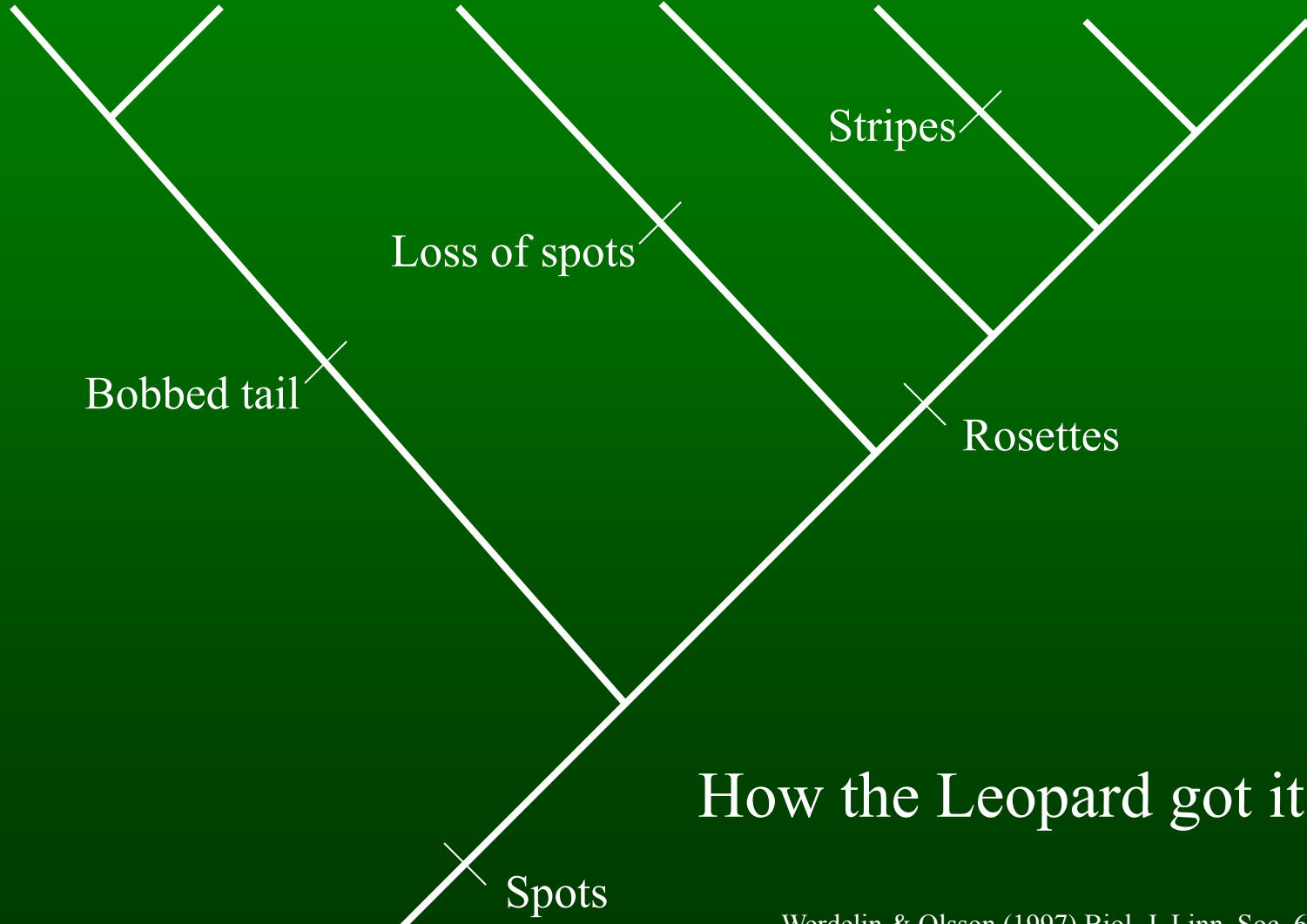


Patterns in Evolution - Novelty



Uses of Phylogenetic Analysis

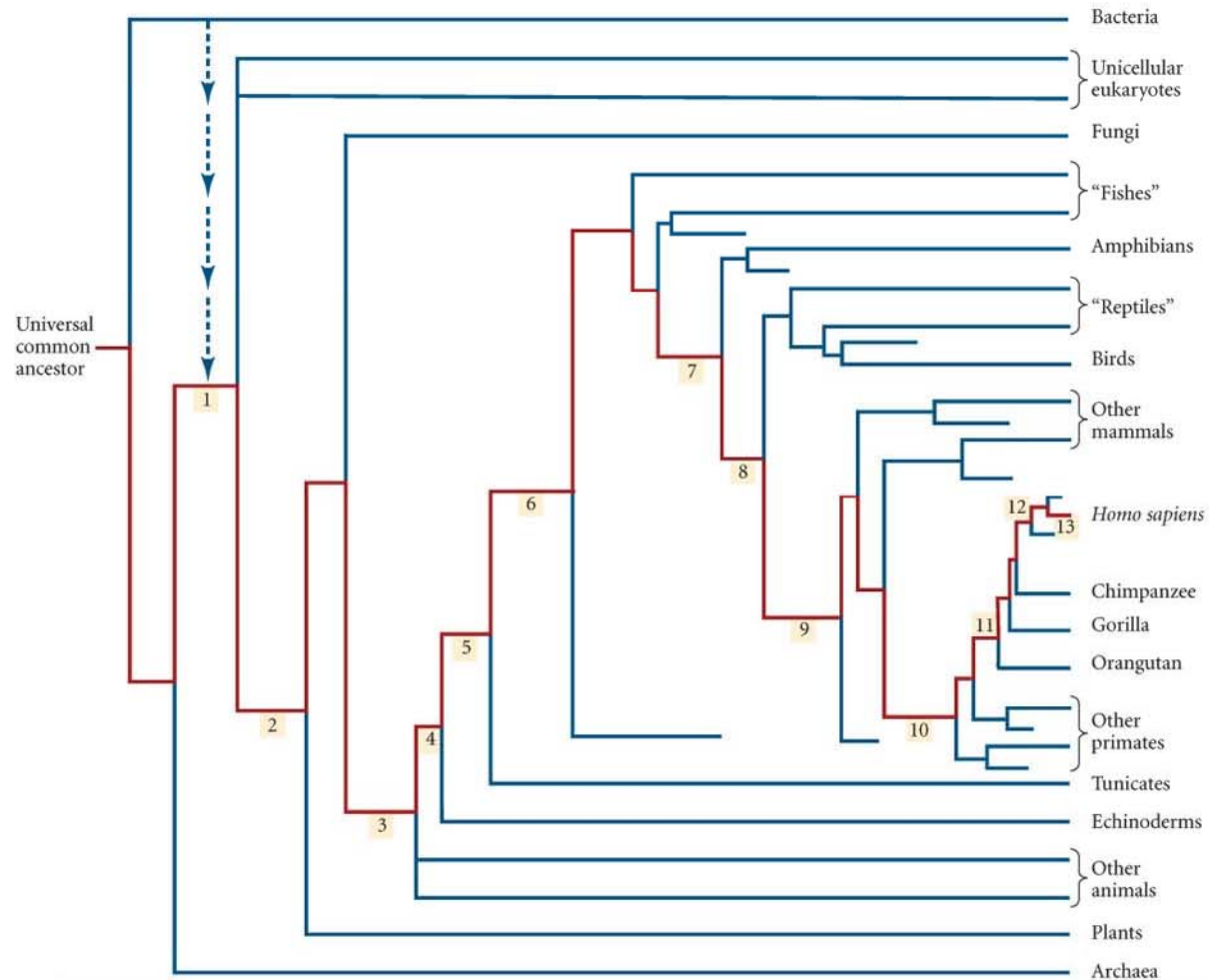
- Allows mapping order of character state changes
- Documents evolutionary trends in development
- Reveals that Homoplasy is common
- Can attempt to equate timing with fossil record events



How the Leopard got its spots

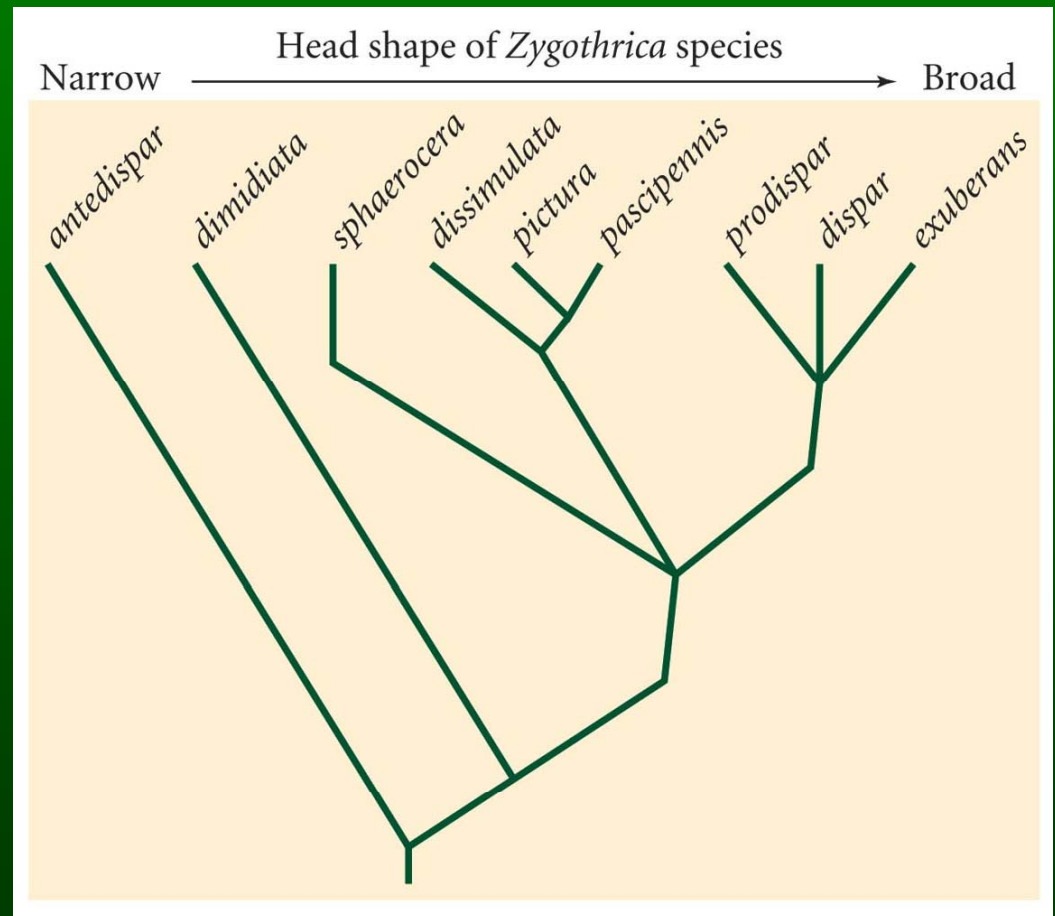
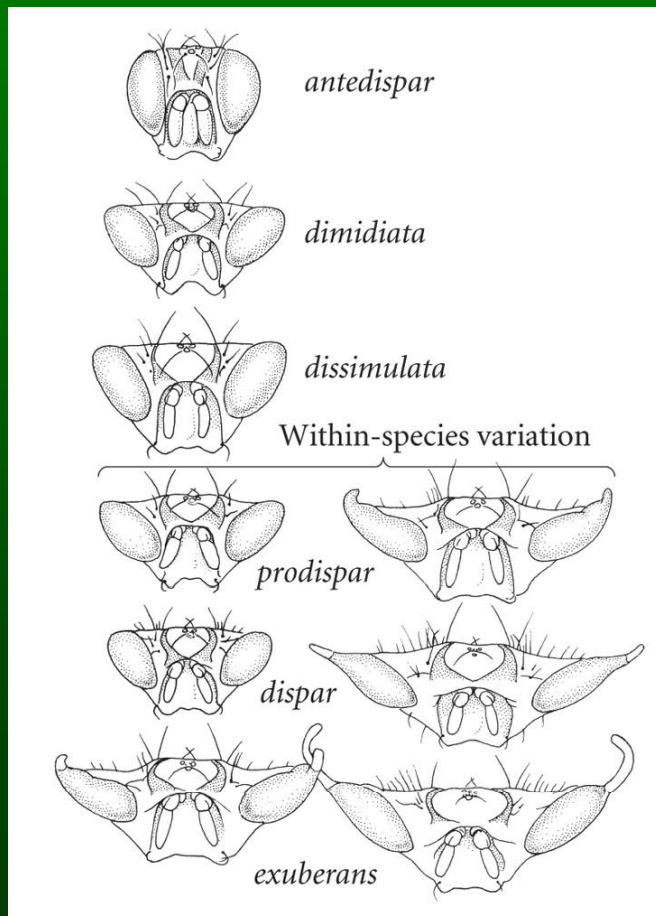
Werdelin & Olsson (1997) Biol. J. Linn. Soc. 62: 383-400

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



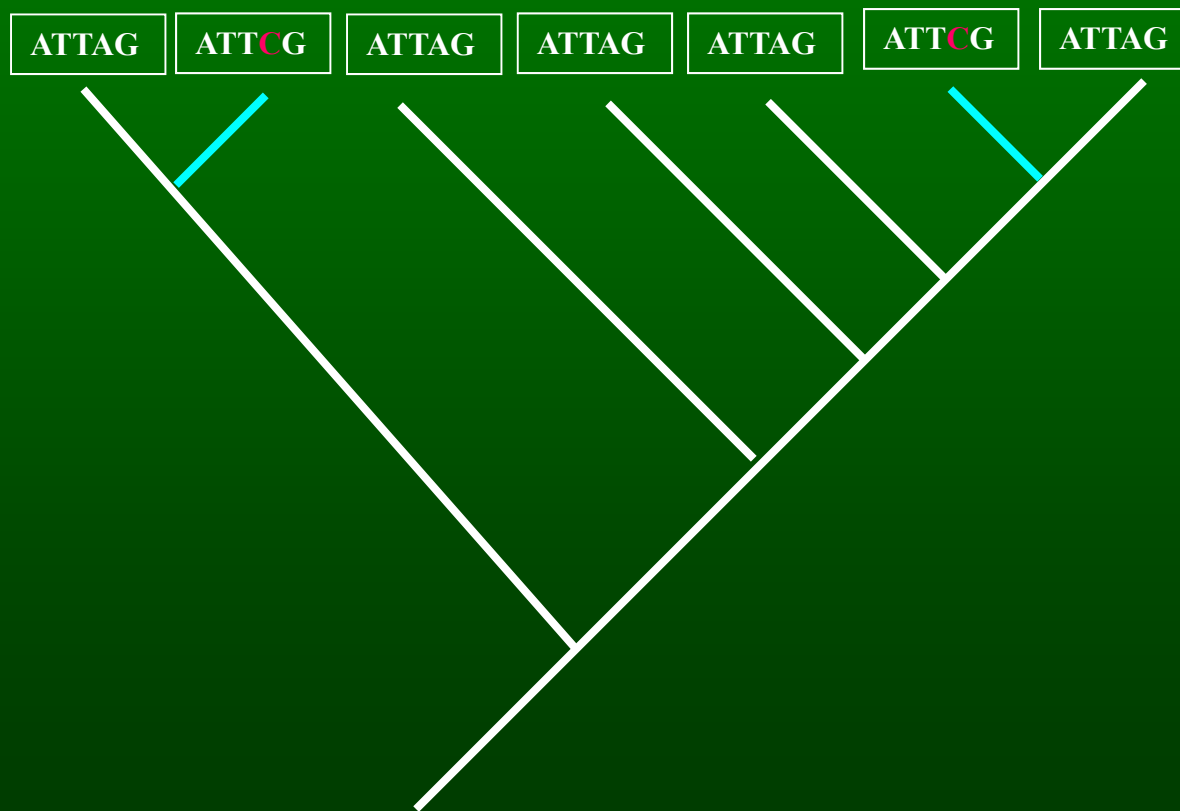
1. Origin of eukaryotes: a symbiotic bacterium becomes the mitochondrion.
2. Multicellularity evolves; cell and tissue differentiation
3. Animals: internal digestive cavity; muscles
4. Deuterostomes: embryonic blastopore develops into anus
5. Chordates: notochord; dorsal nerve cord
6. Vertebrates: bony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

Phylogenetic Analysis Documents Evolutionary Trends in Development: In fruit flies



Phylogenies Reveal that Homoplasy is Common

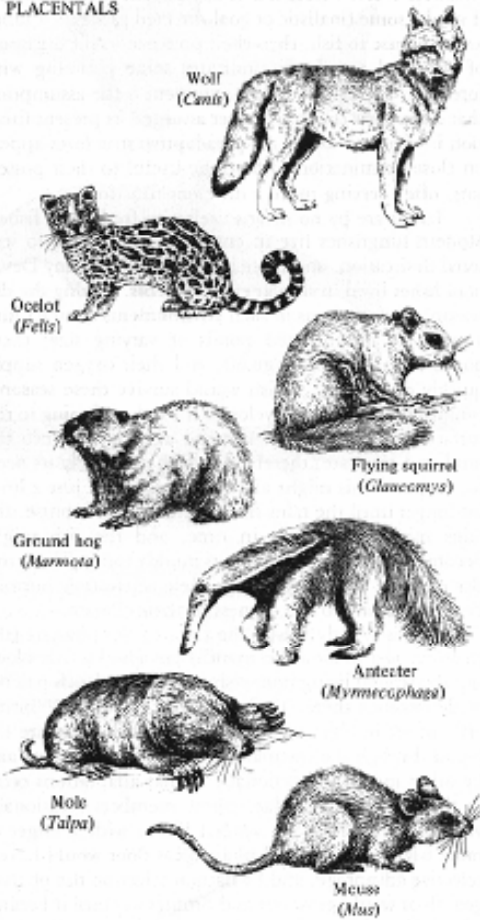
- **Convergent** and **parallel** evolution - the independent gain of a trait



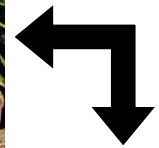
Convergent Evolution among Placental Mammals and Marsupials



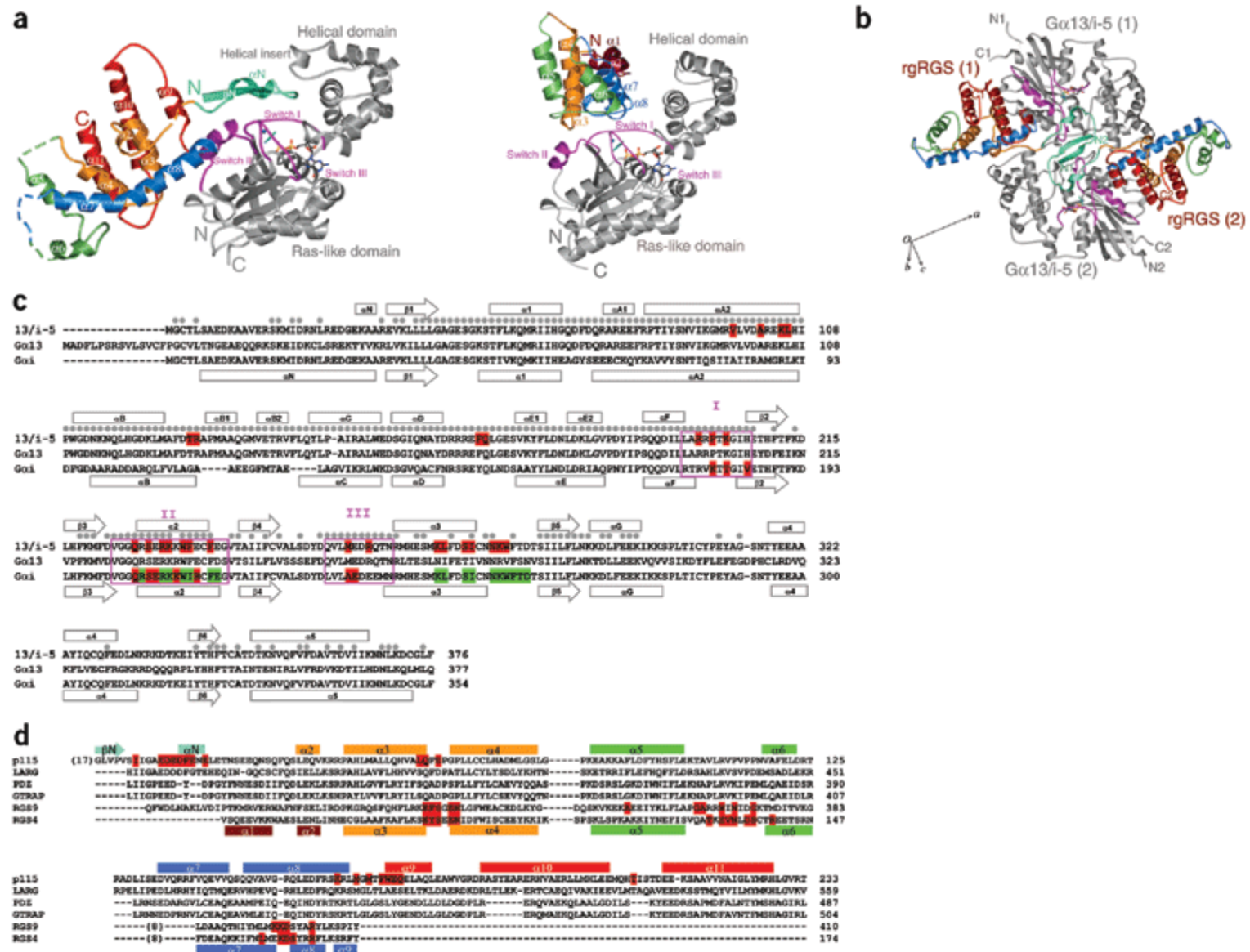
PLACENTALS



MARSUPIALS

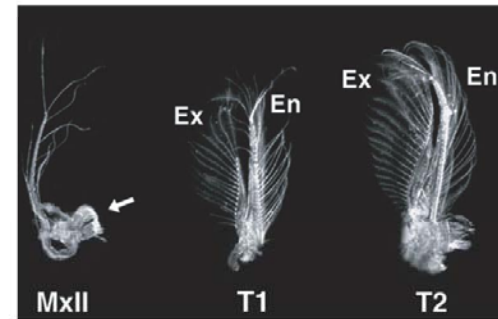
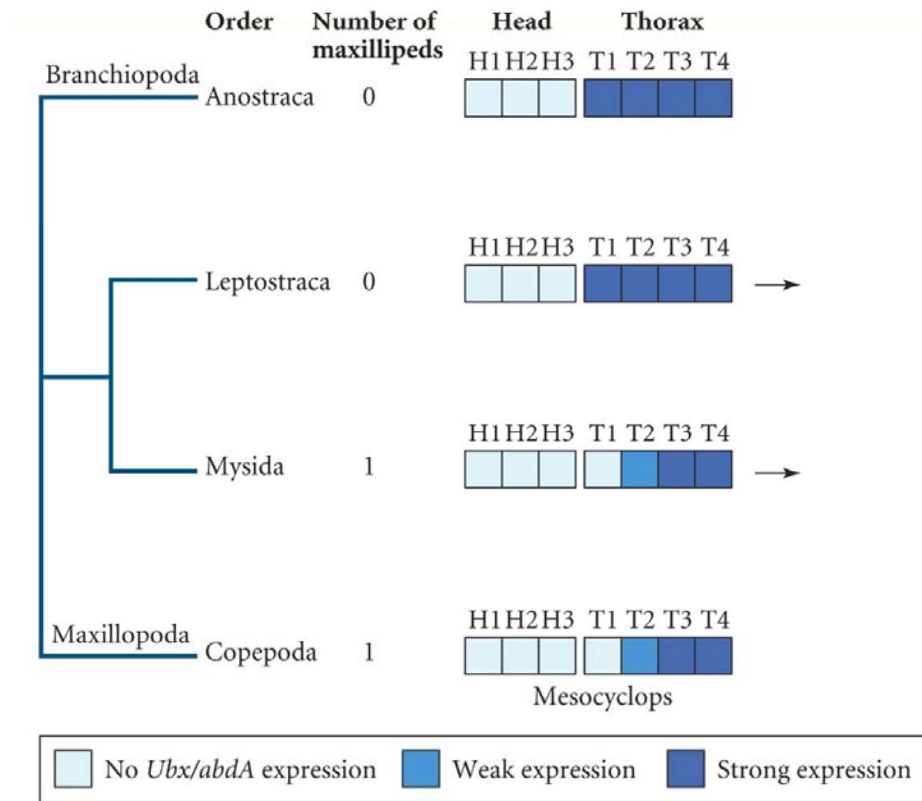


Structure of the p115RhoGEF rgRGS domain–Gα13/i1 chimera complex suggests **convergent evolution** of a GTPase activator.

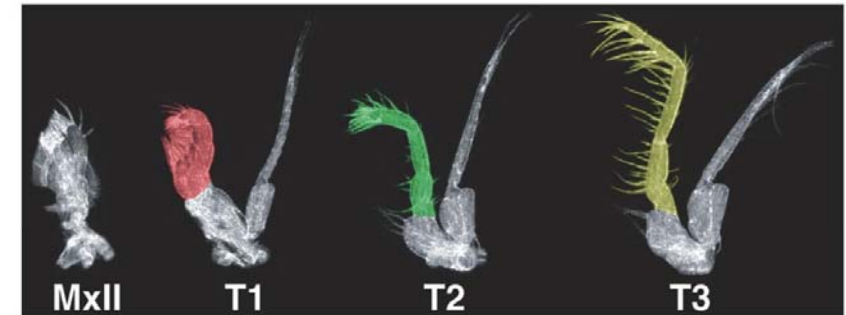


Parallel evolution: Special case of Convergent evolution

Feeding structures (maxillipeds) from thoracic legs in crustaceans.



Paranebalia

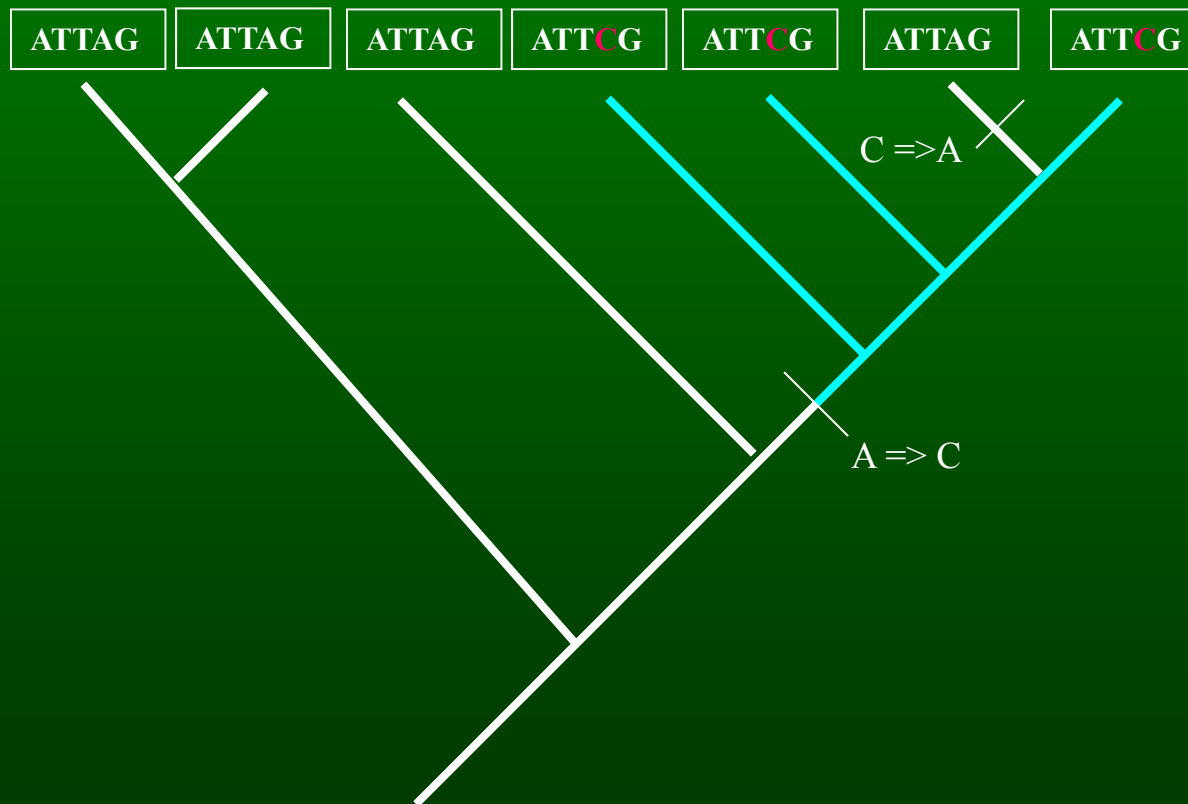


Mysidium

Ancestral state: head had mouth parts, thorax legs.

Phylogenies Reveal that Homoplasy is Common

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

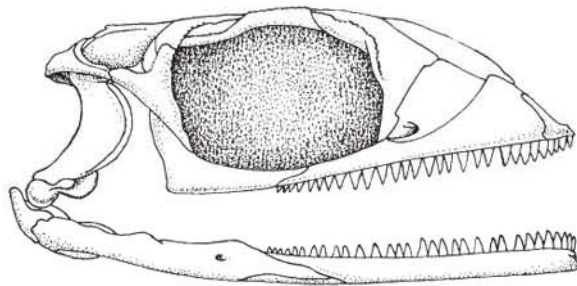


Reversal:

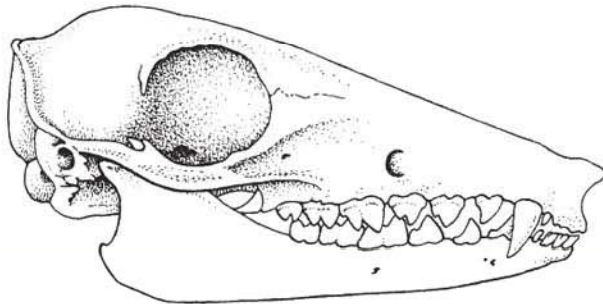
An example of the acquisition and loss of individualization

Homodonts vs. Heterodonts

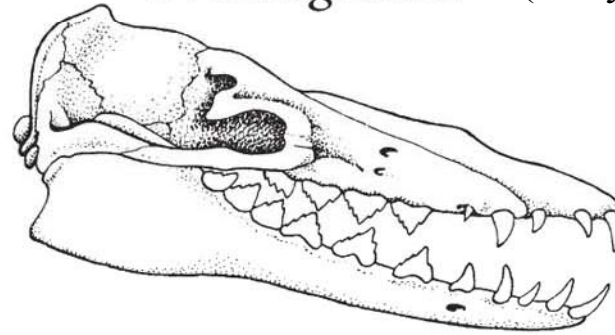
Kuehneosaurus



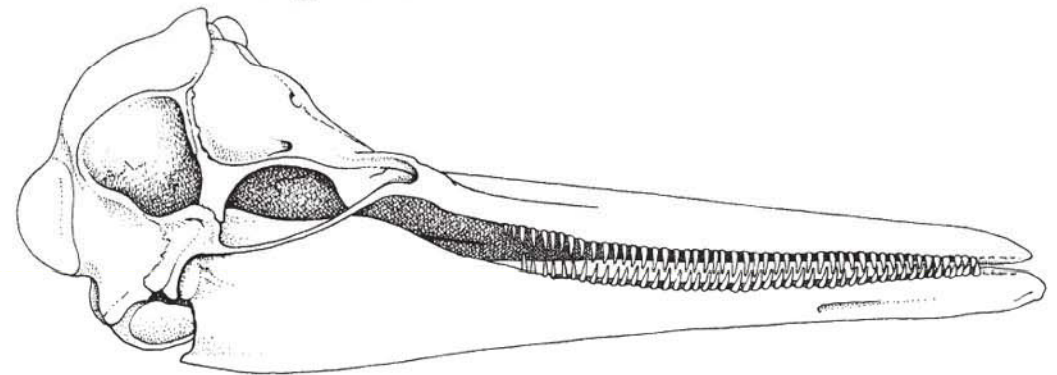
Elephant shrew



Prozeuglodon (Early Eocene Whale)



Dolphin





Reconciling the Fossil Record with phylogenetic analysis?

Can really only work with
morphology-based cladistics.

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



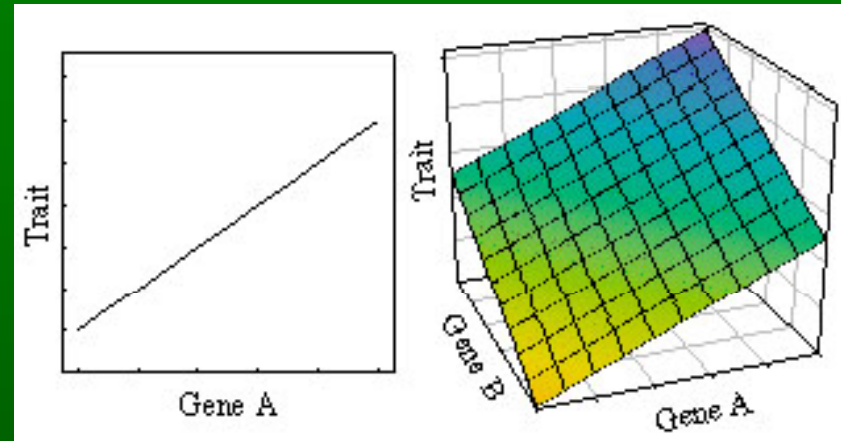
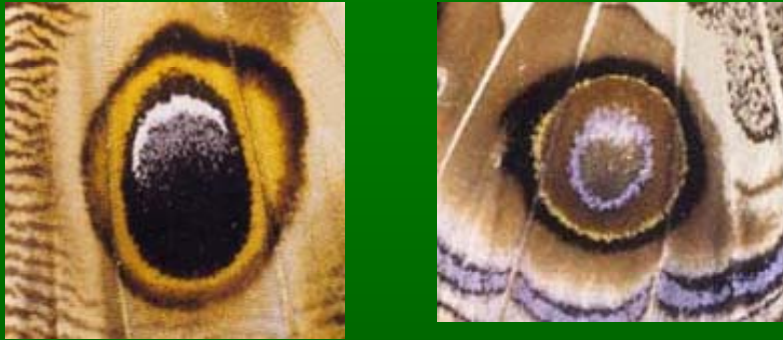
Biological traits come about through developmental processes and physiological regulatory mechanisms. Most of these processes are nonlinear. Examples of nonlinear processes are:

- 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

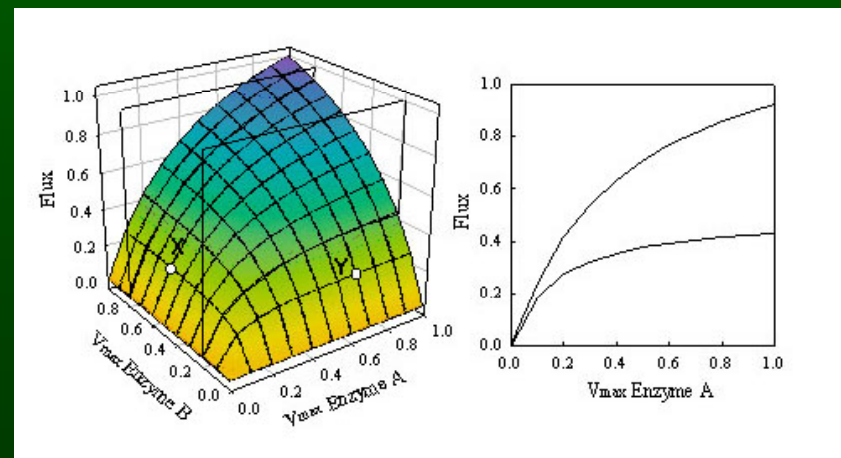
Any mechanism that contains one or more of these processes (and most regulatory mechanisms in biology do) will have a nonlinear relationship between variation in its determinants and variation in the trait affected by the process.

The Evolution of Traits aka phenotypes

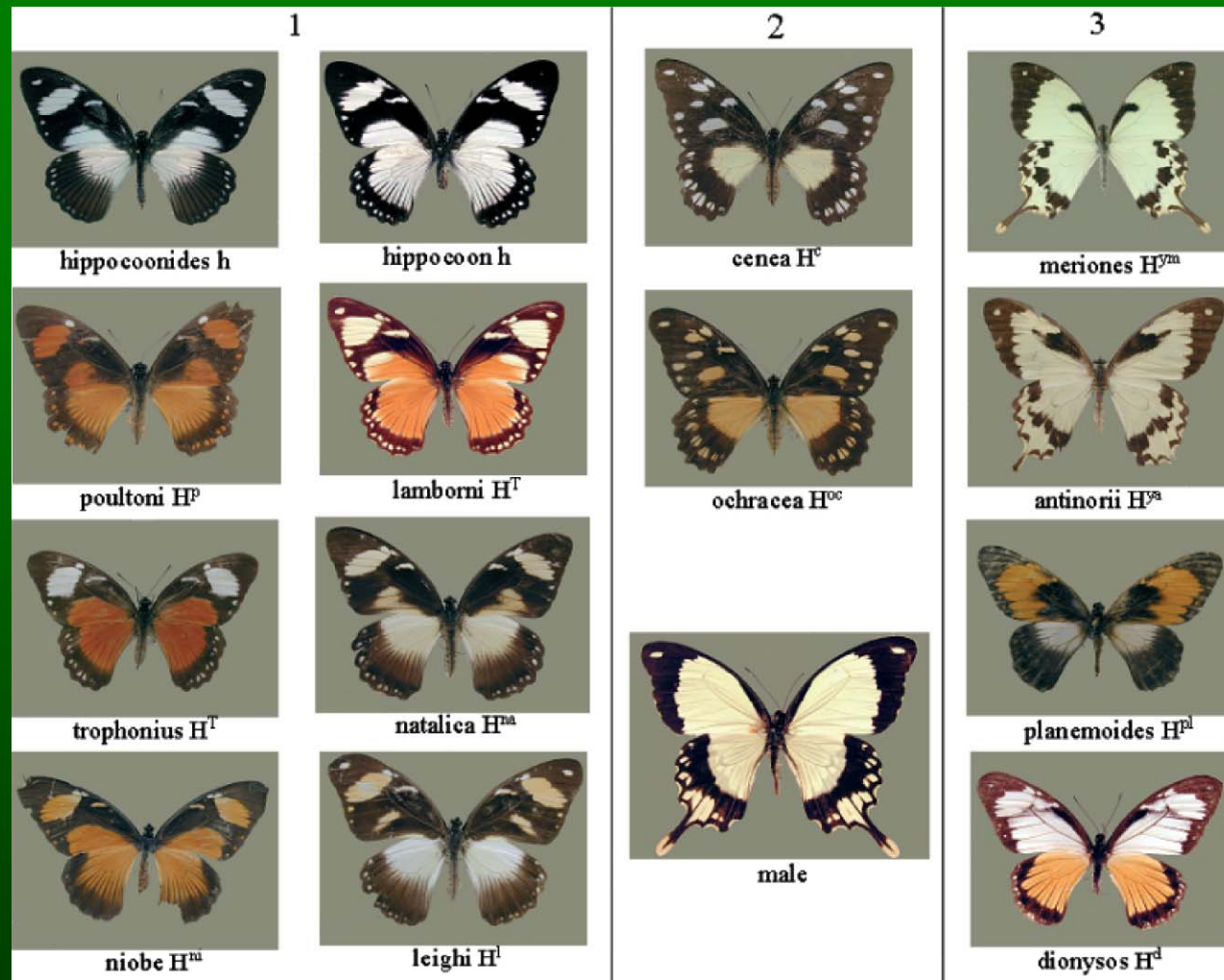
Linear interactions



Non-linear interactions

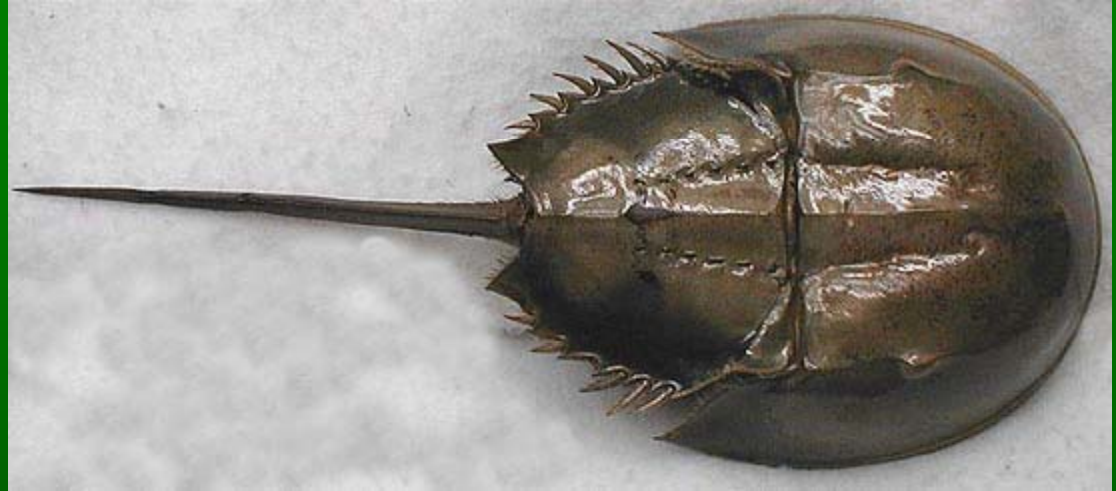


Polymorphic mimicry in *Papilio dardanus* (The mocker swallowtail): accurate mimics of different species of distasteful butterflies.

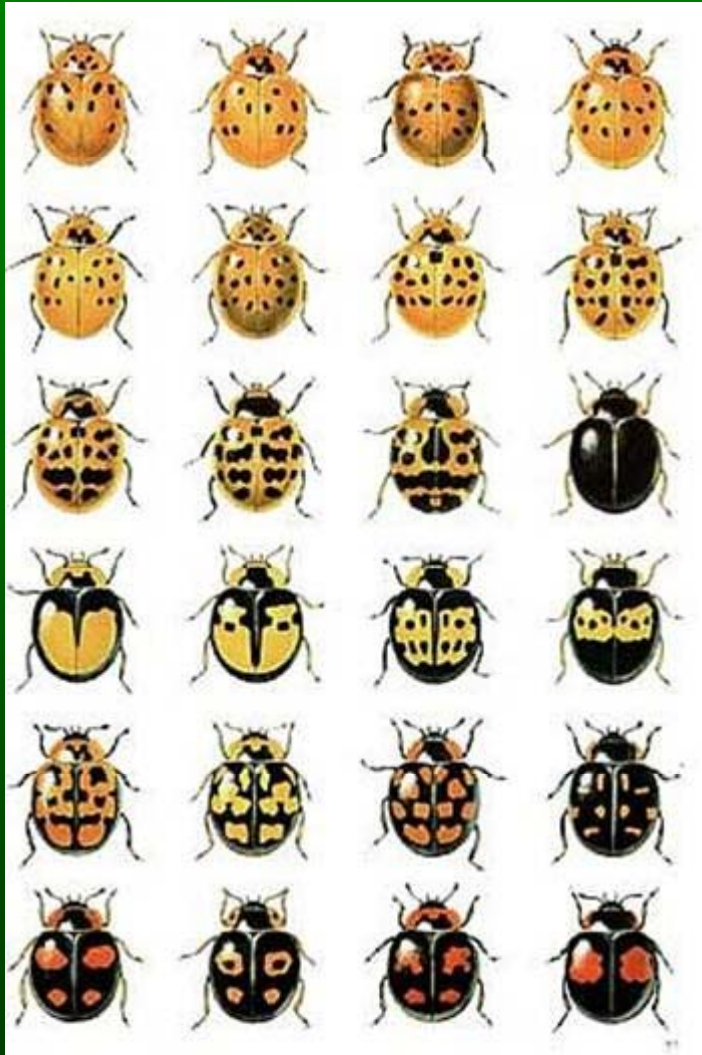


Single Locus; ~11 mimicking alleles that are more variable.

Rates of Evolution Vary Among Lineages



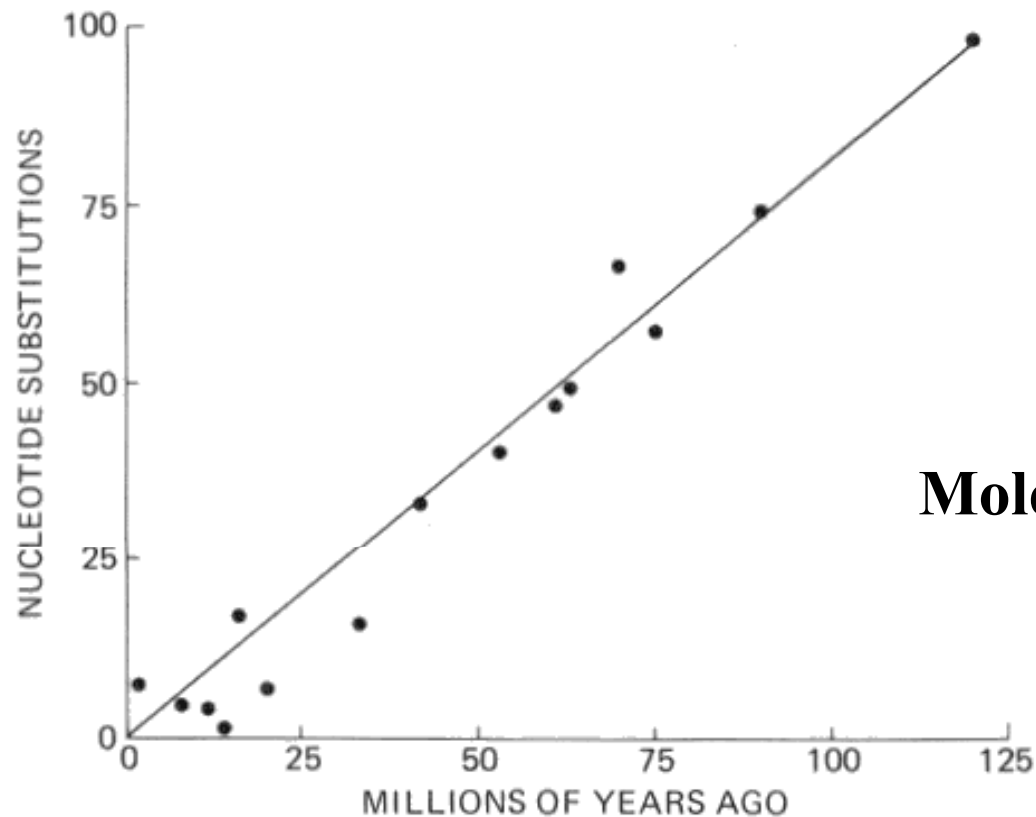
Rates of Evolution Vary Among Characters



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

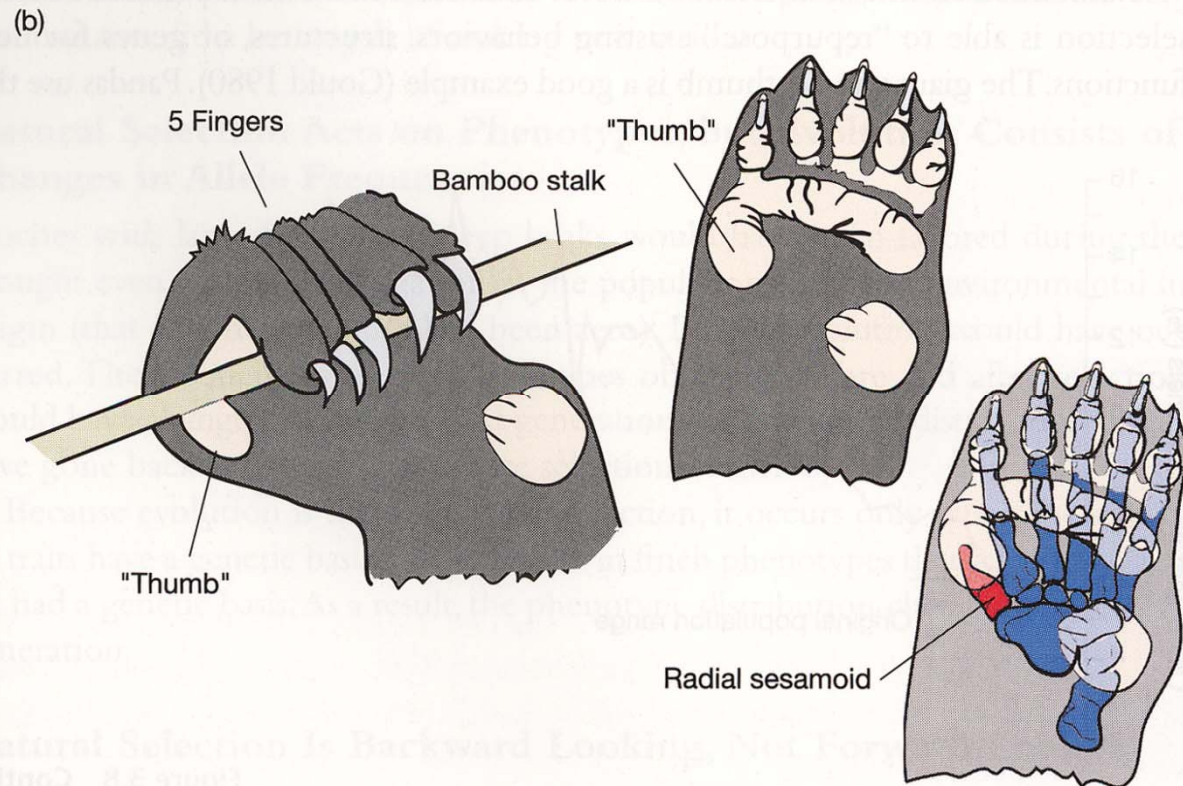


Figure 3.9 The panda's thumb (a) Giant pandas strip the leaves from bamboo by passing the stalk through their hands. (Bill Kamin/Visuals Unlimited) (b) This drawing shows how the panda's "thumb" forms a slot for bamboo stalks to pass through. After Endo et al. 1999.

Exaptation, co-option, and preadaptation are related terms referring to shifts in the function of a trait during evolution.

(1) A character, previously shaped by natural selection for a particular function (an adaptation), is co-opted for a new use.

(2) A character whose origin cannot be ascribed to the direct action of natural selection (a nonadaptation), is co-opted for a current use.

There are many examples of exaptations:

- A classic example is how feathers, which initially evolved for heat regulation, were co-opted for display, and later co-opted for use in bird flight.
- Another example is the lungs of many primitive fish, which evolved into the lungs of terrestrial vertebrates but also underwent exaptation to become the gas bladder, a buoyancy control organ, in more advanced fish.
- A behavioural example pertains to subdominant wolves licking the mouths of alpha wolves as a sign of submissiveness. (Similarly, dogs, which are domesticated wolves, lick the faces of their human owners.) This trait can be explained as an exaptation of wolf pups licking the faces of adults to encourage them to regurgitate food.

Heterochrony:

Changes in the Rate or Timing of Developmental Events

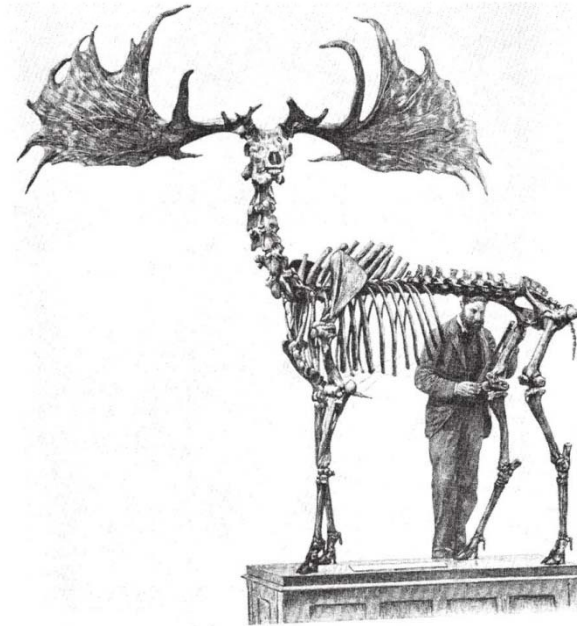
(A)



(B)



(C)



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

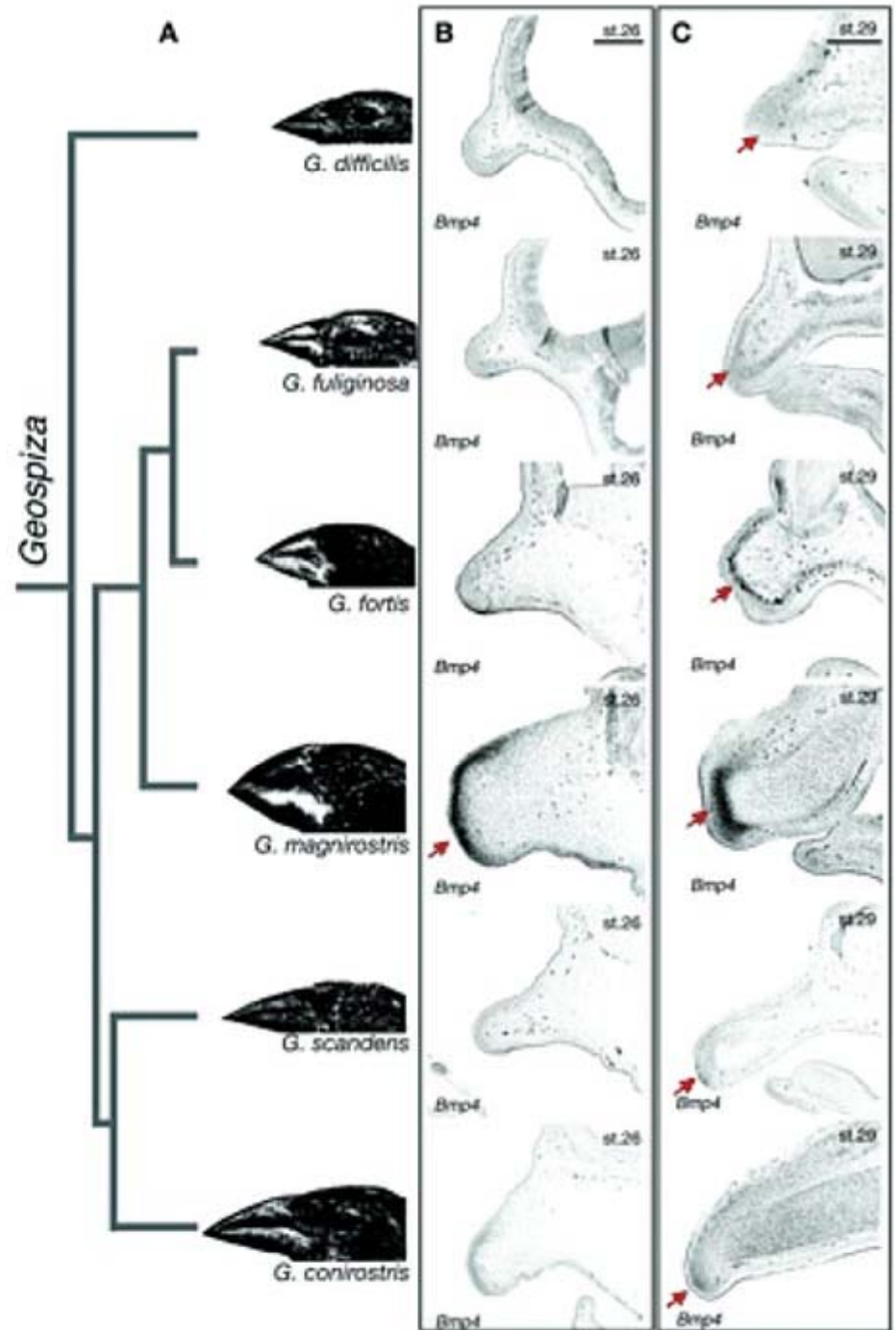
Philodendron switching stem and root positions.



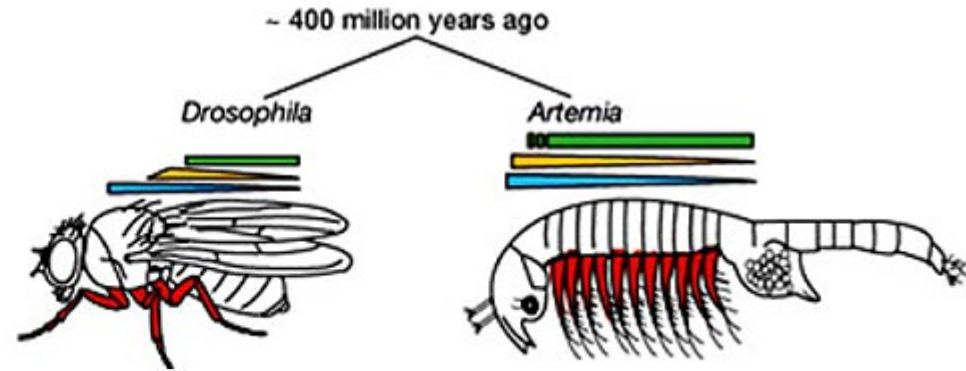
Stems

Roots

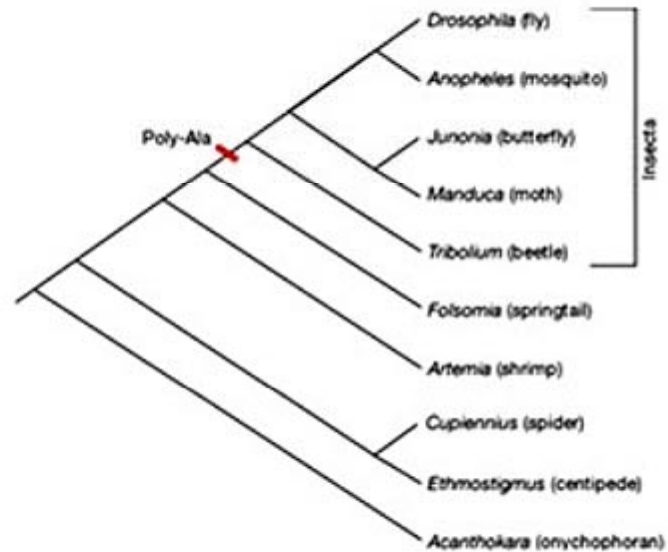
HETEROMETRY: Change in amount



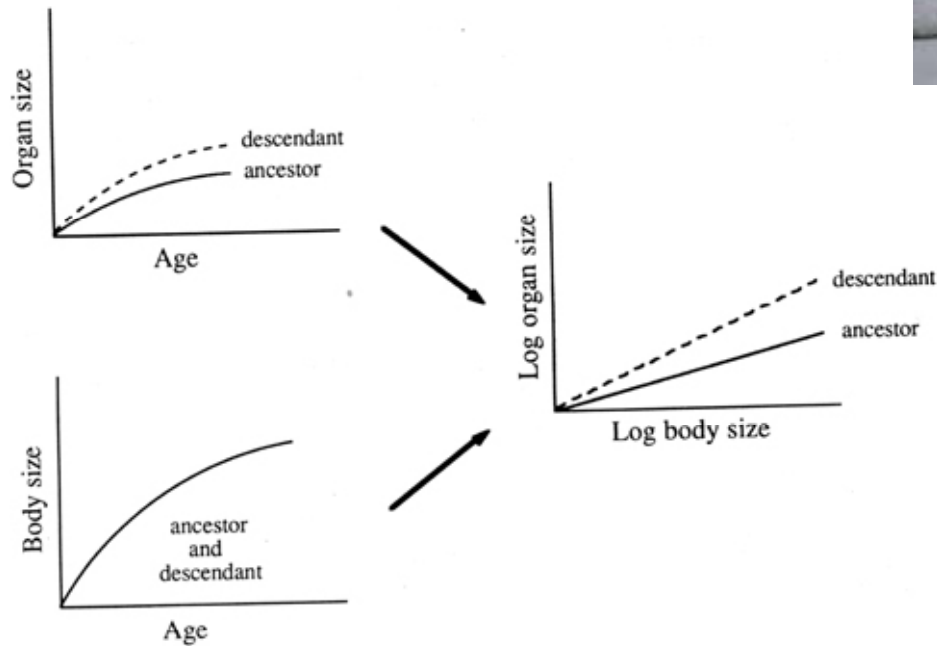
HETEROTYPY: Change in quantity



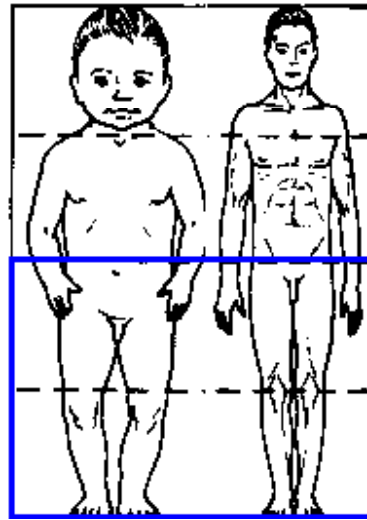
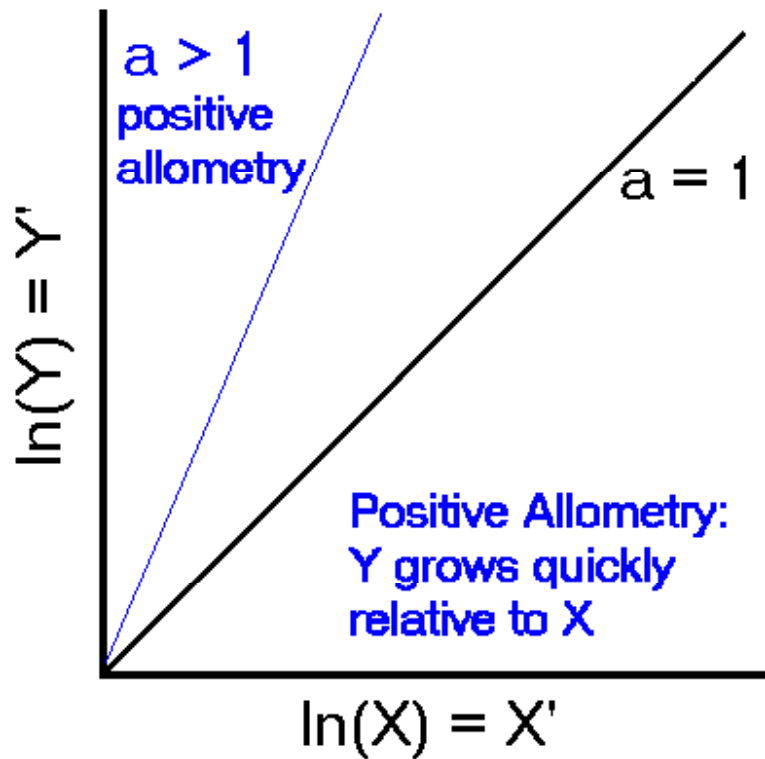
	HD	UbdA peptide	QAQA	Poly-Ala
DmUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQKAAAAAAAAAA	VQGGHELDQ*
AgUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQKAAAAAAAAAA	ALHEQN*
JcUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQKAAAAAAAAAA	COHPEH*
MsUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQRKAAAAAAAAAA	COHPEH*
TcUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQKAAAAAAAAA	VAAQVDPN*
FcUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQAALP	INLGLIANSP...
ErUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQAQANATV	TPATTIDGTPPTQAN*
CsUbx-1	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAALAAHQK	SSSTTSGGNNANNNDSTA-----SATKT...
CsUbx-2	HPQNRSMKLIKKEI	QAT KELNSQEK	KQAQAQAKTA---	STSTVSSNSNSNTPTKDGGSTPLTATKT*
AlUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	KRI	TPSKLHNSC-SSPTGILVTMKQMK-SPNLI TE*
AkUbx	HPQNRSMKLIKKEI	QAT KELNSQEK	K---	CDTLSTV*



Allometry: Impact of body size on biology

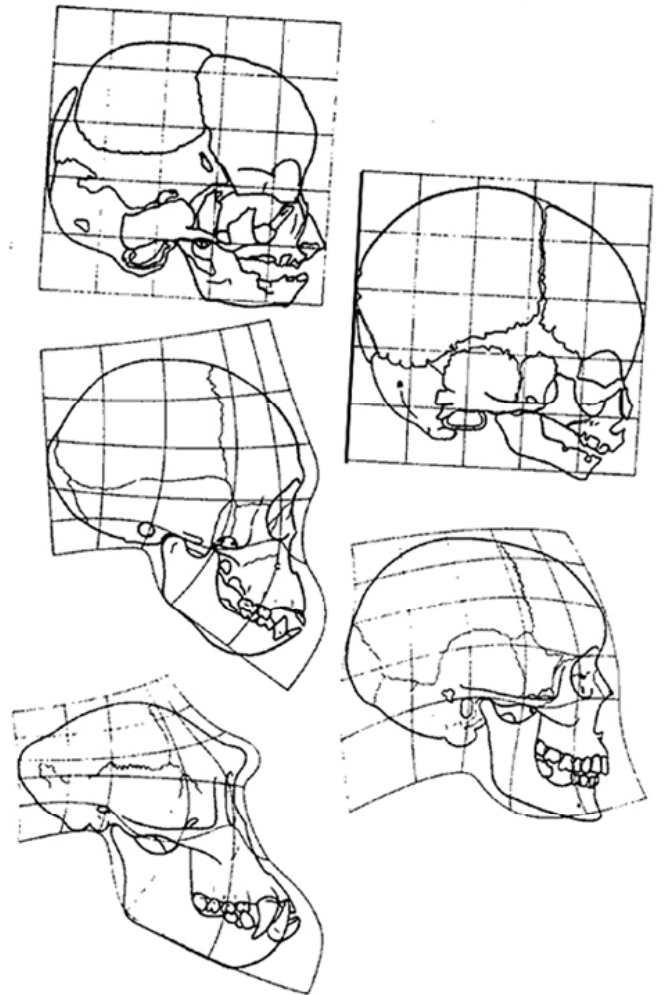


The differential growth rate of different body parts or dimensions of an organism during its ontogeny.



Legs grow quickly
relative to torso

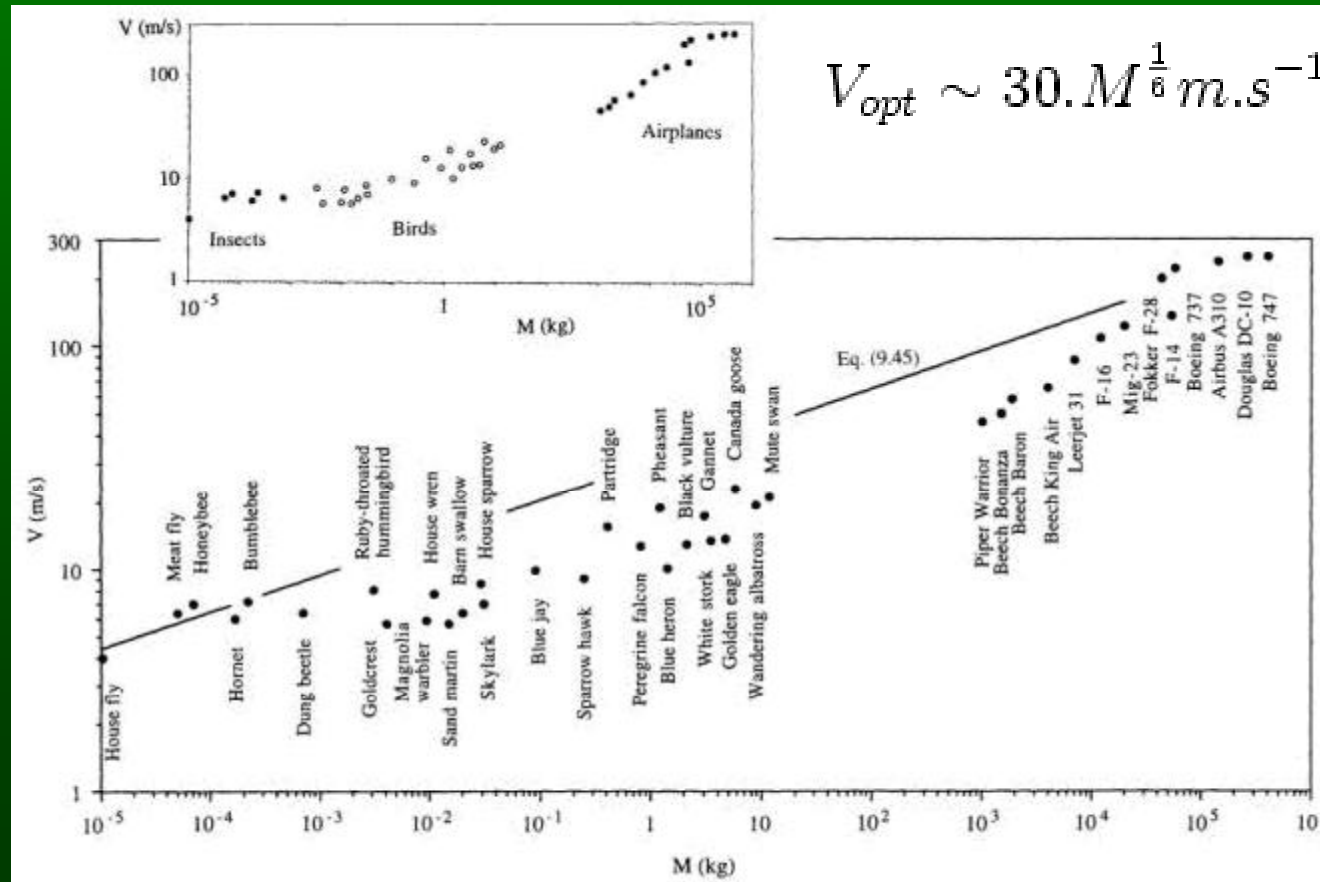
Are we just baby chimps?
A tale of heterochrony and allometric growth.



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*).

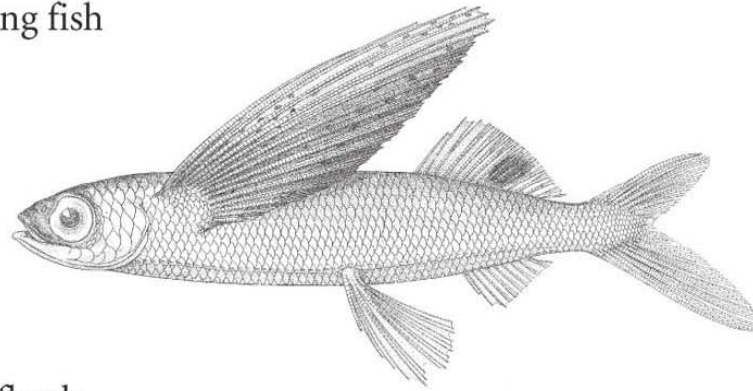
Allometric Law of Body Mass vs. Cruising Speed

- 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.

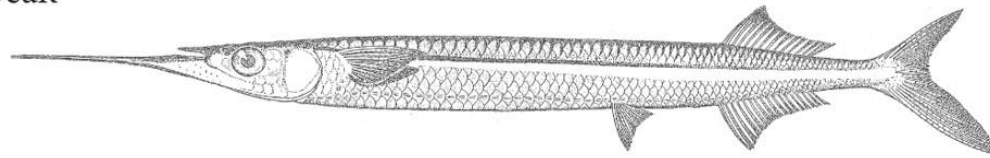


Allometric differences in the jaws among three closely related families of fishes.

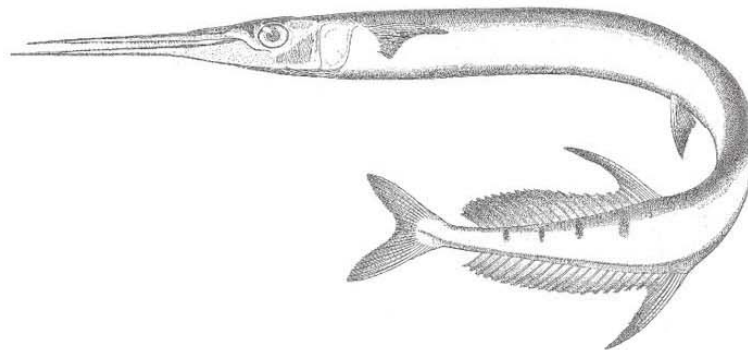
(A) Flying fish



(B) Halfbeak

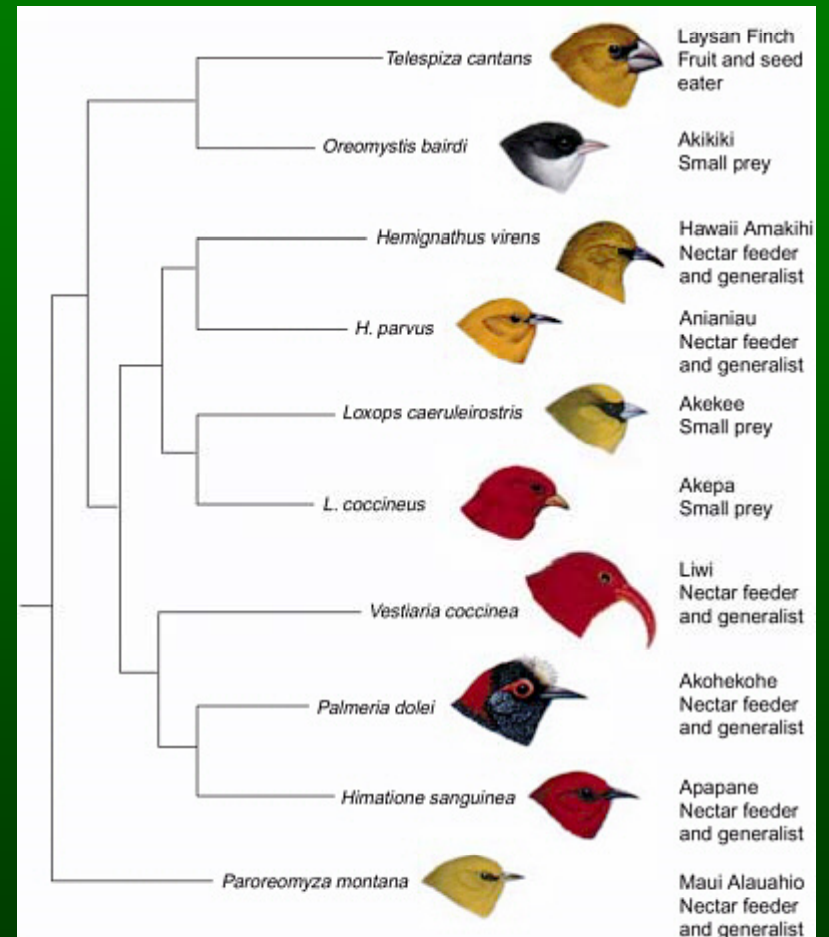


(C) Needlefish



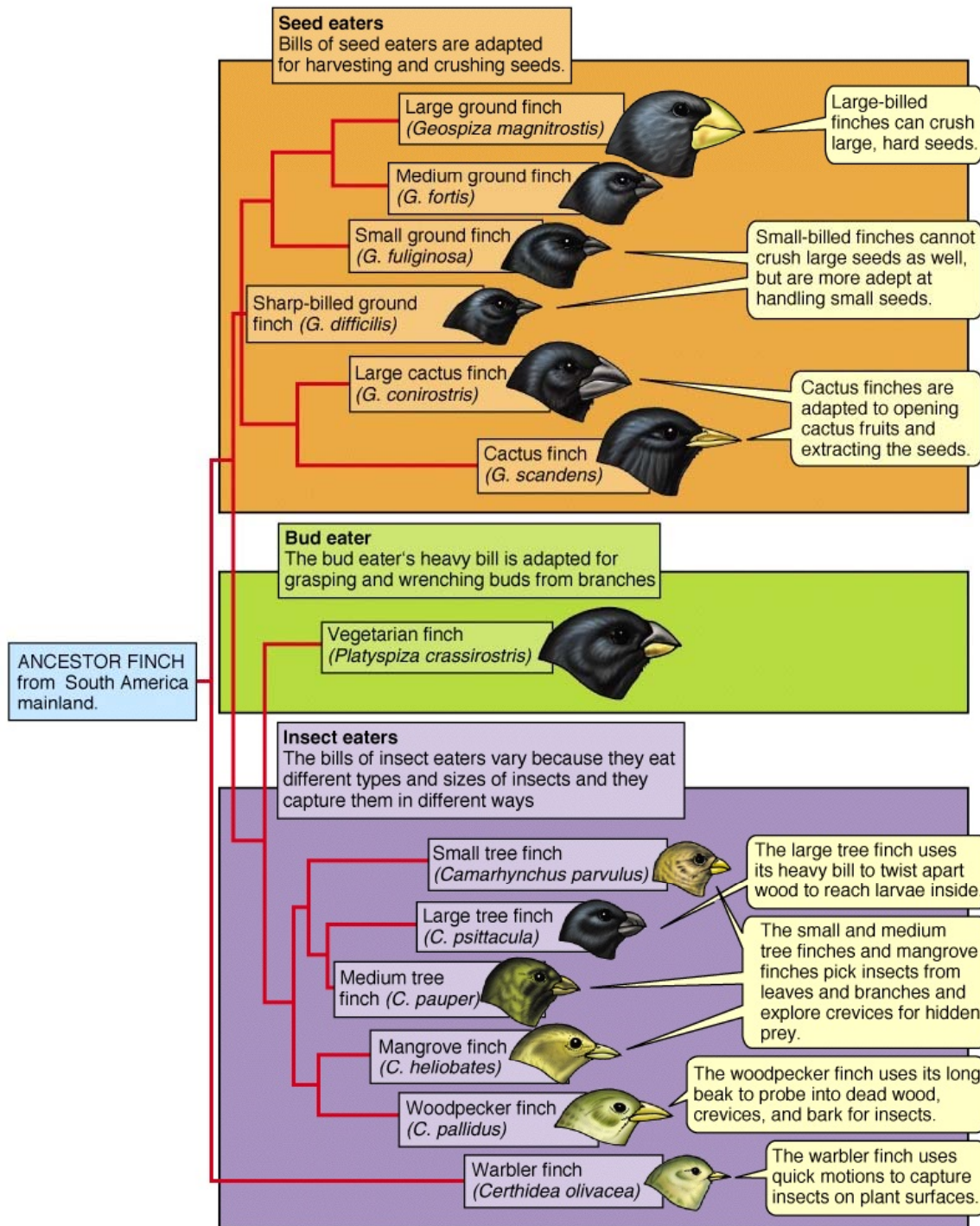
Adaptive Radiation is Widespread aka Divergent Evolution

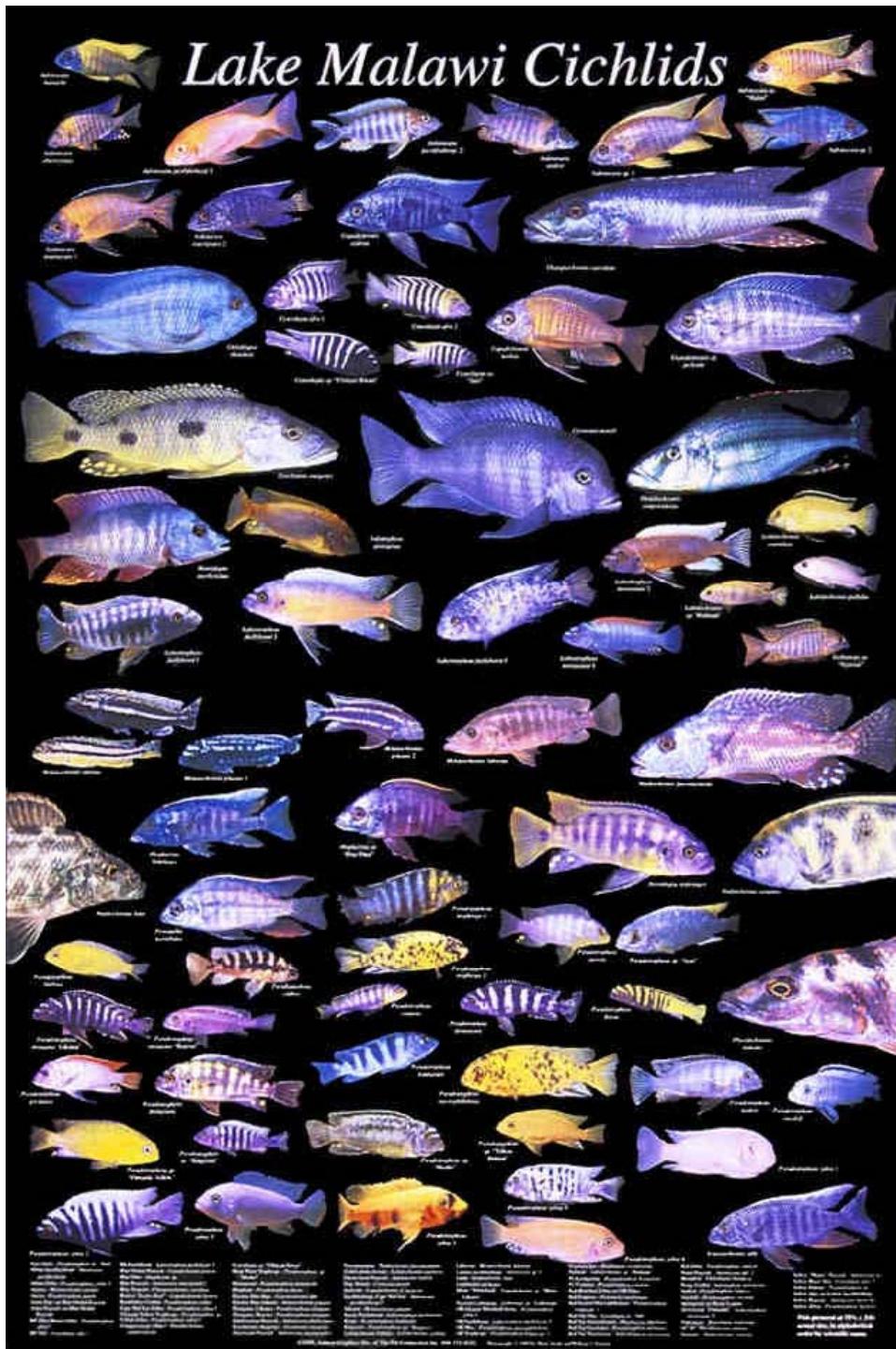
Hawaiian Honeycreepers



Adaptive Radiation is Widespread

Darwin's Finches are the classic example.





Adaptive Radiation is Widespread

Lake Malawi Cichlids (>500 spp.)



Coevolution

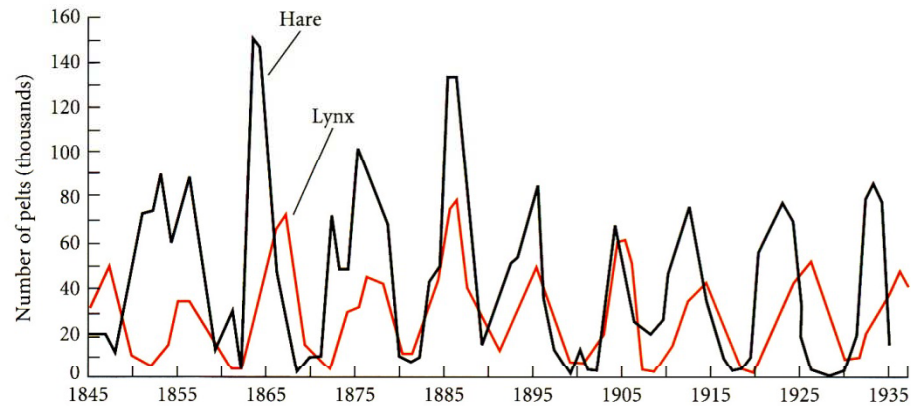


FIGURE 4.20 Fluctuations in abundance of lynx and hares in northern Canada, based on numbers of furs purchased by the Hudson Bay Company. The causes of the coupled cycles are still unclear. (After Purves et al. 1998.)

- 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.

Bee orchid video

Modification of Preexisting Features

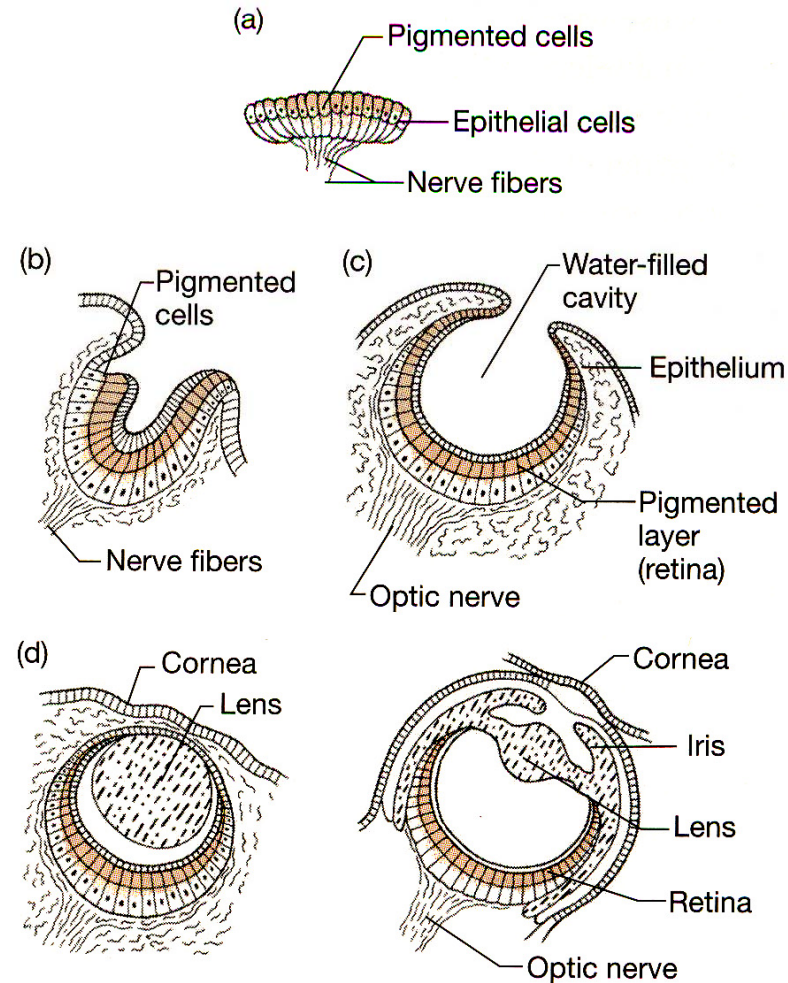
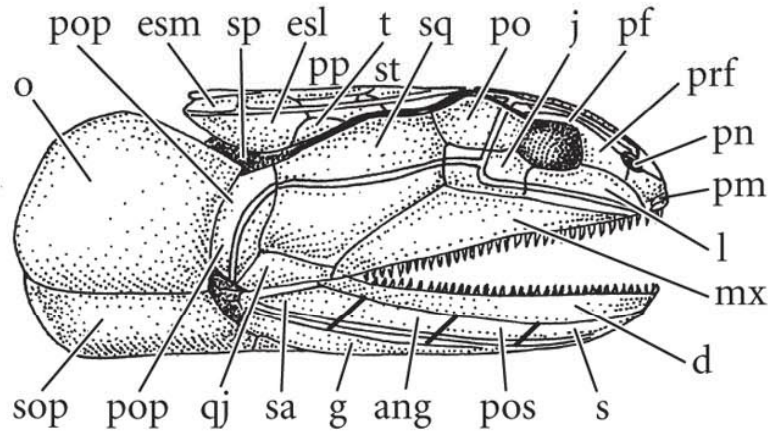


Figure 3.11 Variation in mollusc eyes (a) A pigment spot; (b) a simple pigment cup; (c) the simple optic cup found in abalone; (d) the complex lensed eyes of a marine snail called *Littorina* and the octopus. Pigmented cells are shown in color.

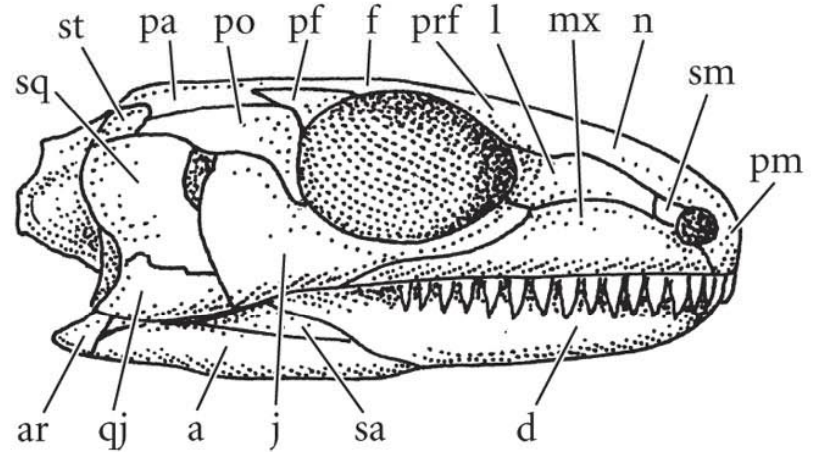
Increases and decreases in complexity:

An example of **reduction and loss** of skull & lower jaw bones during evolution.

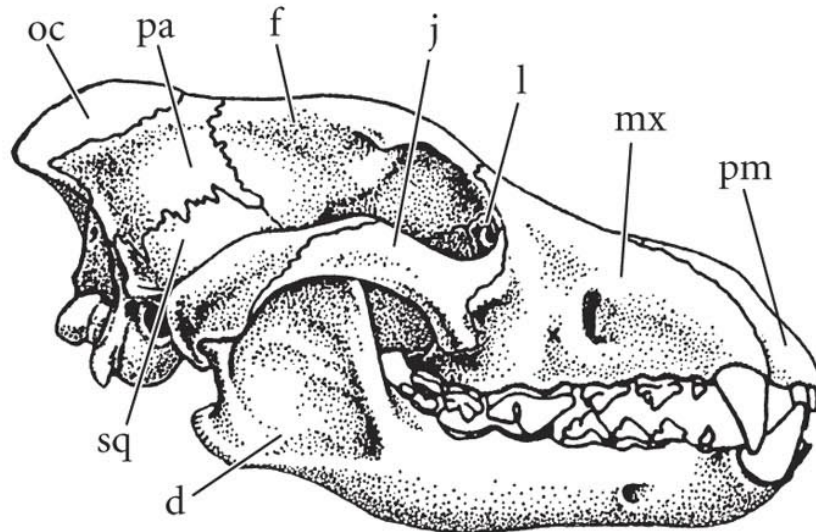
(A) *Eusthenopteron* Devonian fish

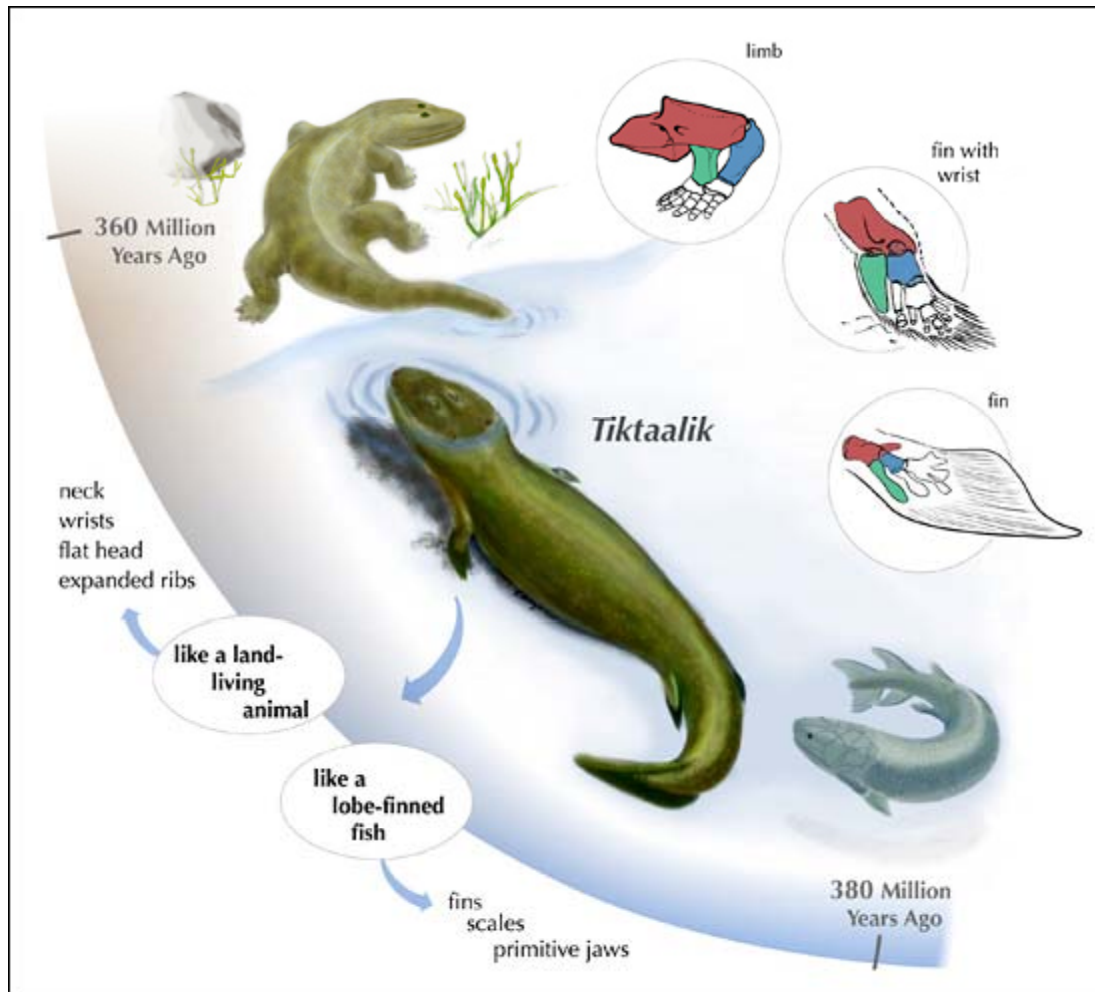


(B) *Milleretta* Permian tetrapod



(C) *Canis* Domestic dog





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).

CHUCKIE 'D' SAYS:

EMBRACE



YOUR INNER FISH

Art by [unreadable]



TWO WORLDS