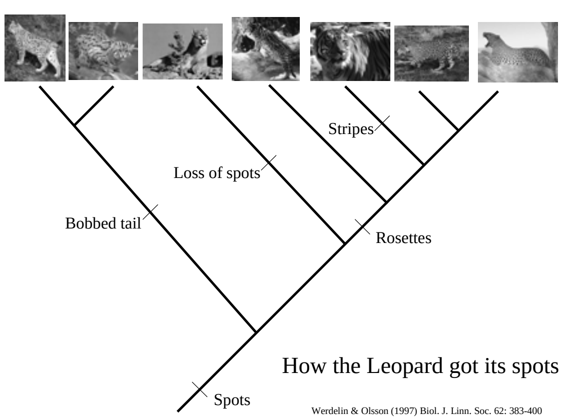
General Patterns in Evolution

Uses of Phylogenetic Analysis

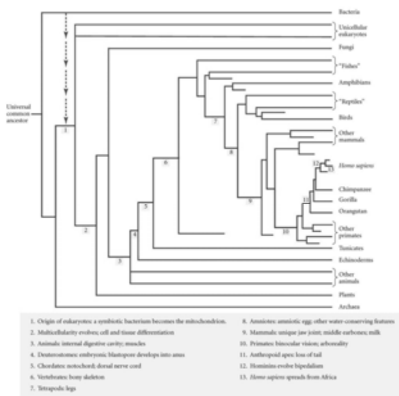
- Allows mapping order of character state changes
- Documents evolutionary trends in development
- Reveals that Homoplasy is common
- Can attempt to equate timing with fossil record events



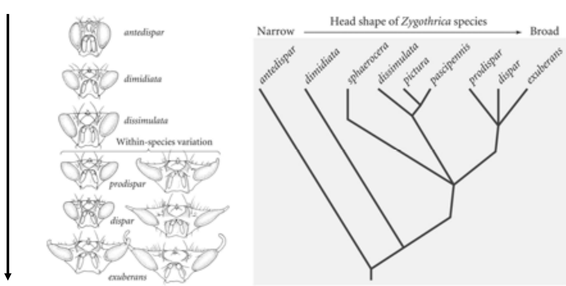
How the Leopard got its spots

Werdelin & Olsson (1997) Biol. J. Linn. Soc. 62: 383-400

Tracing the path of evolution to *Homo sapiens* from the universal ancestor of all life

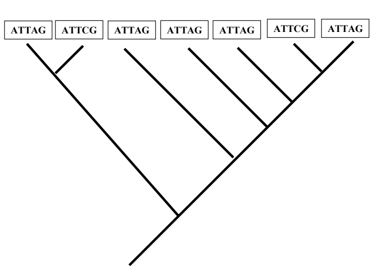


Phylogenetic Analysis Documents Evolutionary Trends in Development: In fruit flys

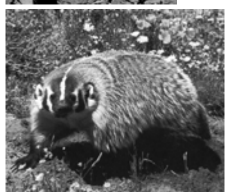


Phylogenies Reveal that Homoplasy is Common

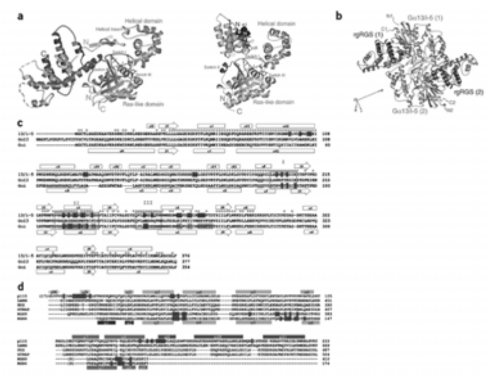
- **Convergent** and **parallel** evolution - the independent gain of a trait



Convergent Evolution among
Placental Mammals and Marsupials



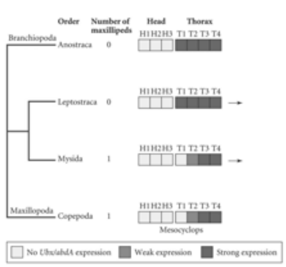
Structure of the p115RhoGEF rgRGS domain−Gα13/i1 chimera complex suggests convergent evolution of a GTPase activator.

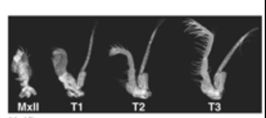


Zhe et al. (2005) Nature Structural & Molecular Biology. **12**:191 – 197.

Parallel evolution: Special case of Convergent evolution

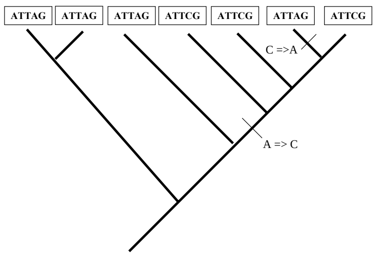
Feeding structures (maxillipeds) from thoracic legs in crustaceans.



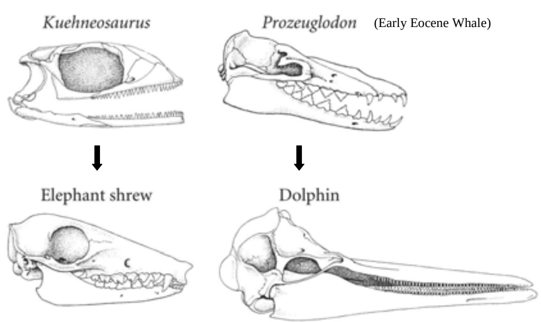


Phylogenies Reveal that Homoplasy is Common

• Evolutionary **reversal** - the loss of a trait



Reversal:
An example of the acquisition and loss of individualization
Homodonts vs. Heterodonts

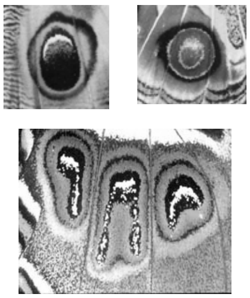


Reconciling the Fossil Record with phylogenetic analysis?

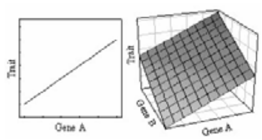
Can really only work with morphology-based cladistics.

These images taken from Heck's *Iconographic Encyclopedia* (1851).

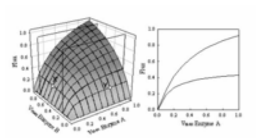
The Evolution of Traits aka phenotypes



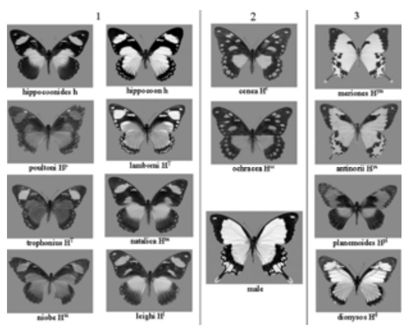
Linear interactions



Non-linear interactions



Polymorphic mimicry in *Papilio dardanus* (The mocker swallowtail): accurate mimics of different species of distasteful butterflies.



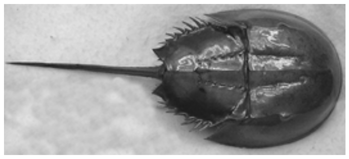
Single Locus; ~11 mimicking alleles that are more variable.

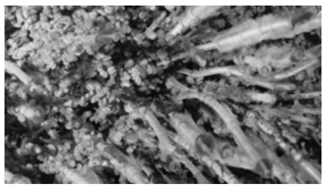
Biological traits come about through developmental processes and physiological regulatory mechanisms. Most of these processes are nonlinear. Examples of nonlinear processes are:

- The sensitivity of reaction rate to substrate concentration
- inhibition
- negative feedback
- positive feedback
- cooperativity
- most non-steady state processes
- any process that depends on diffusion

Any mechanism that contains one or more of these processes (and most regulatory mechanisms in biology do) will have a nonlinear relationship between variation in its determinants and variation in the trait affected by the process.

Rates of Evolution Vary Among Lineages

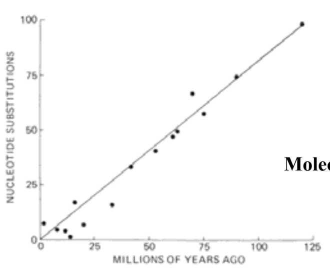




Rates of Evolution Vary Among Characters

Evolution of different characters at different rates within a lineage:
Mosaic Evolution

Combines concepts of **Gradualism** vs. **Saltation**



Molecular Clock?

Inferred pairwise nucleotide substitutions among 17 mammal species from seven gene products, as estimated from protein studies, plotted against date of divergence, as estimated from the fossil record. The line is drawn from the origin through the oldest point (marsupial/placental divergence at 125 MYA). The strong linear relationship suggests that **molecular differences between pairs of species are proportional to the time of their separation,** rather than the degree of organismal difference. Therefore, measures of genetic divergence can be used to date the time of divergence for species pairs for which no fossil data are available: genes function as **Molecular Clocks**. (from **A. C. Wilson** 1976)

Change in Form is Often Correlated with Change in Function

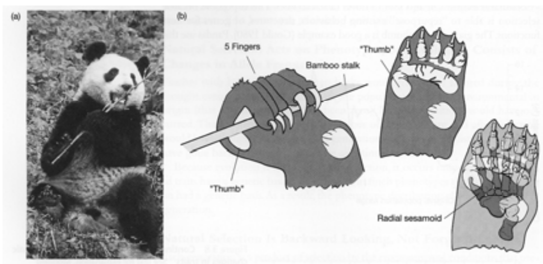
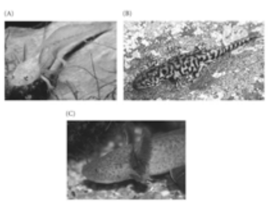


Figure 3.9 **The panda's thumb** (a) Giant pandas strip the leaves from bamboo by passing the stalk through their hands. (Bill Kamin/ Visuals Unlimited) (b) This drawing shows how the panda's "thumb" forms a slot for bamboo stalks to pass through. After Endo et al. 1999.

Heterochrony:
Changes in the Rate or Timing of Developmental Events

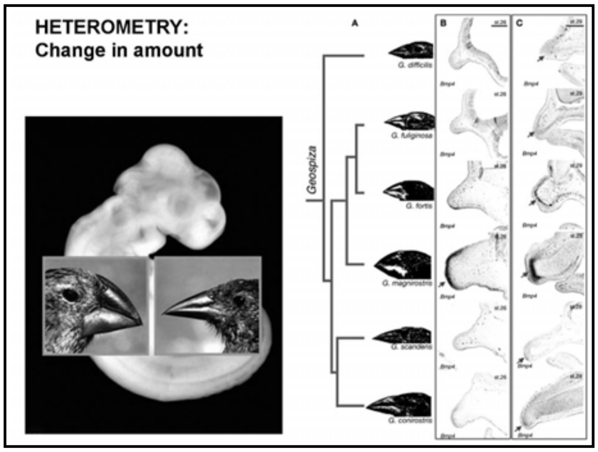


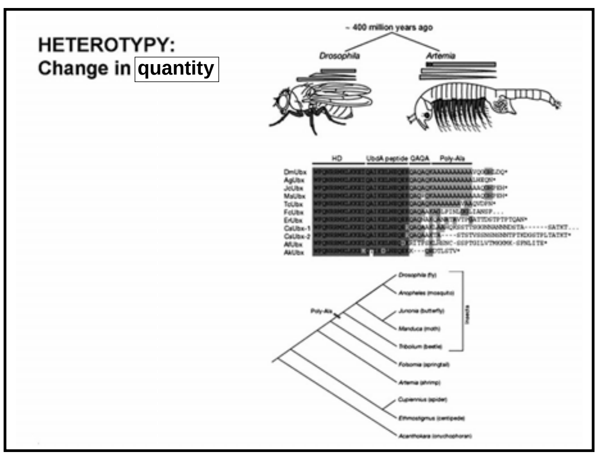
Paedomorphosis: the retention of juvenile features in the reproductive adult.

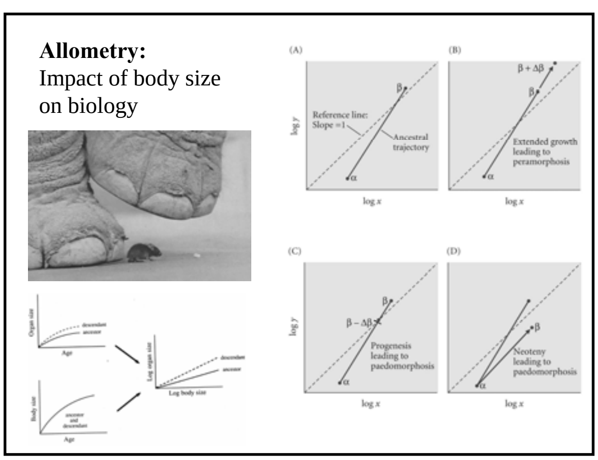
Peramorphosis: ‘hyper-adult’ features in the reproductive adult.

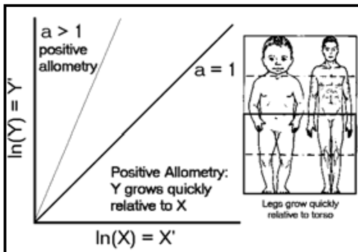
Heterotopy:
Changes in the Position in which a Trait is Expressed

Philodendron switching stem and root positions.

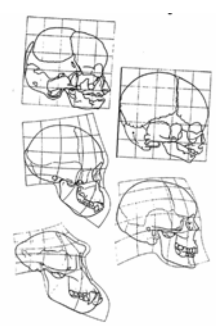

HETEROMETRY:
Change in amount
Geospiza
G. difficilis
G. fuliginosa
G. fortis
G. magnirostris
G. scandens
G. conirostris
Bmp4


HETEROTYPY:
Change in quantity
~ 400 million years ago
Drosophila
Artemia
HD
UbdA peptide
QAQA
Poly-Ala


Allometry:
Impact of body size on biology
(A)
(B)
(C)
(D)
log y
log x
Reference line: Slope =1
Ancestral trajectory
β + Δβ
Extended growth leading to peramorphosis
β − Δβ
Progenesis leading to paedomorphosis
Neoteny leading to paedomorphosis



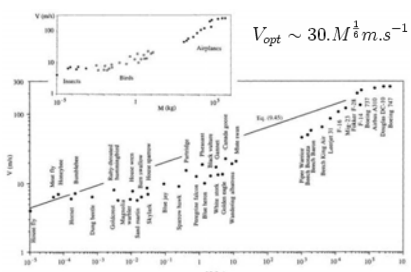
Are we just baby chimps?
A tale of heterochrony and allometric growth.



Homo sapiens, whose prolonged brain development period and relatively flat face may be reflections of a prolonged juvenile period, relative to that of our closest relatives, the bonobos and chimpanzees (*Pan paniscus* and *P. troglodytes*).

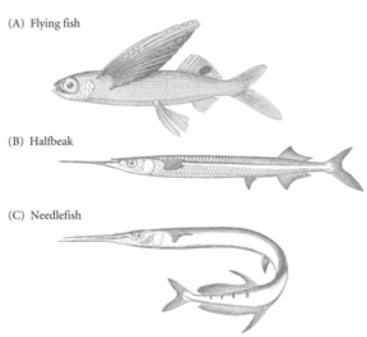
Allometric Law of Body Mass vs. Cruising Speed

- The proportionality between the optimal cruising speed V_{opt} of flying bodies (insects, birds, airplanes) and body mass M in *kg* raised to the power 1/6 is an allometric law predicted by constructional theory.



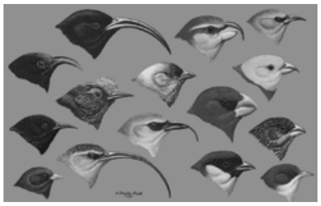
$$V_{opt} \sim 30.M^{\frac{1}{6}} m.s^{-1}$$

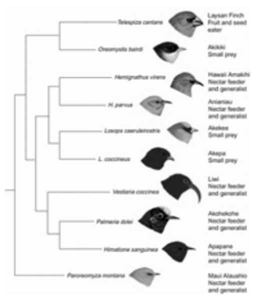
Allometric differences in the jaws among three closely related families of fishes.

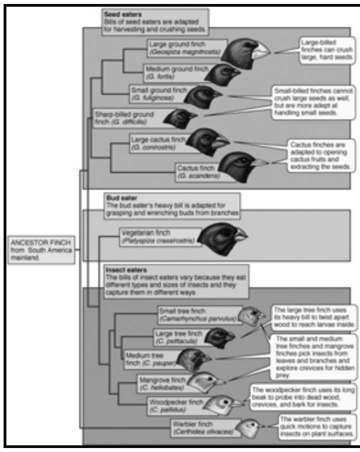


Adaptive Radiation is Widespread aka Divergent Evolution

Hawaiian Honeycreepers





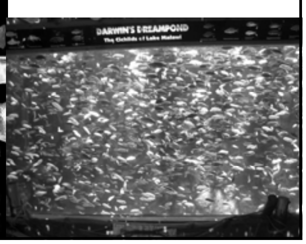


Adaptive Radiation is Widespread

Darwin's Finches are the classic example.

Adaptive Radiation is Widespread

Lake Malawi Cichlids (>500 spp.)



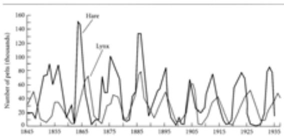


FIGURE 4.20 Fluctuations in abundance of lynx and hares in northern Canada, based on numbers of furs purchased by the Hudson Bay Company. The causes of the coupled cycles are still unclear. (After Purves et al. 1998.)

Coevolution

- Predators and their prey.
- Parasites and their hosts.
- Plant-eating animals and the plants upon which they feed.
- Coevolution is the joint change of two or more species in close interaction.
- Plants and the animals that pollinate them.

Modification of Preexisting Features

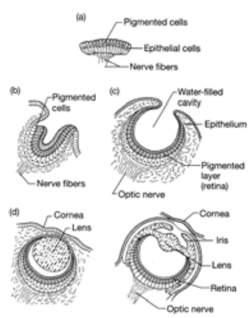
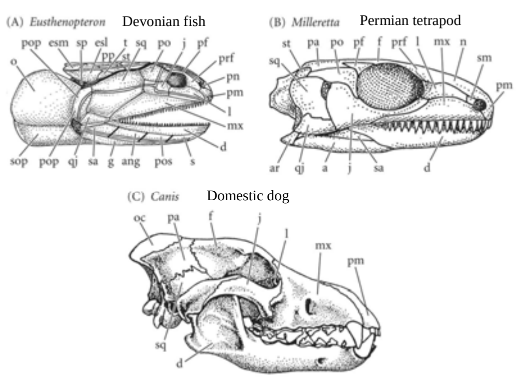
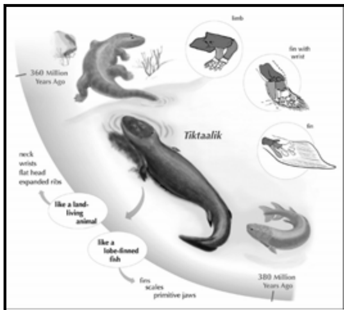


Figure 3.11 Variation in mollusc eyes (a) A pigment spot; (b) a simple pigment cup; (c) the simple optic cup found in abalone; (d) the complex lensed eyes of a marine snail called *Littorina* and the octopus. Pigmented cells are shown in color.

Increases and decreases in complexity:
An example of **reduction and loss** of skull & lower jaw bones during evolution.





A model of the species **Tiktaalik**, and a recreated skeleton of the animal.

Paleontologists working in northern Canada recently found an animal skeleton that may bridge the gap between fish and the first four-legged land animals. The 375-million-year-old (Devonian) creature, with a head like a crocodile's, has a body built for swimming. But its front legs are a compromise between fins and feet. This new species also has a **shortened skull roof, a modified ear region, a mobile neck, a functional wrist joint, and other features** that presage tetrapod conditions.

Daeschler E. B., Shubin N. H., Jenkins F. A. Jr, *Nature*, **440**. 757 - 763 (2006).
Shubin N. H. Daeschler E. B., , Jenkins F. A. Jr, *Nature*, **440**. 764 - 771 (2006).