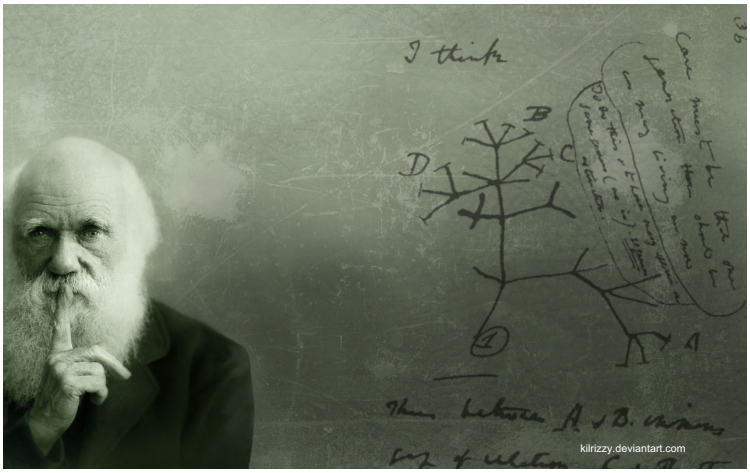
Passion Flower diversity – how are they related?

Darwin's first evolutionary tree



In July 1837 Darwin began his notebook on "*The Transmutation of Species*" and on page 37 he wrote "I think" above his first evolutionary tree

Lecture 11

Phylogenetics & macroevolution

1. How best to classify life – systematics, taxonomy, and cladistics
2. Phylogenetic trees and the reconstruction of evolutionary history using molecular data
3. Character evolution, the origin of adaptations and key innovations

Carolus Linnaeus (1707-1778)

The "father" of taxonomy

- Binomial nomenclature
- Hierarchical system of classification

kingdoms
phyla
classes
orders
families
genera
species

What is the purpose of a biological classification?

- Name is a key to the literature on an organism
- Therefore has predictive power
- Enables interpretation of origins and evolutionary history

Taxon

- A named taxonomic unit at any level (plural = taxa)

kingdoms
phyla
classes
orders
families
genera
species

Taxonomy

- The theory and practice of classification

Systematics

- The study of biodiversity and the evolutionary relationships among organisms

Schools of Taxonomy:

Philosophical wars of the 70s & 80s

Phenetics

- Classifying species based solely on overall resemblance. Now largely dead!

Cladistics

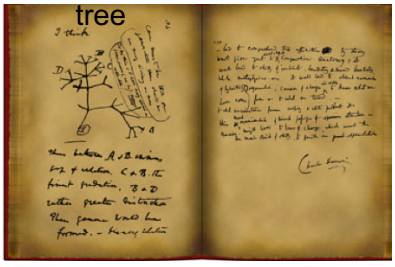
- Classifying species on the basis of their phylogenetic relationships

The birth of cladistics and the building of phylogenetic trees

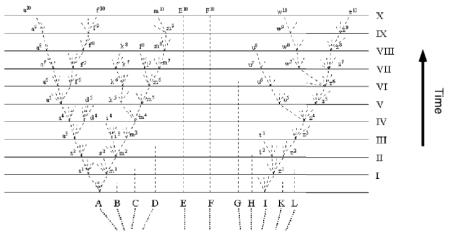
Willi Hennig (1913-1976)

phylogenetic trees provide a depiction of the evolutionary relationships among groups of organisms – important to appreciate they are an hypothesis about evolutionary history

Darwin's first tree



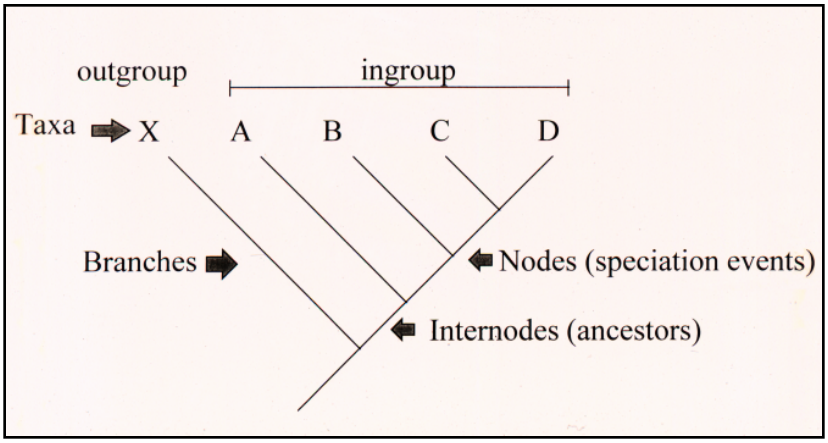
The only figure in the "Origin" was a tree



"The affinities of all beings… have sometimes been represented as a great tree … and so by generation I believe it has been with the great tree of life"

Darwin 1859

A phylogenetic tree



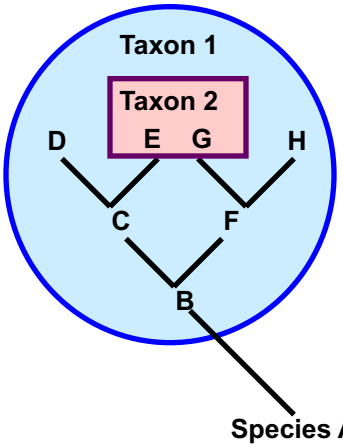
Monophyletic group

- A single ancestor gave rise to all species in that taxon and no species in any other taxon

Non-monophyletic group

- A taxon whose members are derived from two or more ancestral forms not common to all members

Grouping species into higher taxa



- Taxon 1 is **monophyletic and constitutes a clade (all taxa derived from an immediate common ancestor)**
- Taxon 2 is **non-monophyletic**

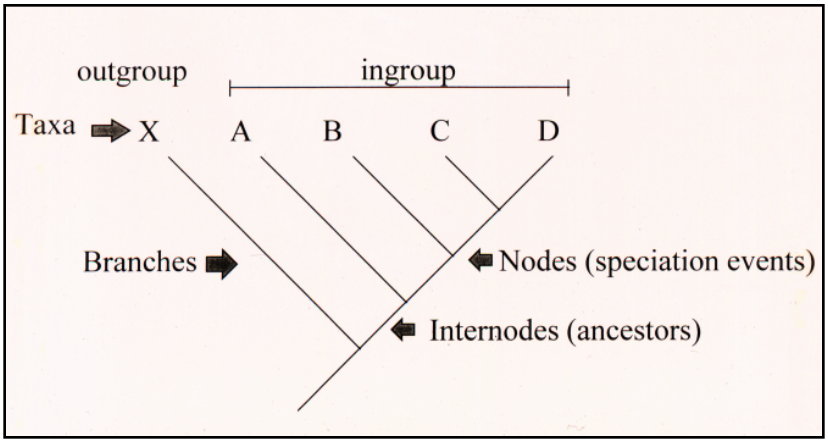
- **Monophyletic** classifications are much preferred

A critical step in the reconstruction of phylogenetic history is:

the identification of ancestral and derived traits.

- **Ancestral** trait = A trait shared with a common ancestor
- **Derived** trait = A trait that differs from the ancestral trait in a lineage

A phylogenetic tree



Homology & homoplasy

Homology

- Similarity of traits due to shared ancestry

Homoplasy

- Similarity of traits as a result of convergent evolution

Human & fish skeletons are homologous structures

Human Skeleton

Fish Skeleton

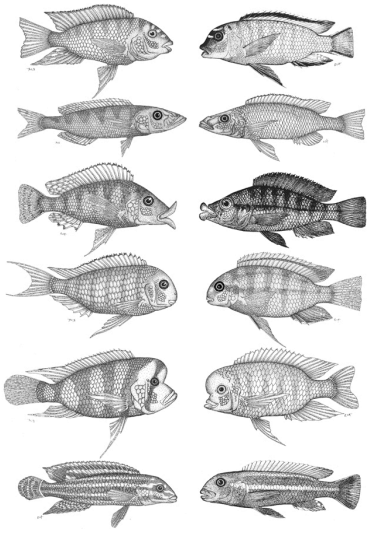
Convergent Evolution

- The evolution of structures that resemble one another and perform similar functional roles due to the shared ecology of unrelated organisms

Convergent evolution of succulence & spiny growth form in desert environments

Milkweed family

Convergent evolution in cichlid fishes of the African Great lakes



- independent evolutionary radiations in two lakes

- The similarity in form indicates convergence in feeding strategies

Kocher (2004) *Nature Reviews Genetics*

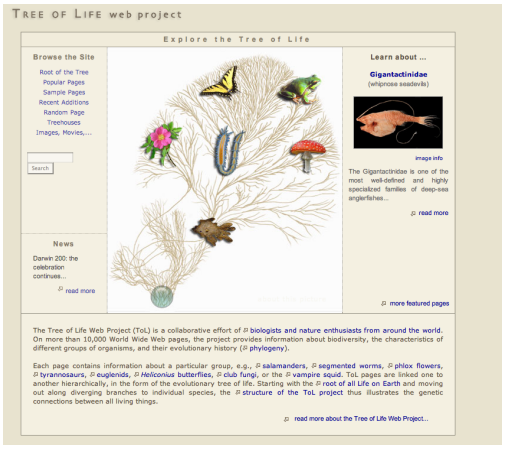
Why is molecular biology relevant to evolution & phylogeny reconstruction ?

- All life is related through branching descent
- Common genetic code is evidence that all life is related
- Evolutionary relationships among species are reflected in their DNA and proteins

Inferring species relationships from nucleotide sequences

- Genes or parts of a gene can be sequenced for different species
- Species can be assessed for changes in the sequence of nucleotides
- These changes can be used to construct relationships in a branching diagram (phylogeny)

DNA sequencing is enabling rapid construction of the tree of life



http://tolweb.org/tree

Wayne Maddison
UBC

Dave Maddison
Univ. of Arizona

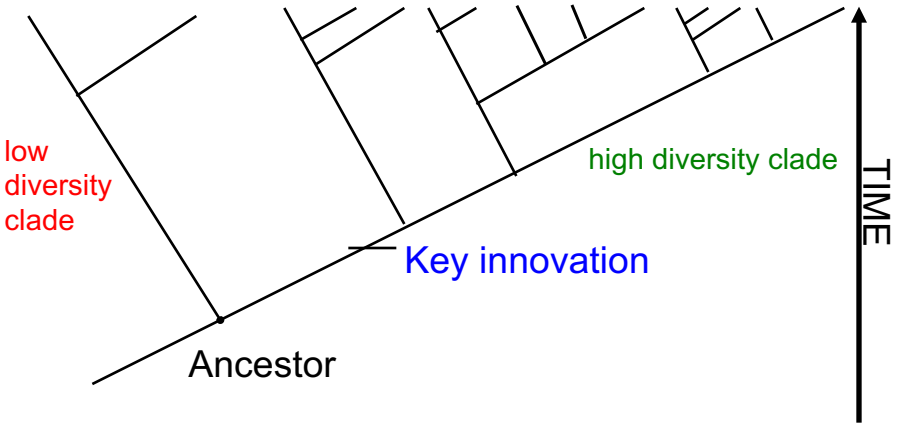
- Tree of life web project provides 10,000 webpages about biodiversity and phylogenetic relationships

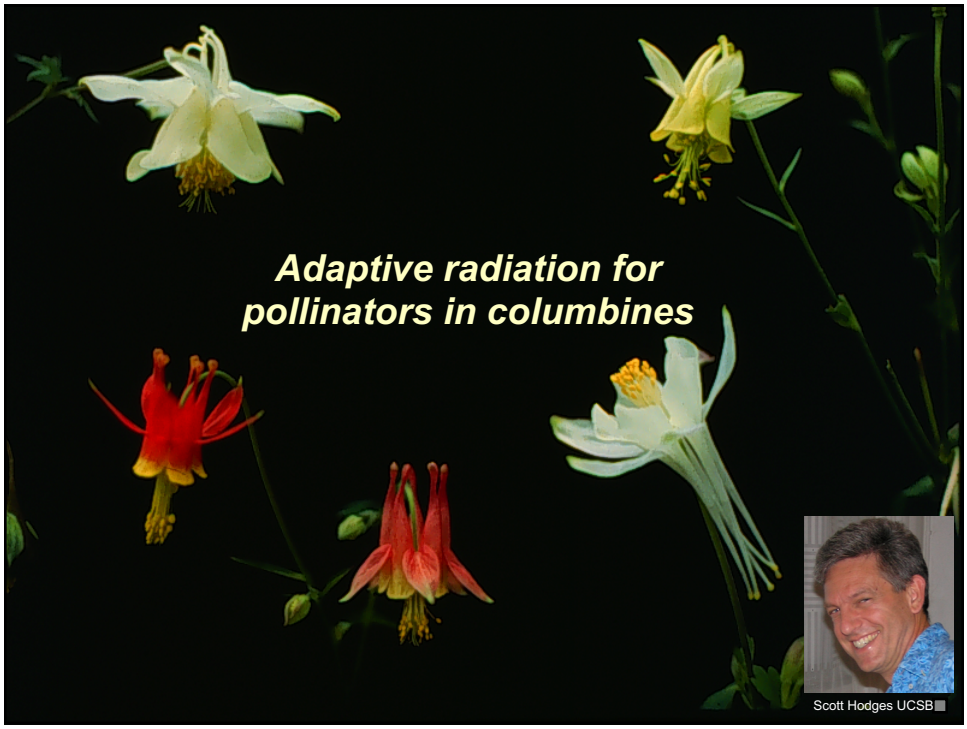
Using phylogenies to understand the origin and evolution of traits

Key innovations:

- Origin of a novel trait resulting in adaptive radiation
- Carriers of the trait can exploit new resources or sets of habitats
- Usually associated with rapid evolutionary diversification (e.g. adaptive radiations)

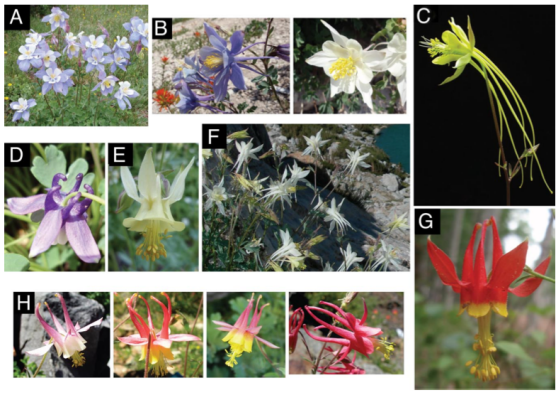
Origin of trait associated with increased diversification rate

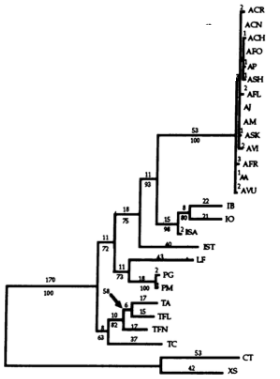




Columbines display diverse flowers associated with different pollinators

Molecular phylogeny

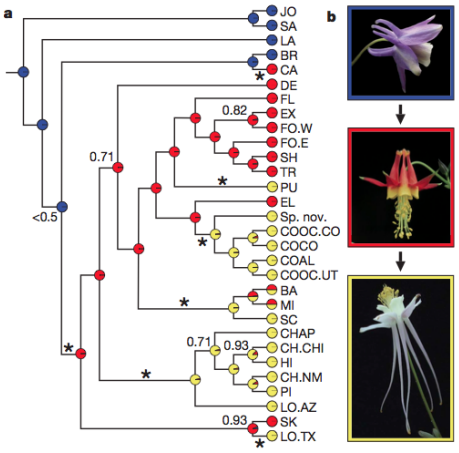


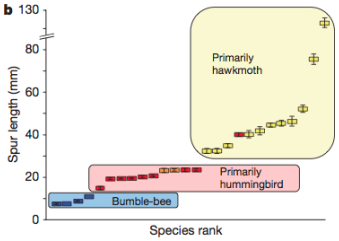


• phylogeny shows rapid burst of speciation with aquistion of nectar spur – short branch lengths in comparison with sister group

PNAS (1994)

Evolution of nectar spur length in Columbines associated with pollinator shifts





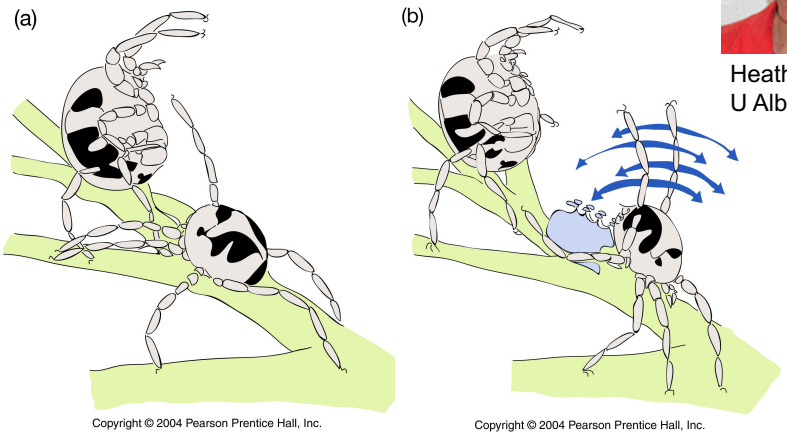
Nature 2007

Key points from the Nature paper on columbines

- 16 fold variation in nectar spur length among species
- 7 independent pollinator shifts – 2 from bee to bird; 5 from bird to hawkmoth
- Clear directionality in spur length evolution with no evidence of reversal to shorter spurs
- pollinator shifts associated with speciation events due to premating isolation

Male courtship display in water mites

Heather Proctor
U Alberta



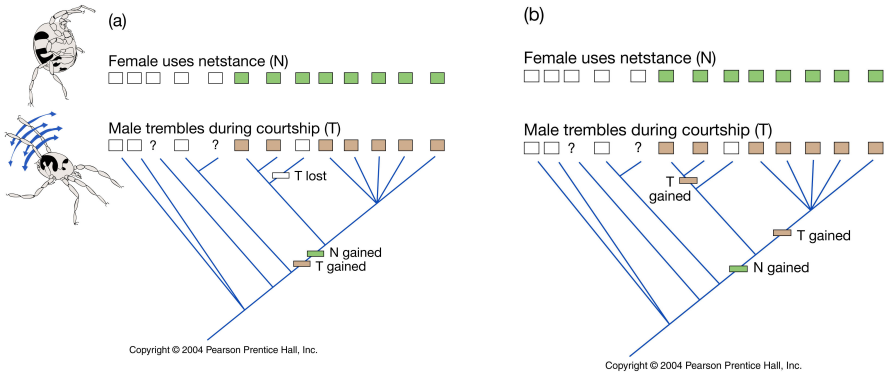
Male courtship display in water mites

- Water mite is ambush predator who hunts copepods in water column using ‘net stance’
- Male courtship display involves leg trembling
- Are males mimicking prey so female will clutch males?
- male leg-trembling frequencies fall within range of vibrations of copepod prey
- females were more likely to orient and clutch males when they were deprived of food

Sensory bias

- Preference for a trait evolved in a non-mating context and it was then exploited by one sex to get more mating opportunities
- How can we use a phylogeny to test this hypothesis?

Using cladistics to test for sensory bias



Key points from test of sensory bias in water mites

- Females use net stance to hunt prey
- Male vibrate legs to mimic prey
- Two equally parsimonious cladograms for evolution of these traits
- Only one cladogram supports sensory bias hypothesis