

## Patterns in Evolution - Novelty



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## 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

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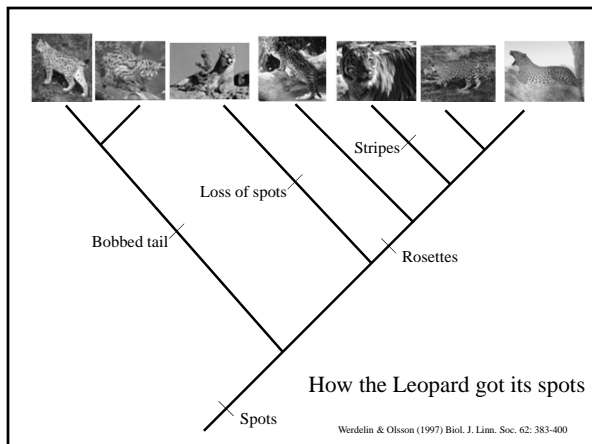
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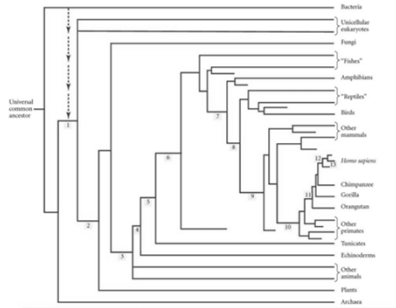
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Tracing the path of evolution to *Homo sapiens* from the universal ancestor of all life



1. Origin of eukaryotes: a symbiotic bacterium becomes the mitochondrion.
2. Multicellularity evolves: cell and tissue differentiation
3. Animals: ventral digestive cavity evolves
4. Deuterostomes: embryonic blastopore develops into anus
5. Chordates: notochord, dorsal nerve cord
6. Vertebrates: bony skeleton
7. Synapsids: legs
8. Amniotes: amniotic egg, other water-conserving features
9. Mammals: unique jaw joints, milk teeth, milk
10. Primates: binocular vision, adaptability
11. Anthropoid apes: loss of tail
12. Hominins: evolve bipedality
13. *Homo sapiens* spreads from Africa

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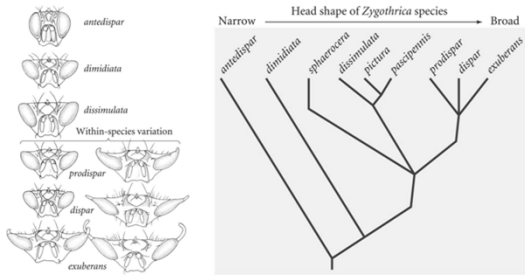
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Phylogenetic Analysis Documents Evolutionary Trends in Development: In fruit fly




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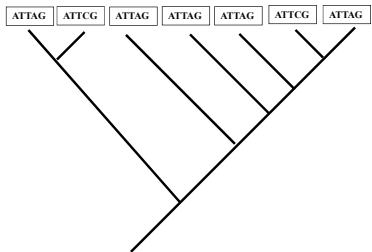
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Phylogenies Reveal that Homoplasy is Common

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




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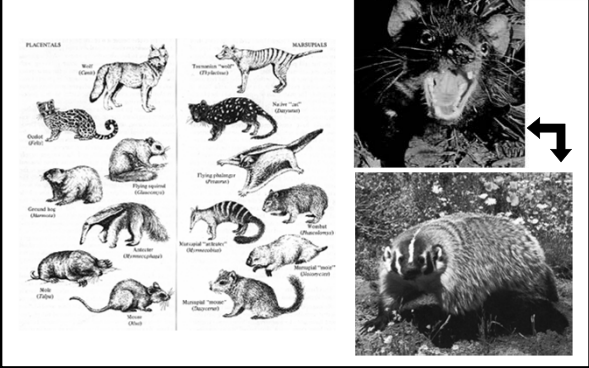
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### Convergent Evolution among Placental Mammals and Marsupials




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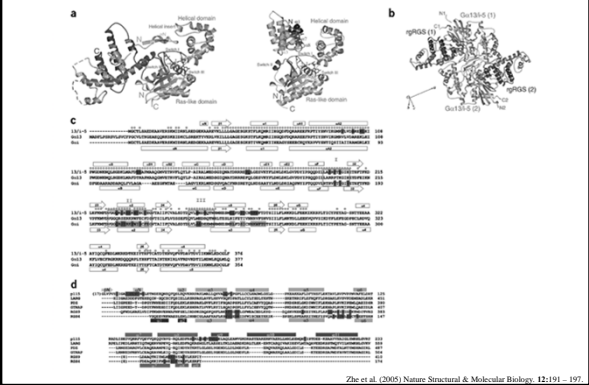
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### Structure of the p115RhoGEF rgRGS domain-Gα13/11 chimera complex suggests convergent evolution of a GTPase activator.




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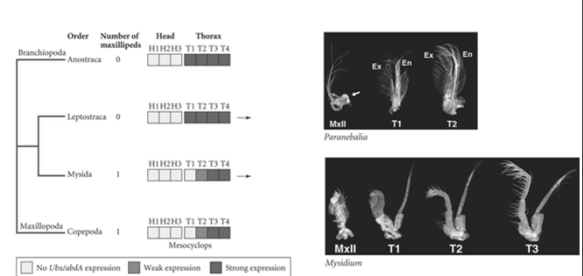
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### Parallel evolution: Special case of Convergent evolution

Feeding structures (maxillipeds) from thoracic legs in crustaceans.



Ancestral state: head had mouth parts, thorax legs.

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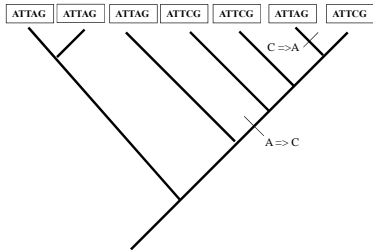
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### Phylogenies Reveal that Homoplasy is Common

- Evolutionary reversal - the loss of a trait




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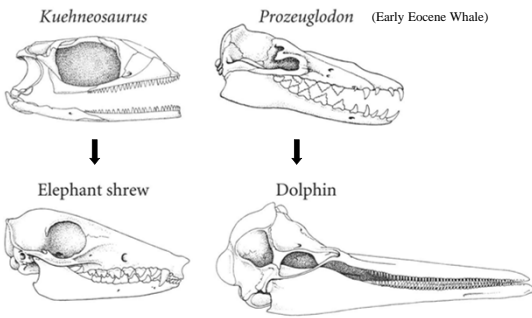
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### Reversal:

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




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### Reconciling the Fossil Record with phylogenetic analysis?

Can really only work with morphology-based cladistics.

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




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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.

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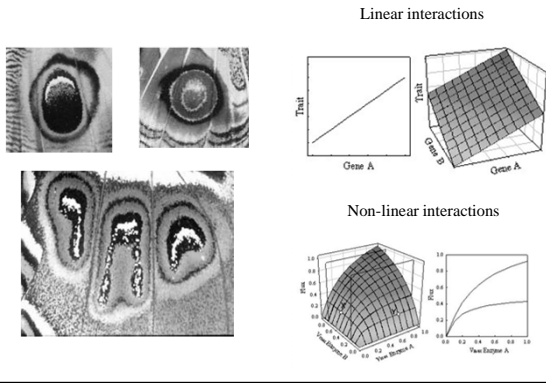
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### The Evolution of Traits aka phenotypes




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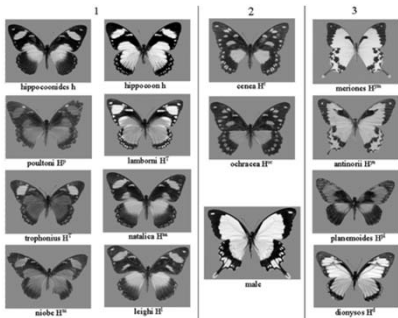
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Polymorphic mimicry in *Papilio dardanus* (The mocker swallowtail): accurate mimics of different species of distasteful butterflies.



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

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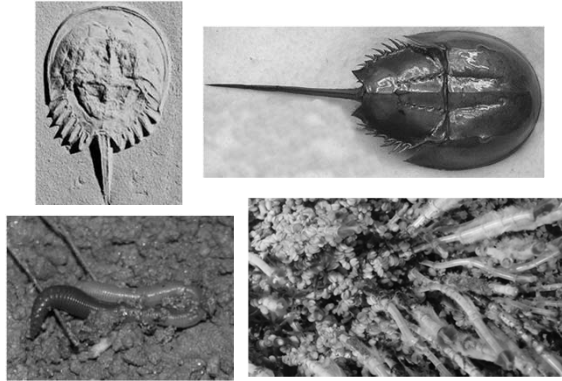
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**Rates of Evolution Vary Among Lineages**




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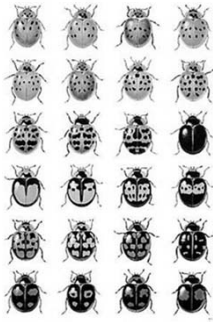
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**Rates of Evolution Vary Among Characters**



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

Combines concepts of **Gradualism vs. Saltation**

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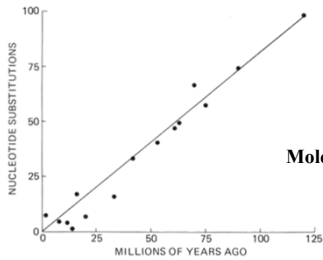
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**Molecular Clock?**

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)

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**Change in Form is Often Correlated with Change in Function**

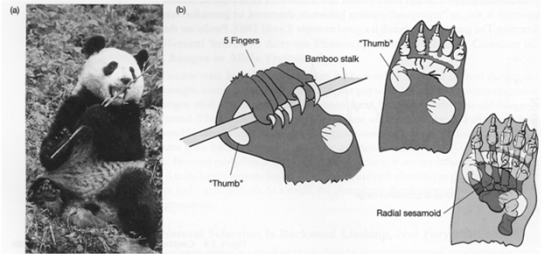


Figure 3.9 The panda's thumb (a) Giant pandas strip the leaves from bamboo by passing the stalk through their hands. (Bill Kamin/Visuals Unlimited) (b) This drawing shows how the panda's "thumb" forms a slot for bamboo stalks to pass through. (After Endo et al. 1999.)

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**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.

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

Philodendron switching stem and root positions.




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$\ln(Y) = Y'$

$a > 1$   
positive allometry

$a = 1$

Positive Allometry:  
Y grows quickly relative to X

$\ln(X) = X'$

Legs grow quickly relative to torso

**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*).

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**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.

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

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

(A) Flying fish

(B) Halfbeak

(C) Needlefish

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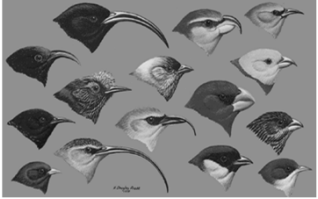
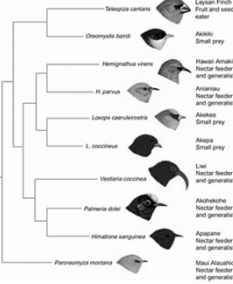
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## Adaptive Radiation is Widespread aka Divergent Evolution

Hawaiian Honeycreepers

The tree shows the following species and their adaptations:

- Scolecopax candollei*: Laysan Finch, Fruit and seed eater
- Oreomyza borealis*: Akaka, Small prey
- Hemignathus virens*: Hawaii Amakihi, Nectar feeder and generalist
- H. parvus*: Amakihi, Nectar feeder and generalist
- Lewinia camouflatorum*: Jaegers, Small prey
- L. coccinea*: Akepa, Small prey
- Myzadobicha coccinea*: Lei, Nectar feeder and generalist
- Palmeria dohrnii*: Akialoa-like, Nectar feeder and generalist
- Himatione sanguinea*: Apapane, Nectar feeder and generalist
- Paromomyza nana*: Maui Akialoa, Nectar feeder and generalist

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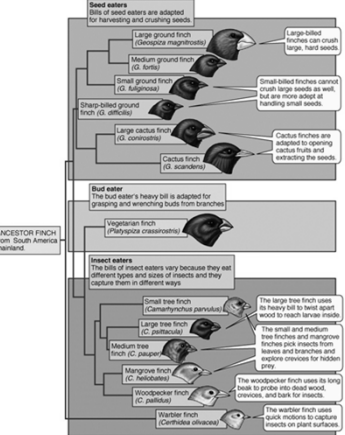
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## Adaptive Radiation is Widespread

Darwin's Finches are the classic example.



The tree illustrates various feeding adaptations:

- Seed eaters**: Bills of seed eaters are adapted for harvesting and crushing seeds.
  - Large ground finch (*Geospiza magnirostris*): Large-billed finches can crush large, hard seeds.
  - Medium ground finch (*G. fortis*)
  - Small ground finch (*G. fuliginosa*): Small-billed finches cannot crush large seeds as well, but are more adept at handling small seeds.
  - Sharp-billed ground finch (*G. difficilis*)
  - Large cactus finch (*G. stricklandi*): Cactus finches are adapted to opening cactus fruits and extracting the seeds.
  - Cactus finch (*G. scandens*)
- Beak eater**: The beak eater's heavy bill is adapted for grasping and wrenching buds from branches.
  - Vegetarian finch (*Phoenicurus versicolor*)
- Insect eaters**: The bills of insect eaters vary because they eat different types and sizes of insects and they capture them in different ways.
  - Small tree finch (*Camarhynchus parvulus*): The large tree finch uses its heavy bill to break apart wood to reach larvae inside.
  - Large tree finch (*C. pallasi*)
  - Medium tree finch (*C. julianae*): The small and medium tree finches and mangrove finches pick insects from leaves and branches and peck open crevices for hidden prey.
  - Mangrove finch (*C. melanotos*)
  - Woodpecker finch (*C. palmarum*): The woodpecker finch uses its long beak to probe into dead wood, crevices, and bark for insects.
  - Warbler finch (*Certhidea coccinea*): The warbler finch uses quick motions to capture insects on plant surfaces.

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## Adaptive Radiation is Widespread

Lake Malawi Cichlids (>500 spp.)

The image shows a vast array of cichlid species, illustrating the high degree of adaptive radiation in this group.

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## Coevolution

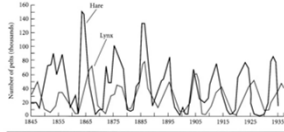


FIGURE 4.20 Fluctuations in abundance of lynx and hares in northern Canada, based on numbers of furs purchased by the Hudson Bay Company. The cause of the coupled cycles are still unclear. (After Purves et al. 1998.)

- 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.

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Bee orchid video

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## Modification of Preexisting Features

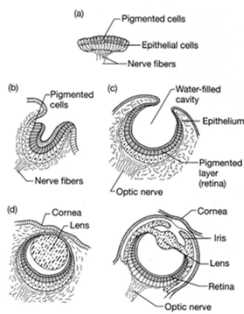


Figure 3.11 Variation in mollusc eyes (a) A pigment spot; (b) a simple pigment cup; (c) the simple optic cup found in abalone; (d) the complex lensed eyes of a marine snail called *Littorina* and the octopus. Pigmented cells are shown in color.

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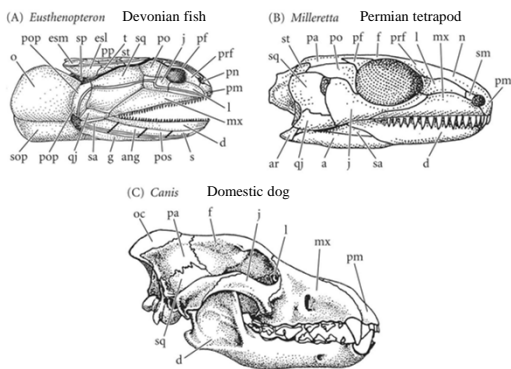
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**Increases and decreases in complexity:**  
 An example of **reduction and loss of skull & lower jaw bones** during evolution.




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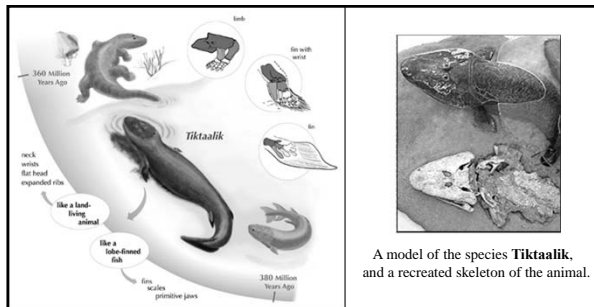
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A model of the species **Tiktaalik**, and a recreated skeleton of the animal.

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).

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