Systematics and Phylogenetics of the Amphibia: An Introduction

Taxonomy and Systematics

- ***Taxonomy***, **the science of describing biodiversity, mainly naming unnamed species, and arranging the diversity into a classification system, and developing identification keys based on diagnostic morphologies.**



Taxonomy and Systematics

Cumberland Dusky Salamander 2003

Patch-Nosed Salamander 2009

Taxonomic Ranks

- Origin with Linnaeus 1758
- Kingdom, Phylum, Class, Order, Family, Genus, Species

Taxonomy Ranks

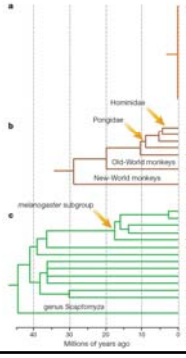
- Domain: Eukaryota
- Kingdom: Animalia
- Phylum: Chordata
- Class: Lissampibia
- Order: Caudata
- Family: Plethodontidae
- Genus: *Gyrinophilus*
- Species: *Gyrinophilus gulolineatus* Brandon

Taxonomic Ranks

- Recognized ranks should reflect evolutionary history
- But are ranks above species equivalent or even comparable?

Taxonomic Ranks-Not comparable

Nine genera of Lake Victoria cichlids



Anthropoid primates, multiple families and genera

***Drosophila*, species in a single genus**

Taxonomic Ranks-Not comparable

- **Diversity: Ranks do not have the same number of member lineages. A genus may have very different numbers of species than another genus.**

- **Age: A genus may be much older than another genus. The genus *Drosophila* is much older than the genus *Pan*.**

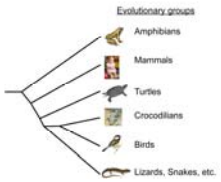
Taxonomy and Systematics

- **Classifications and evolutionary hypotheses are dynamic, and will change as more data is collected and analyzed for particular questions.**

- **How do we construct hypotheses about evolutionary relationships?**

Taxonomy and Systematics

- ***Systematics*, the science of resolving the evolutionary relationships among organisms.**



Phylogenetic Systematics

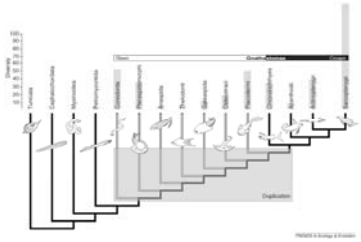
- ***Phylogenetic Systematics* – the study of the evolutionary relationships among various groups of organisms, both extinct and extant, using molecular and/or morphological data**
  - **Construction of evolutionary trees**
  - **Does not attempt to rank organisms**
  - **Names are associated with clades and not ranks**
  - **Attempts to provide hypotheses regarding the historical/ genealogical relationships among lineages or organisms.**
  - **Uses an objective and standard methodology to develop hypotheses-data driven**
  - **Not standard practice until late 1970s-early 1980s**

Phylogenetic Systematics - Outline

- **What is a phylogenetic tree?**
- **How are phylogenetic trees constructed?**
- **What are the main uses of phylogenetic trees?**

Phylogenetic Trees

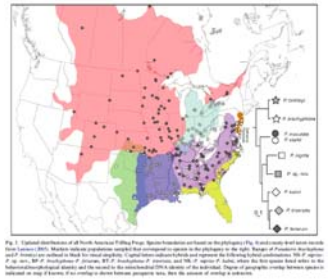
- **Phylogenies can represent different levels of evolutionary relationships**



Major vertebrate clades

Phylogenetic Trees

- **Phylogenies can represent different levels of evolutionary relationships**



Closely related species

Pseudacris

Phylogenetic Trees

- **Phylogenies can represent different levels of evolutionary relationships**

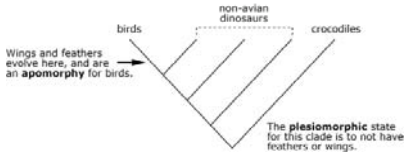
Populations within a species

Phylogenetic Systematics

- Uses characteristics, or *characters*, as data points
- Assumptions:
  - Changes in characters occur in lineages over time
  - Any group of organisms is related by descent from a common ancestor
  - Ancestral lineages split into just two descendant lineages (bifurcation)

Phylogenetic Systematics

- Changes in characters occur in lineages over time



Phylogenetic Systematics

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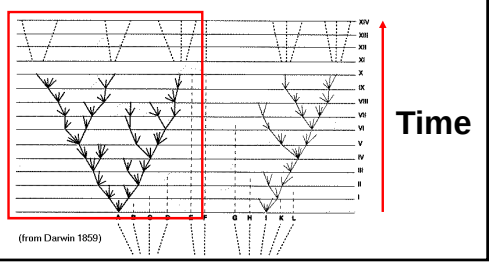

Phylogenetic Systematics

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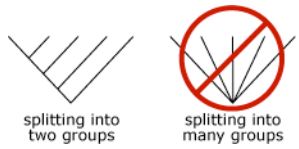
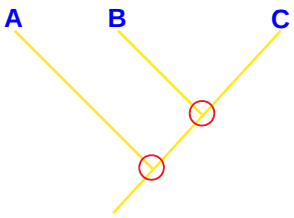


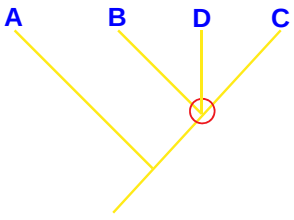
Phylogenetic Systematics

- Ideally, phylogenetic trees are bifurcating



Phylogenetic Systematics

- *Polytomies* are when more than two lineages emerge from an ancestor (MRCA)



Phylogenetic Systematics

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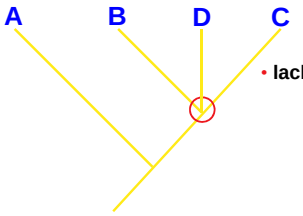
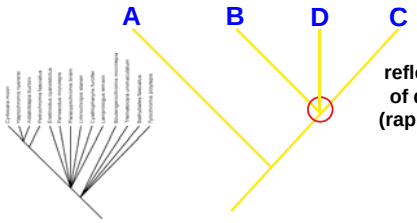


- **lack of characters**

Phylogenetic Systematics

- ***Polytomies*** **are when more than two lineages emerge from an ancestor (MRCA)**



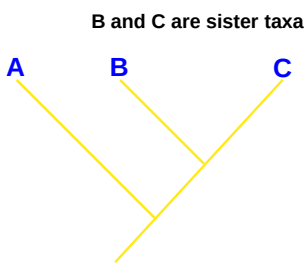
reflect true pattern of diversification (rapid speciation)

Phylogenetic Systematics

- Traditional Evolutionary Taxonomy (TET) – uses two principles for designating taxa.
  - Common descent
  - Amount of adaptive evolutionary change
- The second criterion leads to the idea that groups may be designated as higher level taxa because they represent a distinct “adaptive zone” because they have undergone adaptive change that fits them to a unique role (e.g., humans).

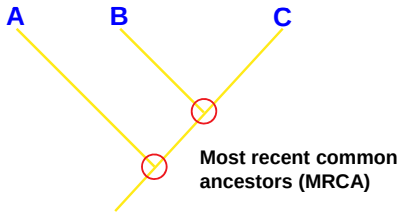
Phylogenetic Trees

- Depict ancestor-descendent relationships



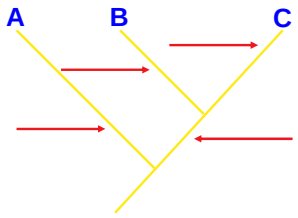
Phylogenetic Trees

- *Nodes*, represent the most recent common ancestor, which is the "species" from which the two lineages have descended from



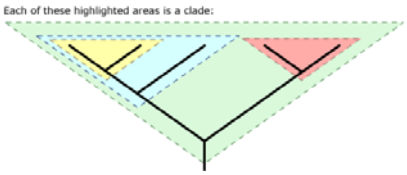
Phylogenetic Trees

- *Branches*, connect nodes, and lead to terminal taxa, the units of species or lineages in the phylogenetic analysis



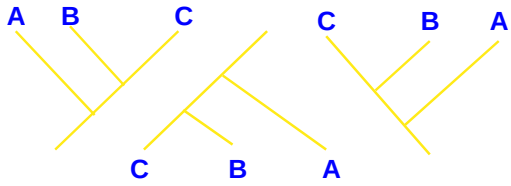
Phylogenetic Trees

- ***Clade***, **a group of organisms that includes an ancestor and *all* descendents of that ancestor.**



Phylogenetic Trees

- **Topology = The ancestor-descendent relationships in tree like form. Can look very different but depict the same tree.**



Constructing a Phylogenetic Tree

- **1. Choose taxa of interest**
- **2. Determine the characters and character states to use**
  - **Molecular, morphological, behavioral data**
- **3. Determine order of evolution for each character**
  - **Use of outgroup**
- **4. Group taxa by synapomorphies (shared derived characters)**
- **5. Work out conflicts that arise (e.g., parsimony)**
- **6. Construct the tree**

Homology and Analogy

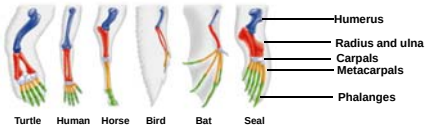
- Homology – character that is similar in group of organisms because it was inherited from a common ancestor.
  - Examples: limbs in tetrapods, mammary glands in mammals
- Analogy – character similar because of convergent evolution and not because of common ancestry
  - Examples: wings in birds and bats

Analogy

- Example: Being hairy might mislead us concerning evolutionary relationships

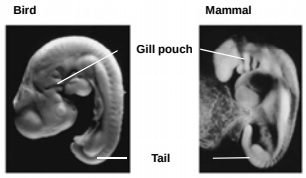



Homology



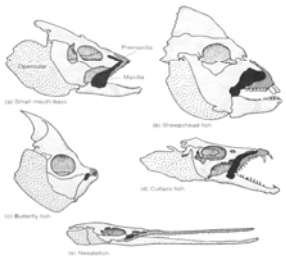
Homology

Embryology:



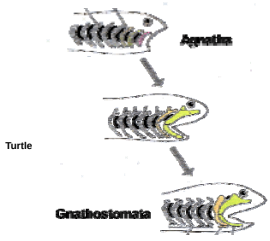
Homology

Morphology:



Homology

Morphology-Transitions



Homology

Genetics – amino acid sequence of proteins

Homoplasy

Homoplasy **– when two species share a derived character state because of *convergent evolution* or *evolutionary reversal*, but not because of common descent.**

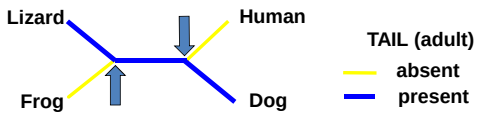
Convergent Evolution **– independent evolution of a derived character state in two or more taxa.**

Causes of homoplasy:

convergence
character reversal – secondary appearance of an ancestral character state

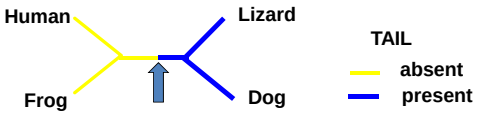
Homoplasy - Convergence

- **Loss of tails evolved independently in humans and frogs - there are two steps on the true tree**



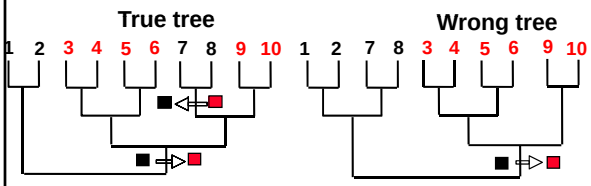
Homoplasy - Convergence

- If misinterpreted as a synapomorphy, the absence of tails would be evidence for a wrong tree: grouping humans with frogs and lizards with dogs



Homoplasy – Character Reversal

- Reversals are evolutionary changes back to an ancestral condition
- As with any homoplasy, reversals can provide misleading evidence of relationships



Constructing a Phylogenetic Tree

- 2. Determine the characters and character states to use

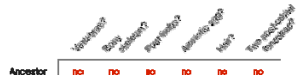
	Vertebrae*	Bony skeleton?	Four limbs?	Amniotic egg?*	Hair?	Two post-orbital fenestrae?**
Sharks and relatives	YES	no	no	no	no	no
Ray-finned fishes	YES	YES	no	no	no	no
Amphibians	YES	YES	YES	no	no	no
Primates	YES	YES	YES	YES	YES	no
Rodents and rabbits	YES	YES	YES	YES	YES	no
Crocodiles and relatives	YES	YES	YES	YES	no	YES
Dinosaurs and birds	YES	YES	YES	YES	no	YES

*amniotic egg: an egg in which the embryo is surrounded by the moisture-retaining amnion membrane

**post-orbital fenestrae: holes in the skull behind the eye

Constructing a Phylogenetic Tree

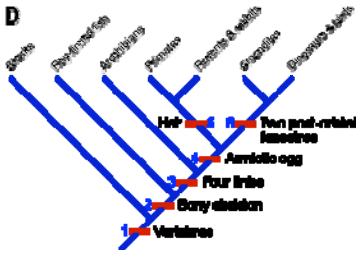
- 3. Determine order of evolution for each character



- 4. Group taxa by synapomorphies (shared derived characters)

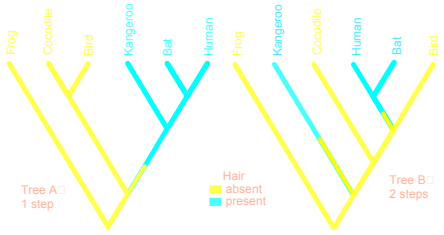
Constructing a Phylogenetic Tree

- 6. Construct the tree



Phylogenetic Systematics

- The best phylogeny is one that results in the fewest number of changes of the characters on the tree, *parsimony*

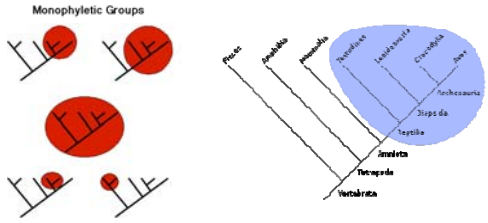


Parsimony

- **Advantages:**
  - **Simple method - easily understood operation**
  - **Does not seem to depend on an explicit model of evolution**
  - **Should give reliable results if the data are well structured and homoplasy is either rare or widely (randomly) distributed on the tree**
- **Disadvantages:**
  - **Doesn't always provide the best estimate of phylogeny**
    - **Maximum likelihood**
    - **Bayesian analysis**

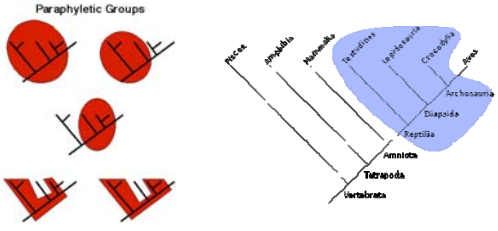
Phylogenetic Trees

- ***Monophyletic groups*** **(clades) - includes the most recent common ancestor of a group and all of its descendents.**



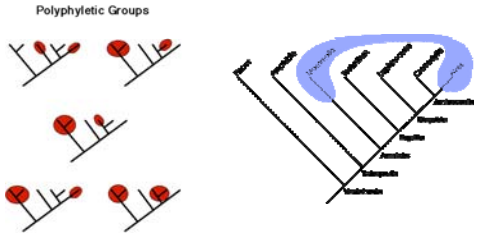
Phylogenetic Trees

- ***Paraphyletic groups*** **- includes the most recent common ancestor of a group *and some but not all* of its descendents.**

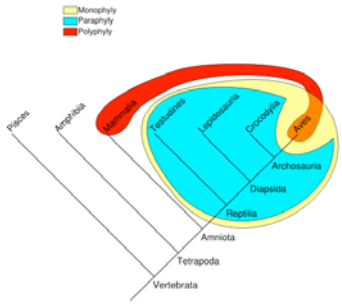


Phylogenetic Trees

- ***Polyphyletic groups*** **- does not contain the most recent common ancestor of all members of the group.**

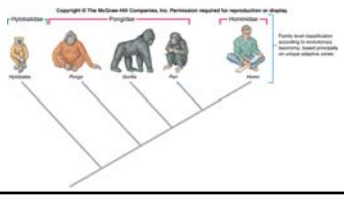


Phylogenetic Trees



Phylogenetic Systematics

- Classification of anthropoid primates.
- The genera *Gorilla*, *Pan* (chimpanzee) and Pongo (orangutan) are grouped into family Pongidae and humans (genus *Homo*) into family Hominidae even though humans are phylogenetically closer to Gorilla and Pan than either of those is to Pongo.



Phylogenetic Systematics

- Under TET designation of family Hominidae is because humans represent a different **grade** of organization.
  - Humans are terrestrial, intelligent, omnivores with advanced cultures.
  - Members of Pongidae are arboreal, less intelligent, herbivores.
- Under cladistics approach all groups must be monophyletic. Thus, cladists group the Pongidae and Hominidae into one group the Hominidae.

Causes of Paraphyly and Polyphyly

- Inadequate phylogenetic information
  - Little variation in molecular or morphological data
- Inaccurate species limits
  - Too many or too few recognized taxa
- Gene flow
  - Hybridization, introgression, hybrid speciation
- Incomplete lineage sorting
- Unrecongized paralogy
  - Gene duplication, pseudogenes

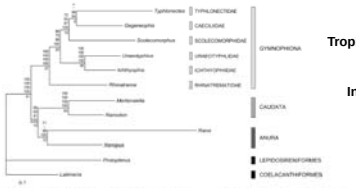
Amphibia

~5430 species

~560 species

~170 species

Gymnophiona



Aquatic caecilians

Common caecilians

Tropical caecilians

Indian caecilians

Fish caecilians

Beaked caecilians

San Mauro et al. 2004

Caudata

Plethodontidae

Amphiumidae

Rhyacotritonidae

Ambystomatidae

Dicamptodontidae

Salamandridae

Proteidae

Hynobiidae

Cryptobranchidae

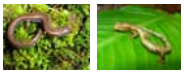
Sirenidae

Plethodontidae

Plethodontinae

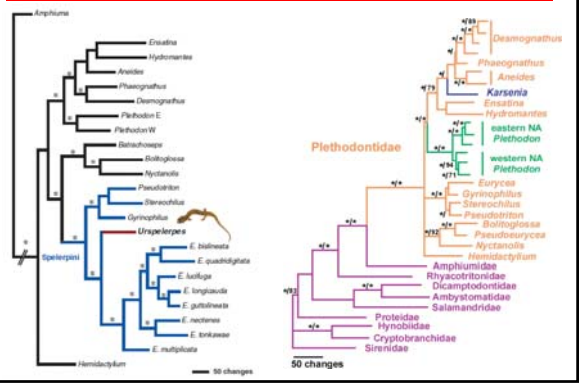
Spelerpinae

Bolitoglossinae

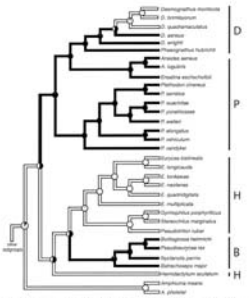


Hemidactyliinae

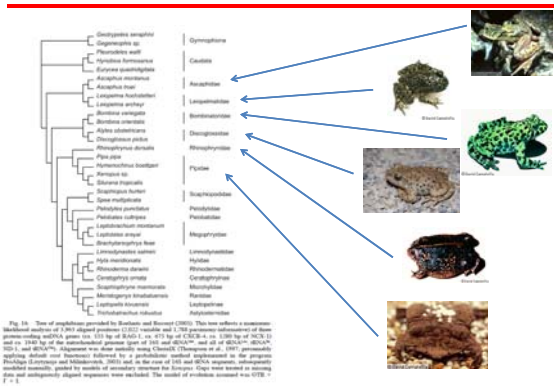
Plethodontidae – contd.



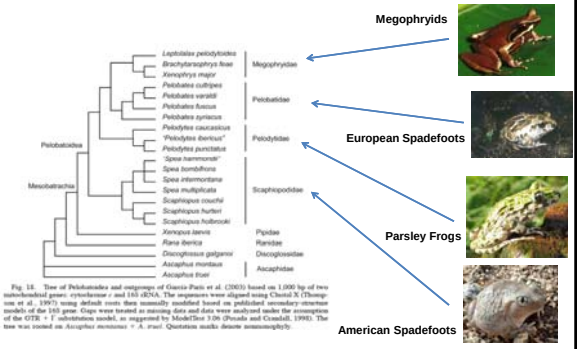
Plethodontidae – contd.



Anura



Pelobatoidea



Neobatrachia