TAXONOMY AND PHYLOGENY

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Things to remember…

- Systematics
- Taxonomy
- Phylogenetic tree or cladogram
- Kinds of characters
- Homology & analogy
- Mono-, para- & polyphyletic groups

Reading material: Invertebrate Paleontology and Evolution, by Clarkson

Practice of classification

- People have classified the natural world for thousands of years based on traits such as:
  - edibility - “We can eat these plants, but not these.”
  - cultural meaning - “These animals are sacred, these are evil.”
  - utility - “These animals pull our plows, those we shear for wool.”

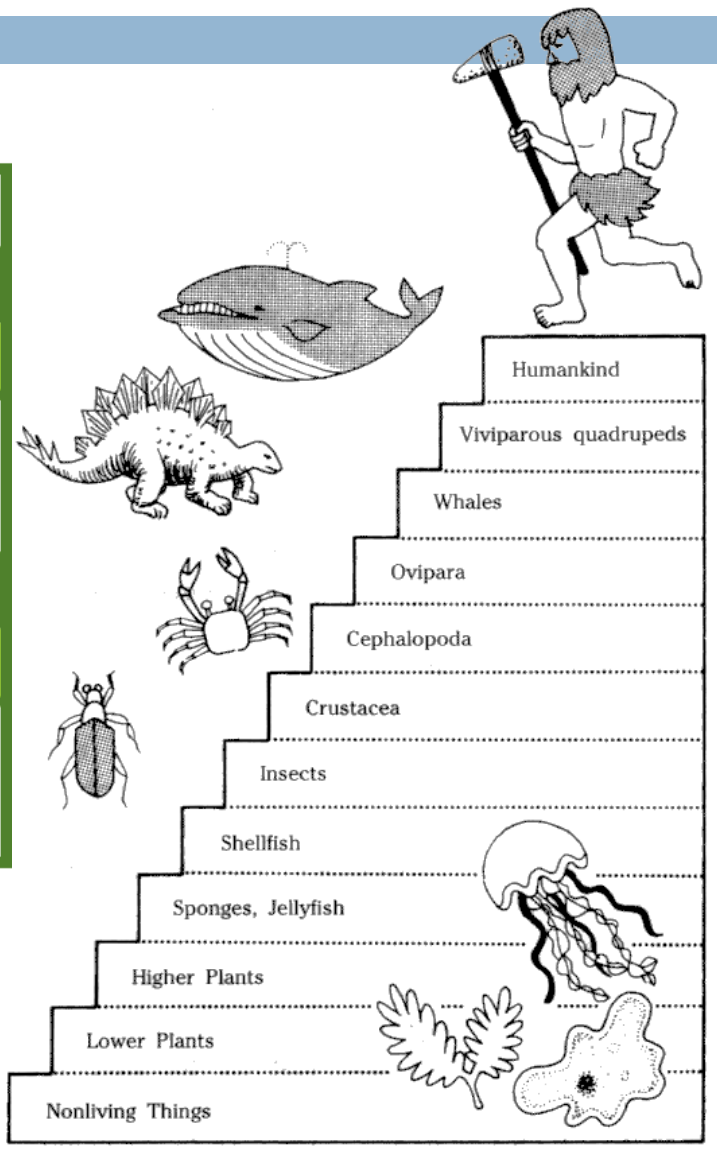
Classifying organisms

- More than 2000 years ago, Aristotle developed the first widely accepted system of biological classification

- Aristotle's System- Classified organisms as either animals or plants
  - Plants were classified by size (trees, shrubs or herbs
  - Animals were classified as “bloodless” or “red-blooded”

Finding order in nature

Aristotle's Classification System		
Plants		
Herbs	**Shrubs**	**Trees**
Violets Rosemary Onions	Blackberry bush Honeysuckle Flannelbush	Apple Oak Maple
Animals with red blood		
Land	**Water**	**Air**
Wolf Cat Bear	Dolphin Eel Sea bass	Owl Bat Crow



Naturalistic Systematics

- Around the 18th century, naturalists sought to classify nature in a way that reflected nature, rather than the way humans use nature.
- Of course, there was disagreement about what constituted a "natural" system, or even if a "natural" system was necessary.

Carolus Linnaeus (1707-1778)

There's no systematic organization of *anything!* I'm going to fix that!

- broadened Aristotle's classification
- created the 1st formal system of taxonomy.

- Taxonomy- branch of biology that identifies, names and classifies species based on their natural relationships

Systematics

- **Systematics** is the study of biological diversity in an evolutionary context

- Includes
  - *Speciation*
  - *Taxonomy*
  - *Phylogeny*

- Goal: to Determine Evolutionary History (**Phylogeny**) of Life

Taxonomy

- Taxa - group of organisms at a particular level in a classification system (taxonomy)
- **Taxonomy** is the branch of systematics concerned with naming and classification.

- Includes **DINC**
  - **D**escription
  - **I**dentification
  - **N**omenclature
  - **C**lassification

Taxonomy: I. Description

= assign features

- **Character** = a feature (e.g., "body height")
- **Character states** = two or more forms of a character (e.g., "short," "tall").
- Biologists can use DNA characters, Paleontologists have only morphology of hard skeleton

Taxonomy: II. Identification

- = associate an unknown with a known using taxonomic key or characters

- Tree
  - Leaves simple ..... Species *B*
  - Leaves pinnate ..... Species C
- Herb
  - Flowers red .....Species *D*
  - Flowers white ..... Species *E*

Taxonomy: III. Nomenclature

- Naming, according to a formal system.
- Binomial: Species are two names (Linnaeus):
- E.g., ***Homo sapiens***
  - ***Homo*** = genus name
  - ***sapiens*** = specific epithet
  - ***Homo sapiens*** = species name

Taxonomy: IV. Classification

- Organizing different things into groups

- Classification organisms first classified by Aristotle over 2,000 years ago
  - Classification scheme of the Middle Ages was replaced with a binomial system by Linnaeus about 250 years ago.

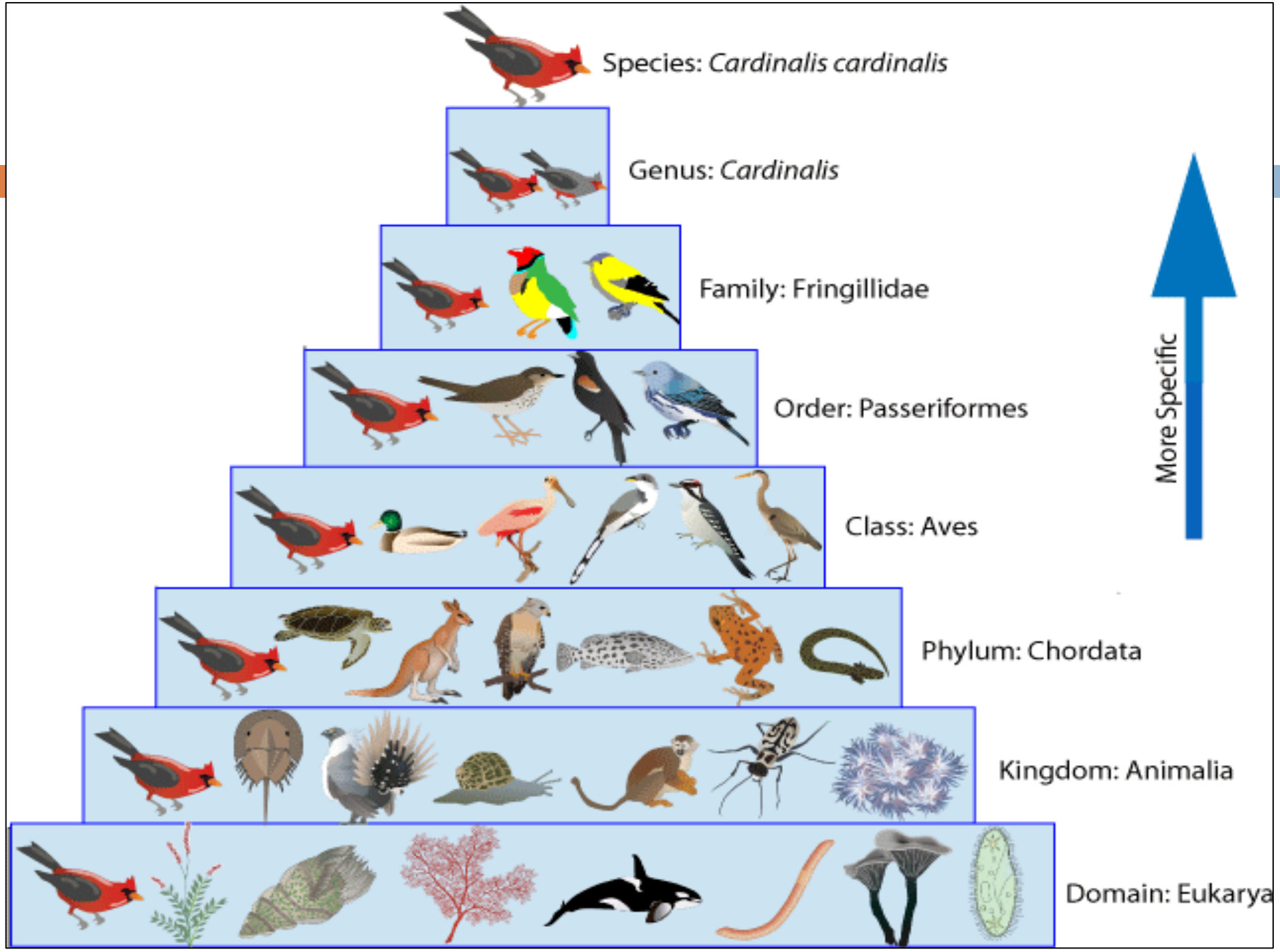
Taxonomical hierarchy

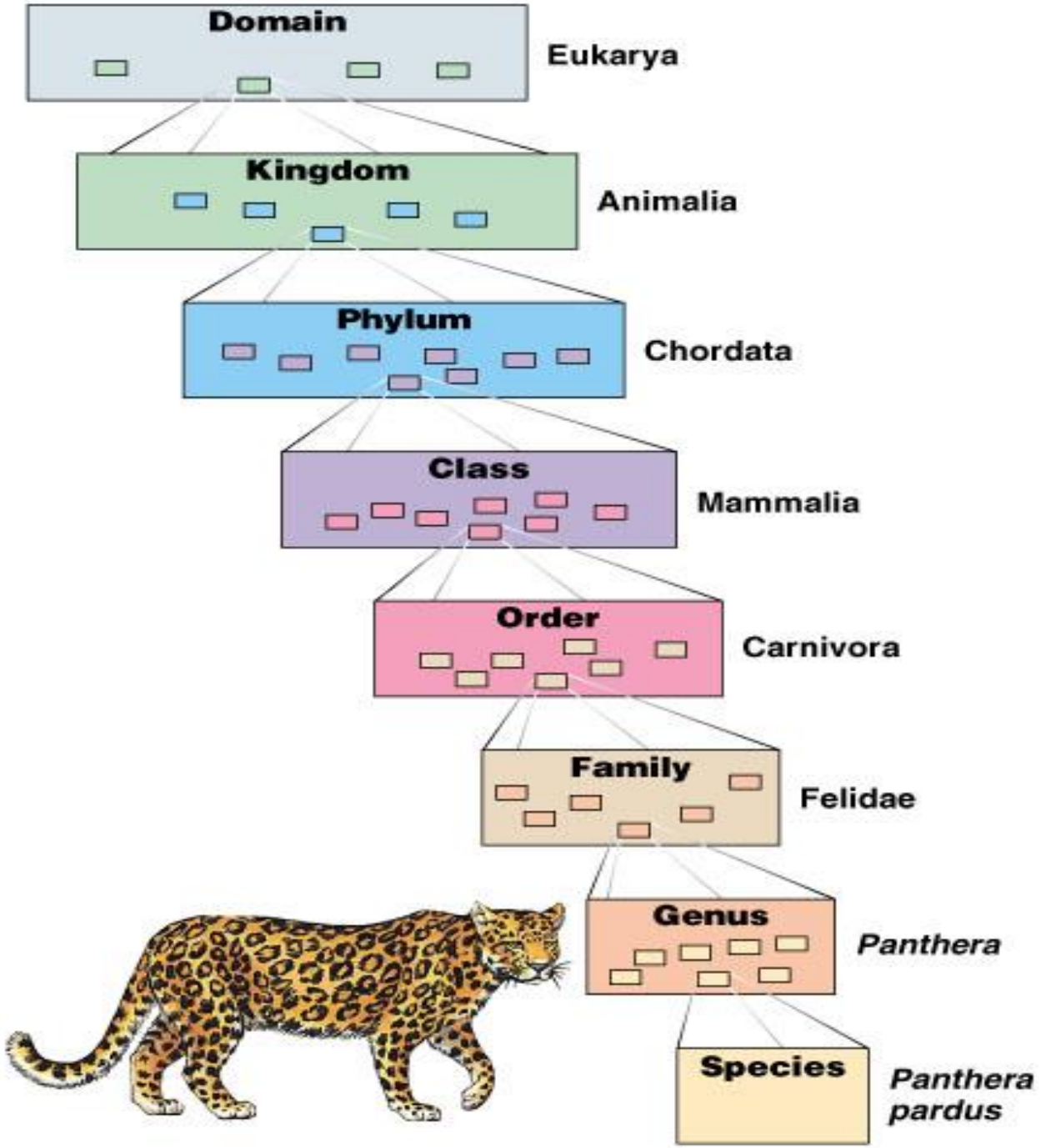
- Domain
  - Kingdom
    - Phyla
      - Classes
        - Orders
          - Families
            - Genera
              - Species

Biological classifications are hierarchical: each taxonomic group is nested within a more inclusive higher order group.

Taxonomic hierarchy

- **Species**- group of organisms that can interbreed and produce fertile offspring
- **Genus**- group of species that are closely related and share a common ancestor
- **Family**- group of related genera
- **Order**- group of related families
- **Class**- group of related orders
- **Phylum**- group of related classes
- **Kingdom**- group of related phyla
- **Domain**- Broadest of all taxa and contains 1 or more Kingdoms


Species: *Cardinalis cardinalis*
Genus: *Cardinalis*
Family: Fringillidae
Order: Passeriformes
Class: Aves
Phylum: Chordata
Kingdom: Animalia
Domain: Eukarya
More Specific



Phylogeny

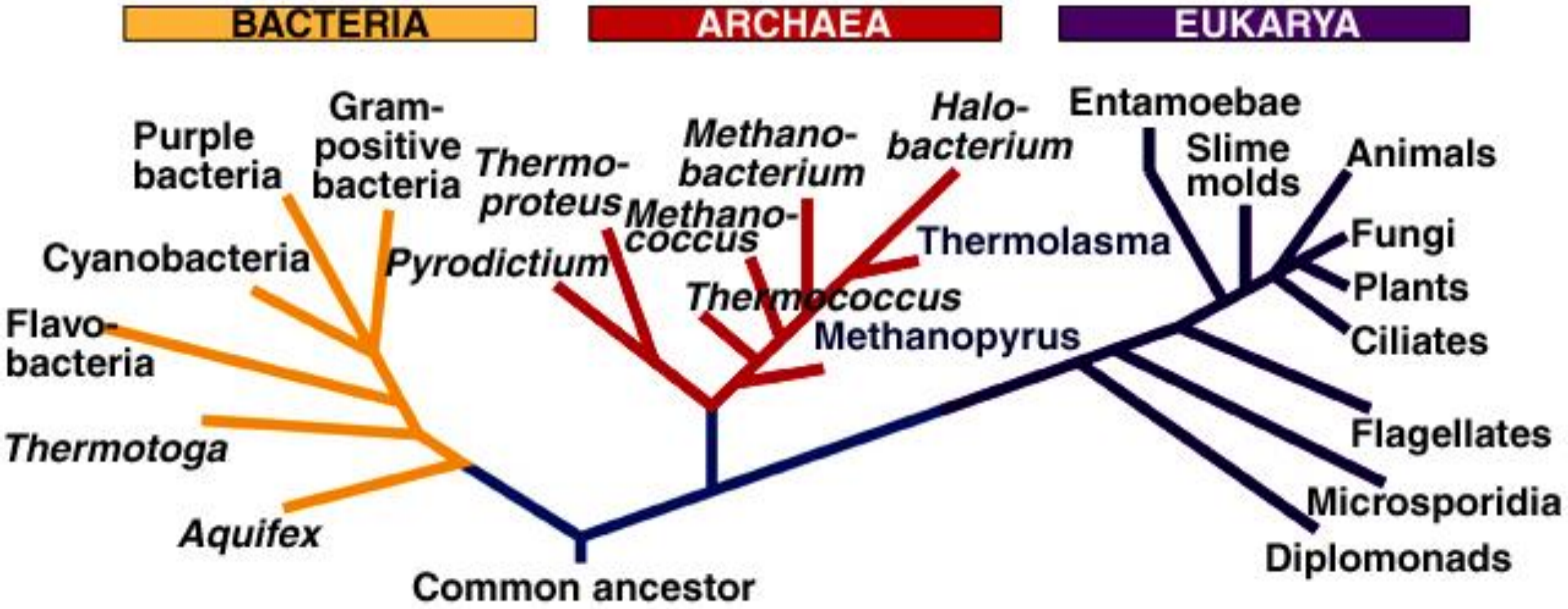
- Based on known (inferred) evolutionary history.

- Advantage:
  - Classification reflects pattern of evolution
  - Classification not ambiguous

- **Phylogenetic trees** are used to place different taxonomic schemes together, and to show connection between classification and phylogeny.

Species	*Panthera pardus* (leopard)	*Mephitis mephitis* (striped skunk)	*Lutra lutra* (European otter)	*Canis familiaris* (domestic dog)	*Canis lupus* (wolf)
Genus	*Panthera*	*Mephitis*	*Lutra*	*Canis*	
Family	Felidae	Mustelidae		Canidae	
Order	Carnivora				

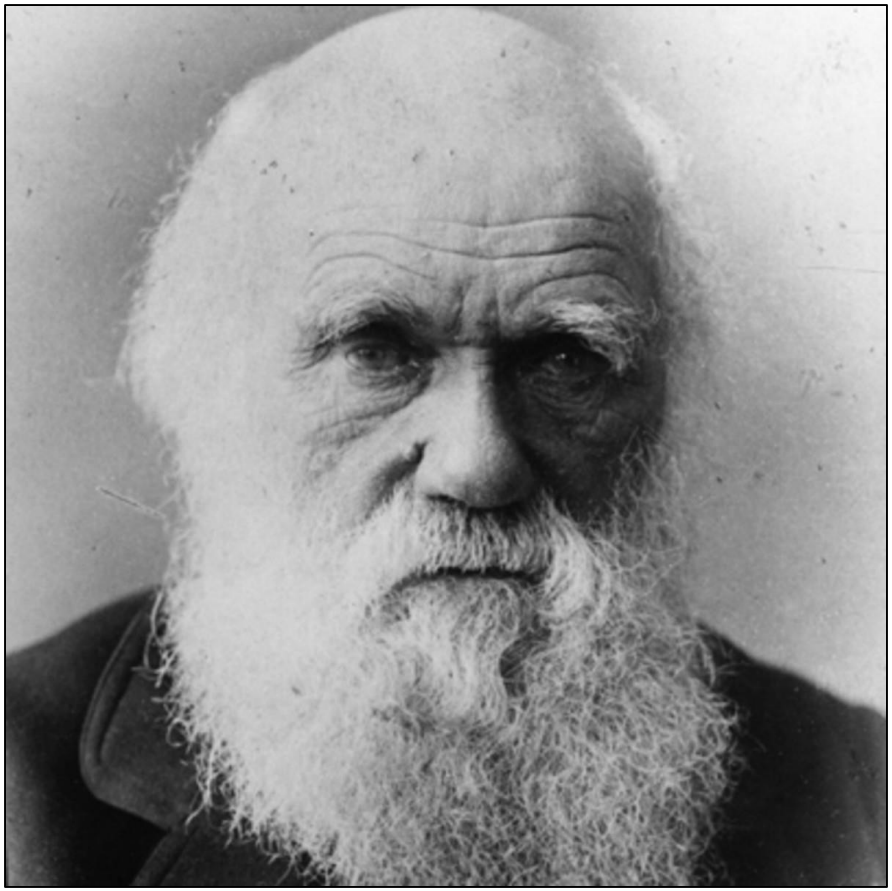
Tree of Life


BACTERIA
ARCHAEA
EUKARYA
Purple bacteria
Gram-positive bacteria
Cyanobacteria
Flavo-bacteria
Thermotoga
Aquifex
Thermo-proteus
Pyrodictium
Methano-bacterium
Methano-coccus
Thermococcus
Methanopyrus
Halo-bacterium
Thermolasma
Entamoebae
Slime molds
Animals
Fungi
Plants
Ciliates
Flagellates
Microsporidia
Diplomonads
Common ancestor

Phylogeny and Classification

"Our classifications will come to be, as far as they can be so made, genealogies."

- Charles Darwin, 1859



Taxonomy and Phylogeny

- Taxonomic characters allow phylogenetic grouping
- Useful taxonomic characters
  - Morphological
  - Molecular (biochemical)
    - Chromosomal
    - Proteins
    - DNA
- Homologies
  - Character similarities attributed to common ancestry

Cladogram

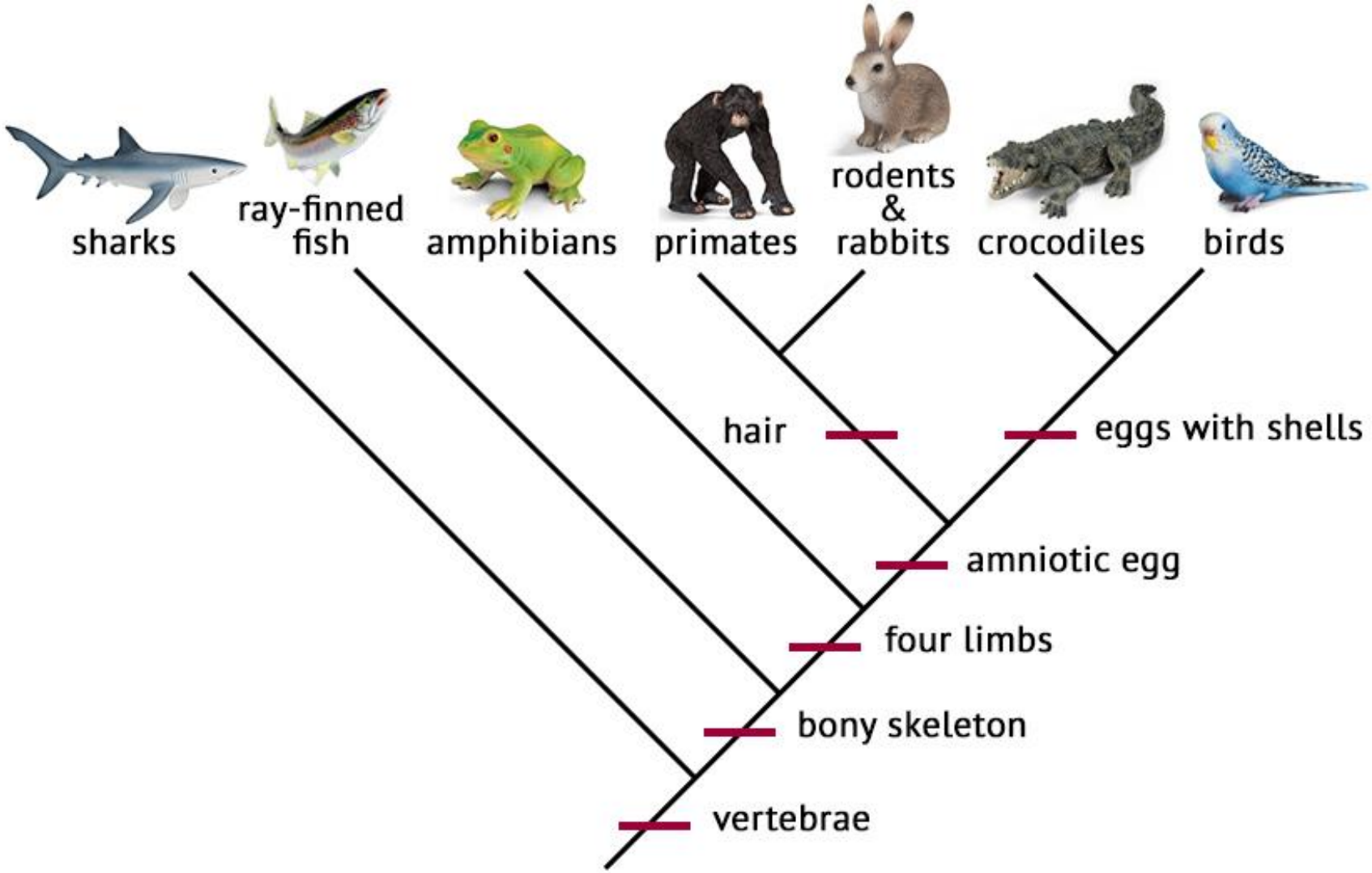
- Modern phylogenetic systematics are based on cladistic analysis

- A phylogenetic diagram (tree) is also called a cladogram.

- A cladogram is constructed that depicts hypothesis of evolutionary relationships
  - Species that share derived characters belong to a clade.
  - Each node represents a hypothetical ancestral species.

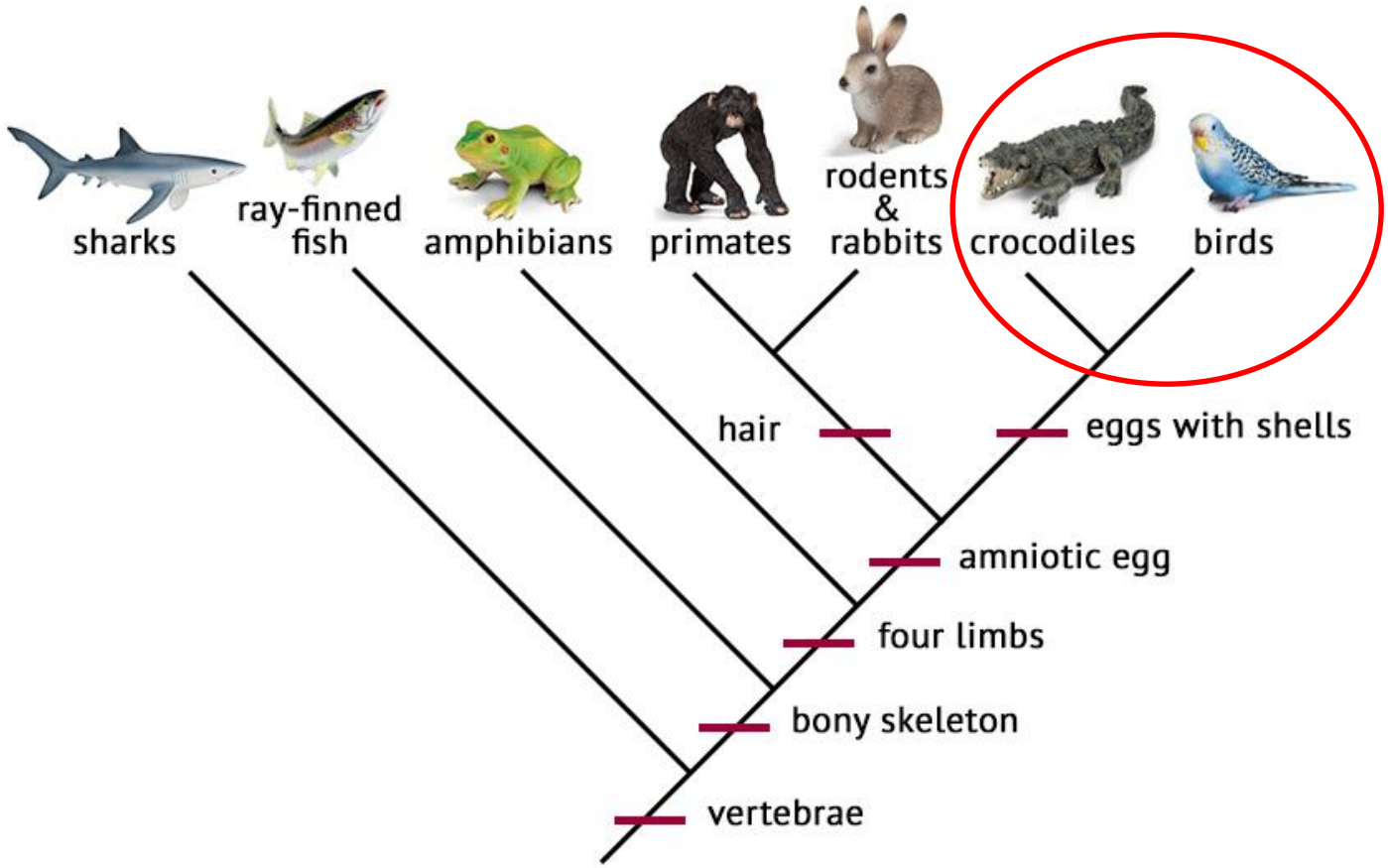
- Each branch in the tree is called a clade.

Cladogram


sharks
ray-finned fish
amphibians
primates
rodents & rabbits
crocodiles
birds
hair
eggs with shells
amniotic egg
four limbs
bony skeleton
vertebrae

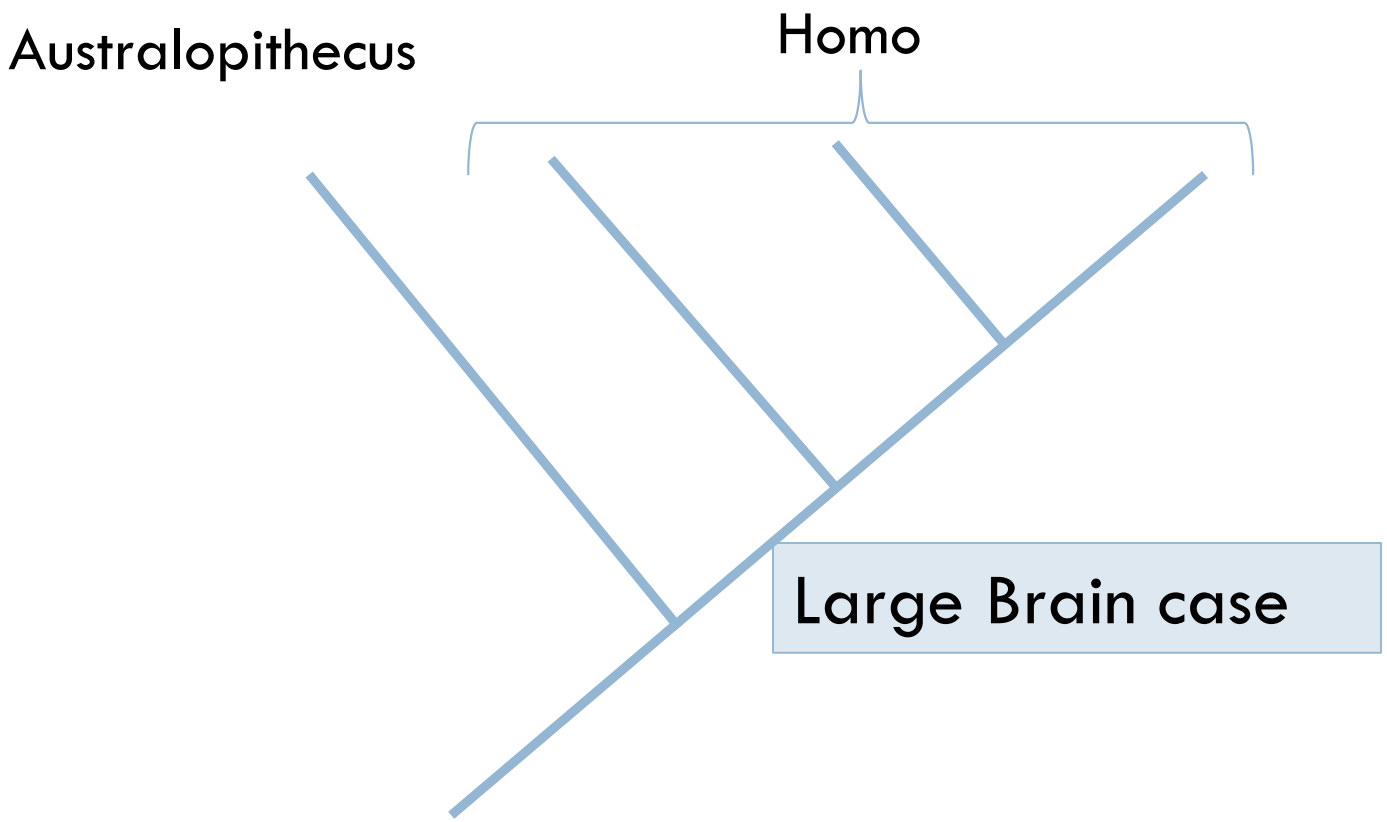
Clade

- one branch on the diagram showing a group of species that share a single common ancestor



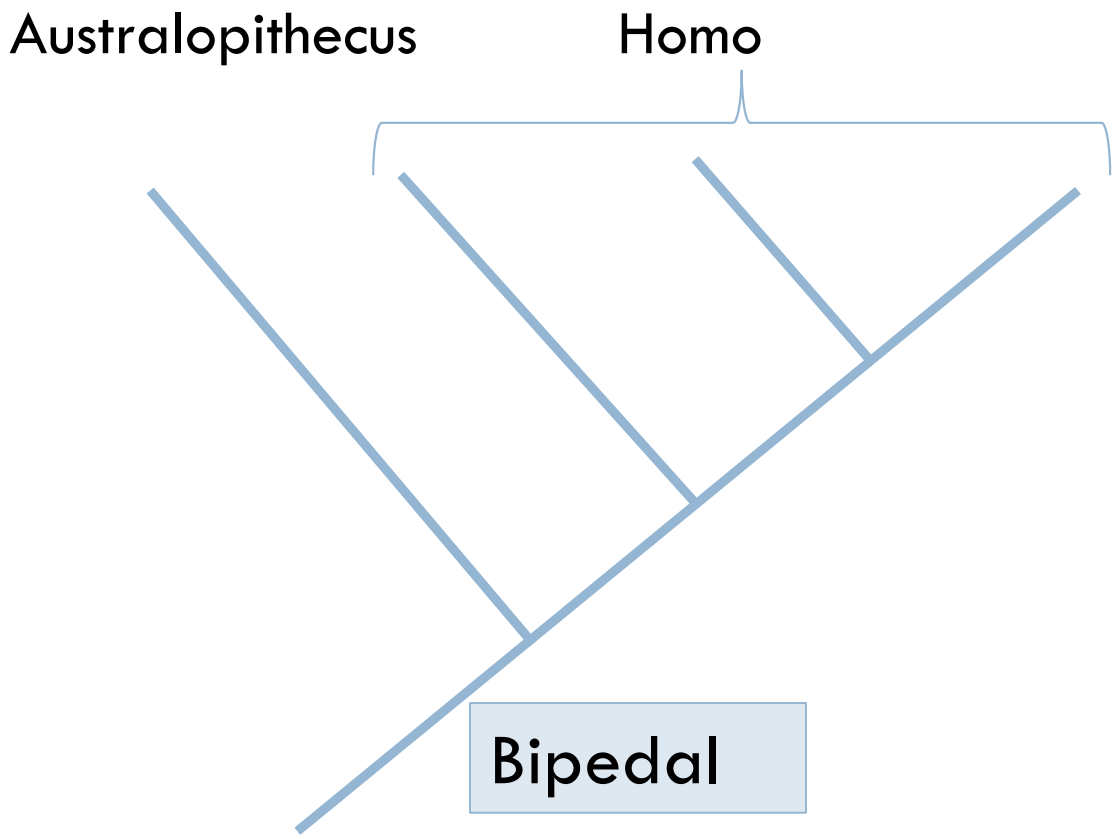
Synapomorphy

- a shared derived character state



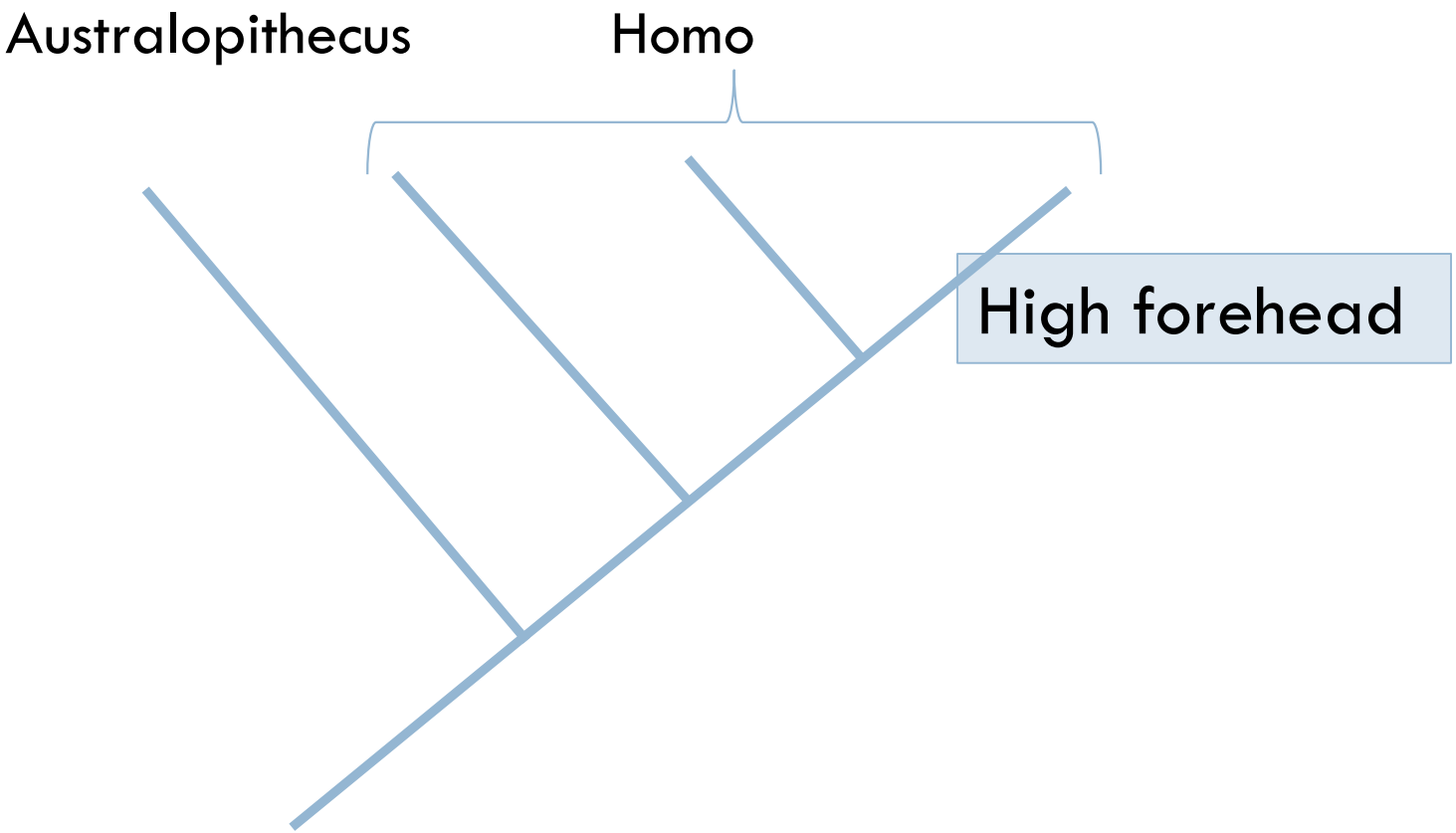
Symplesiomorphy

- a shared ancestral character state



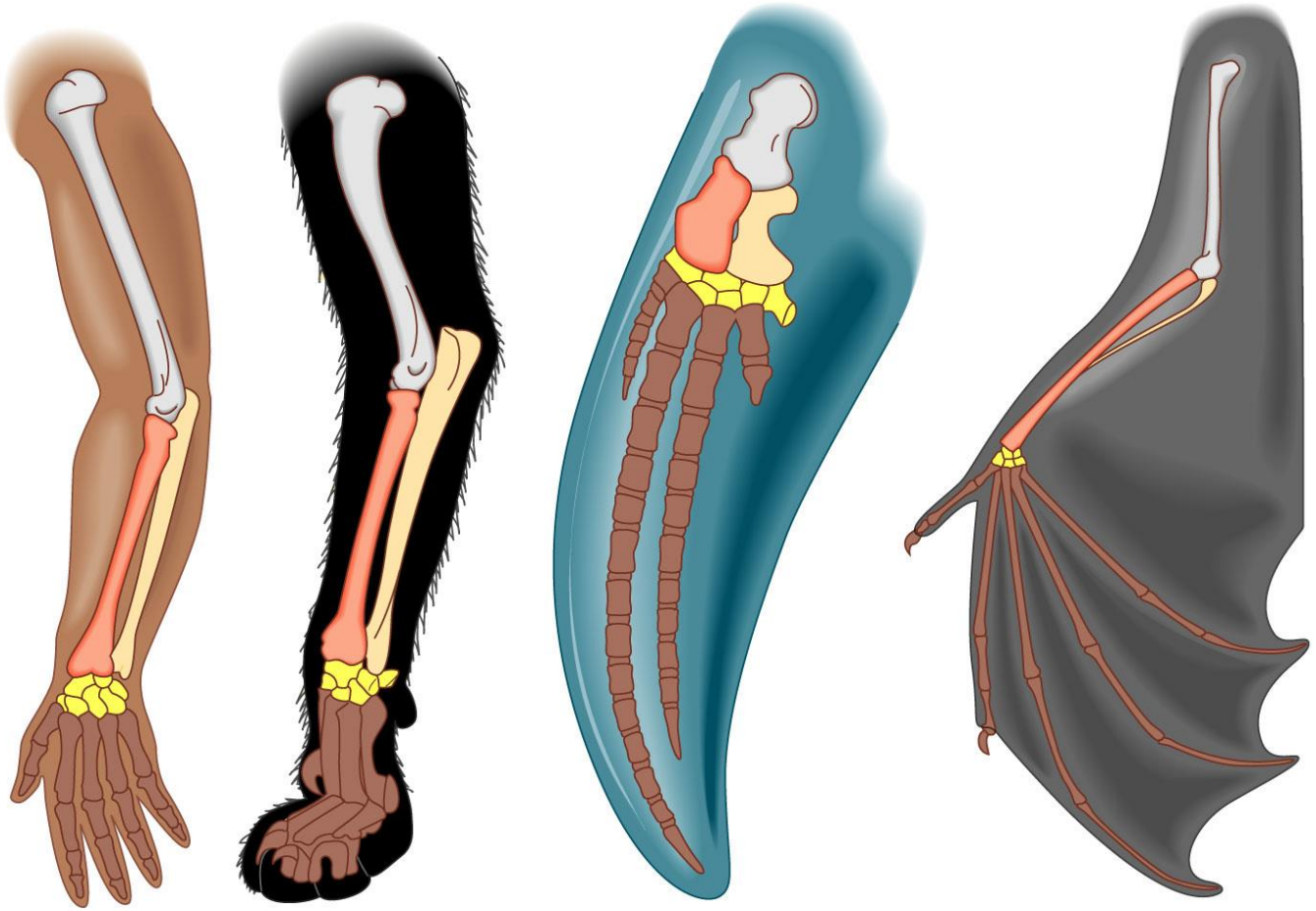
Autapomorphy

- a derived character state unique to one study group member



Homology

- Similarity resulting from common ancestry.



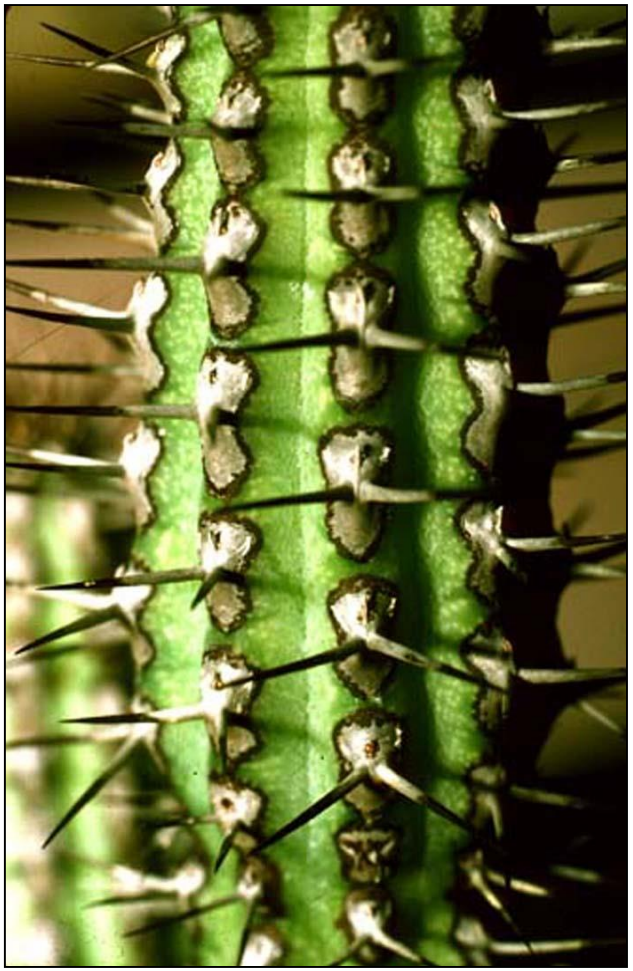
Homoplasy (analogy)

- Similarity ***not*** due to common ancestry
- **Convergence** (parallelism) – gain of new, similar features independently.
- **Reversal** – loss of new (apomorphic) feature, resembles ancestral (old) feature.

Analogy: Convergence

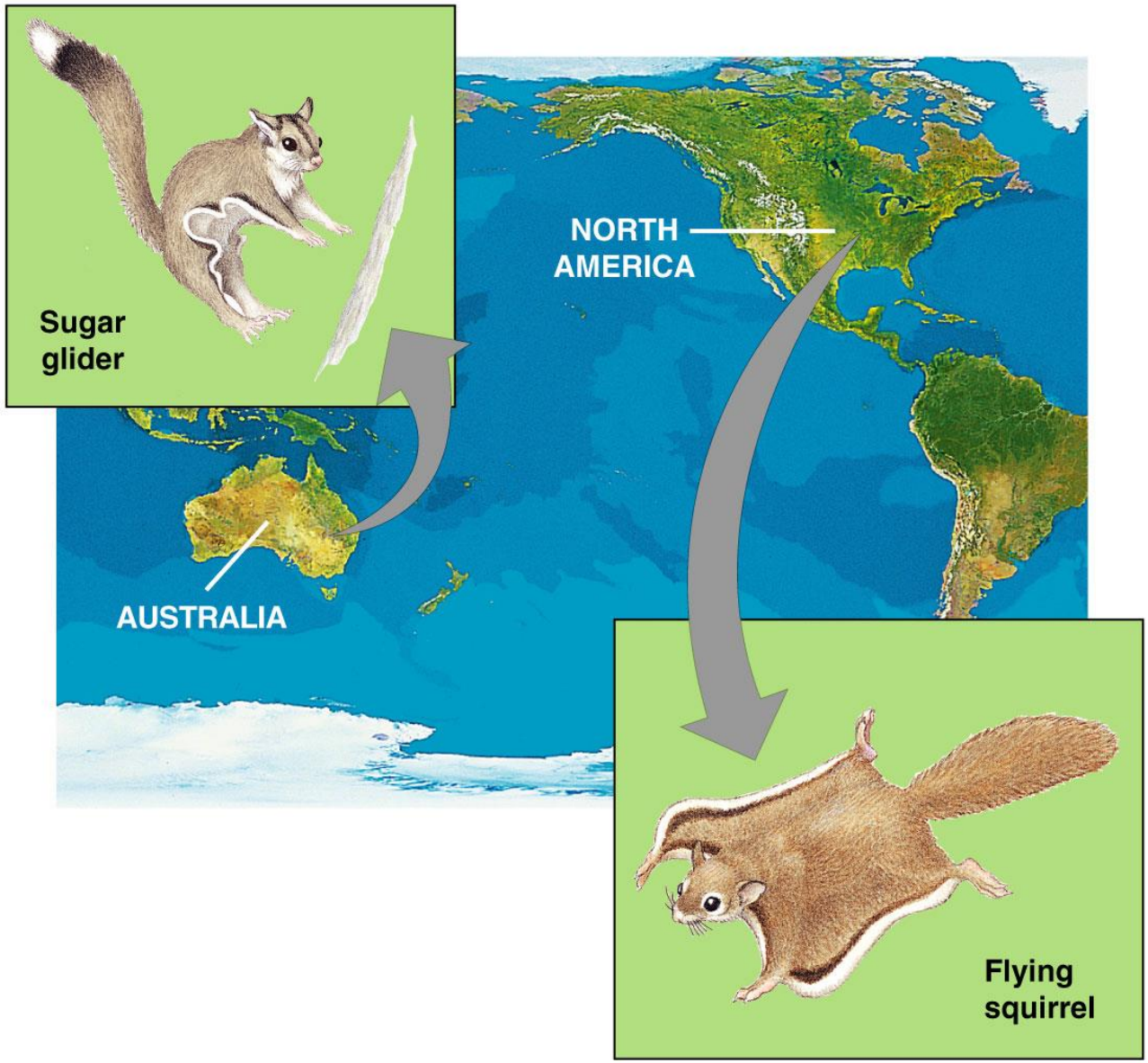
spines of cacti & euphorbs

Cactus



Euphorb

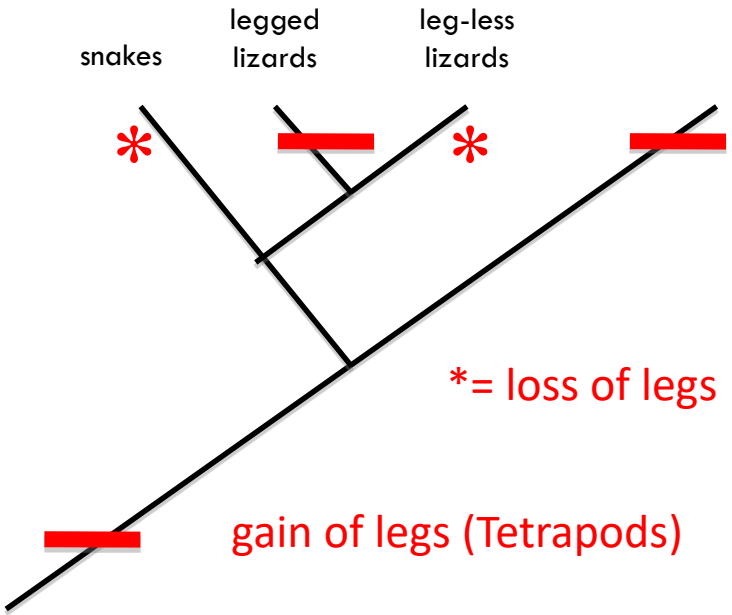
Convergent evolution:
wings of some animals evolved independently



Analogy: Reversal

Leg-less lizards

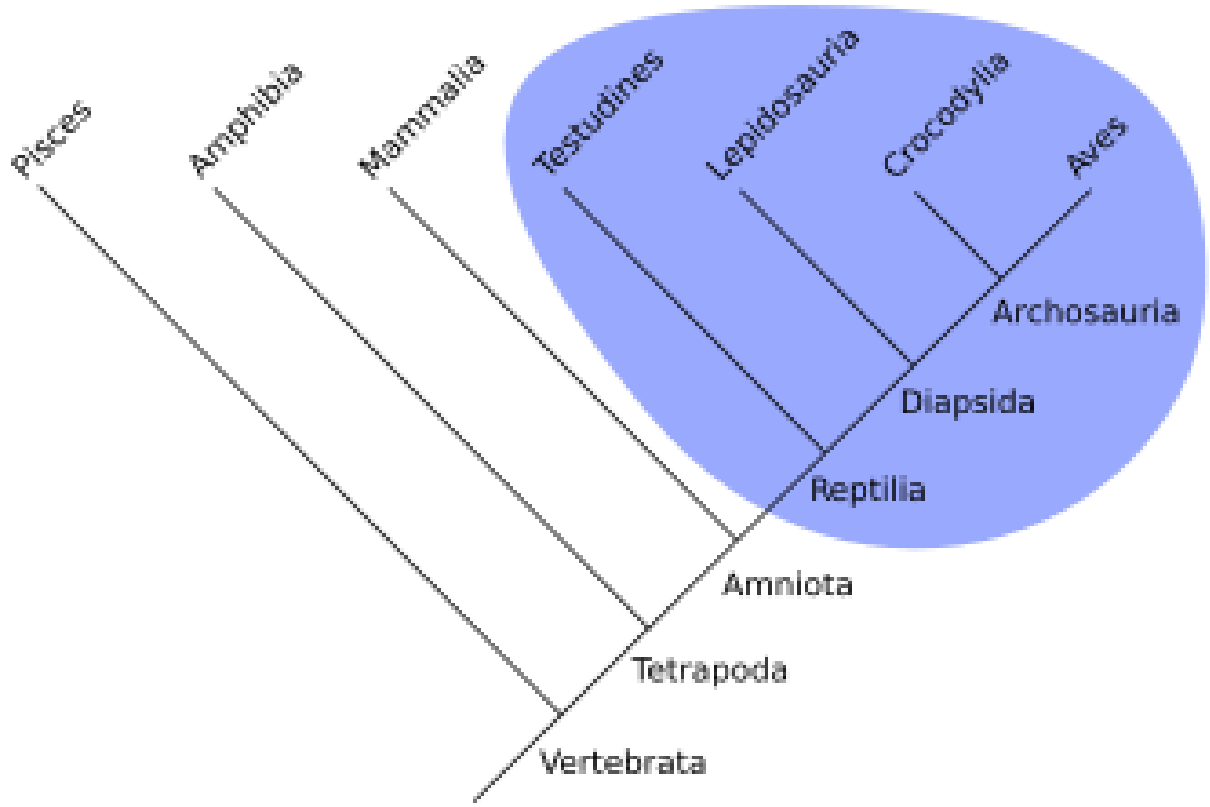
Snake



reversal within Tetrapods: loss of a derived feature – forelimbs.

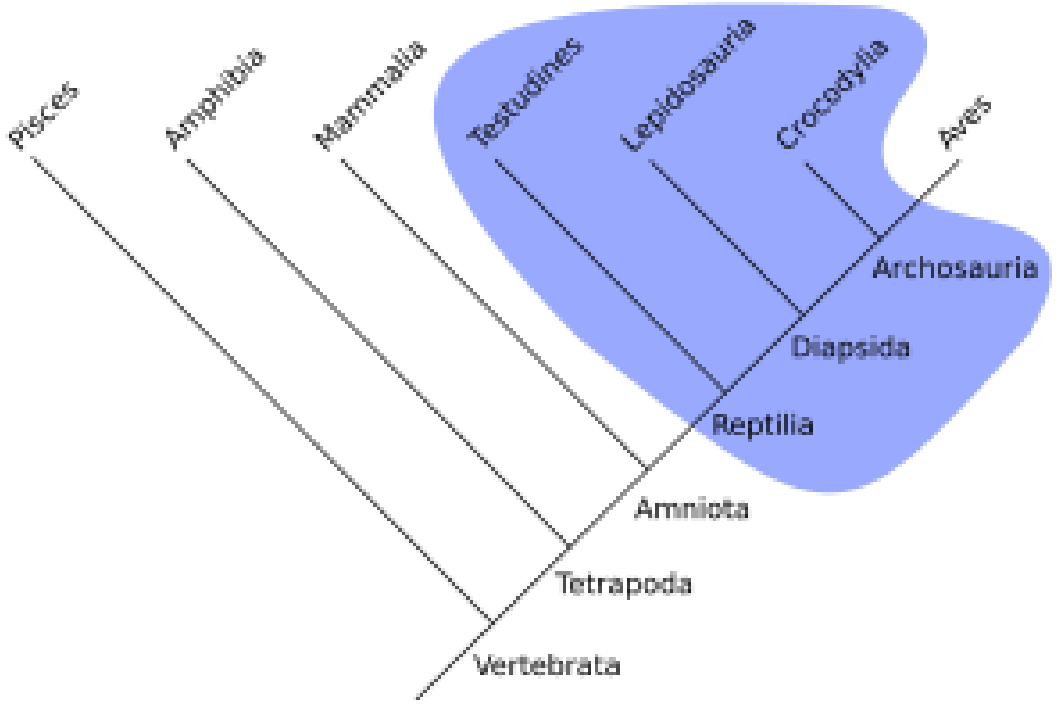
Monophyletic group

- A *monophyletic* group includes a common ancestor and all of its descendents



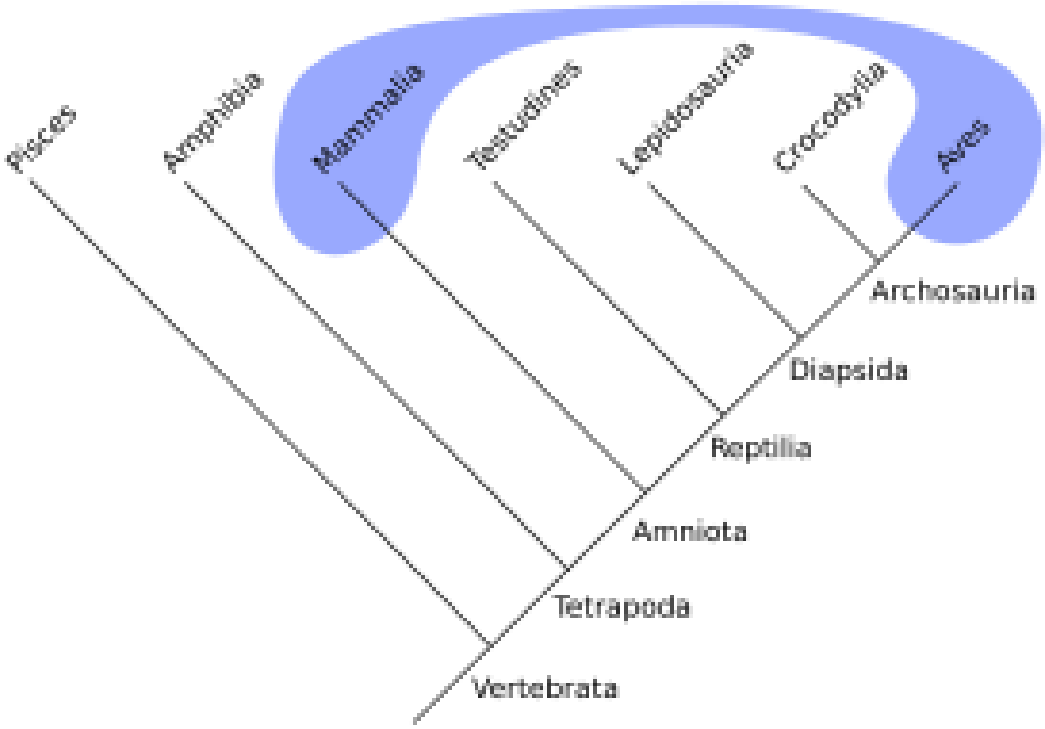
Paraphyletic group

- A *paraphyletic* group includes a common ancestor and some but not all of its descendents



Polyphyletic group

- A *polyphyletic* group is a group whose members do not share a recent common ancestor



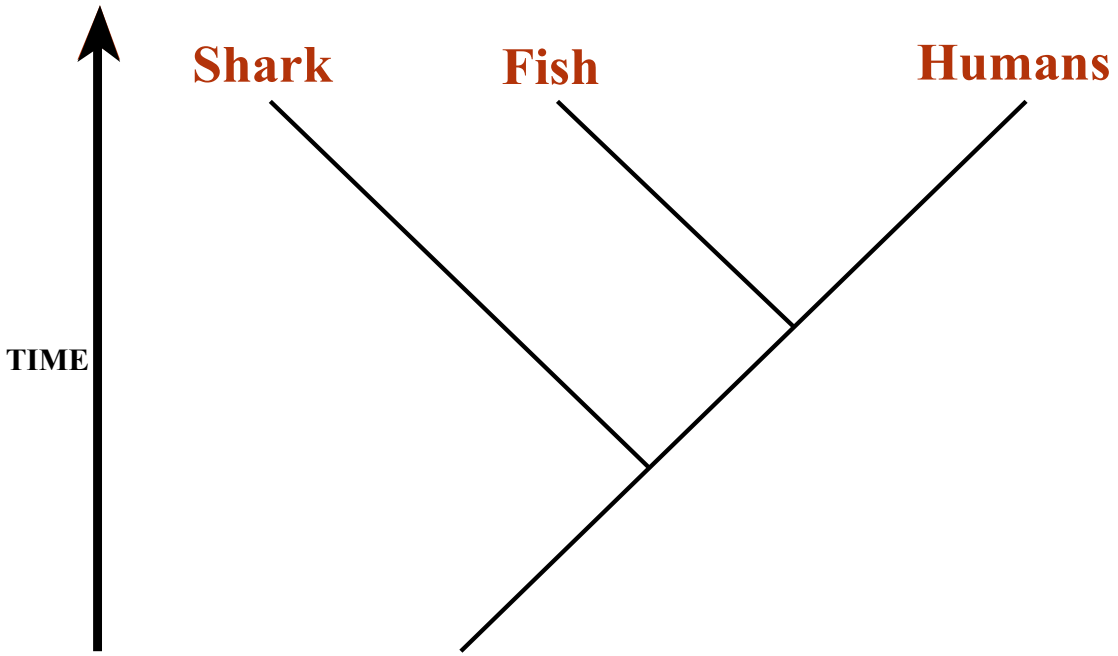
Relationships

- = recency of common ancestry

  i.e., taxa sharing a common ancestor
  more recent in time are more closely related than those sharing common ancestors more distant in time.

Example

- Are fish more closely related to sharks or to humans?



Example

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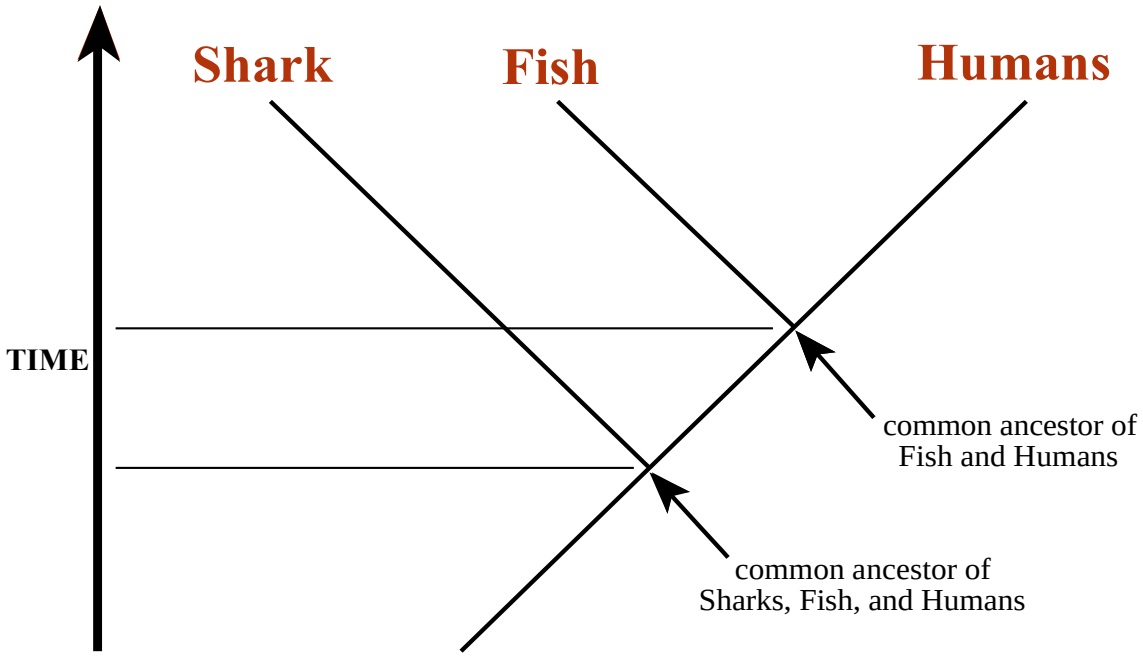
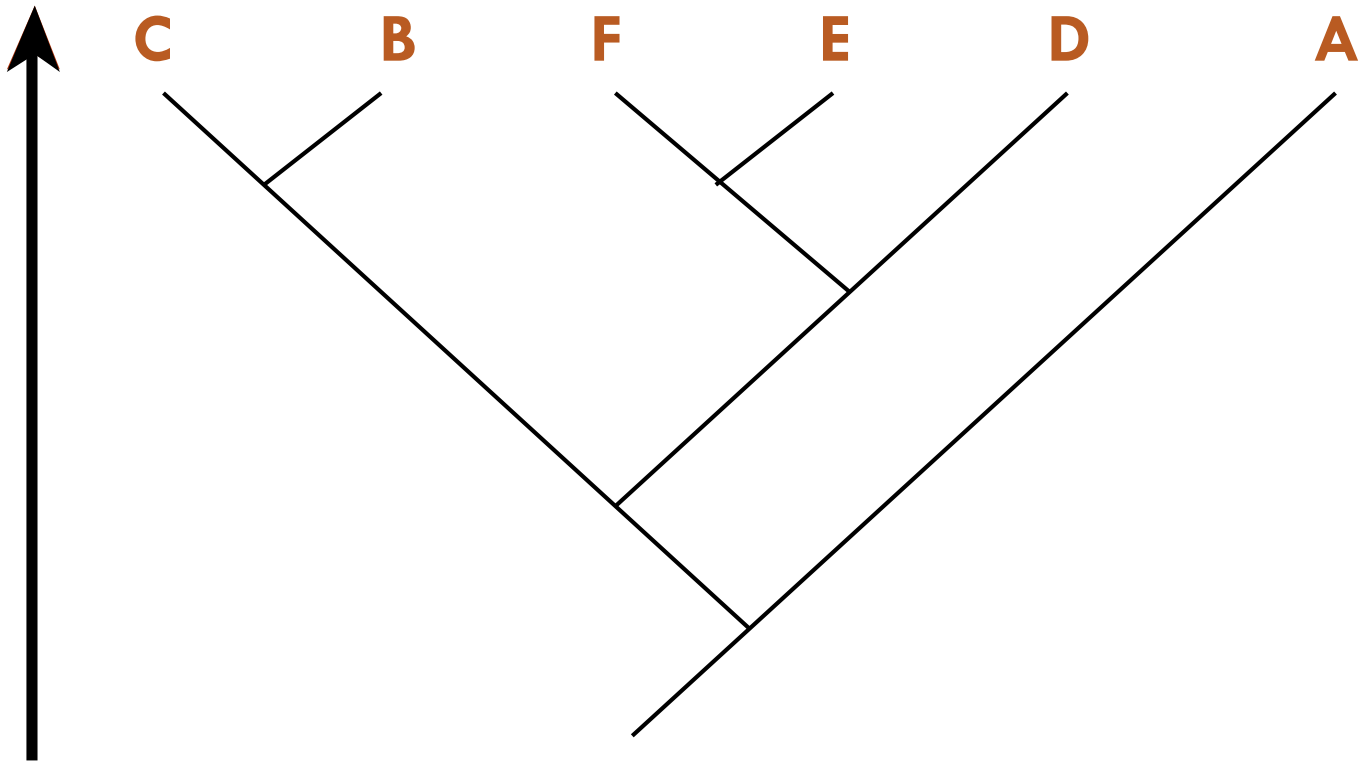
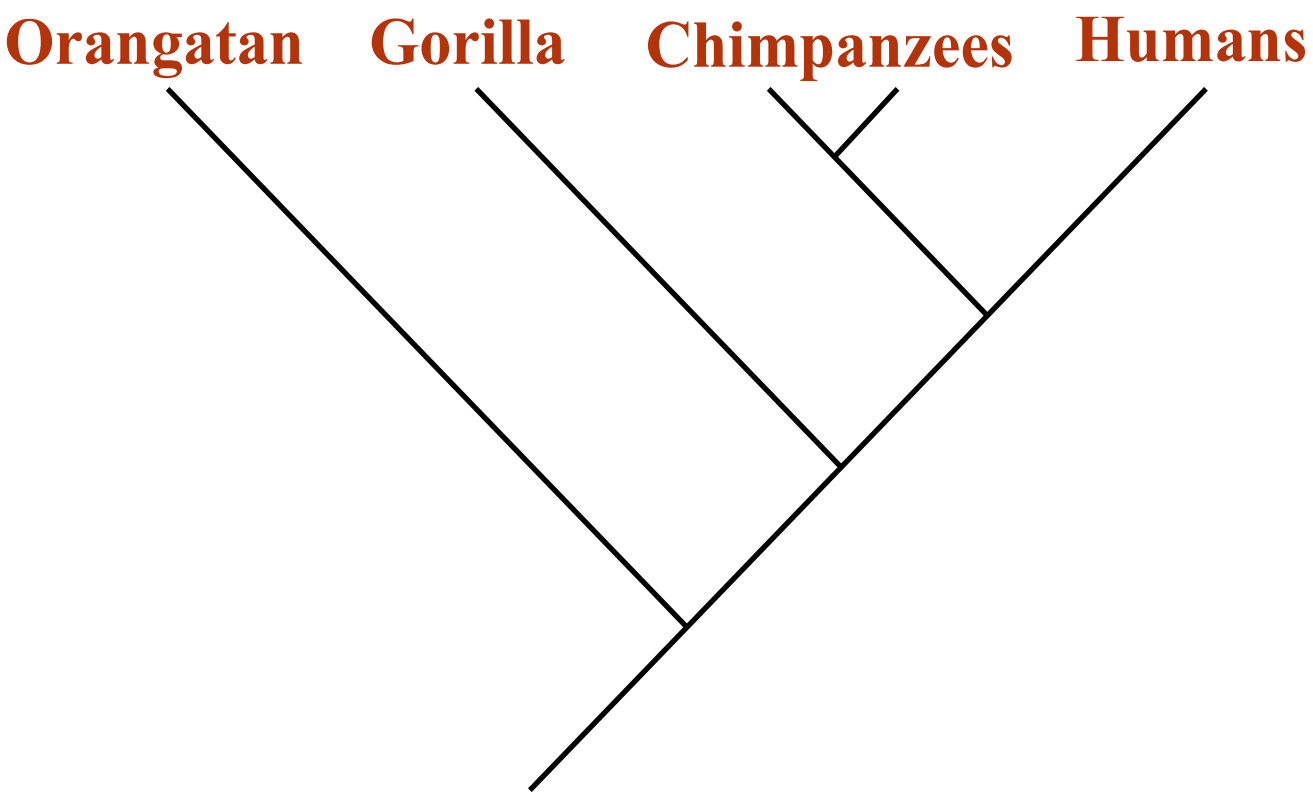


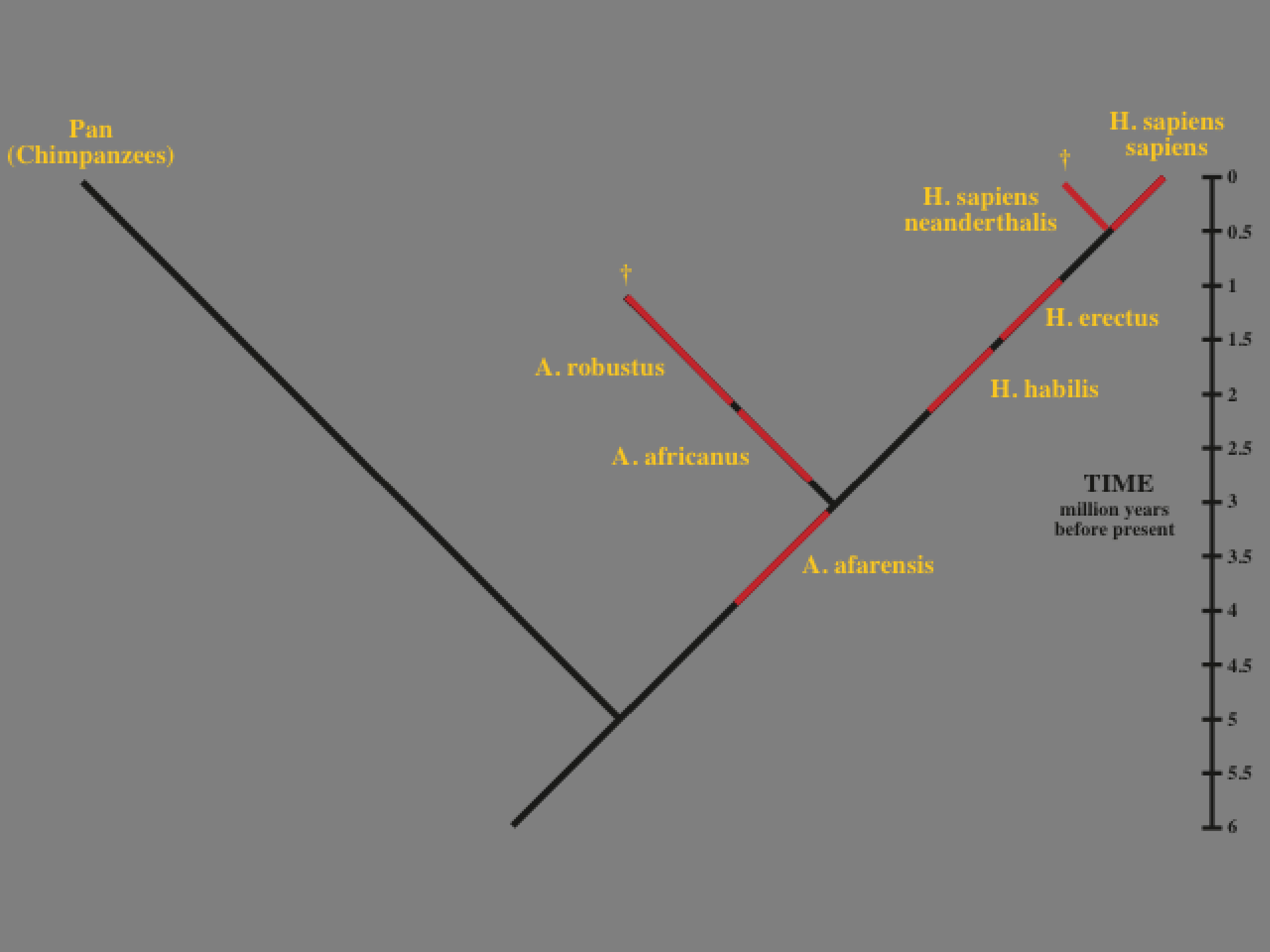
Let's see…

- Is "E" more closely related to "D" or to "F"?
- Is "E" more closely related to "B" or to "A"?
- Is "E" more closely related to "B" or to "C"?



Did humans evolve from apes?




Pan
(Chimpanzees)
†
A. robustus
A. africanus
A. afarensis
†
H. sapiens
neanderthalis
H. erectus
H. habilis
H. sapiens
sapiens
TIME
million years
before present
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6

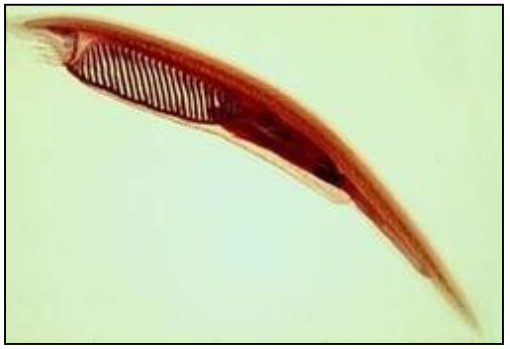
We are human, but we are also apes

- We share unique human features.
- We also share features with other apes (and with other animals, plants, fungi, bacteria, etc.).
- Humans didn't evolve from apes, humans are apes.

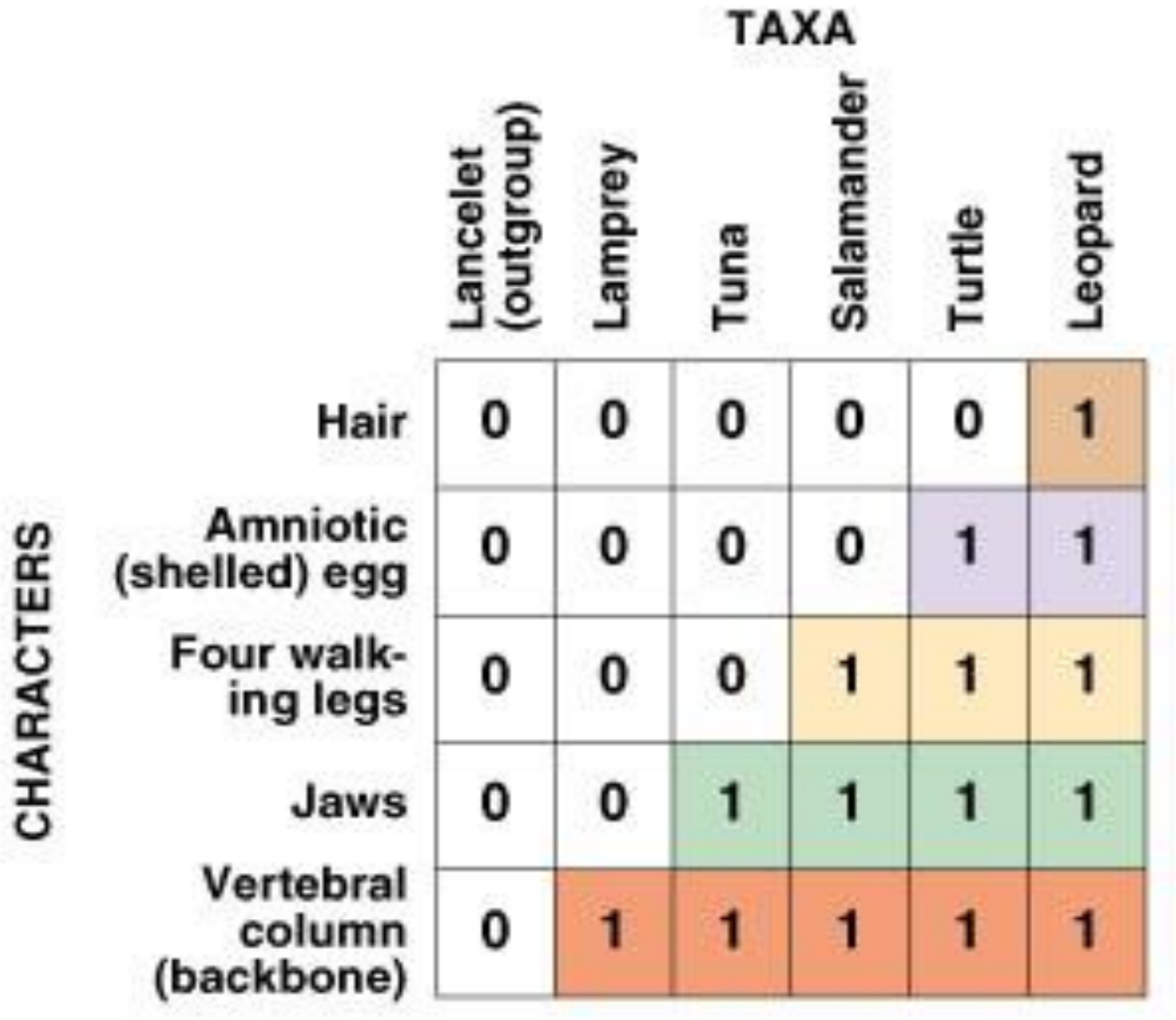
Let's construct a cladogram (1)…

- Study group

- Outgroup member
  - a species that is closely related to the species under study, the outgroup has a shared primitive character that is common to all species.



Let's construct a cladogram (II)…



CHARACTERS	Lancelet (outgroup)	Lamprey	Tuna	Salamander	Turtle	Leopard
	TAXA					
Hair	0	0	0	0	0	1
Amniotic (shelled) egg	0	0	0	0	1	1
Four walking legs	0	0	0	1	1	1
Jaws	0	0	1	1	1	1
Vertebral column (backbone)	0	1	1	1	1	1

Final cladogram