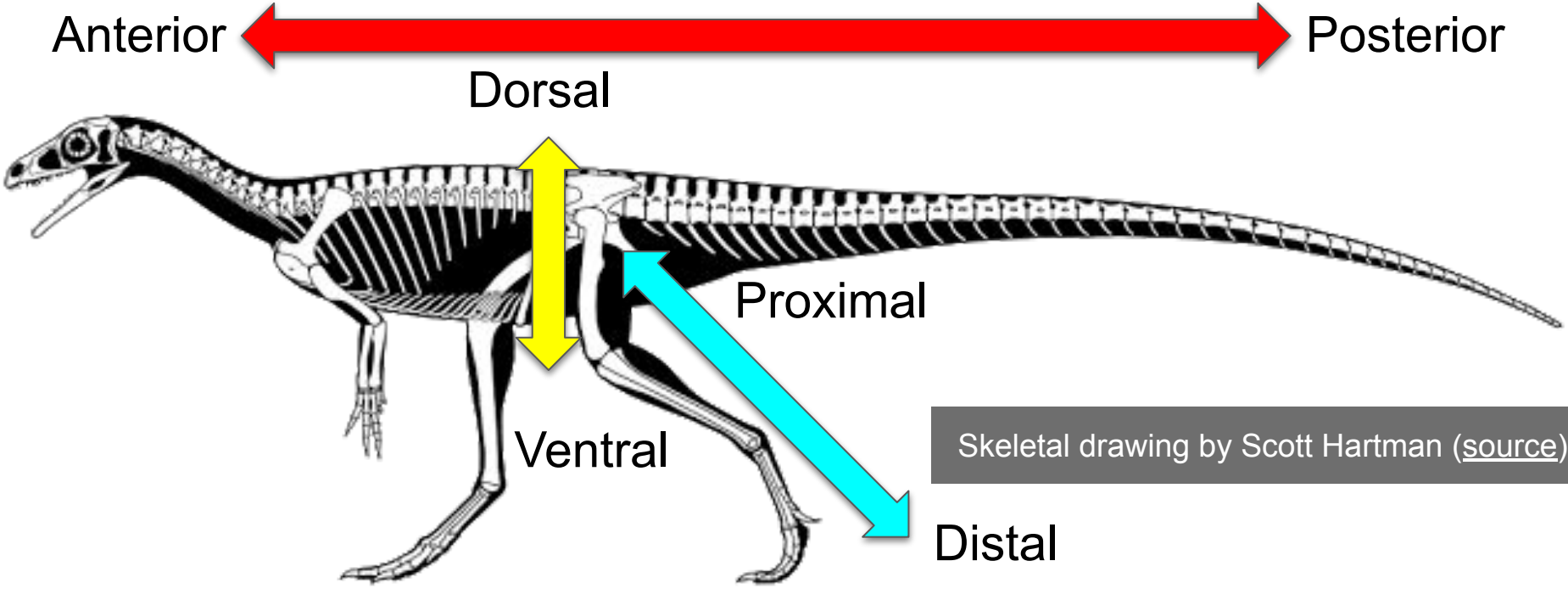
Eoraptor

Latin: “eo” = dawn, “raptor” = thief



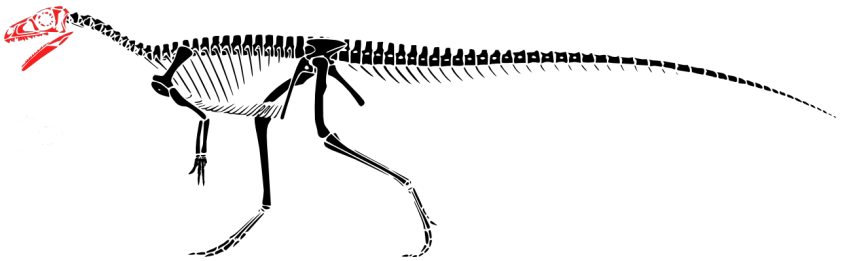
- *Eoraptor* is one of the oldest known dinosaurs (~231–228 Mya)
- Its anatomy gives us insight into what the first dinosaurs looked like (the **ancestral condition**)

Discussing anatomy

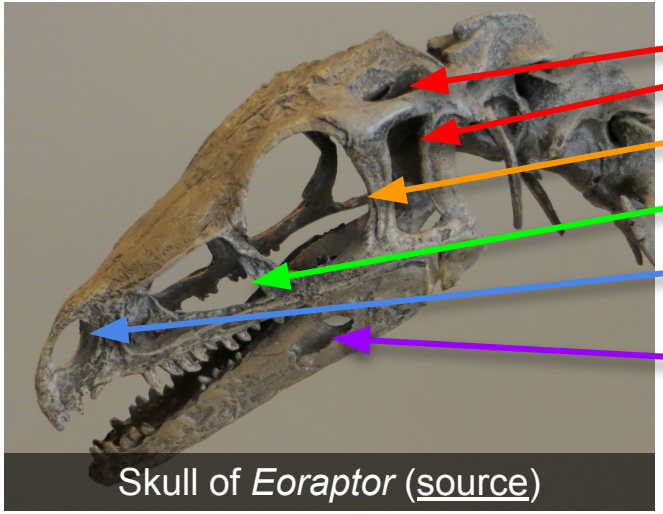


Skeletal drawing by Scott Hartman (source)

The dinosaur head



- Lightweight skull with lots of holes (fenestra)



Skull of *Eoraptor* (source)

Postorbital fenestrae

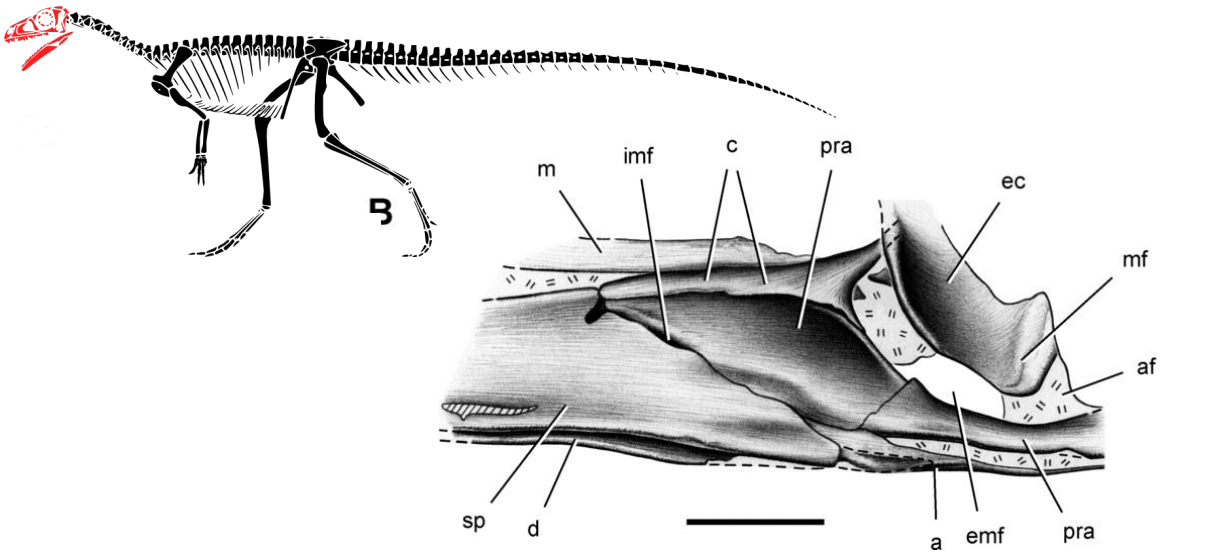
Orbit (eye socket)

Antorbial fenestra

Naris (nostril)

Mandibular fenestra

The dinosaur head

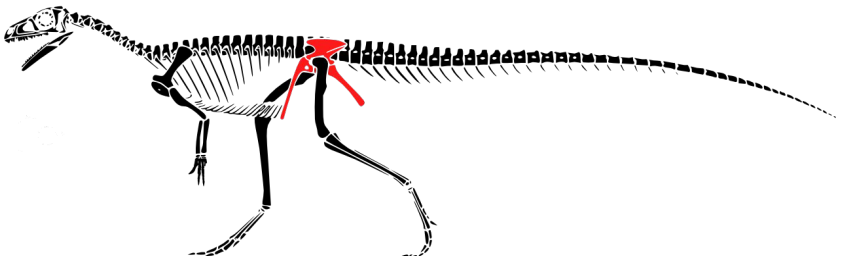


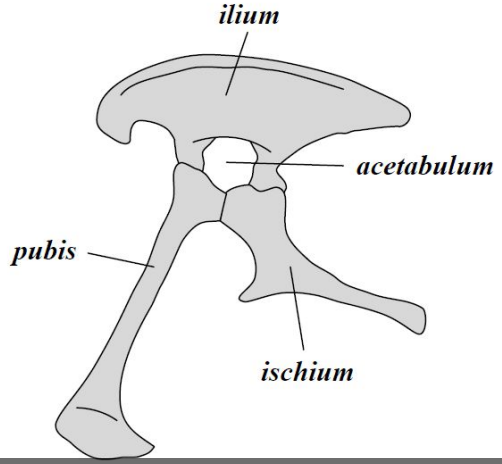
Drawing of the lower jaw of *Eoraptor* (source)

- The skull is was partially kinetic
- **Kinetic skull** (cranial kinesis): significant movement of skull bones relative to each other

Sereno, Paul C., Ricardo N. Martínez, and Oscar A. Alcober. Journal of Vertebrate Paleontology 32.sup1 (2012): 83-179.
Holliday, Casey M., and Lawrence M. Witmer. Journal of Vertebrate Paleontology 28.4 (2008): 1073-1088.

The dinosaur pelvis



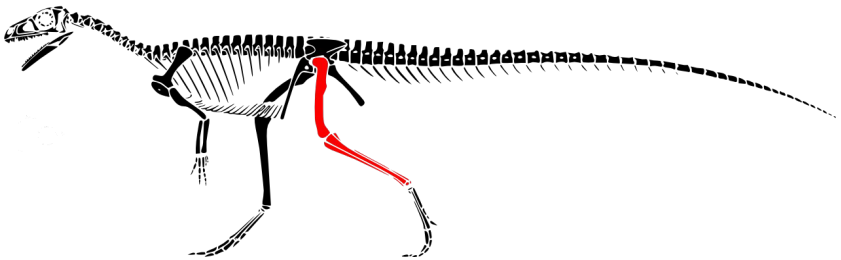


Saurischia pelvis (source)

- The pelvis is made up of three bones: the **ilium**, **ischium**, and **pubis**

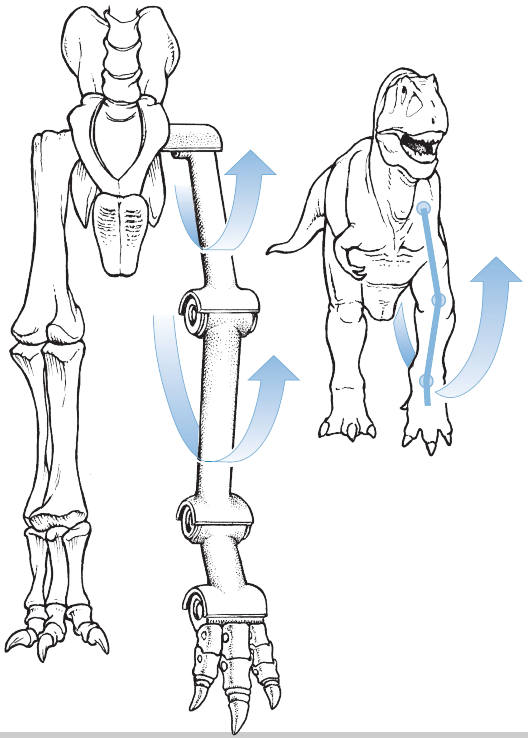
- A hole in the pelvis (the **acetabulum**) allows the femur to lock in place and gave dinosaurs an upright stance like birds and mammals

The dinosaur leg



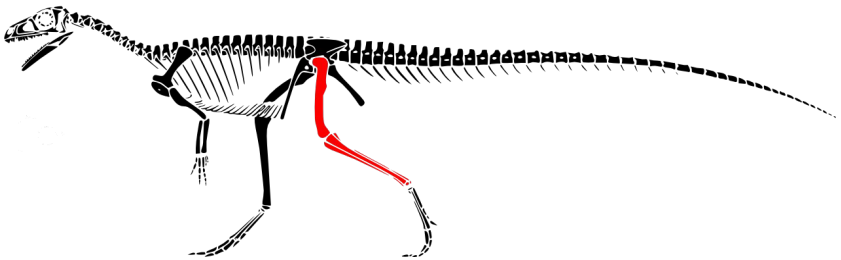
- The legs are much longer than the arms in Eoraptor, giving it a **bipedal** posture

- The femur bone had a barrel-shape (instead of a ball shape seen in mammals) restricting movement to forward and backward motion.

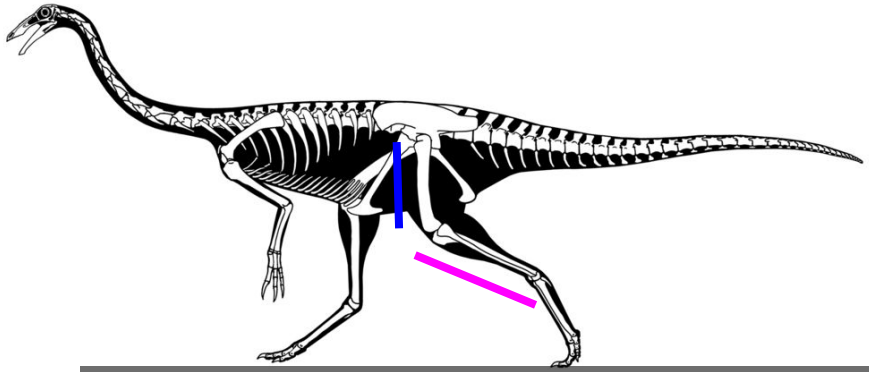


Fastovsky, David E., and David B. Weishampel. *Dinosaurs: a concise natural history*. Cambridge University Press, 2016.

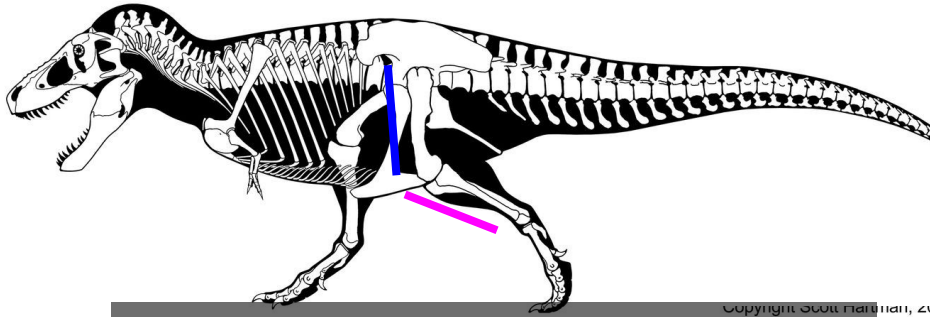
The dinosaur leg



- **Humerus** vs. **tibia/fibula** ratio provides an approximation of speed

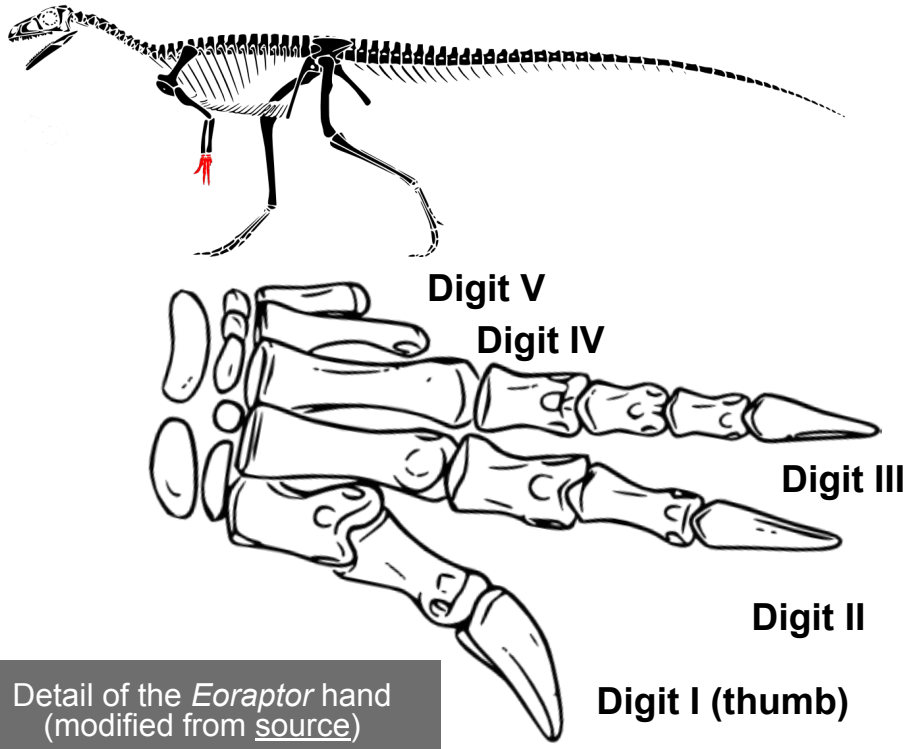


Gallimimus skeleton by Scott Hartman (source)



Tyrannosaurus skeleton by Scott Hartman (source)

The dinosaur hand

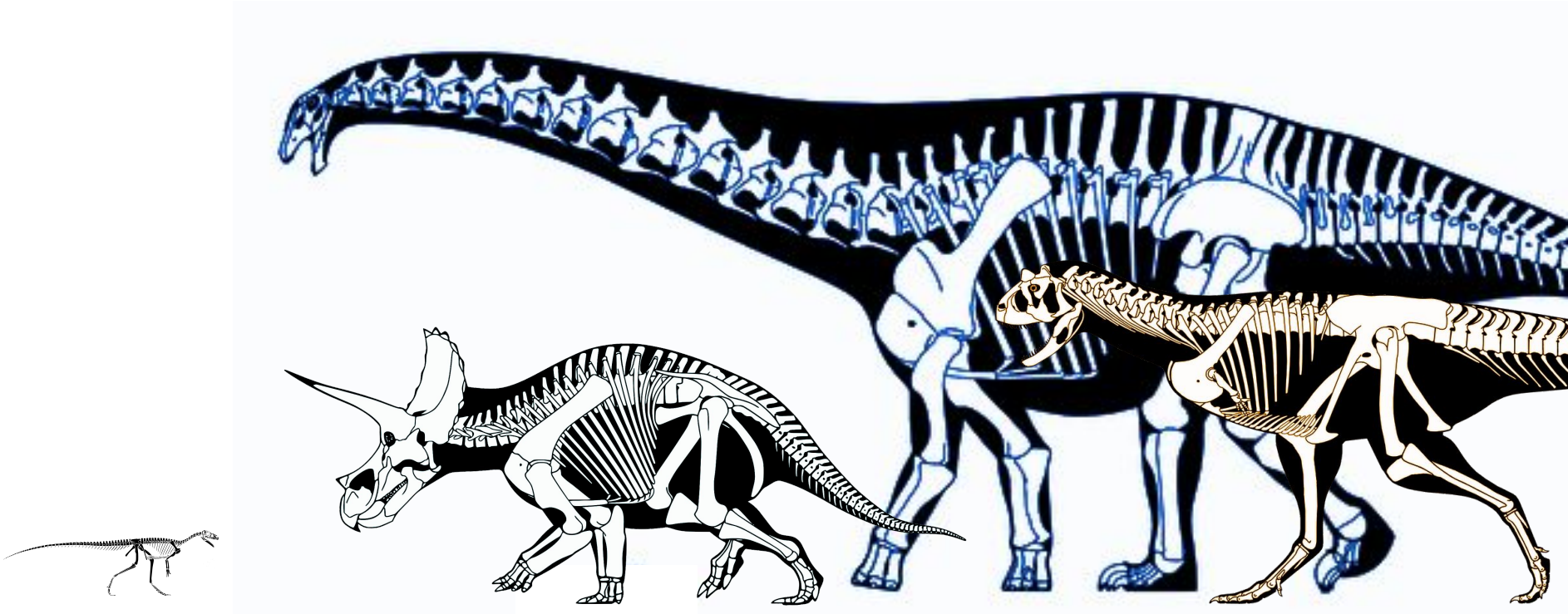


Detail of the *Eoraptor* hand (modified from source)

- The earliest dinosaurs had five fingers on their hands, which is the ancestral condition of tetrapods
- Different clades of dinosaurs will go on to elaborate and/or loose these digits

Martinez, Ricardo N., et al. "A basal dinosaur from the dawn of the dinosaur era in southwestern Pangaea." *science* 331.6014 (2011): 206-210.

All dinosaur species are modifications of this ancestral bodyplan



Skeletons by Scott Hartman (source)

Interpreting dinosaur skeletons in the context of natural selection

- Most anatomical features were shaped by natural selection
- In this context it is reasonable to hypothesize what the purpose of a morphological trait, or **adaptation**, was

Triceratops skeleton by Scott Hartman (source)

Interpreting dinosaur skeletons in the context of natural selection

- Not all traits in a dinosaur skeleton were directly shaped by natural selection

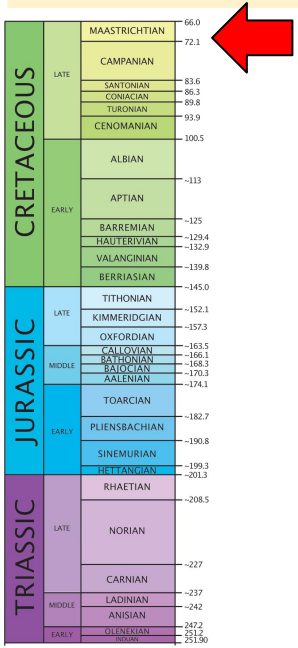
- Natural selection is not the only mechanism that drives evolution but it is the only mechanism known to create adaptations

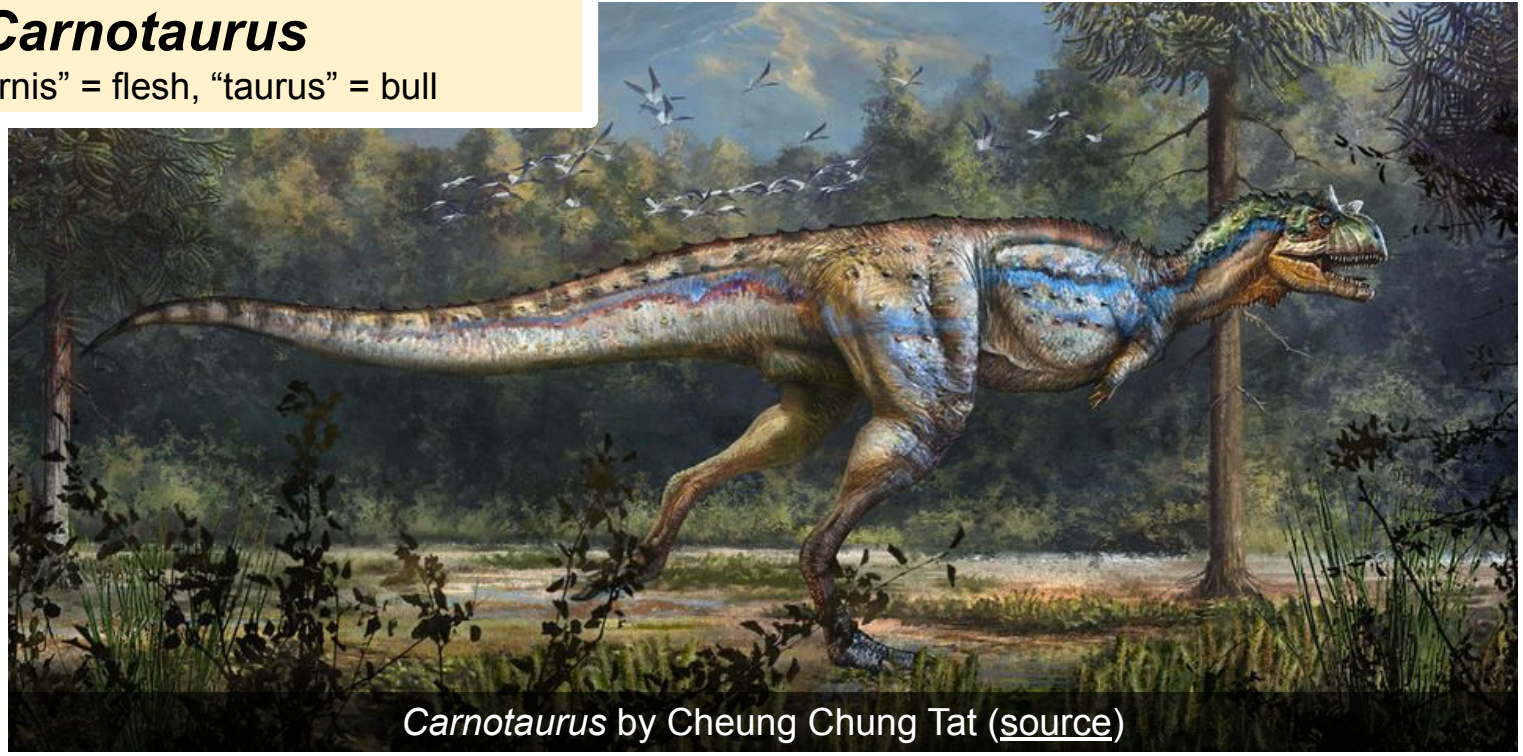
Triceratops skeleton by Scott Hartman (source)

Non-adaptive forms of evolution

Carnotaurus

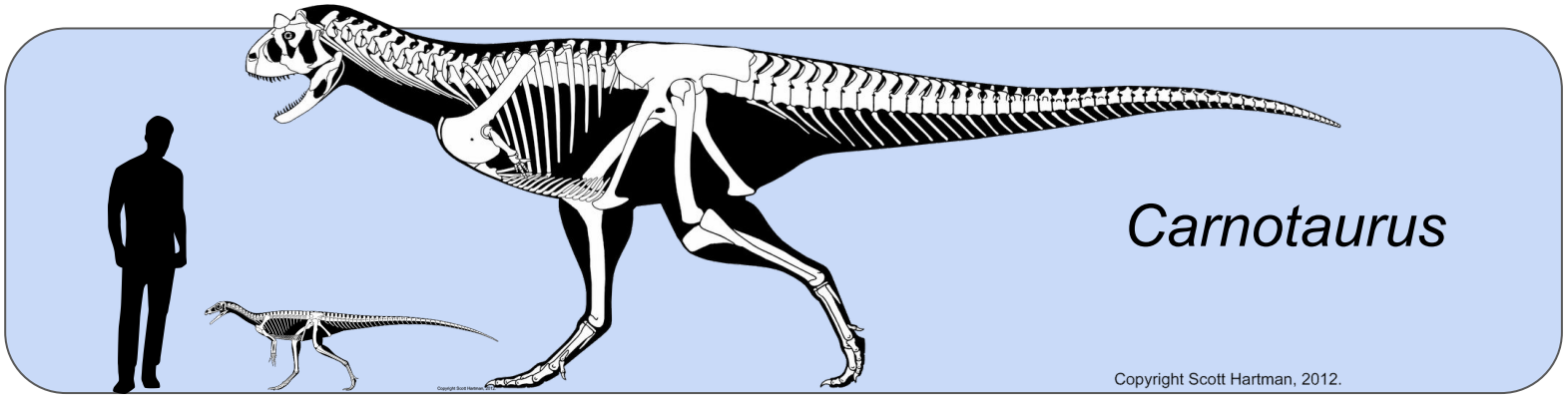
Latin: “carnis” = flesh, “taurus” = bull



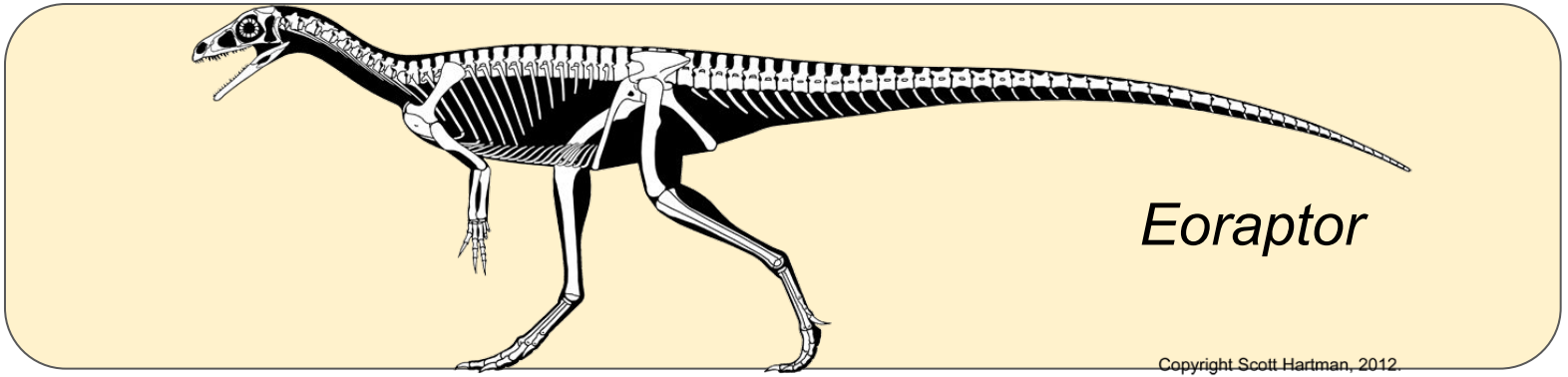


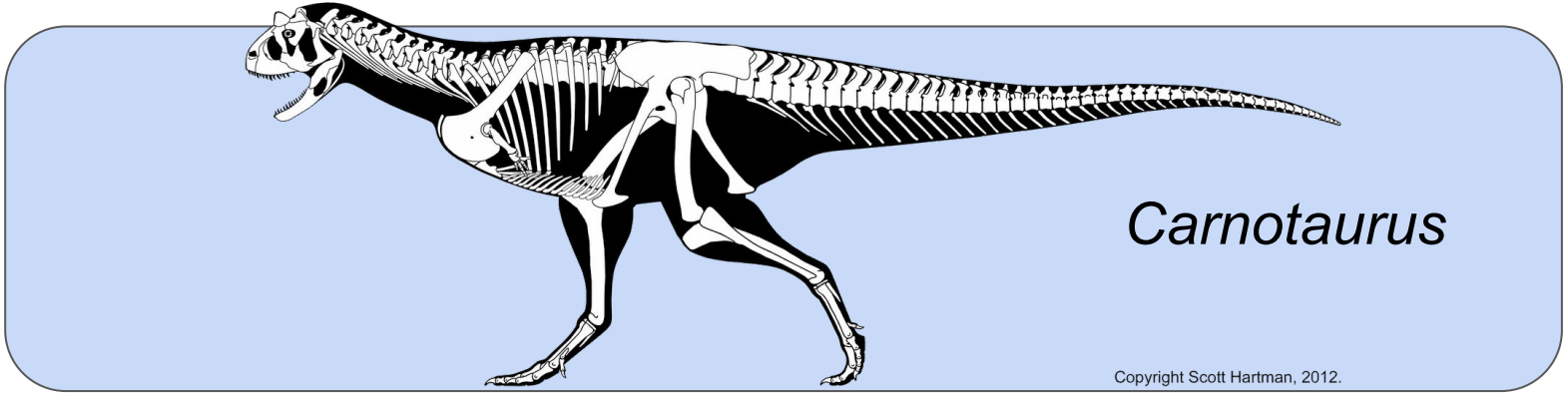
Carnotaurus by Cheung Chung Tat (source)

Non-adaptive forms of evolution



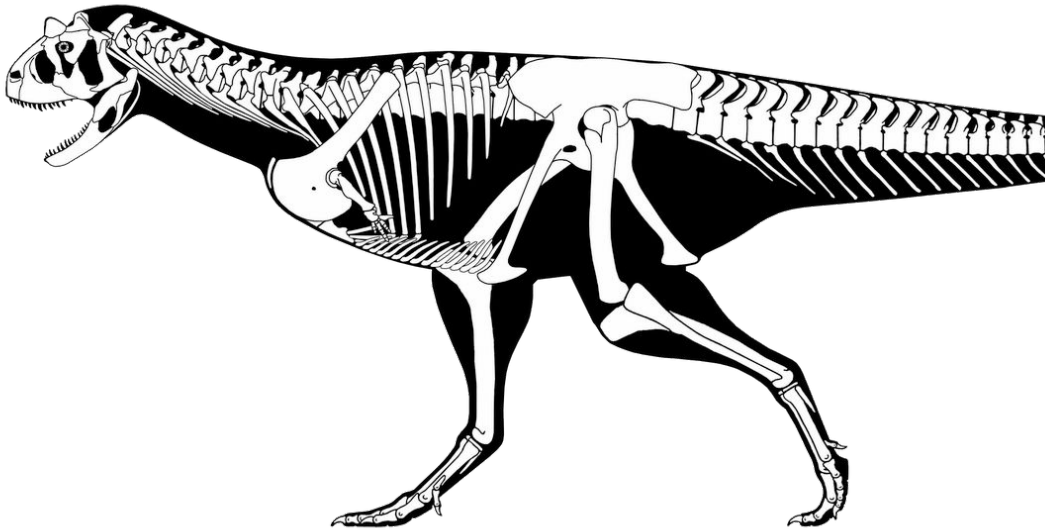
Non-adaptive forms of evolution





Non-adaptive forms of evolution

- *Carnotaurus* has many distinctive features
- Are they all adaptive? In other words, do they serve a purpose?
- Should not be assumed; needs to be tested



Non-adaptive forms of evolution

- One can always hypothesize…

Carnotaurus from “Prehistoric Planet” (2022; Apple TV+) (source)

Conclusion

- Dinosaurs were animals that had to survive in the world, and their **morphologies** (forms) were shaped by two evolutionary processes
- **Natural selection** generated novel adaptations
- **Common descent** limited the range of possibilities natural selection could take