Taxonomy and classification

Goals:

Understand traditional and hierarchical classifications of biodiversity, and what information classifications may contain.

Readings:

1. Chapter 1.

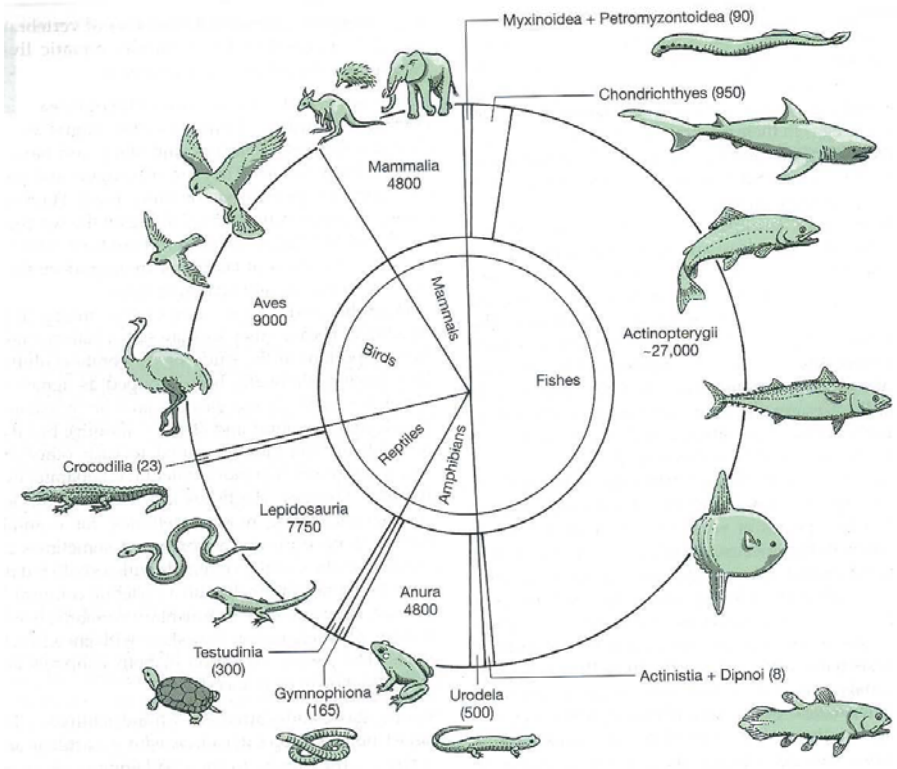


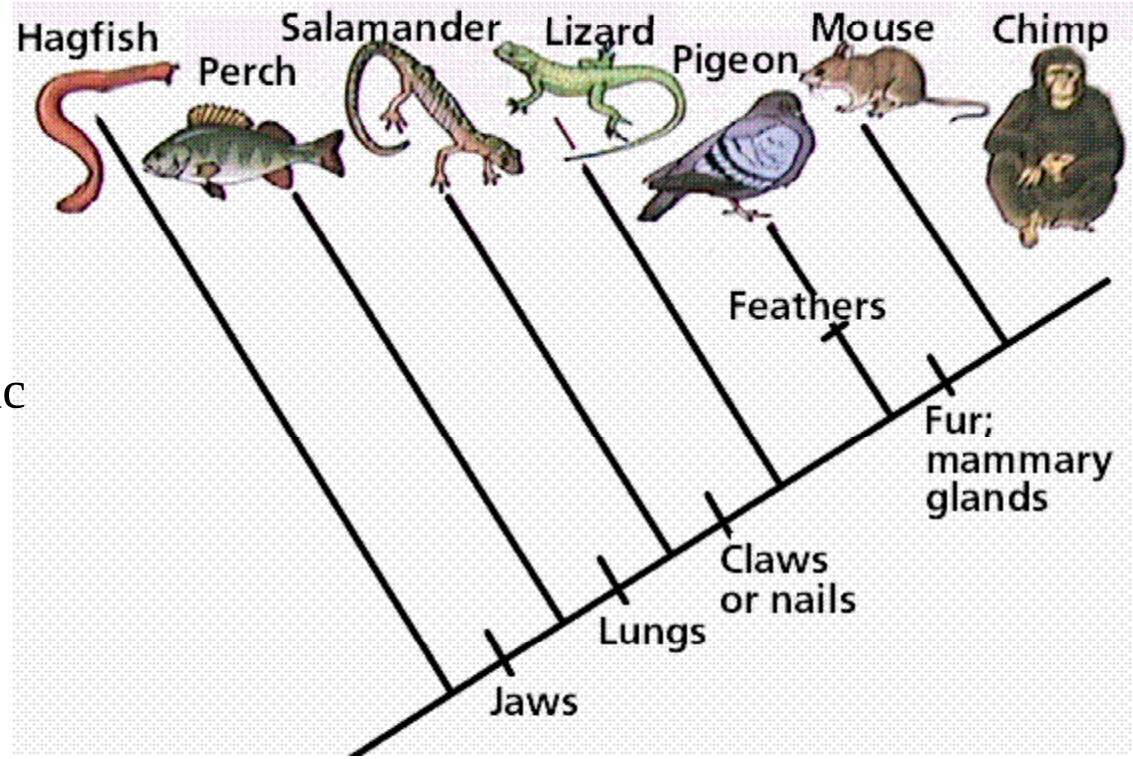
Figure 1-1 from Pough et al.

Taxonomy and classification (cont'd)

Some new words that are very important:

- ✓ Cladogram
- ✓ Clade
- ✓ Synapomorphy (Shared, derived character)
- ✓ Monophyly; monophyletic
- ✓ Paraphyly; paraphyletic
- ✓ Polyphyly; polyphyletic

This is a cladogram. Each branching point is a node. Each branch, starting at the node, is a clade.



Definitions of **cladogram** on the Web:

A dichotomous phylogenetic tree that branches repeatedly, suggesting the classification of molecules or organisms based on the time sequence in which evolutionary branches arise.
xray.bmc.uu.se/~kenth/bioinfo/glossary.html

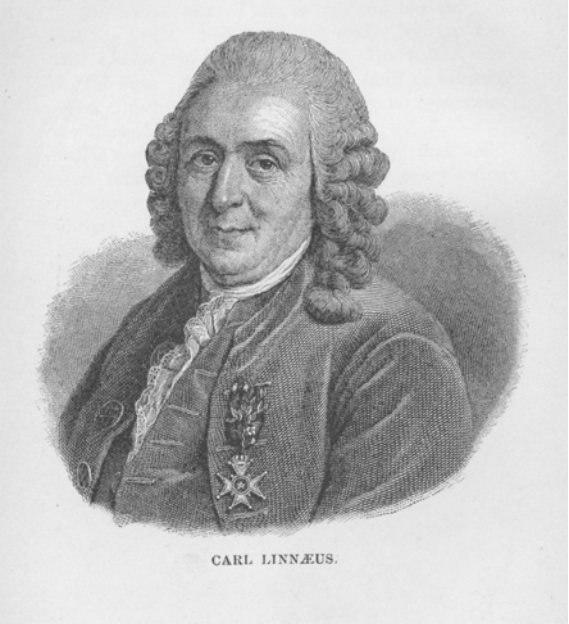
A tree that depicts inferred historical branching relationships among entities. Unless otherwise stated, the depicted branch lengths in a cladogram are arbitrary; only the branching order is significant. See phylogram.
www.bcu.ubc.ca/~otto/EvolDisc/Glossary.html

TAKE-HOME MESSAGE: Cladograms tell us about the *history* of the relationships of organisms. Key word: History.

Historically, classification of organisms was mainly a bookkeeping task.

For this monumental job, *Carrolus Linnaeus* invented the system of binomial nomenclature that we are all familiar with. *(Did you know that his name was Carol Linne? He latinized his own name the way he named species!)*

Merely giving species names and arranging them according to similar groups was acceptable while we thought species were static entities.



We now know that species are not static and that species arise through ancestor-descendant relationships.

Thus to understand the diversity of vertebrates, we should be familiar with the principles of ancestor-descendant relationships and how to study them, because those relationships have caused the diversity of life we see today.
(Isn't the fascinating diversity of life the reason you took Natural History of the Vertebrates to begin with?!?)

A good taxonomy should say something about 2 things:

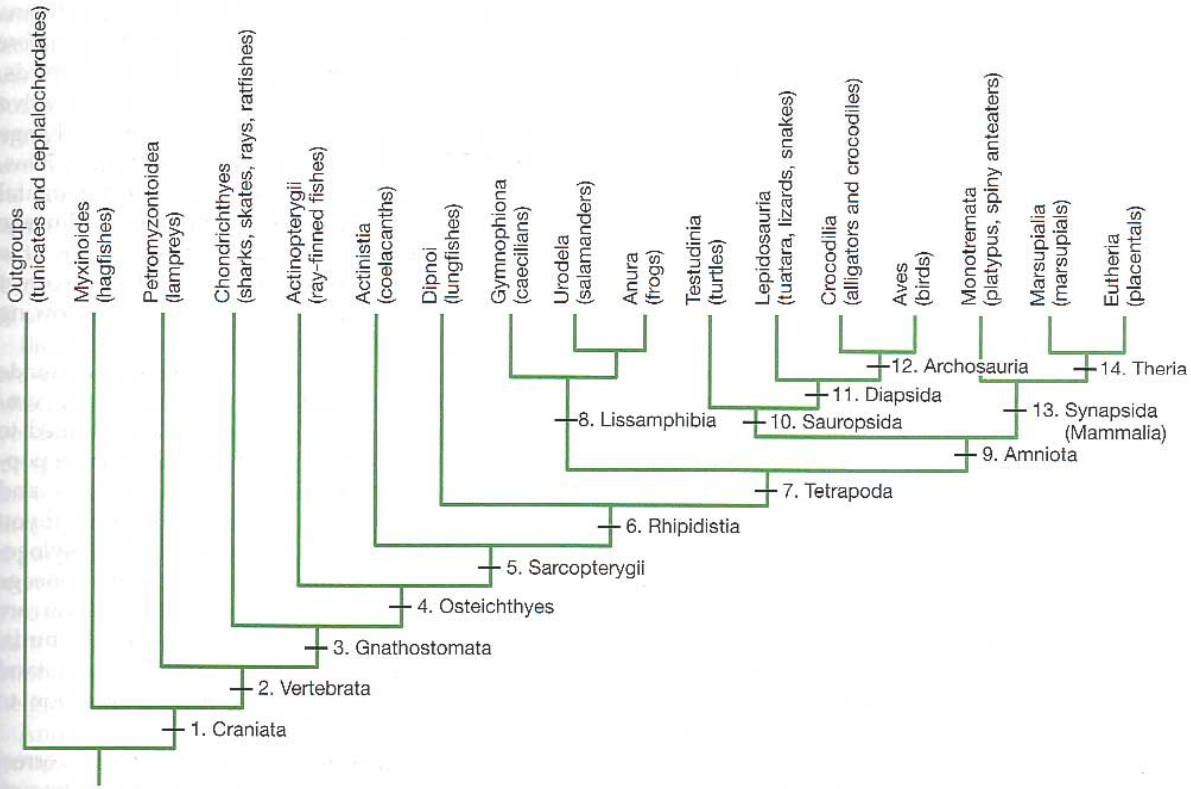
1) The relationships between groups
2) The evolutionary history of the group should be reflected in the taxonomy.

Phenetic classifications, based only on similarities and differences, do not necessarily reflect genealogy.

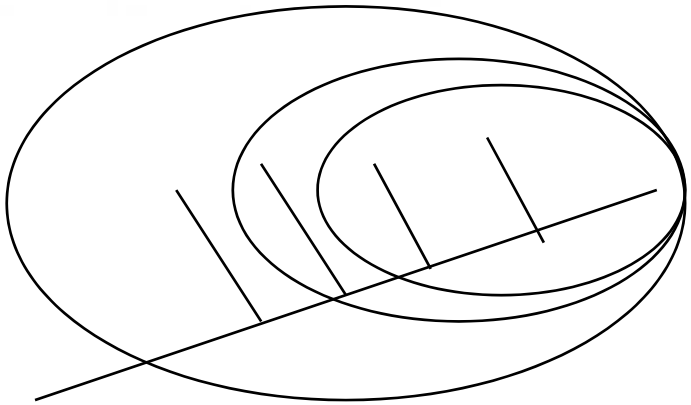
Phylogenetic classifications do reflect genealogy.

Why do taxonomies and species names change?

Simply because scientists get new information all the time, and the process of science requires that new information be incorporated into explanations. Thus with new information about relatedness among species, genera, etc. the taxonomies will change.



▲ **Figure 1–4** Phylogenetic relationships of extant vertebrates. This diagram shows the probable relationships among the major groups of extant vertebrates. Note that the cladistic groupings are nested progressively; that is, all placental mammals are therians, all therians are synapsids, all synapsids are amniotes, all amniotes are tetrapods, and so on.

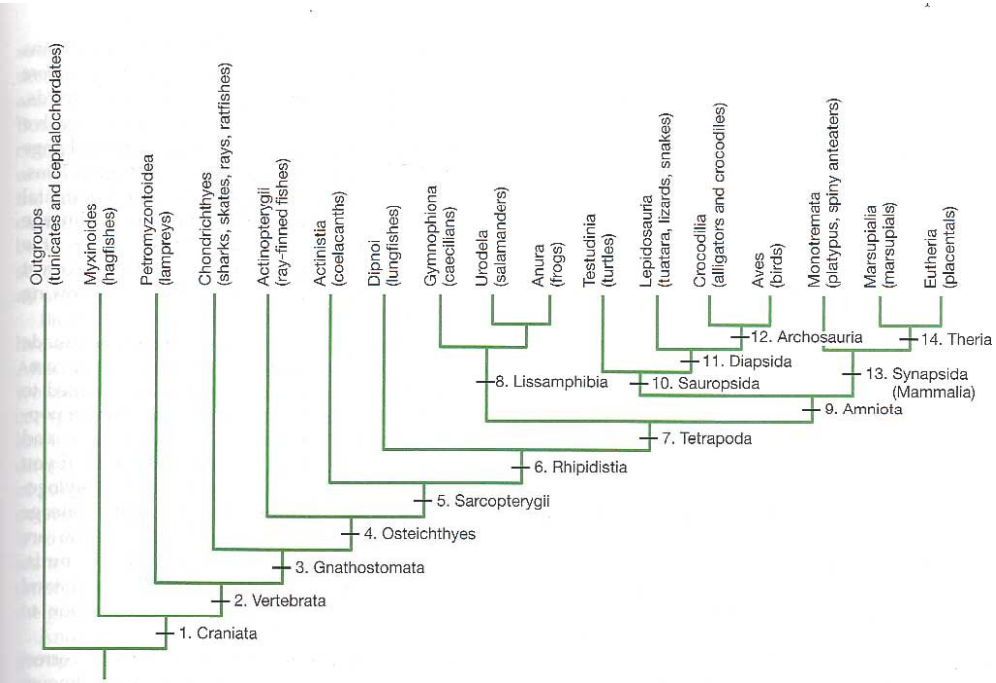


Monophyly: Ancestor and all of its descendants.

Each concentric ring forms a monophyletic group.

Hierarchical classifications

- Hierarchical, or phylogenetic, classifications show more clearly the placement of groups (i.e., amphibians and reptiles)
  - increasingly used in textbooks.
  - Each level of indentation corresponds to sister taxa on an evolutionary tree.
- In the hierarchical classification, the Tetrapoda consists of Amphibia + Amniota, that are each other's closest relatives.
  - Sister taxa
- **Note** the cladistic groupings are nested progressively. Refer to figure 1-4 and understand the legend.
- **You do need to know the names of the nodes, 1-14. We will talk about these groups.**
  - Example: Synapsida is the monophyletic group containing monotremes, marsupials, and placental mammals.
  - Example: Tetrapoda is the monophyletic group containing reptiles (or sauropsids) and the synapsida.



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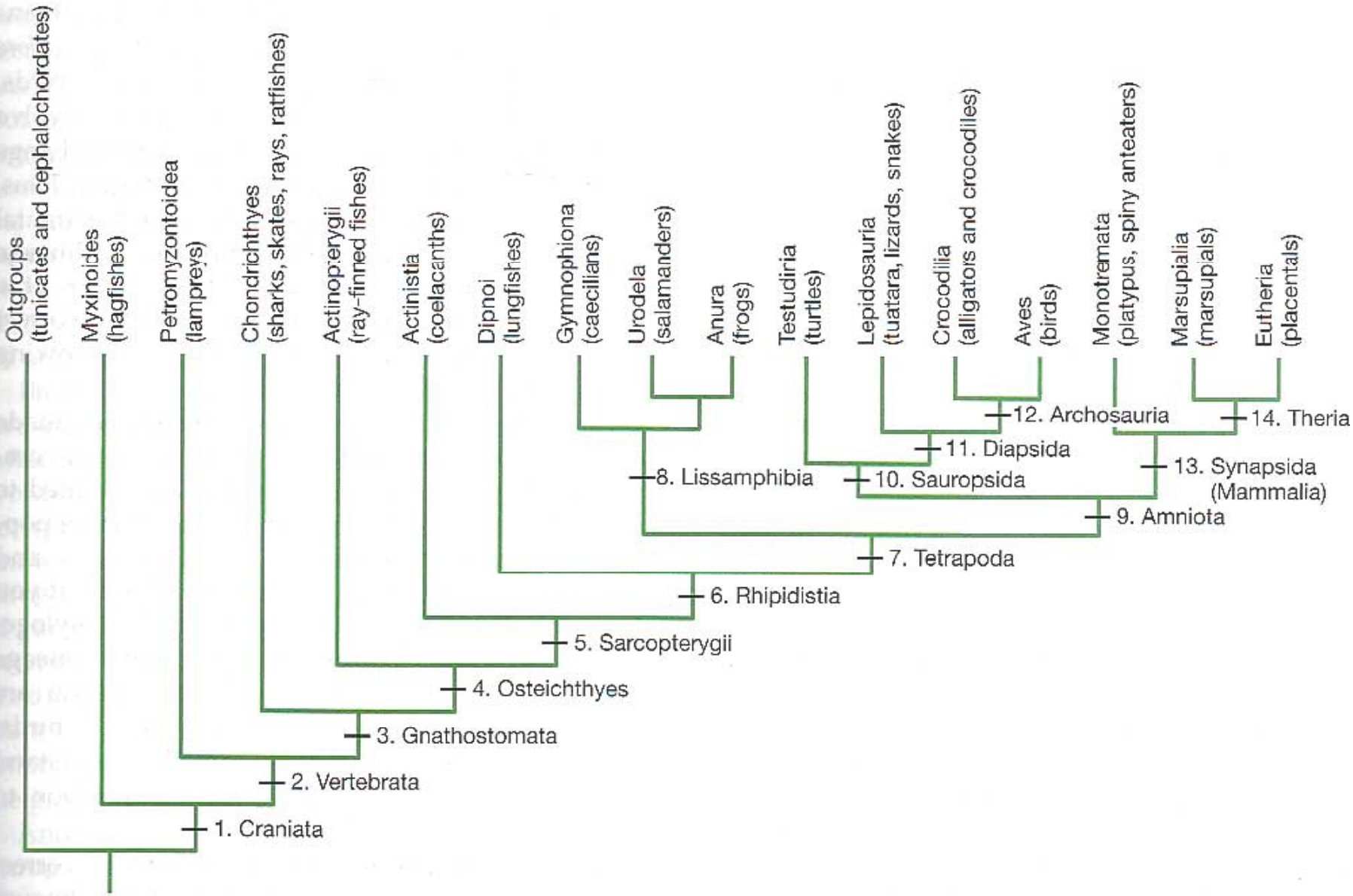

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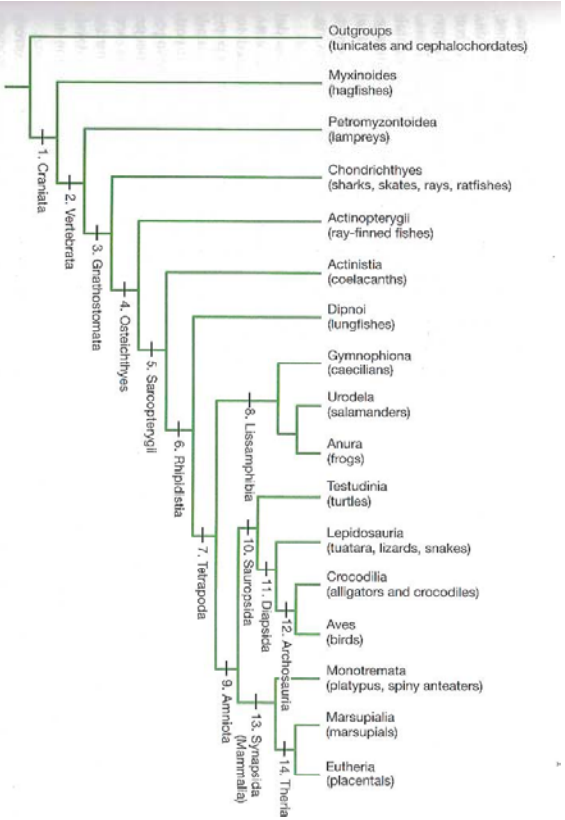
Hierarchical classifications

- Birds are part of an Archosaurian lineage that is either most closely related to dinosaurs or crocodilians, and therefore are part of the same evolutionary branch that includes all other reptiles: turtles, crocodilians, birds, the sphenodon, and lizards + snakes + amphisbaenians.
- By tradition, we elevate birds to the level of Class, but by doing so we obscure their close relationships to crocodilians. The lineages of reptiles, including birds, are much more closely related to each other than to the amphibians, with whom they have not shared a common ancestor in 300 million years.



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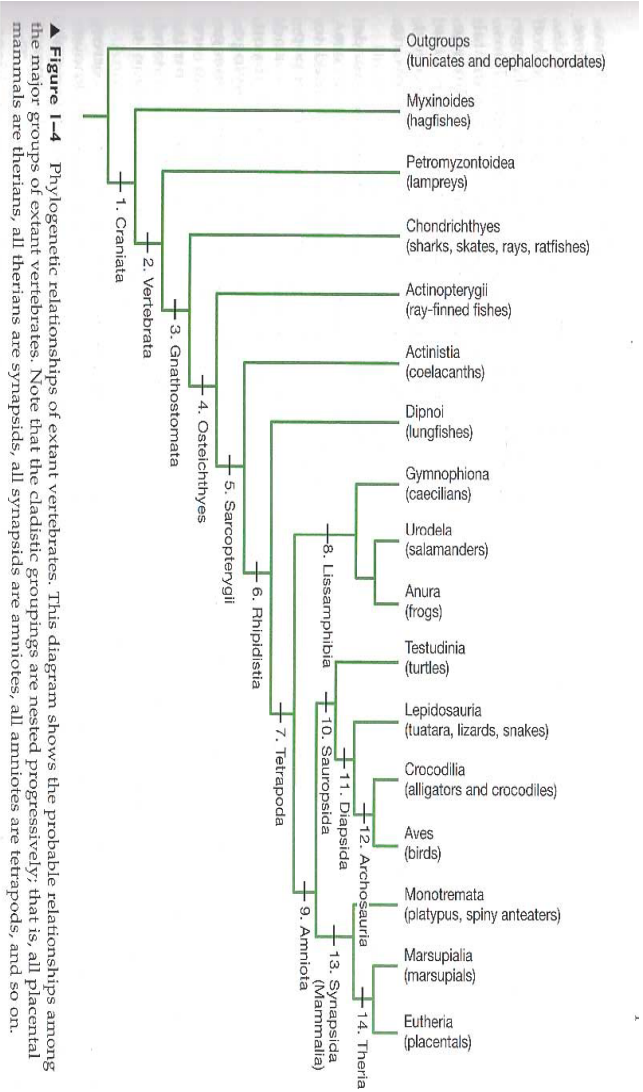
Hierarchical classifications such as this one reveal the relationships among groups. Each level of indentation corresponds to branches in the evolutionary tree, or phylogeny.



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Craniata
- Vertebrata
  - Gnathostomata
    - Osteichtyes
      - Sarcopterygii
        - Rhipidistia
          - Tetrapoda
            - Amphibia (= Lissamphibia)
              - Gymnophiona (caecilians)
              - Urodela (=Caudata) (salamanders)
              - Anura (frogs)
            - Amniota
              - Reptilia* (Sauropsida)
                - Testudinata (turtles)
                - Lepidosauria (tuatara, lizards, and snakes)
                - Archosauria
                - Crocodylia
                - Aves
              - Synapsida
                - Monotremata (egg-laying mammals; platypus, echidna)
                - Theria
                - Marsupialia
                - Eutheria (placental mammals)

*I consider turtles to be diapsids based on recent evidence, turtles+lepidosaurs+archosaurs = Reptilia

A traditional classification

Class Amphibia	Common name
Subclass Lissamphibia	
Order Caudata	Salamanders and newts
Suborder Sirenoidea	
Sirenidae	Sirens
Suborder Salamandroidea	
Amphiumidae	Amphiumas
Plethodontidae	Lungless salamanders
Proteidae	Mudpuppies, waterdogs, and the olm
Salamandridae	Salamandrids
Ambystomatidae	Mole salamanders
Order Anura	Frogs and toads
Pelobatidae	Spadefoots
Bufonidae	Toads
Leptodactylidae	Neotropical frogs
Hylidae	Hylid treefrogs
Microhylidae	Microhylids
Ranidae	Ranid frogs

Traditional classifications are good for listing names of taxa, but may not reflect well the relationships among groups of organisms.

Summarizing Taxonomy and classification

- A good taxonomy should say something about 2 things:
  - The relationships between groups
  - The evolutionary history of the group should be reflected in the taxonomy.
- **Phenetic** classifications, based only on similarities and differences, don’t necessarily reflect genealogy
- **Phylogenetic** classifications do reflect genealogy.

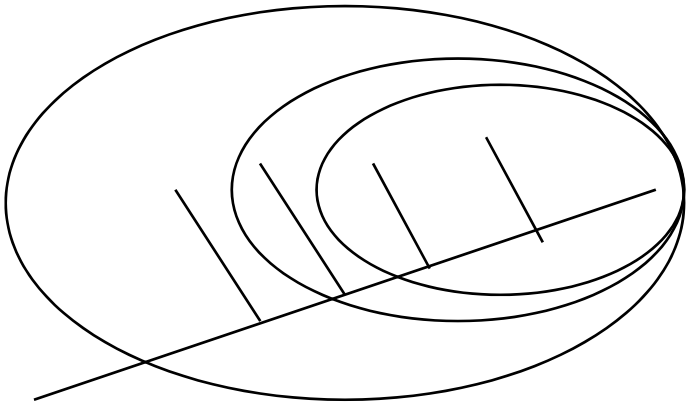
Words to know, if you don't already.

- *Plesiomorphic character*: the ancestral character, unaltered from the ancestral condition.
- *Symplesiomorphic character*: the ancestral character found in more than one lineage.
- *Apomorphic character*: the descendant character, **derived** from the ancestral condition. Derived means different from the ancestral condition.
- *Autapomorphic character*: The descendant character found in only one lineage.
- *Synapomorphic character*: a derived character found in more than one lineage. [syn = together; apo = away from, morph = form]

Synapomorphies are **shared, derived characters**. When derived characters occur in more than one lineage, we can identify the origin of the character and make an hypothesis about the relationships among lineages.

Quick review of phylogenetic systematics

- Willi Hennig's method of analyzing evolutionary relationships is **Cladistics**. Cladistics emphasizes the importance of monophyletic evolutionary origin.
- **Monophyletic** means an ancestor and all of its descendants.
- Revealing monophyletic origin is important because it is the only way to know the evolutionary relationships, i.e. the phylogeny, of taxa.



Monophyly: Ancestor and all of its descendants.

Each concentric ring forms a **monophyletic group**.

READINGS for next week

- Read Chapter 2; KNOW table 2-1, figures 2-2; 2-3; 2-4
- Read Chapter 3;
- Read Chapter 7

I will be plowing through a lot of information before Exam I. Please try to keep up and study as we go along. It will be worth it!

- **Only monophyletic lineages are recognized in phylogenetic lineages.**
- Phylogenetic systematics uses **shared derived characters** to identify monophyletic lineages.
- A **derived** character is just a character, or trait, that differs from the ancestral form. [**Apomorphy]** If it's shared, more than one taxa has the character that is derived. **[synapomorphy]**
  - –Example: Nasolabial grooves in Plethodontid salamanders

Only one group of salamanders has nasolabial grooves.

Thus the nasolabial groove is a derived character of Plethodontids.

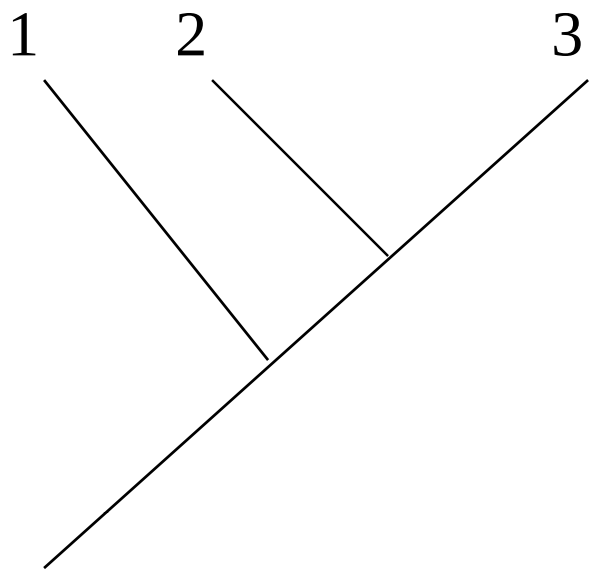
(A derived character can be behavioral, morphological, molecular, physiological, chromosomal etc.)

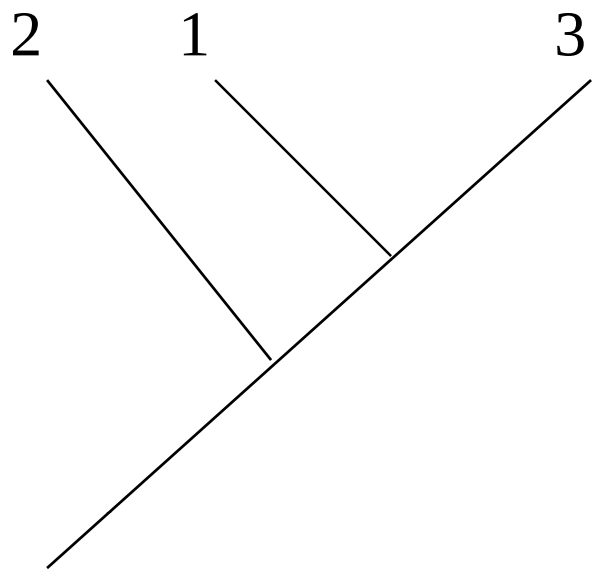
Make a cladogram for 3 species using 3 characters.

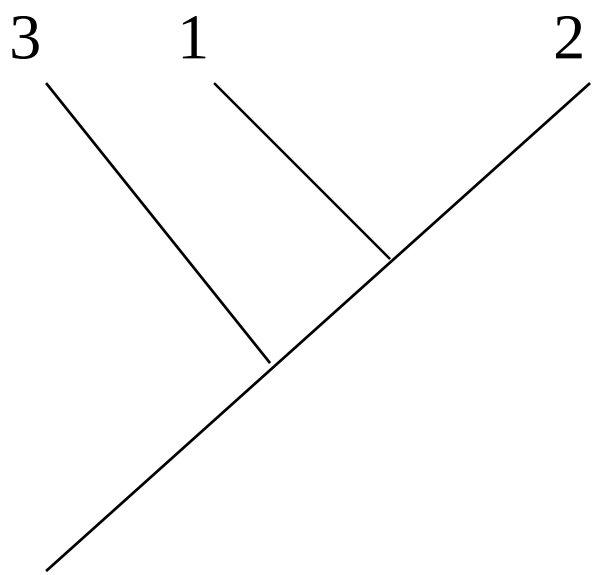
- Use synapomorphies to figure it out.
- Our dataset:
  - 3 species, “1”, “2”, “3”
  - We measured 3 traits on each species: toe configuration, tail presence, skin type
- How are these species related?

Dataset

Species/ Trait	1	2	3
	5 toes	5 toes	4 toes
	Smooth skin	Scaly	Scaly
	Tail	No tail	No tail





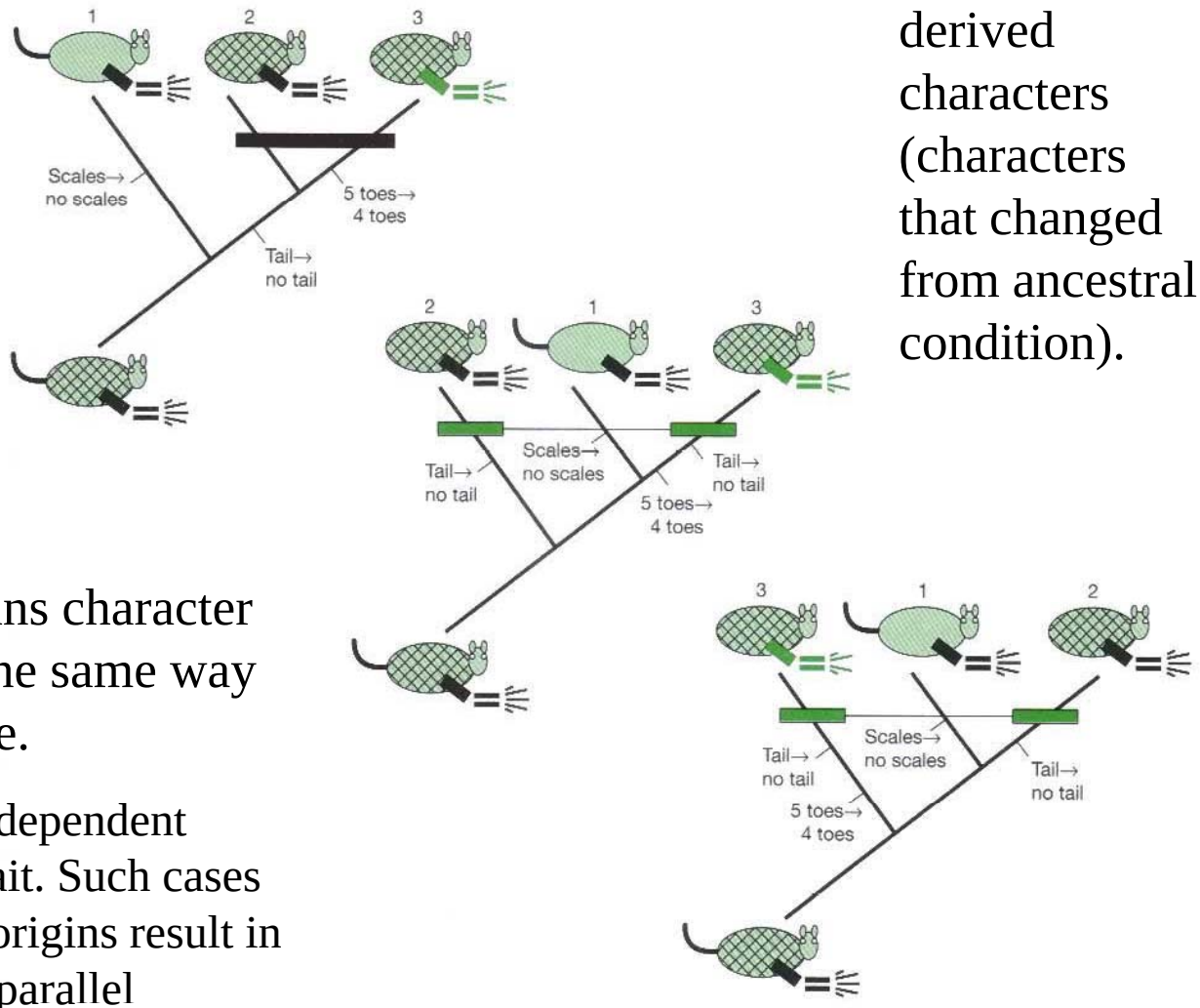


There are only 3 ways three species could be related.

But realize if you are comparing many species, for example all the *Peromyscus* mouse species, then there are many, many, possible cladograms.

Black bar means character that changed, which is shared.

Bars connect derived characters (characters that changed from ancestral condition).

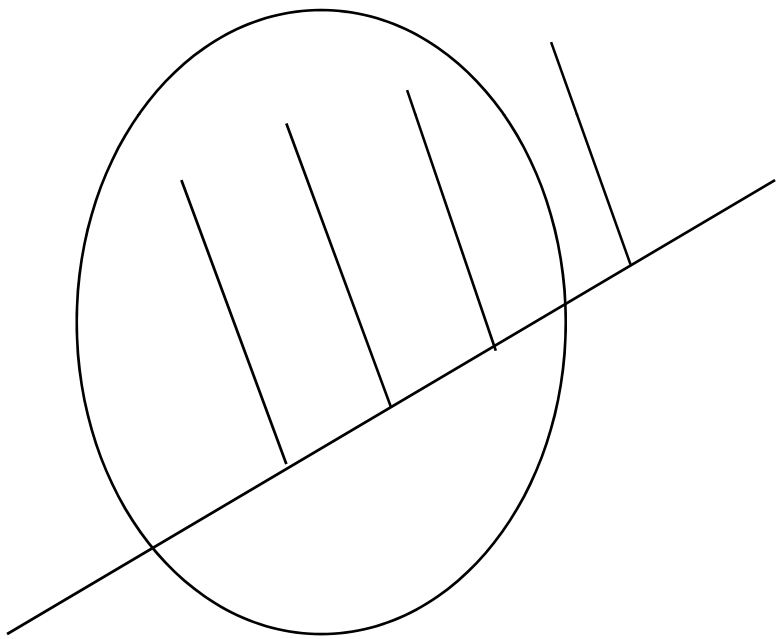


Green bar means character that changed the same way more than once.

This is called independent origins of the trait. Such cases of independent origins result in convergent and parallel evolutionary patterns.

Figure 1-3 in Pough et al.

- A **paraphyletic** group has an ancestor and only some of its descendants.



Paraphyly: Ancestor and only some of its descendants,

The group shown excludes some descendants.

Can you give an example of a paraphyletic group we are accustomed to?

A paraphyletic group

This is a phylogeny of Tetrapoda.

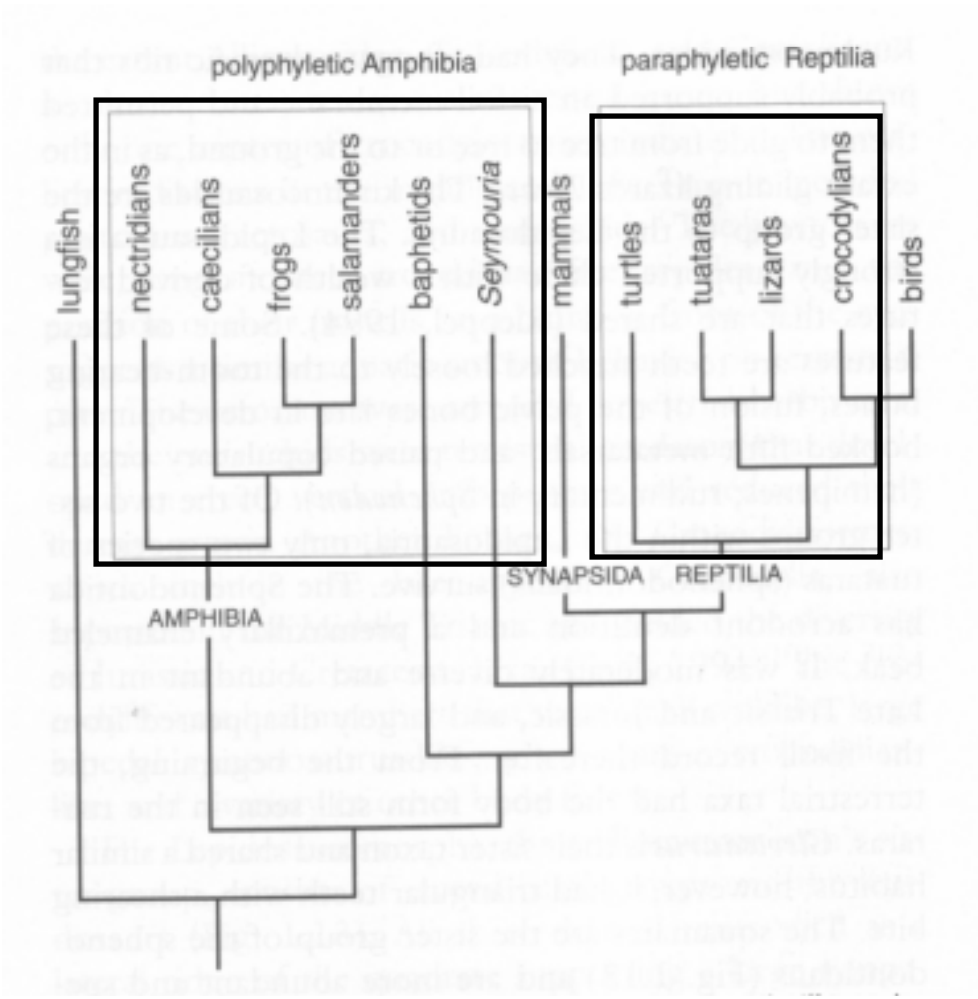
Monophyletic -- includes ancestor and all descendants

Reptilia, without birds, is a paraphyletic group.

Birds are included in Reptilia because they are descendants of the common ancestor that gave rise to all other taxa included in the Reptilia. There is no way to give a name to a monophyletic group consisting of all reptiles except birds.

In herpetology, reptiles really means all reptiles except birds, because herpetologists don't study birds!!

A **polyphyletic** group excludes an ancestor of a lineage.



Polyphyly: A grouping of taxa that excludes some ancestors. The "amphibia" on left excludes some ancestors.

Paraphyly: Again, the "reptilia" on the right excludes a descendant, the birds.

Summary of definitions

- **Monophyletic group** = Natural group consisting of an ancestor and all of its descendants
- **Paraphyletic group** = Not natural group, consists of ancestor and only some of its descendants
- **Polyphyletic group** = Grouping of taxa that excludes some ancestors.
- **Plesiomorph** = Plesiomorphies are ancestral characters. Many characters that a taxon posesses are ancestral in condition, they are plesiomorphies.
- **Symplesiomorph** = A shared, ancestral character. Symplesiomorphies are shared among taxa, but they are not useful for phylogenetic reconstruction.
- **Cladogram** = a branching diagram of phylogenies.

Summary of definitions cont'd.

- **Apomorphy** = a derived character. A character that is different than in the ancestor.
- **Autapomorphy** = an apomorphy that a taxon posesses that is not shared with any other taxa. Not informative for phylogenetic reconstruction.
- **Synapomorphy** = A shared, derived character. Synapomorphies are used to elucidate the relationships among taxa.

Species concepts

Biological species:

Species are groups of interbreeding natural populations that are reproductively isolated from other such groups.

Caveats:

- 1. Depends on sympatry to “test” distinctiveness of species.
- 2. The criterion of reproductive compatibility carries too much weight in this definition. Many different “species” are known to hybridize.
- 3. What about unisexual species? Should unisexual *Cnemidophorus* be considered species?

Evolutionary species:

"A single lineage of ancestral descendant populations which maintains its identity from other such lineages and which has its own evolutionary tendencies and historical fate (George Gaylord Simpson 1961, E.O. Wiley 1978)."

Or:

"The largest entities that have evolved whose parts, if distinguishable, are not likely to be on different phylogenetic trajectories (Frost and Hillis 1990)."

1. Species were delimited from speciation to speciation
2. Not much different from the biological species definition for biparental species.
3. Problem with "largest evolving entities".
   - –No way to identify "largest evolving entities"
   - –Species under this definition can have separate fates now, but later share a joint fate. An analogy that helps me is thinking of a braided stream through time.

- All organisms past and present belong to some evolutionary species.
- Species must be reproductively isolated from each other to the extent that this is required to maintain their separate identities, tendencies, fate.
- Evolutionary species may or may not exhibit recognizable phenetic differences.
  - The fact that species are real doesn’t require that we have to be able to easily tell them apart!
- No separate single evolutionary lineage may be subdivided into a series of ancestral and descendant species.

Benefits to this definition:

- Conceptually clear, applies to asexual species, applies through time, and to allopatric species.
- **Problems: How** to apply the definition? How can you know the future (i.e., the fate and tendencies).
- The evolutionary species concept separates the ideas of what species ***are***, from how species are ***recognized***.
- ***How species are recognized is a separate problem***.
  - *Not what they are, but how they are recognized.* This confuses many people.
- **So, how are species recognized?** This leads to a discussion of monophyly. Since we are comfortable with monophyly, no problem!

- MONOTYPIC SPECIES: a species that has traits or characters that are uniform over its entire range (thus, there are no subspecies designations).

- POLYTYPIC SPECIES: a species that has different traits throughout its range, and shows distinct geographic variation in relation to specific traits (thus, there are typically subspecies designations).