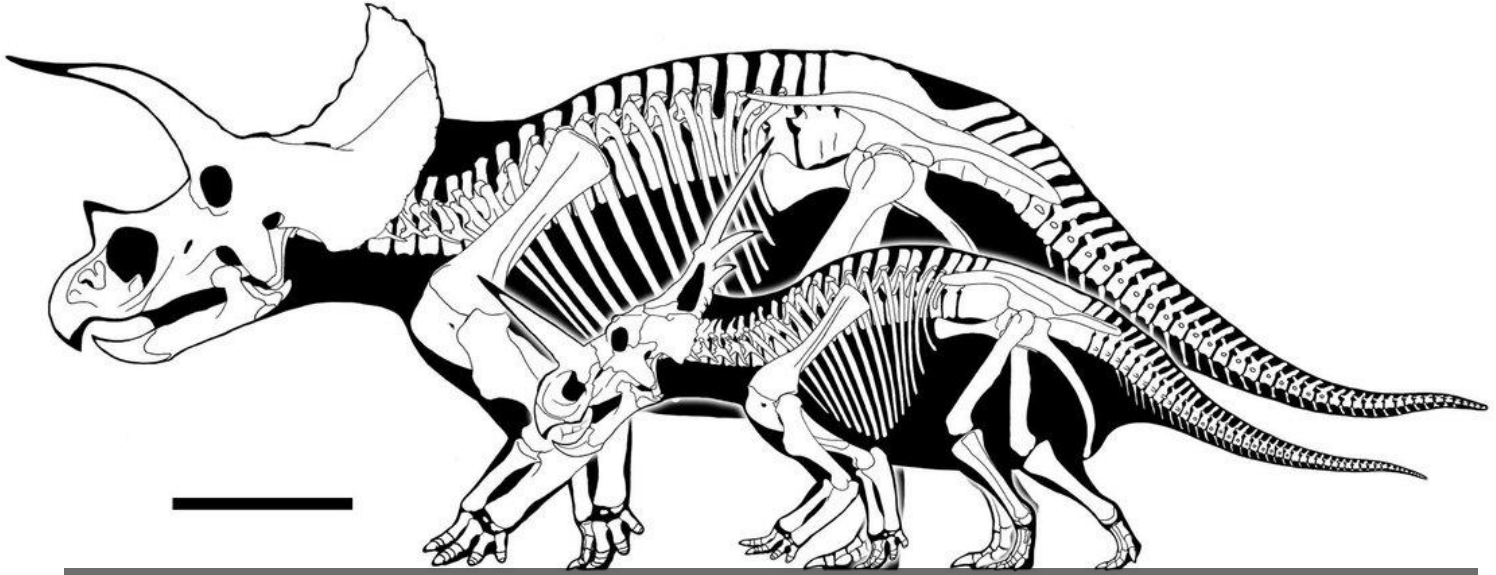
Lecture 8: Cladistics
(Who is related to who?)



Triceratops and *Styracosaurus* (source)

Previous classes

- Dinosaurs (including birds) are a group of animals that share a unique **common ancestor** (the first dinosaur)

- Dinosaurs share many traits in common that were passed on from that common ancestor to its descendants

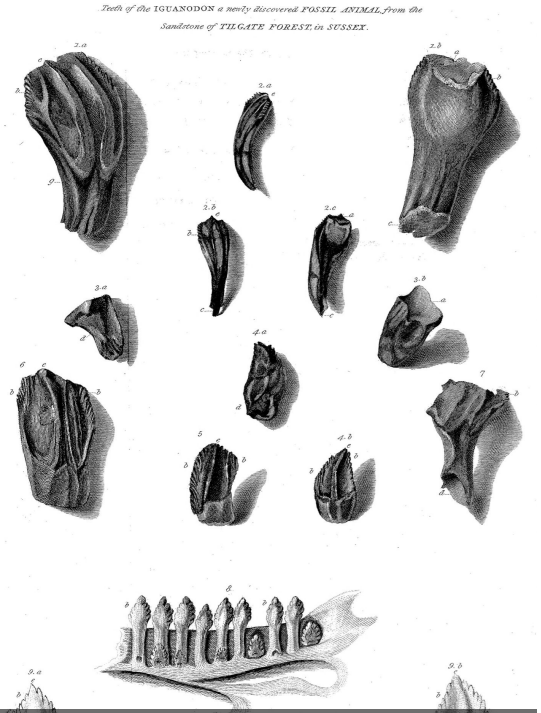
Eoraptor

Latin: “eo” = dawn, “raptor” = thief

The science of comparative anatomy

- **Comparative anatomy**: the study of similarities and differences between species

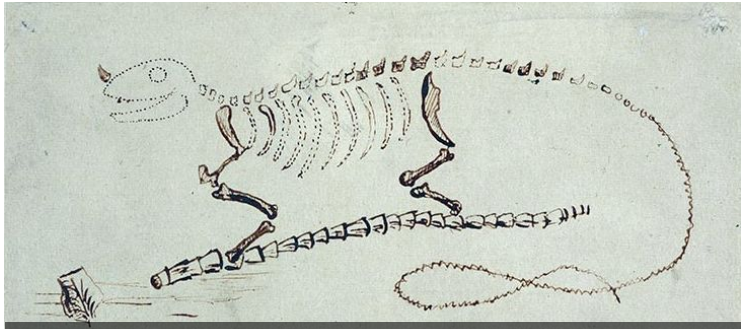
- The first dinosaur to be described, *Iguanodon*, was given the name because of its teeth were similar to an iguanas



Illustrations of the teeth in the original paper on Iguanodon

Mantell, Gideon A. (1825). "Notice on the Iguanodon, a newly discovered fossil reptile, from the sandstone of Tilgate forest, in Sussex". Philosophical Transactions of the Royal Society. 115: 179–186.

The science of comparative anatomy

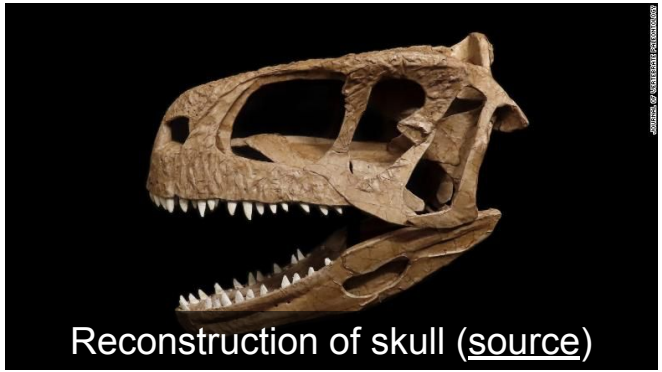


Original reconstruction of an *Iguanodon* skeleton (source)

Modern reconstruction by Raúl Martín (source)

- Based on the size and shape of the teeth, Iguanodon was originally thought to be lizard-like and ~60 feet long
- This is a limitation of comparative anatomy--it is only as good as the things you have to compare your specimen to!

As more dinosaurs were discovered, they were organized into major groups

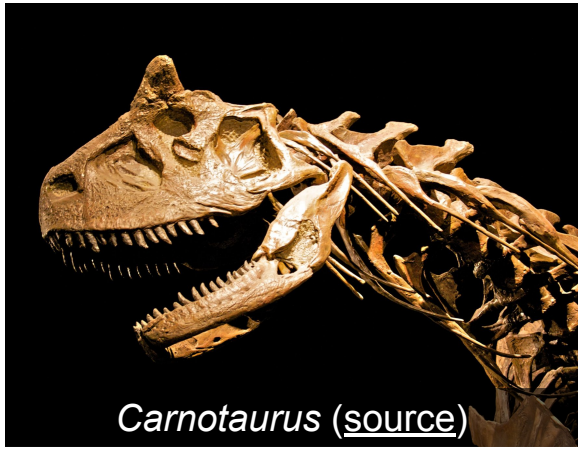


Reconstruction of skull (source)

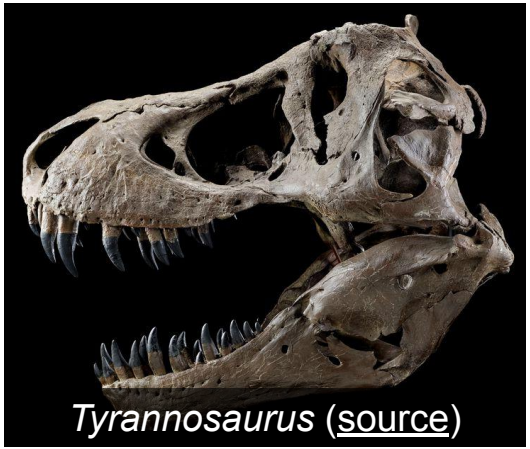
Llukalkan

Mapuche: "the one who causes fear"

Reconstruction of animal (source)

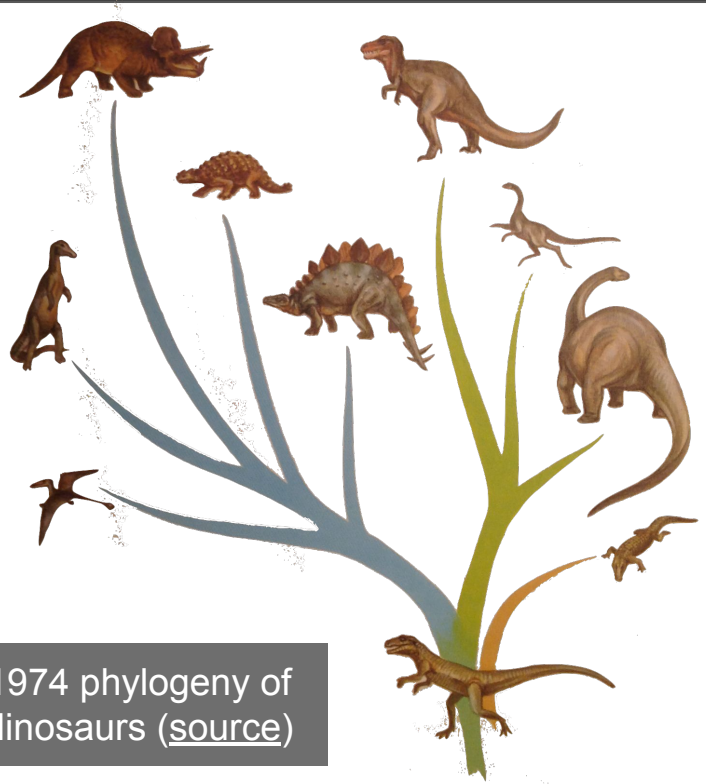


Carnotaurus (source)



Tyrannosaurus (source)

Scientists eventually started hypothesizing about their evolutionary relationships



1974 phylogeny of dinosaurs (source)

- Classic way of showing an **evolutionary tree** (or **phylogeny**) of dinosaurs

- Problems with this approach

Zappler, L. and Zappler, G. (1974). Then and Now. United States: McGraw-Hill.

Cladistics as a method for inferring relationships

- **Cladistics** formalized the process of determining evolutionary relationships (phylogenies)

Lizard (source); alligator (source); macaw (source)

- **Step 1**: determine which taxa you want to include in your tree

Taxa (singular - **taxon**) any unit used in the biological classification of life (**taxonomy**). Can be populations, species, or larger clades

Cladistics as a method for inferring relationships

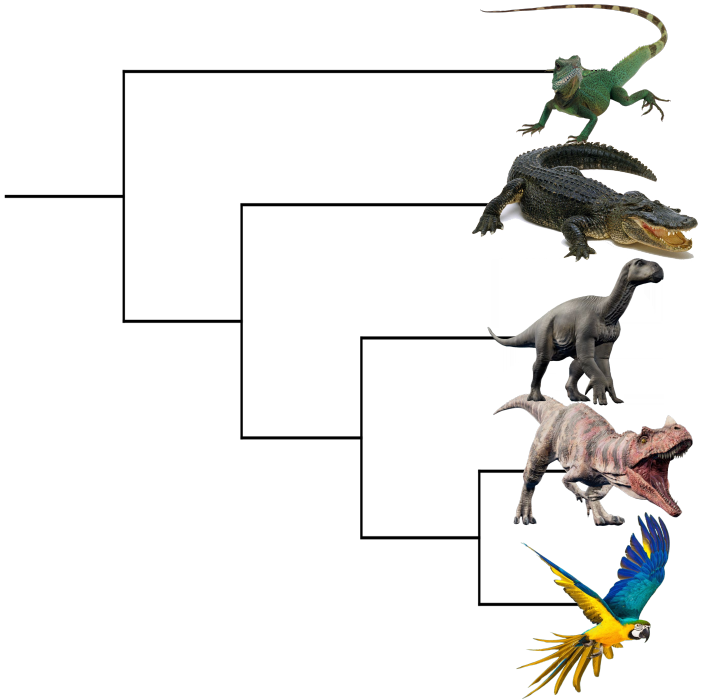
- **Step 2**: create a matrix describing as many relevant character traits as possible

Taxa	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Democricetodon lindsayi	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Plesiodipus leei	1	0	2	1	1	1	0	1	0	2	1	1	1	0	0	0	0	0
Plesiodipus progressus	1	0	2	1	1	1	0	1	0	2	1	1	1	0	1	1	1	0
Gobicricetodon flynni	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Gobicricetodon robustus	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
Prosiphneus qiui	1	0	0	0	2	1	1	2	1	2	2	1	2	1	1	0	0	1
Prosiphneus haoi	1	1	2	0	2	1	1	2	2	2	2	1	2	2	1	0	0	1
Prosiphneus licenti	1	1	2	0	2	1	1	2	2	2	2	1	2	2	1	0	0	1
Prosiphneus murinus	1	1	2	0	2	1	1	2	2	2	2	1	2	2	1	0	0	1
Prosiphneus tianzuensis	1	1	2	0	2	1	0	2	3	2	2	1	2	3	2	0	0	2
P. eriksoni (Ertemte)	1	1	2	0	2	1	1	2	3	2	2	1	2	3	2	0	0	2
P. eriksoni (Zanda)	1	1	2	0	2	1	1	2	3	2	2	1	2	3	2	0	0	2
Prosiphneus cf. *P. eriksoni*	1	1	2	0	2	1	1	2	3	2	2	1	2	3	2	0	0	2

doi:10.1371/journal.pone.0144993.t005

Cladistics as a method for inferring relationships

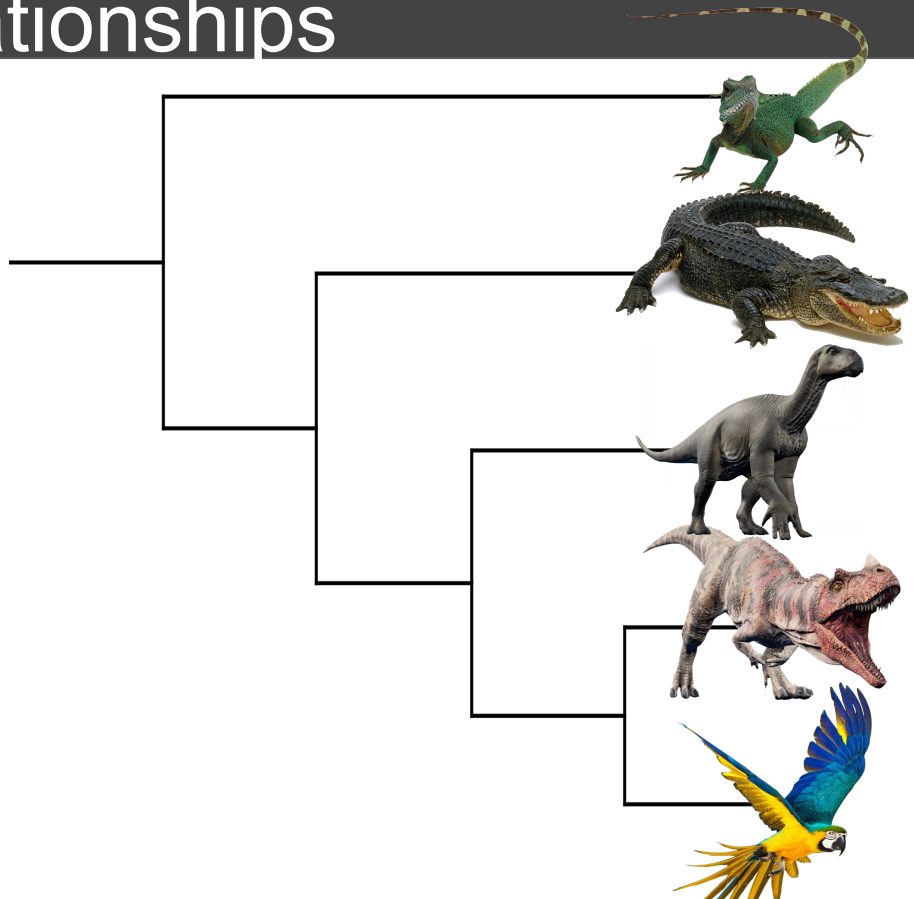
- **Step 3**: use the matrix to infer evolutionary relationships
- Traditionally done using parsimony: what evolutionary tree requires the smallest number of changes
- Now done using more complex mathematical models of evolution



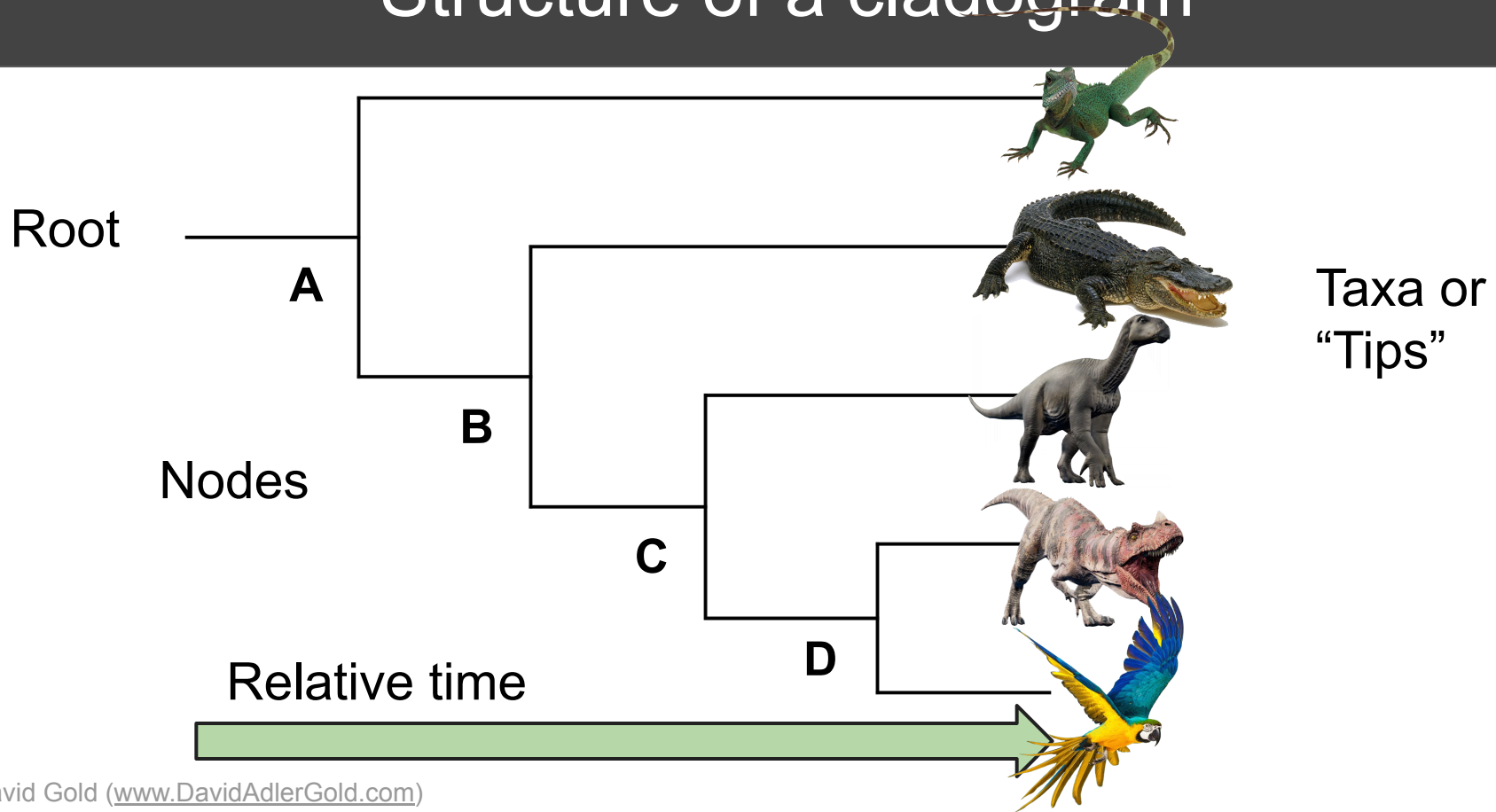
Cladistics as a method for inferring relationships

- The result - a cladogram

Cladogram - An evolutionary tree (phylogeny) made from cladistic analyses



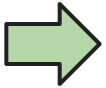
Structure of a cladogram



Structure of a cladogram

Root —— Hypothetical ancestor

Relative time



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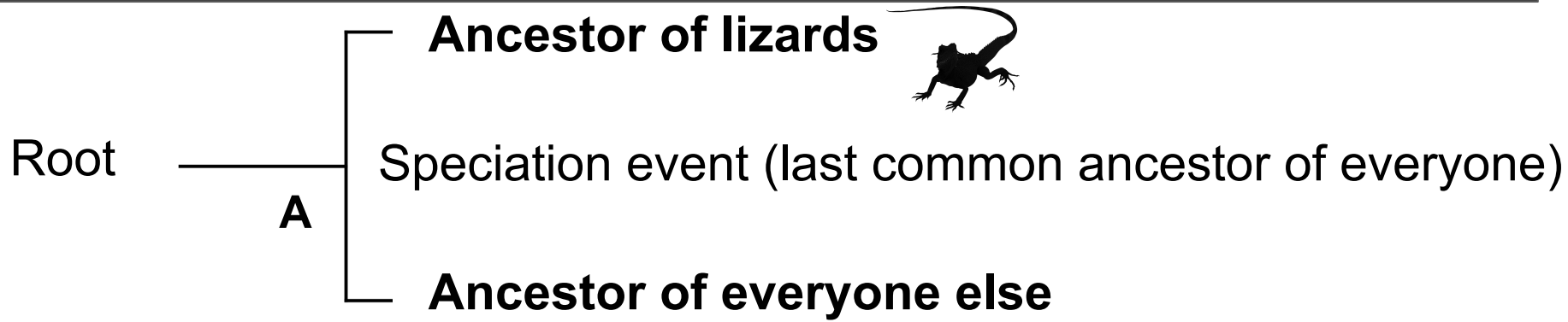
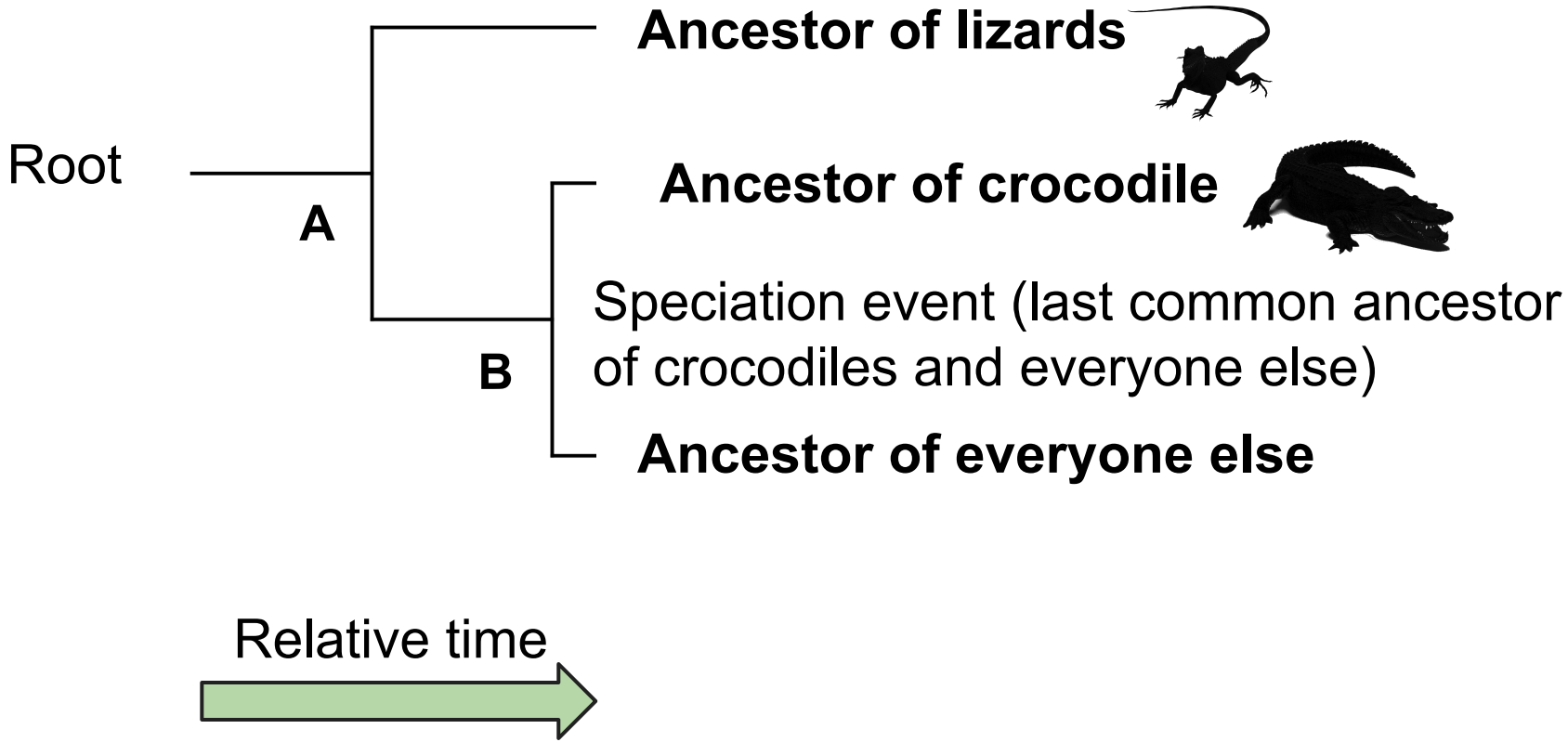
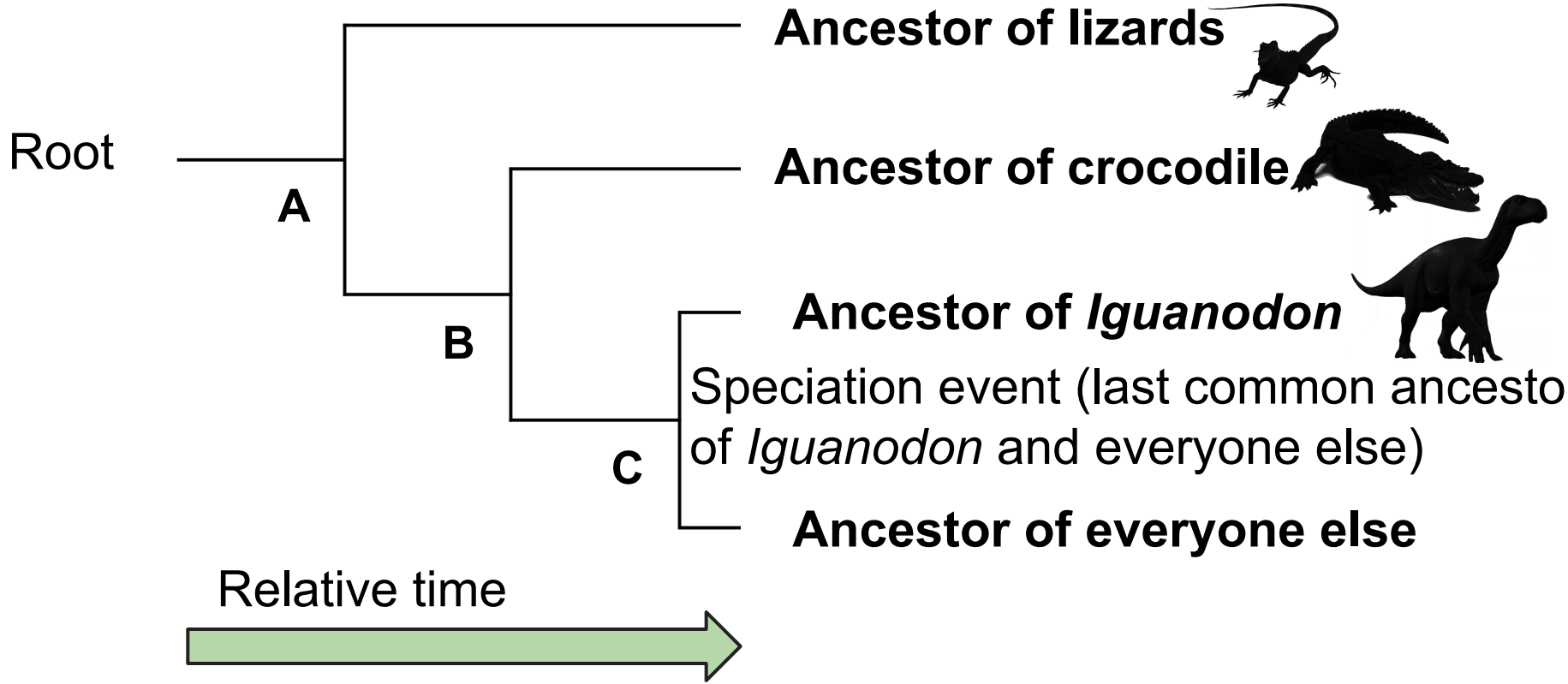


Relative time

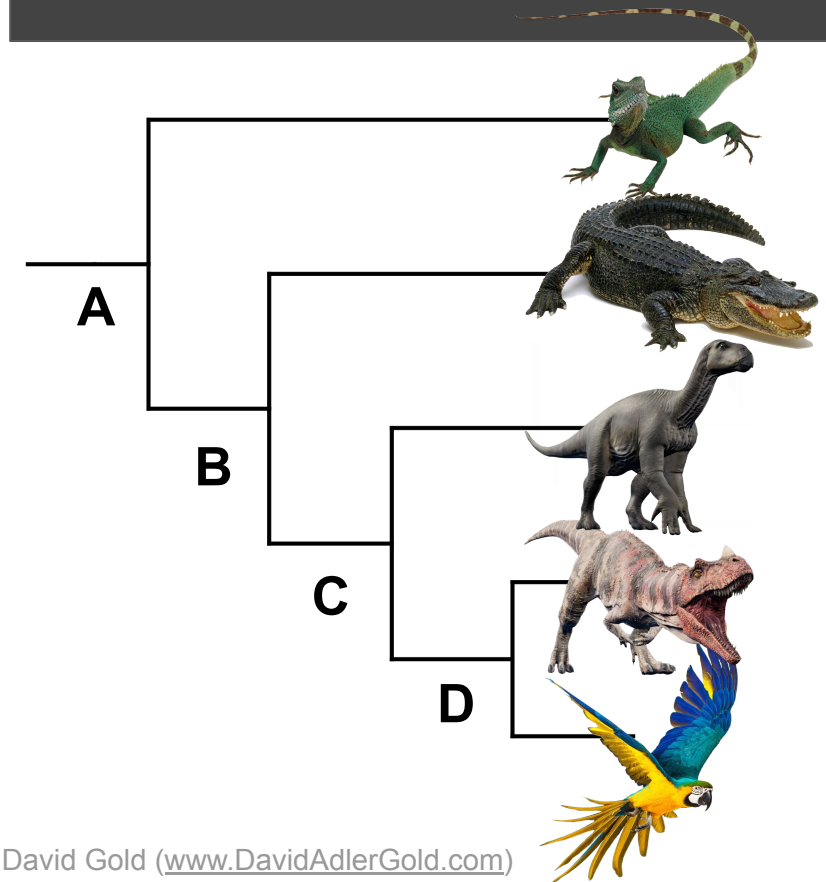
Structure of a cladogram



Structure of a cladogram



Do not be tricked by the order of the tips



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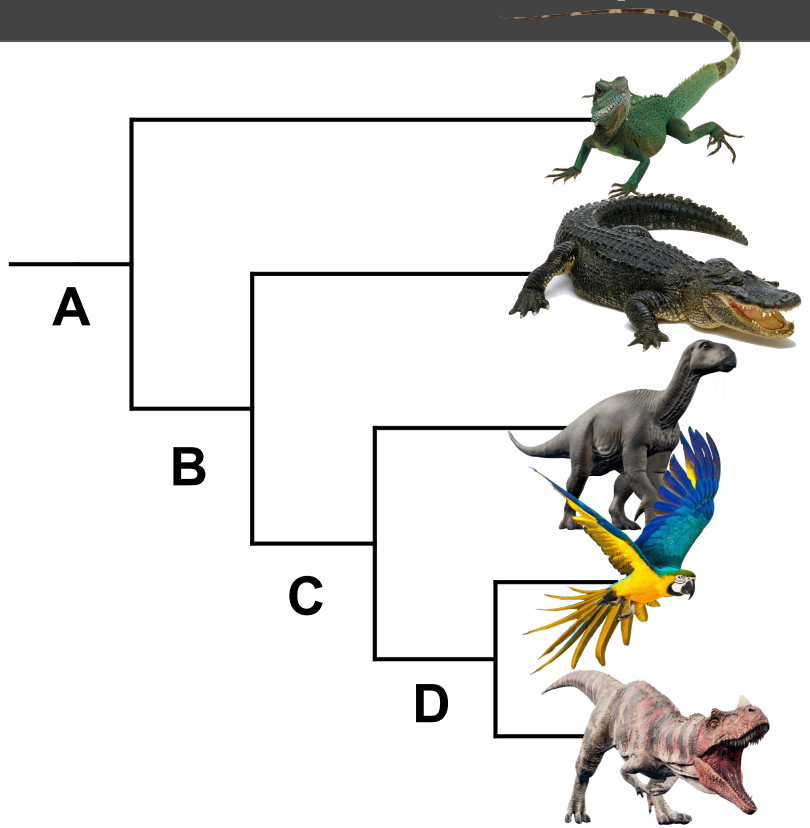

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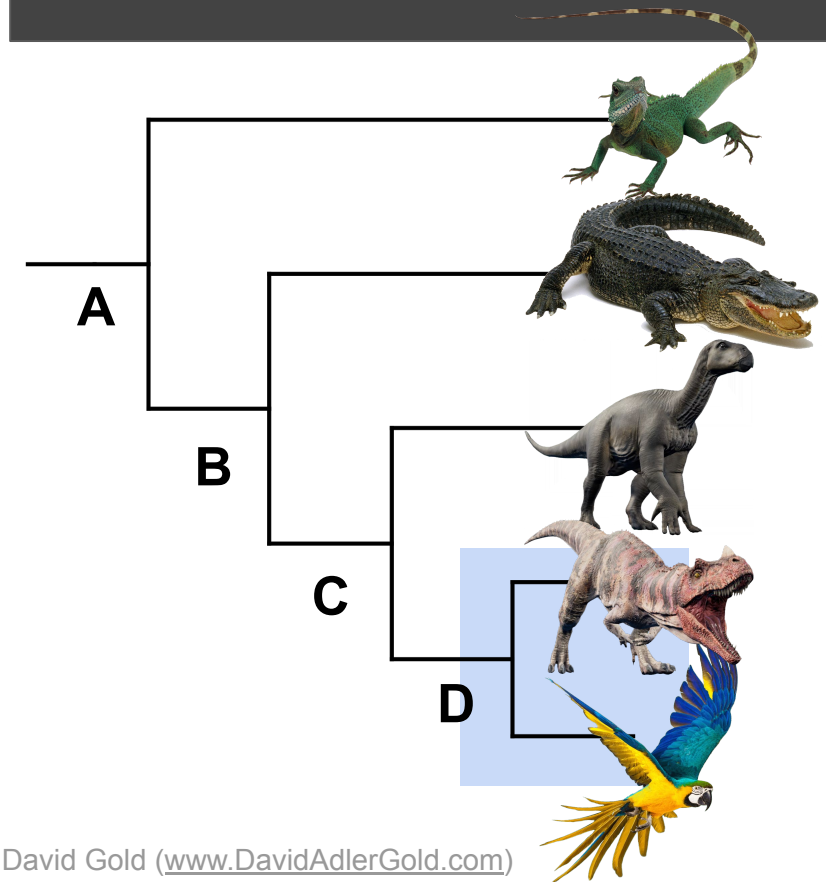

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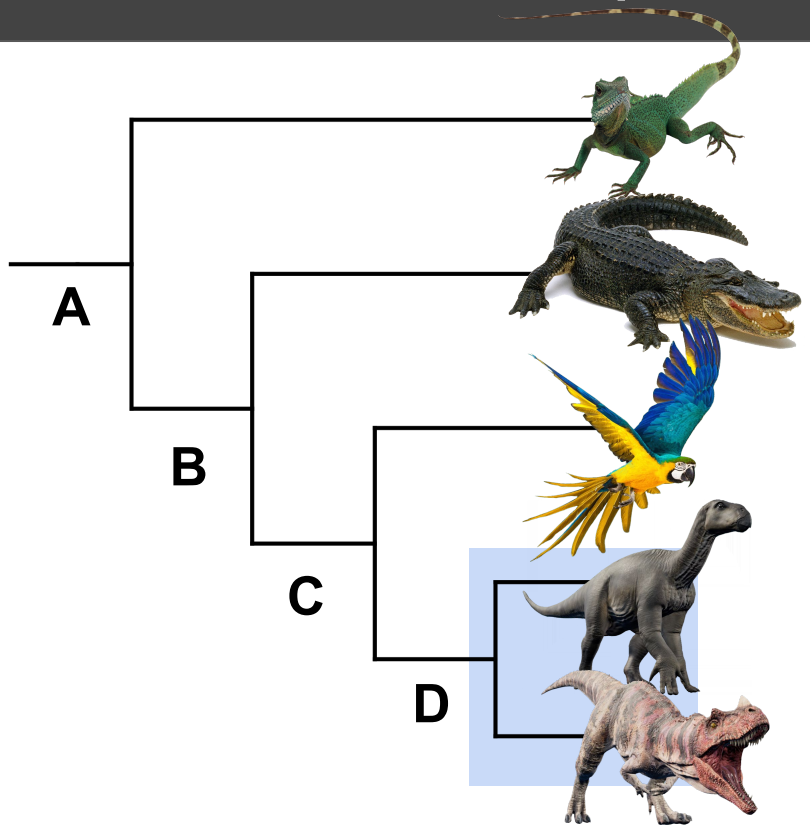
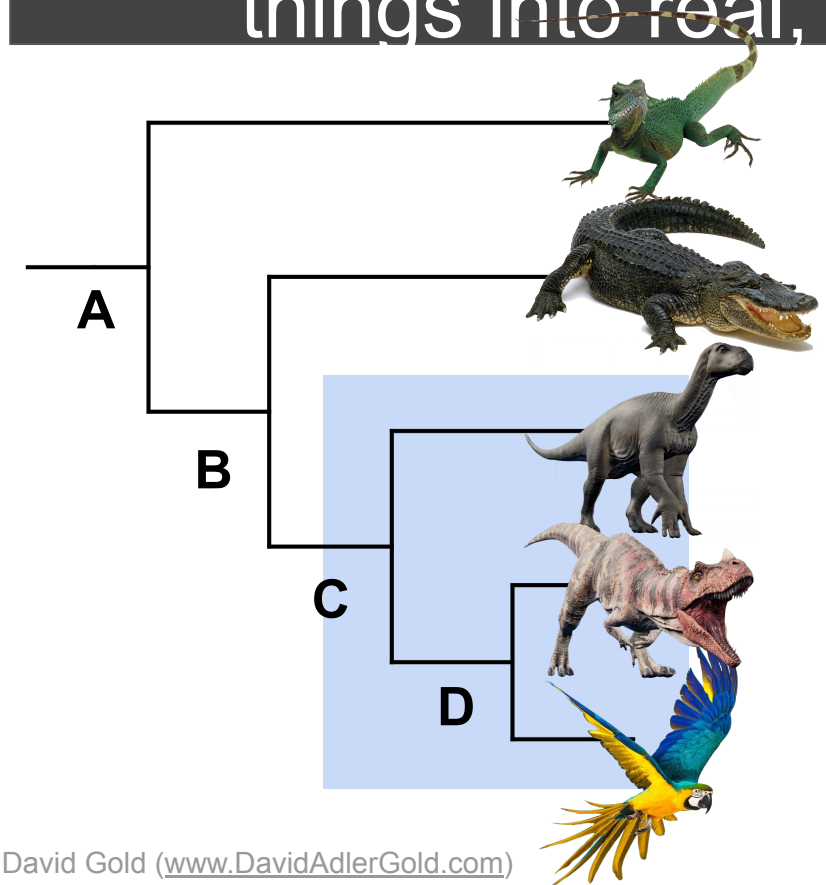


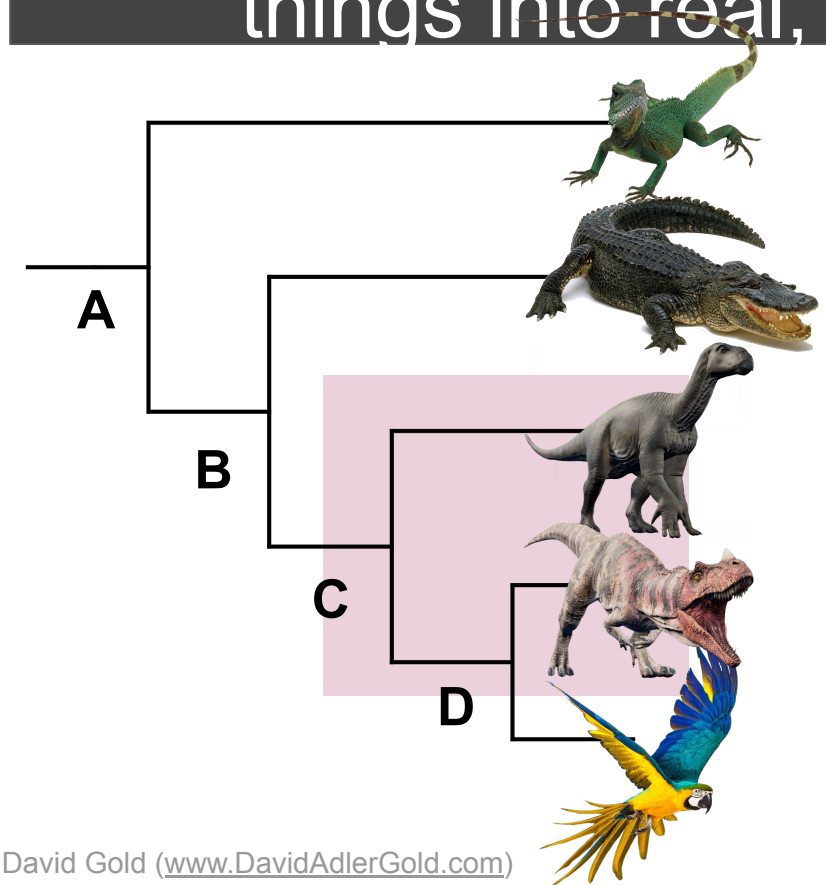
The goal of taxonomy is to organize living things into real, monophyletic groups



- **Monophyletic clade** - A group made up of a common ancestor and all of its descendants

- The traits *shared* between members of a monophyletic group and are *unique* to the group become hypothesized **synapomorphies**

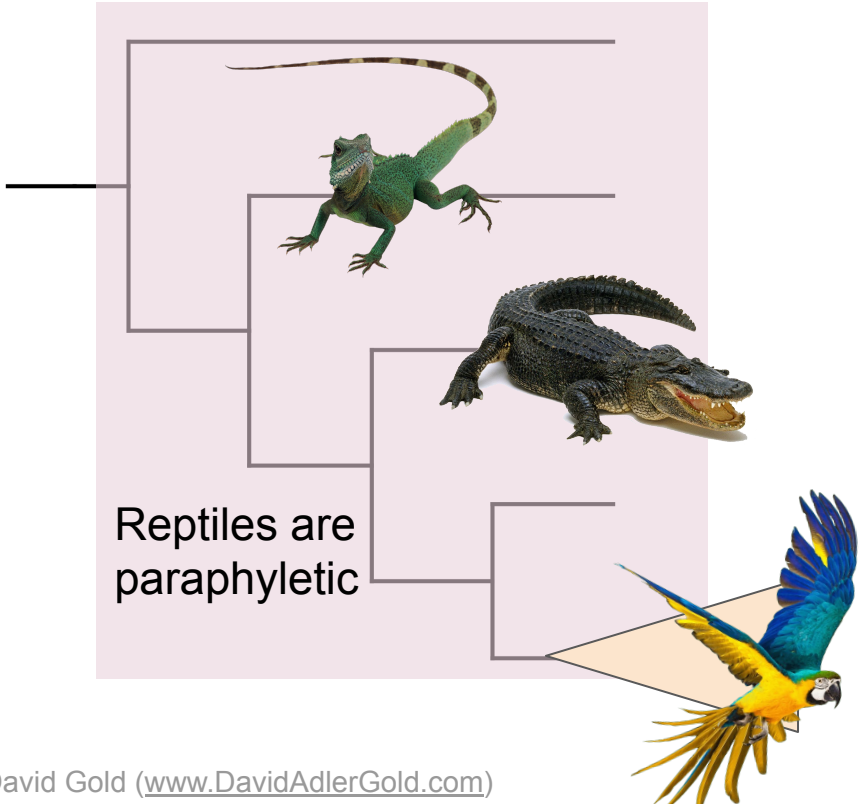
The goal of taxonomy is to organize living things into real, monophyletic groups



- **Paraphyletic clade** - A group made up of a common ancestor and some, but not all of its descendants

- Paraphyletic clades are useful for constraining the **ancestral condition**

The goal of taxonomy is to organize living things into real, monophyletic groups



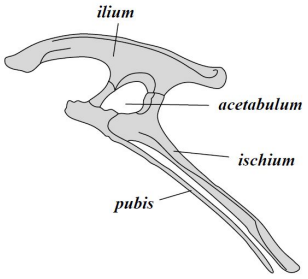
- **Paraphyletic clade** - A group made up of a common ancestor and some, but not all of its descendants

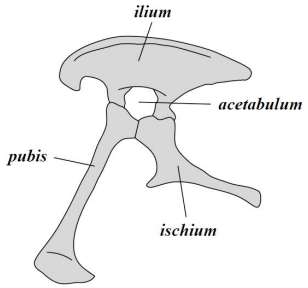
- Paraphyletic clades are useful for constraining the ancestral condition

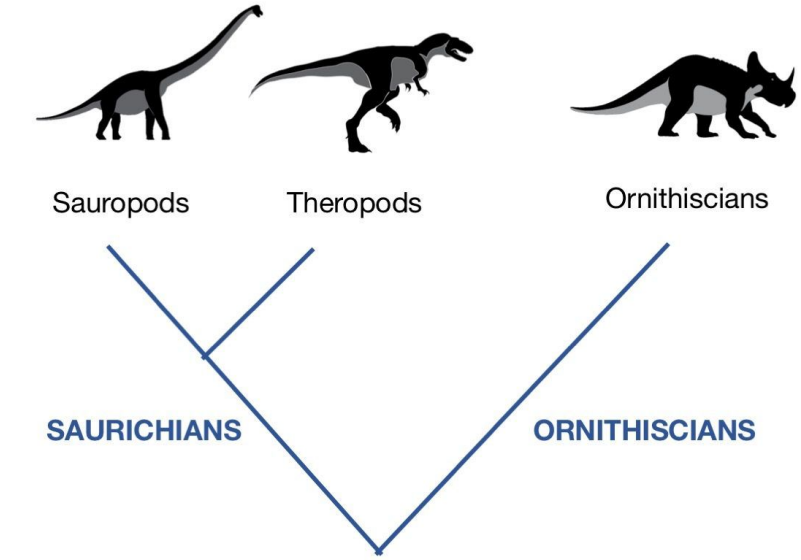
Each cladogram is a scientific hypothesis, and can be changed with new data

- Dinosaurs have traditionally been divided into two groups, the Ornithischians and Saurischians

- The shape of the pelvis is a synapomorphy dividing the two





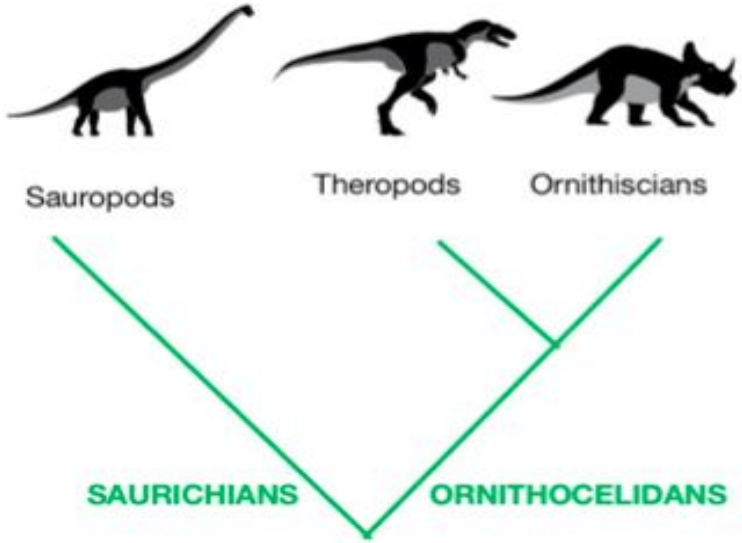


Traditional dinosaur cladogram (source)

Each cladogram is a scientific hypothesis, and can be changed with new data

- In 2017 a new study used more data than any previous study and came to a different conclusion

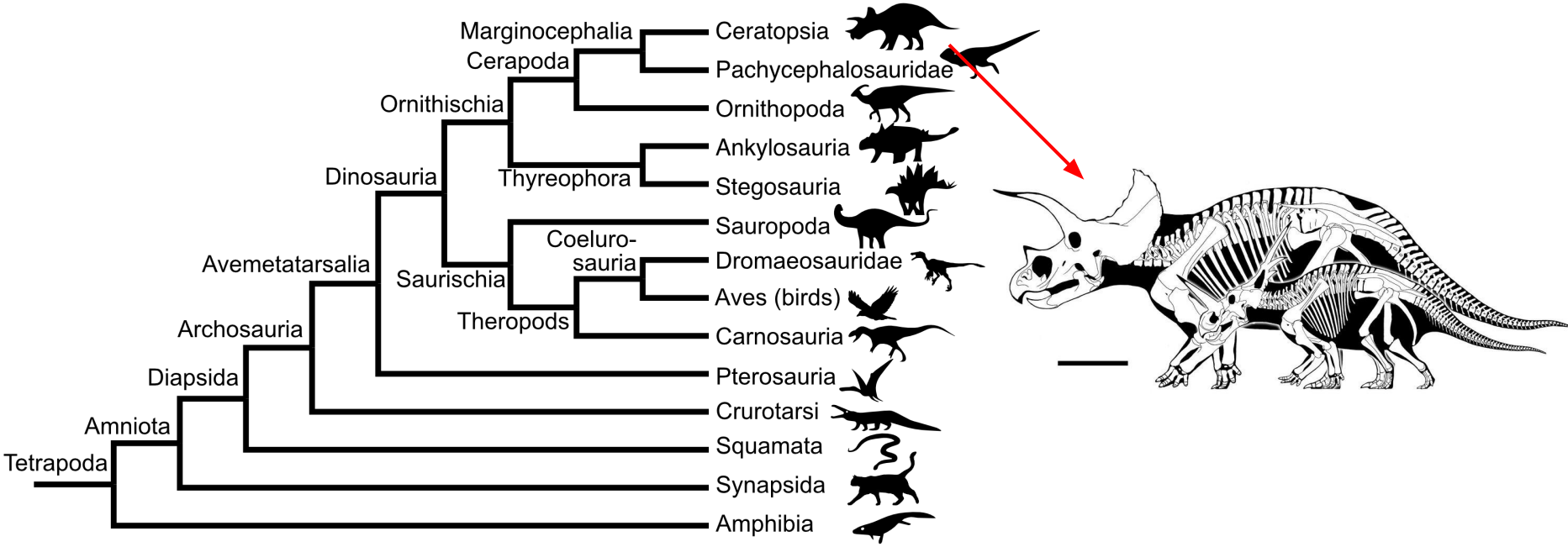
- Some studies since support the traditional cladogram, some the new one. This is an active area of science...



Alternative dinosaur cladogram (source)

Baron, Matthew G.; Norman, David B.; Barrett, Paul (2017). "A new hypothesis of dinosaur relationships and early dinosaur evolution". Nature. 543 (7646): 501–506.

The dinosaur cladogram



Conclusions

- **Comparative anatomy** helps us determine what an animal looks like, even if we only have partial information

- In dinosaur research, comparative anatomy is aided by **cladistics**, a form of phylogenetic (evolutionary tree) inference

- Each **cladogram** is a **hypothesis**