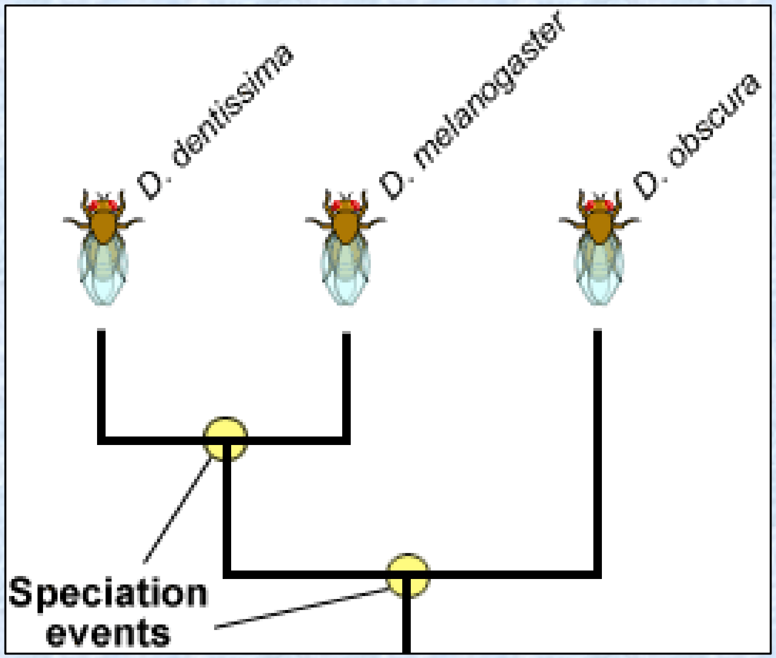
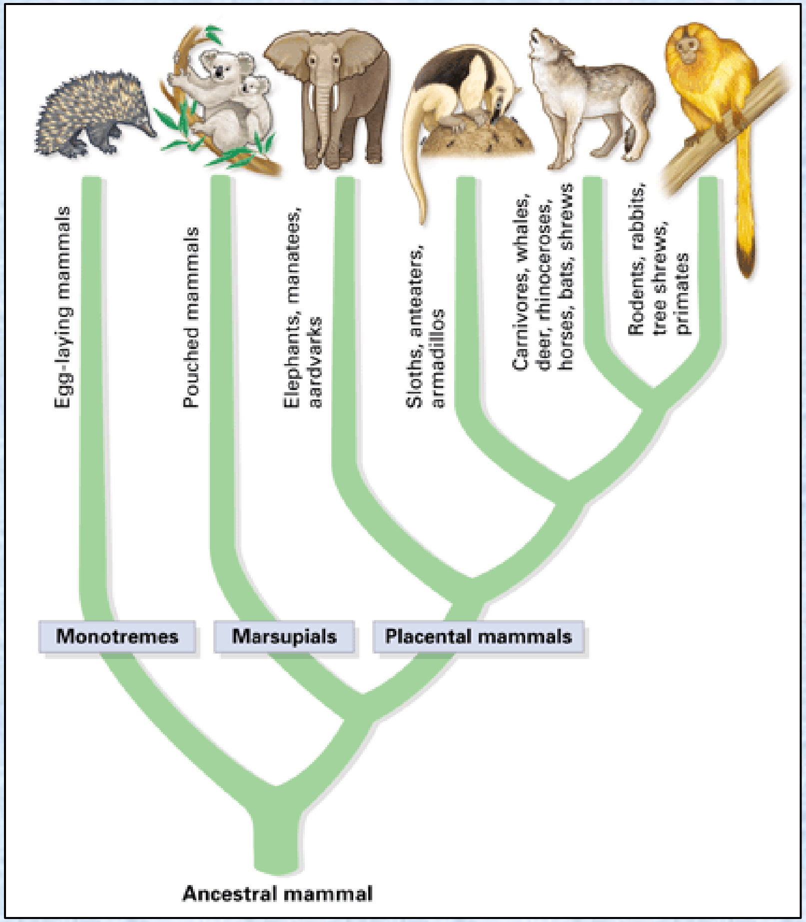
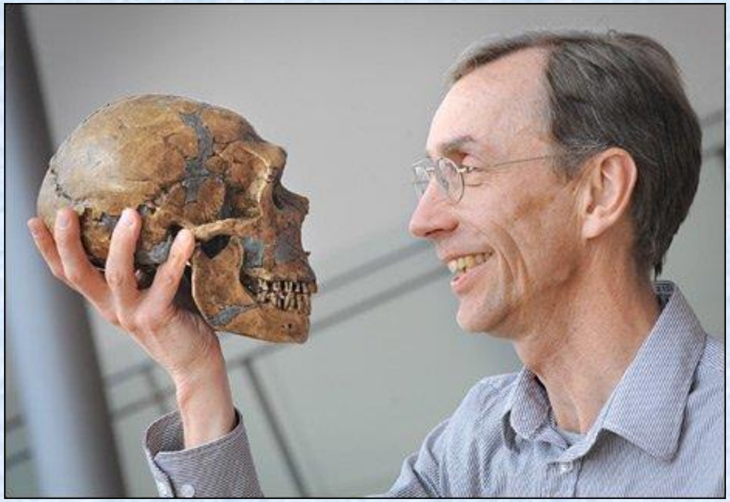
Speciation and Macroevolution
A brief review



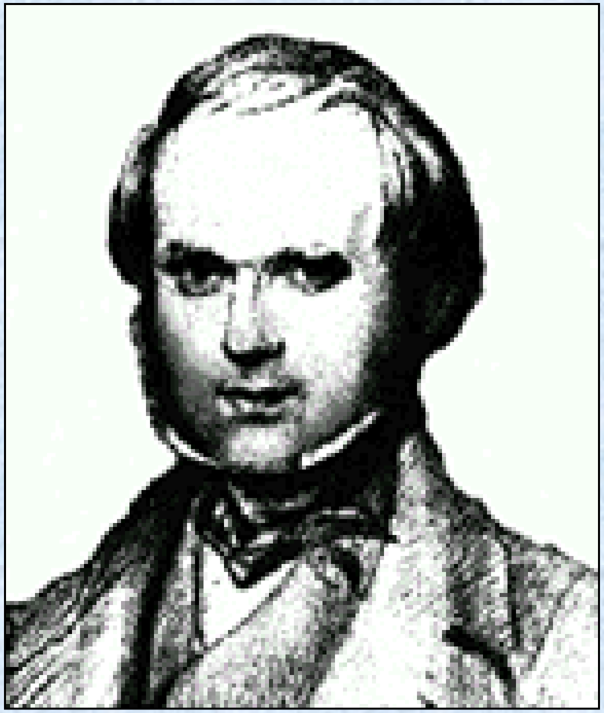


Why study evolution?

- Increase knowledge
- Understand the past
- Predict the future
- Organize our world



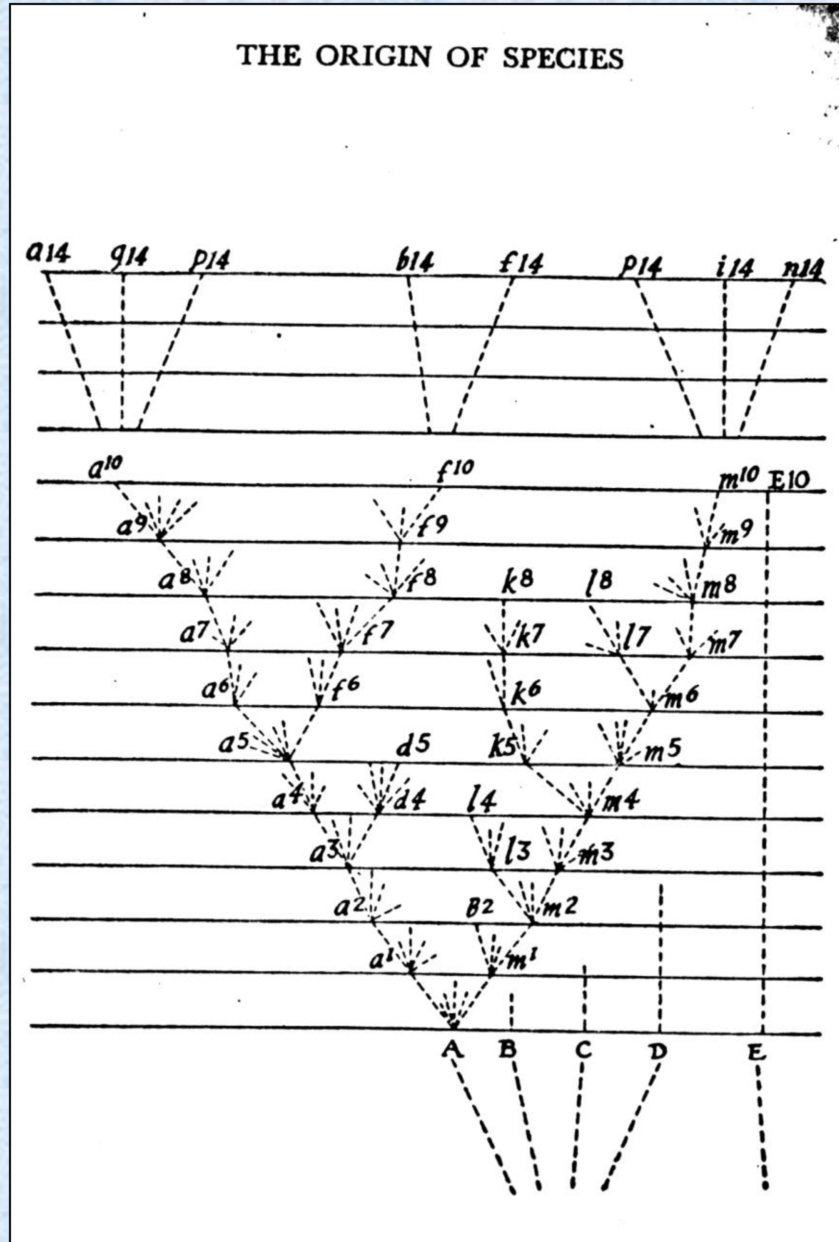
Svante Pääbo
Neanderthal Man: In Search of Lost Genomes



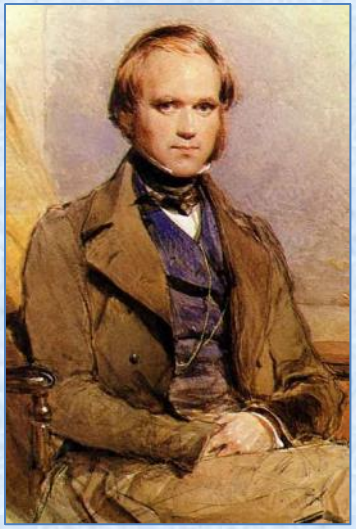
Charles Darwin 1859

Origin of Species by Natural Selection, or the Preservation of Favored Races in the Struggle for Life

- Natural selection
- Descent from Common Ancestor

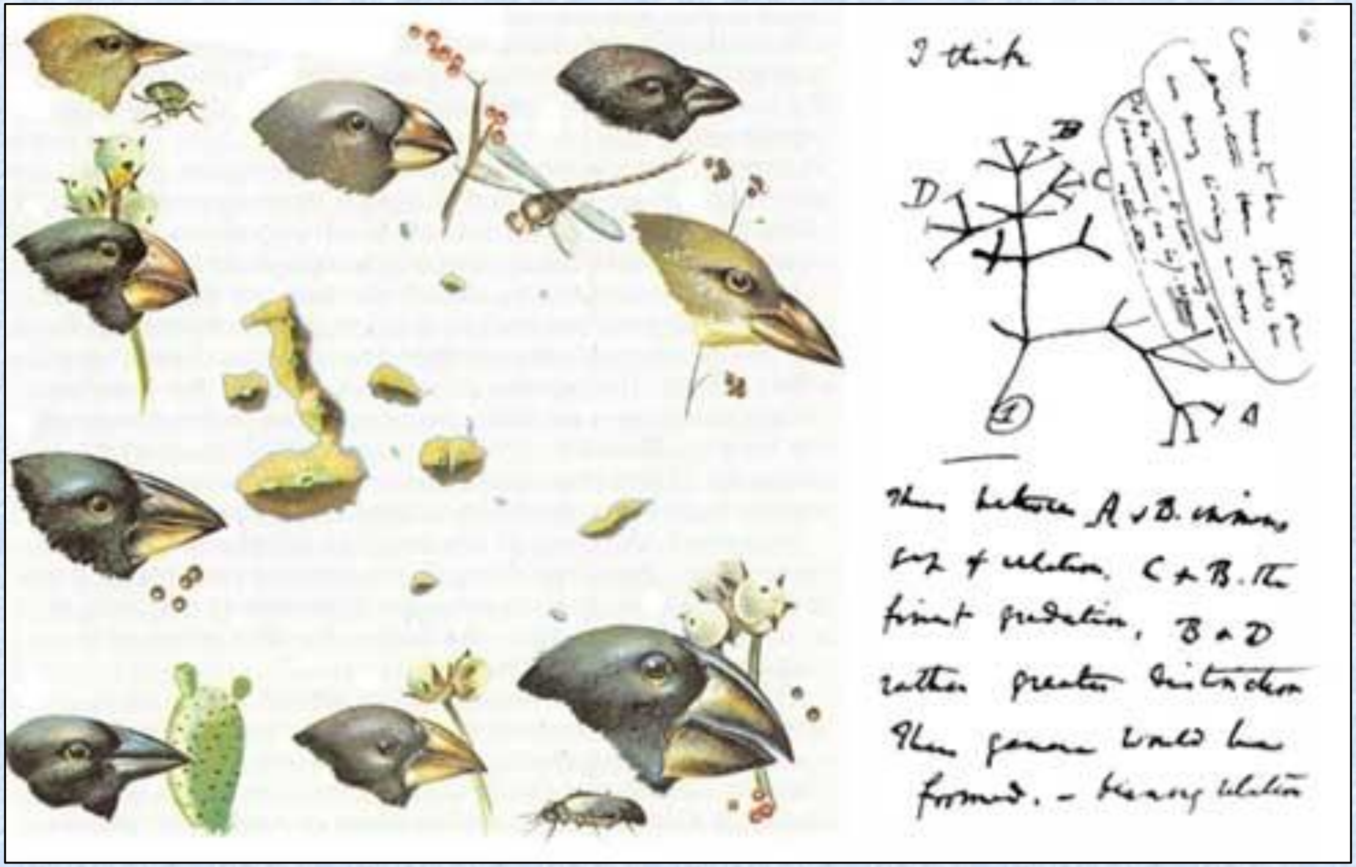


As a young man, Darwin went on a 5-year voyage around the world….

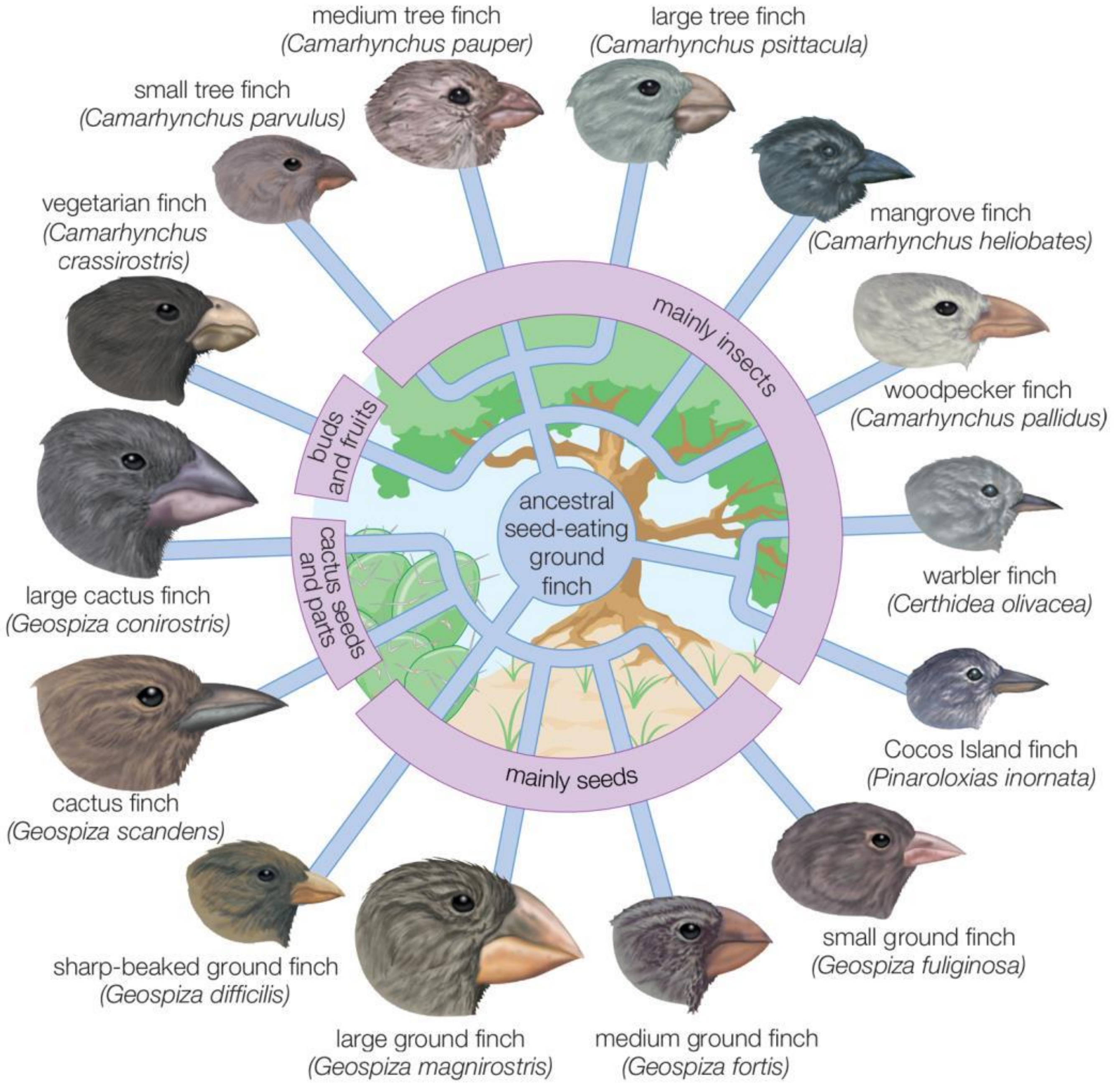


Darwin's Finches

- Adapted to different habitats, niches
- Species derived from a common ancestor
- Adaptive Radiation

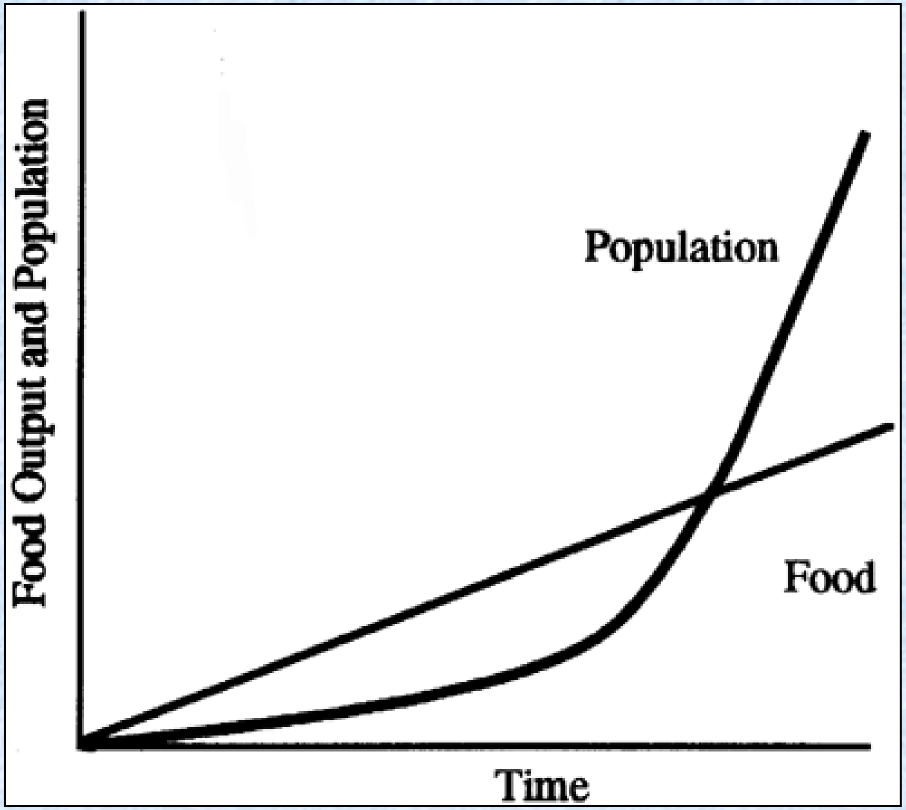


Adaptive radiation in Galapagos finches



Darwin - Influence of Malthus

Two years after he returned, Darwin read **"Essay on the Principle of Population"** by the political economist **Thomas Malthus**, who argued that human populations always increase faster than the food supply.



What is the Mechanism of Evolution?

"Preservation of Favored Races in the Struggle for Life"
= Natural Selection

1. There is **variation** in function or behavior between individuals. Some traits are more adaptive than others.
2. Traits are **heritable**.
3. More offspring are produced than can survive.
4. Individuals **compete** for limited resources. "Struggle for existence."
5. Individuals that are **more adapted** to the environment **live to reproduce or reproduce more**.

Less adaptive traits become less common in populations.
The gene frequencies or proportions in the population change.

What is evolution?

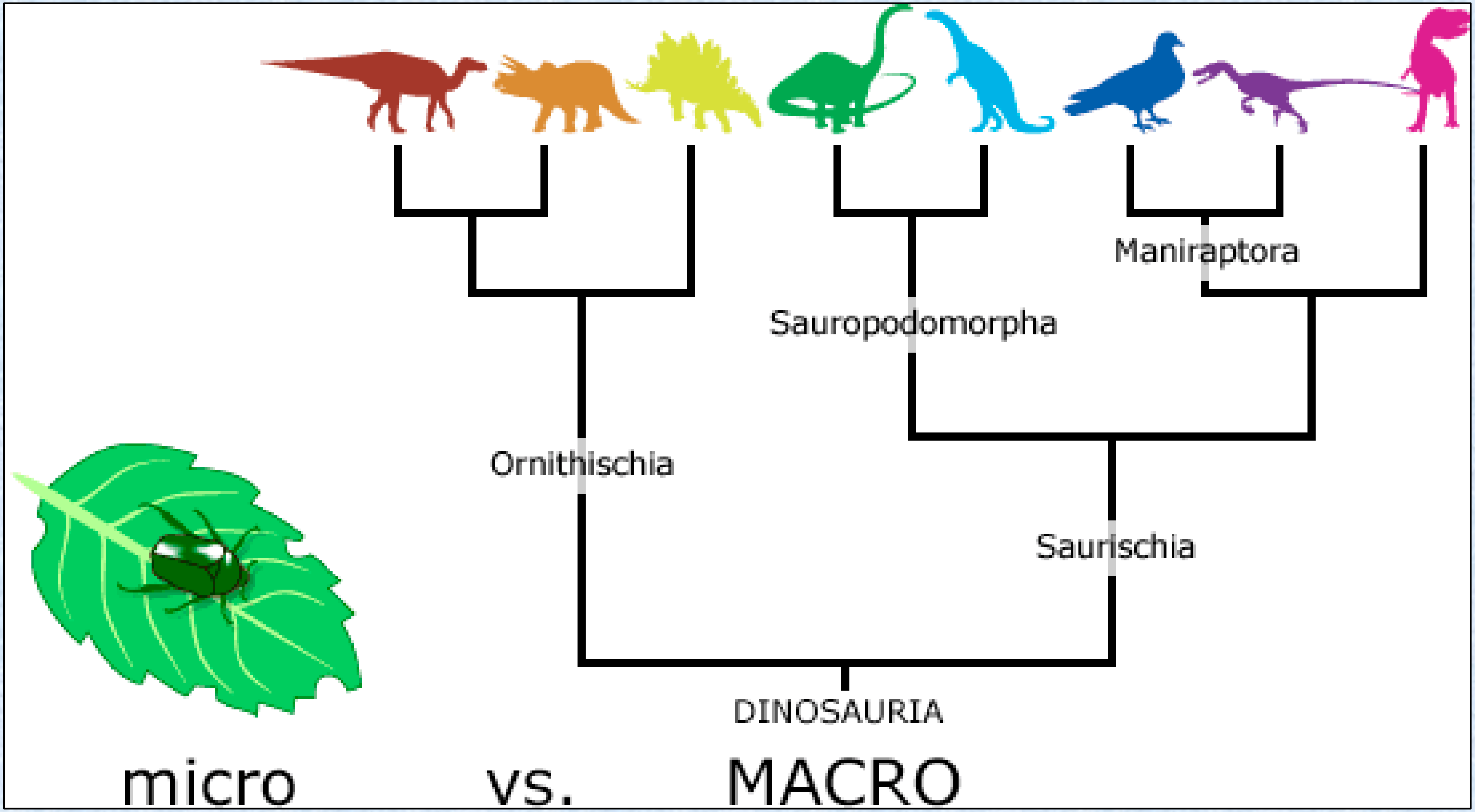
Change through time

- **Biological evolution -** change in gene frequencies in populations over time,small genetic changes in populations lead to larger changes over time

- **Microevolution -** changes within populations and close species due to natural selection and other evolutionary forces (mutation, drift), eventually leading to speciation

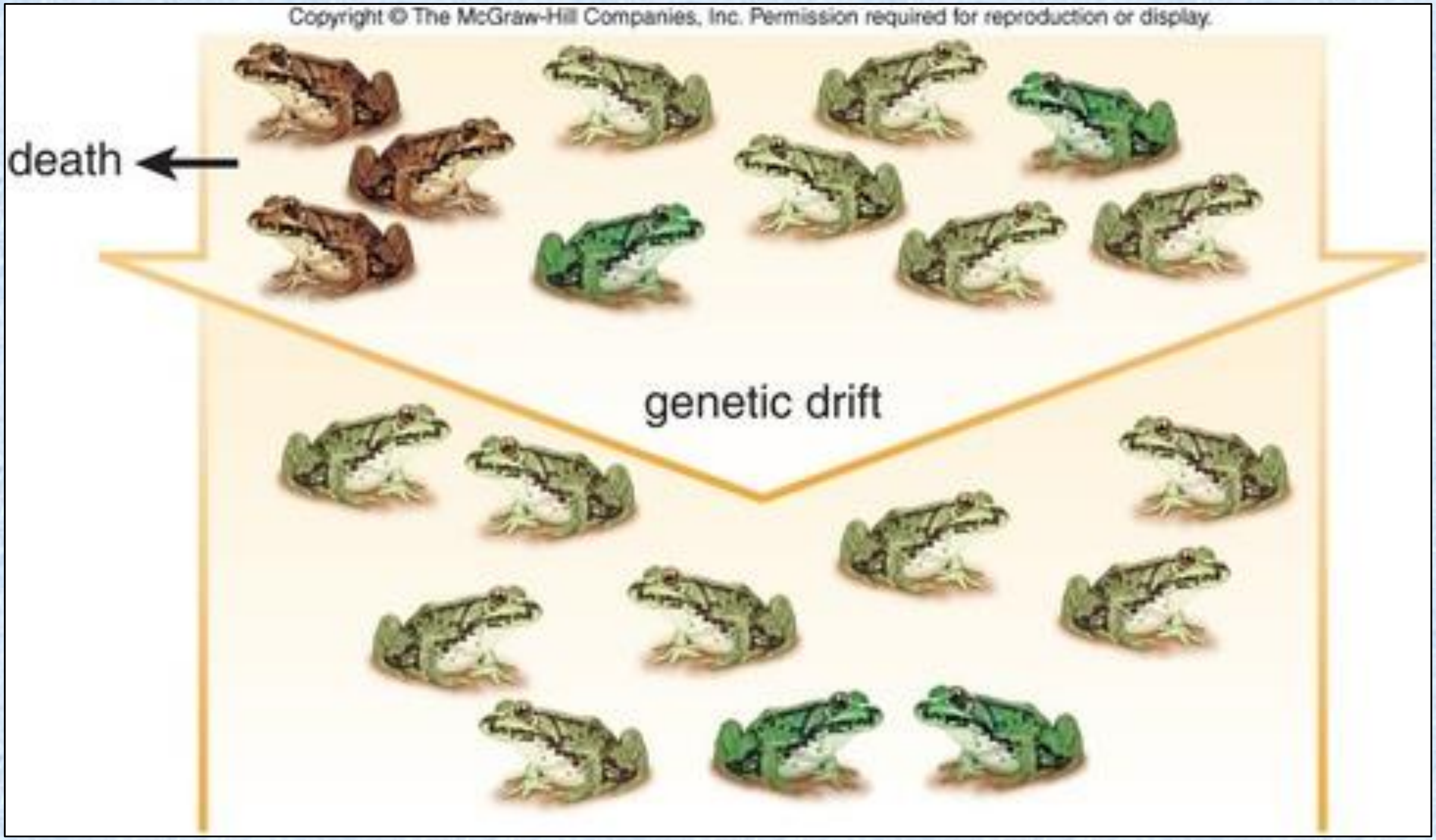
- **Macroevolution -** big changes between species, genera, families, phyla, takes place over long periods of time

Microevolution vs Macroevolution



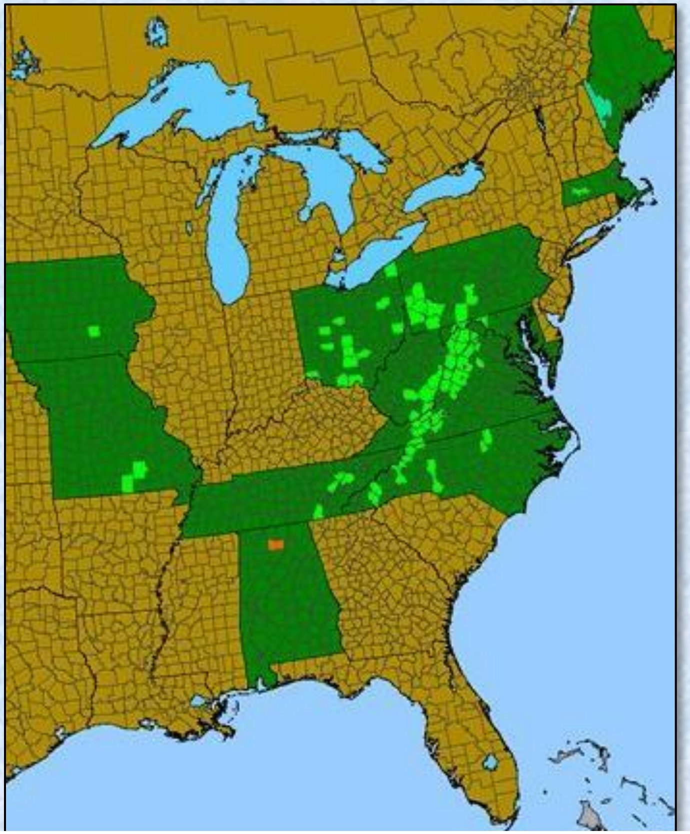
Microevolution – small changes in populations

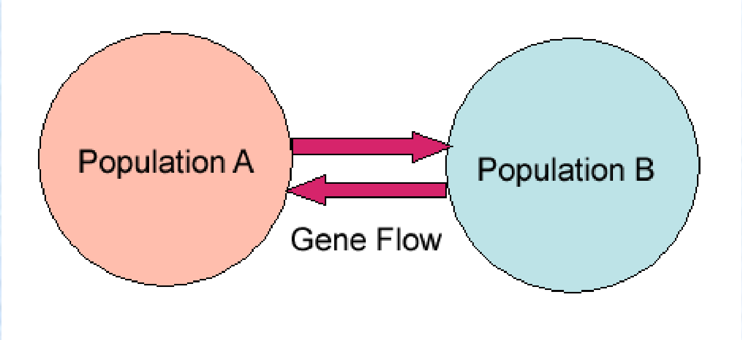
genetic drift, selection, migration



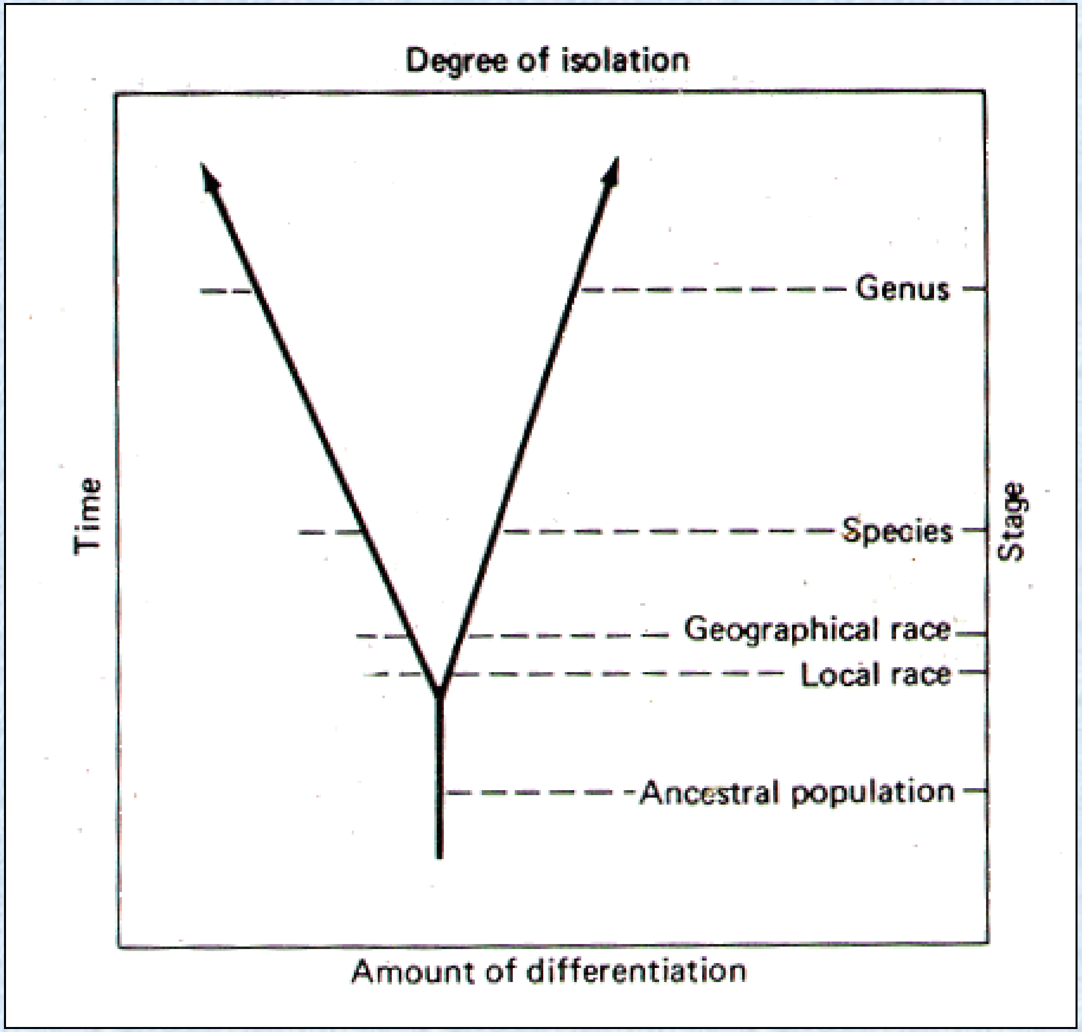
Microevolution

Population Genetics of Tall Larkspur (*Delphinium exaltatum)*





Microevolution – small genetic changes can lead to new species eventually



Microevolution

– can lead to new species (=Speciation)

- These are members of different species –
- Eastern (left) and Western (right) Meadowlark.
- Almost identical, but have different songs, reproductively isolated

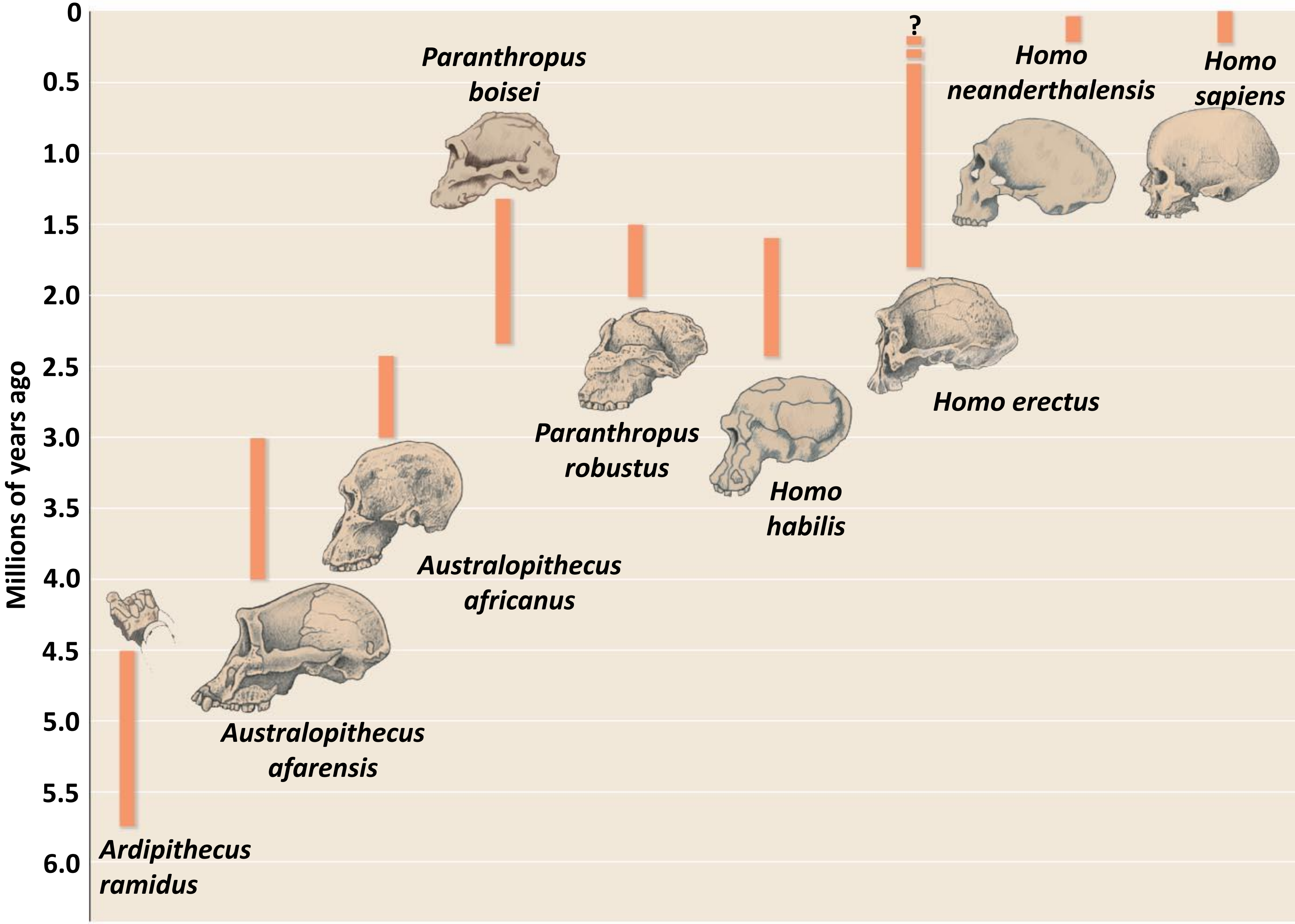
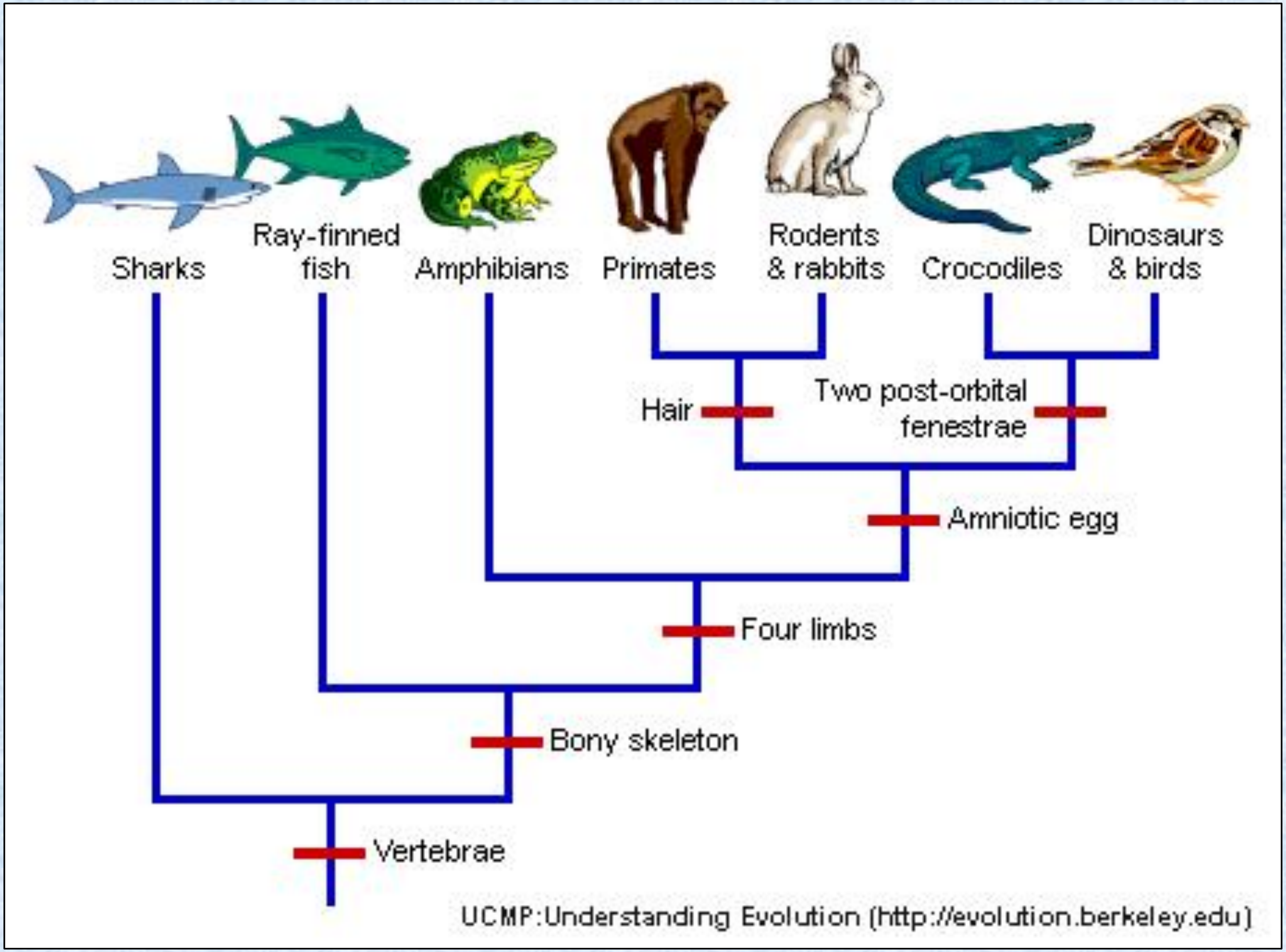
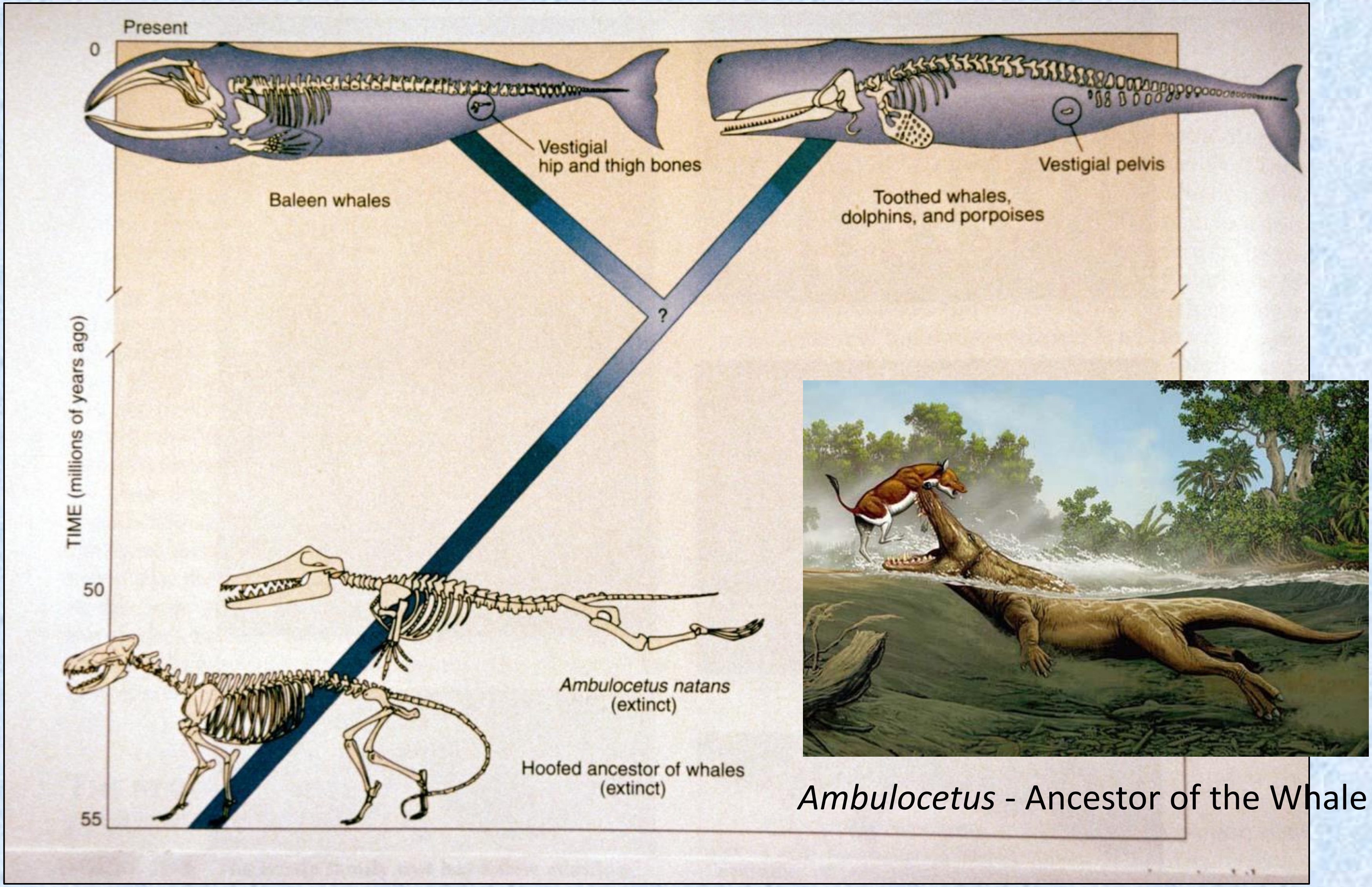

0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
Millions of years ago
?
Paranthropus boisei
Homo neanderthalensis
Homo sapiens
Homo erectus
Paranthropus robustus
Homo habilis
Australopithecus africanus
Australopithecus afarensis
Ardipithecus ramidus

Figure 17.38

Macroevolution – big changes over long periods of time



Macroevolution – example - whales from quadrupeds



Ambulocetus - Ancestor of the Whale

What is a Species?

- The species is the basic biological unit around which classifications are based.
- However, what constitutes a species can be difficult to define and there are multiple definitions of species in use today.

Carolus Linnaeus

1707 - 1778

- Tried to name and classify all species known to him
- Binomial nomenclature
  - *Species Plantarum* - 1753
- System of Classification
  - “Sexual System”
  - Classes - number of stamens
  - Orders - number of pistils
- Basically a creationist

Scientific Names – Binomial Nomenclature

Species names ("scientific names") are <u>Latin binomials</u>

***Lewisia rediviva* Pursh.**

- Genus (pl. genera)
- Always capitalized
- Abbreviated on 2nd use (*L. rediviva*)

- Specific epithet
- Not capitalized
- Often a descriptive adjective
- Not abbreviated

- Authority

➢ Always *italicize* or <u>underline</u> species names (genus + specific epithet)

What is a Species?

"Certainly no clear line of demarcation has yet been drawn between species and sub-species – that is, the forms which…*come very near to, but do not quite arrive at, the rank of species*. …A well-marked variety may therefore be called an *incipient species*.

…From these remarks it will be seen that I look at the term species as one arbitrarily given."

Darwin, *The Origin of Species*

Species Concepts

- There are many difficulties associated with the definition of "species."
- Definitions that work well for some groups of organisms do not necessarily work for other organisms (extant versus fossil species, asexual species).
- Some species concepts take evolution into account and attempt to address problems that are associated with a species being an evolving rather than an immutable biological entity.

Morphological Species Concept (MSC)

- A species is a group of organisms that resemble one another and are distinct from other such groups.
- Evolution not considered at all
- Oldest, intuitive, concept. Used by Linnaeus
- Widely adaptable. Can be used for living or extinct species, and in organisms that reproduce sexually and asexually
- Problem – kind of arbitrary

Evolutionary Species Concept (ESC)

- An evolutionary species is a lineage (ancestor-descendant populations), evolving separately from other lineages.
- Identifies key morphological traits
- Members share same traits and same evolutionary pathway
- Commonly used for fossils

Biological Species Concept (BSC)

- "Species are groups of actually or potentially interbreeding populations that are reproductively isolated from other such groups." E. Mayr (1942)
- Population or group of populations that are able to *interbreed*, under *natural conditions* to produce *fertile offspring*

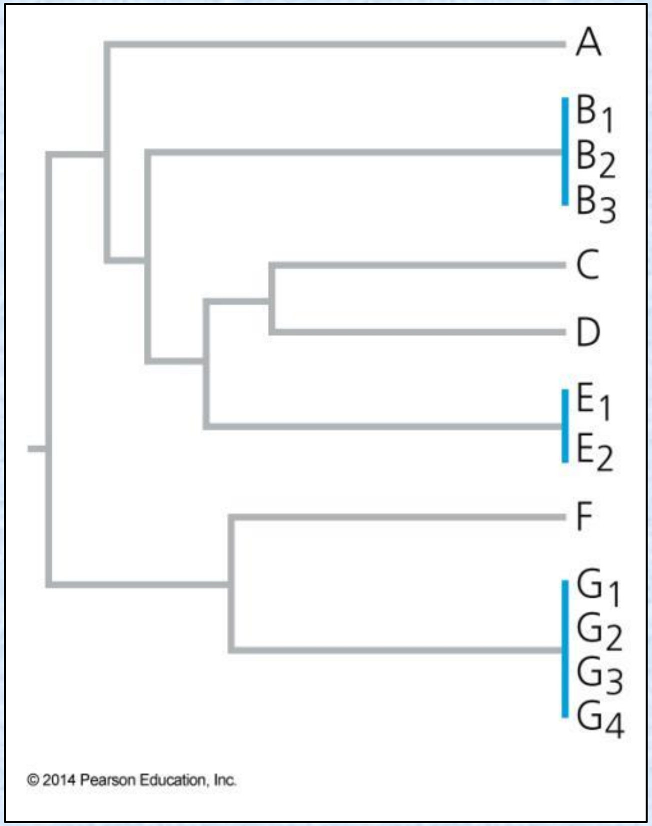
Main criterion is reproductive isolation.

Biological Species Concept (BSC)

- According to the BSC, speciation occurs when populations evolve **reproductive isolating mechanisms**.
- Problems
  - Sometimes hard to prove.
  - Hybrids are common
  - Does not apply to fossils
  - Applies only to sexually reproducing species

Phylogenetic Species Concept (PSC)

- The phylogenetic species concept emphasizes common descent and covers both sexually and asexually reproducing organisms.
- Under the PSC any population that has become separated and has undergone character evolution will be recognized as a species.
- Uses any characters, including DNA
- Problem – leads to many species



Bottom line:

The *Biological Species* concept is the major species concept used by modern biologists in practice.

However, an increasingly large group (cladists) is applying the phylogenetic species concept (or a combination of PSC and BSC), combine DNA phylogeny with morphology.

Determining What Is and What Isn't a Distinct Species Can Have Consequences for Endangered Species

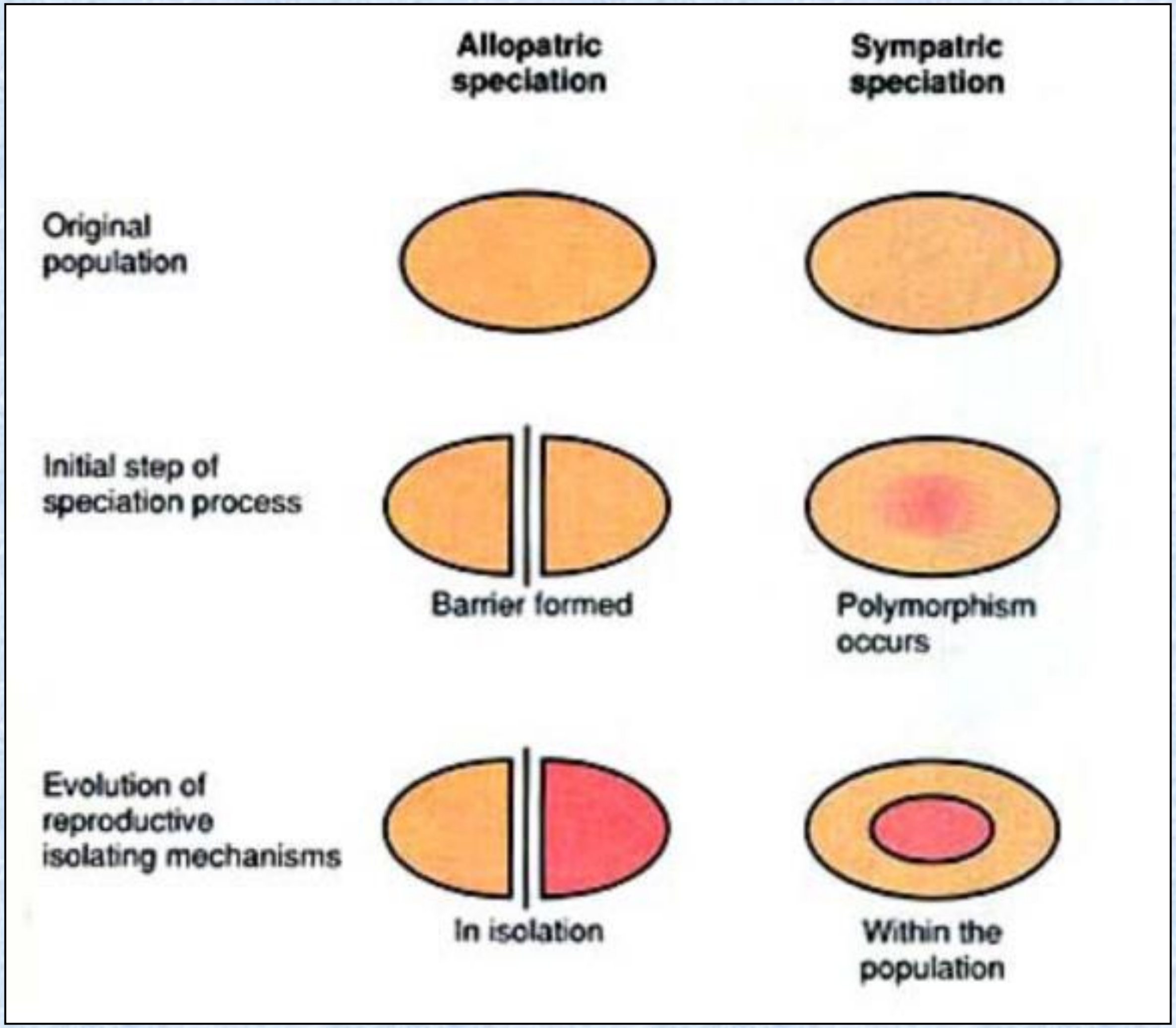
Use "Evolutionary Significant Units" – blend of concepts

Protect subspecies and varieties? Yes, well, sometimes.

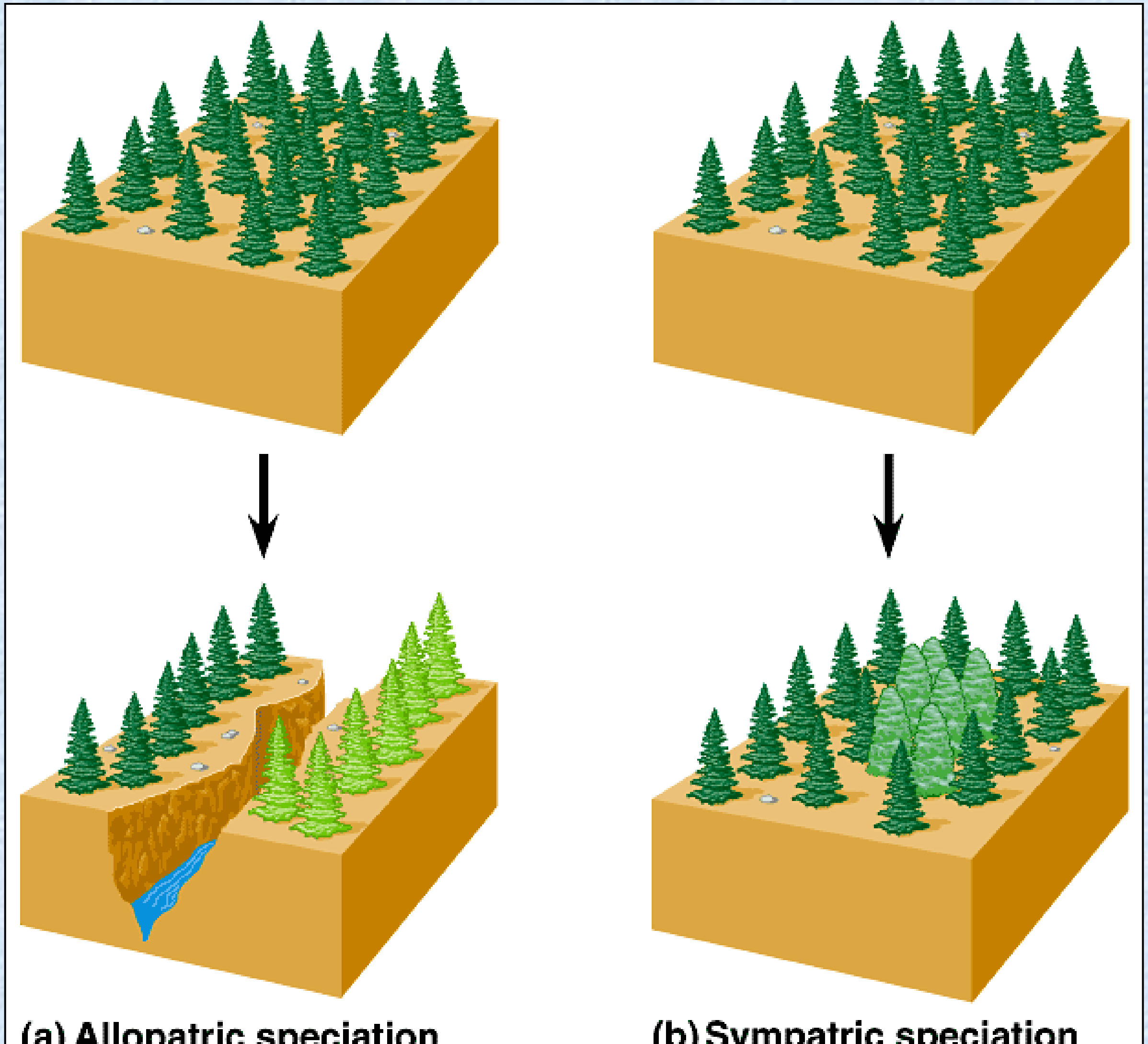
Northern spotted owl (left) and barred owl (right)

How do new species form?

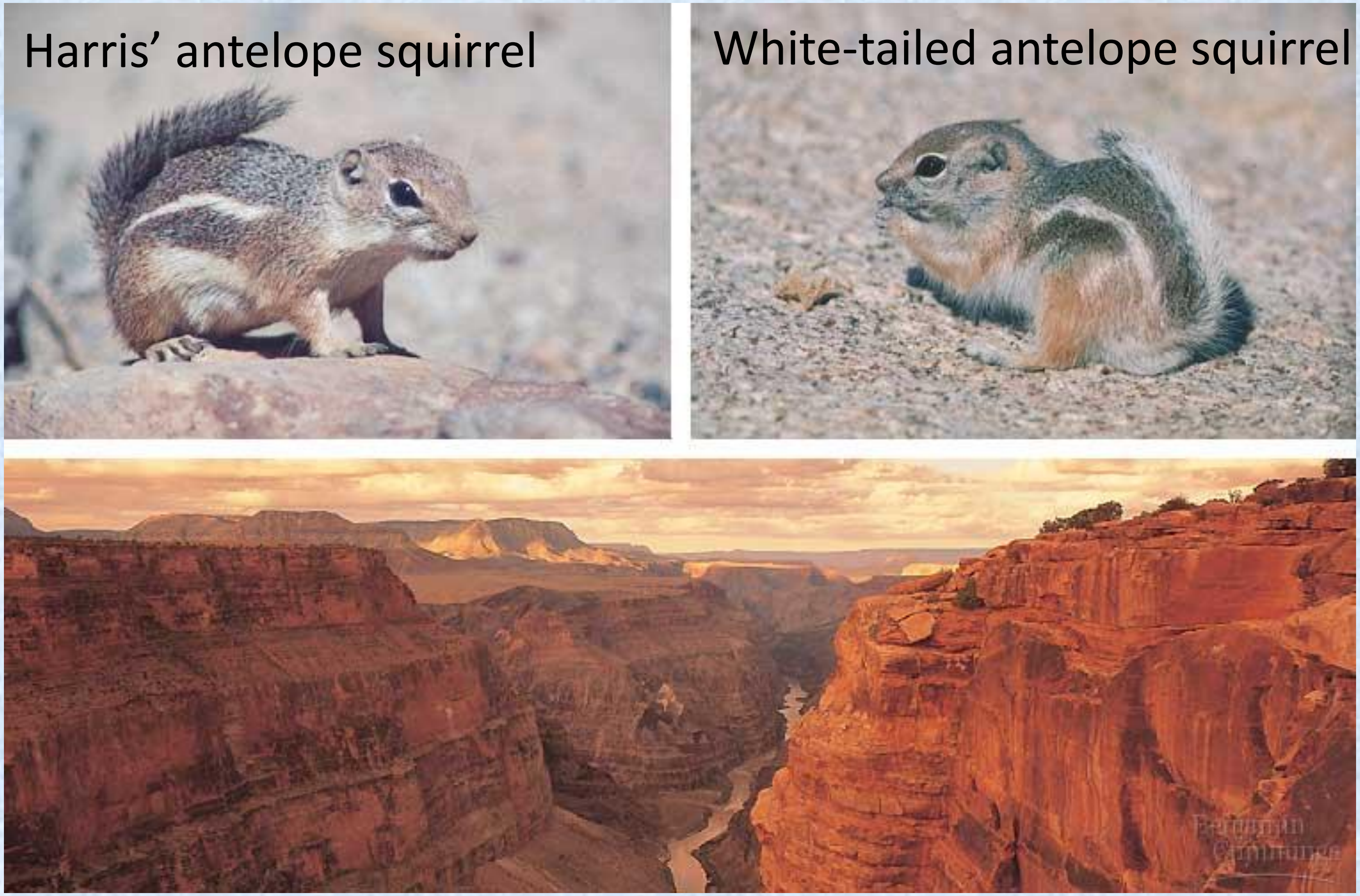
- populations diverge genetically
- two models



Allopatric and Sympatric Speciation



Allopatric Speciation – geographic separation



Two species of ground squirrel are postulated to have descended from a common ancestral population that was separated by formation of the Grand Canyon.

Allopatric Speciation – geographic separation

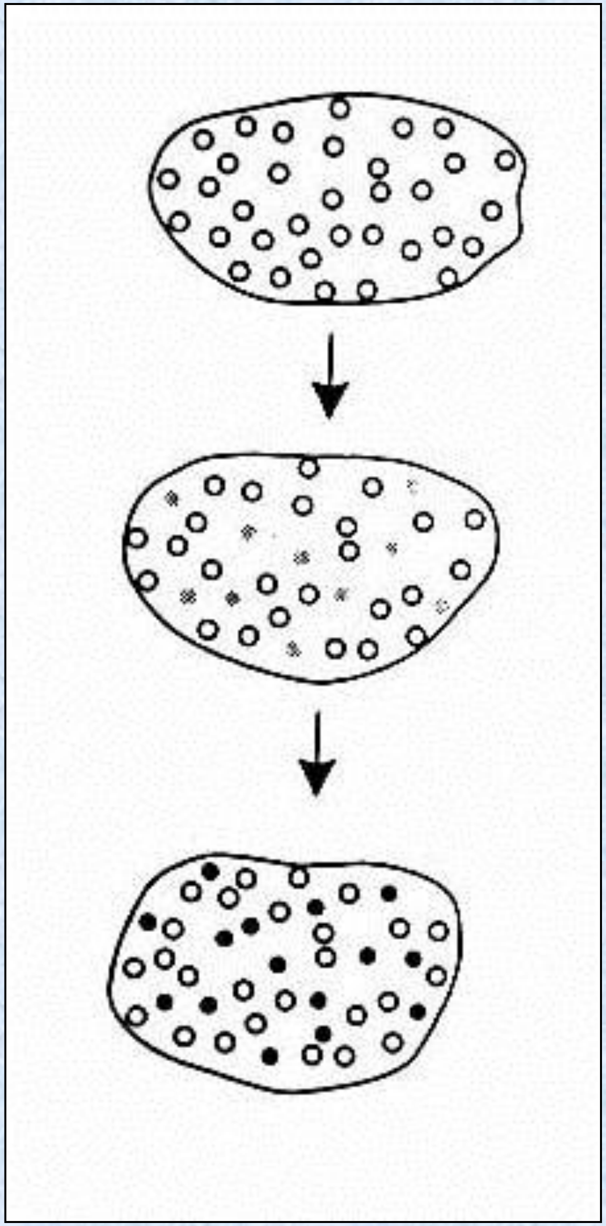
Spotted owl subspecies living in different geographic locations show some genetic and morphological differences. This observation is consistent with the idea that new species form through geographic isolation.

Sympatric speciation

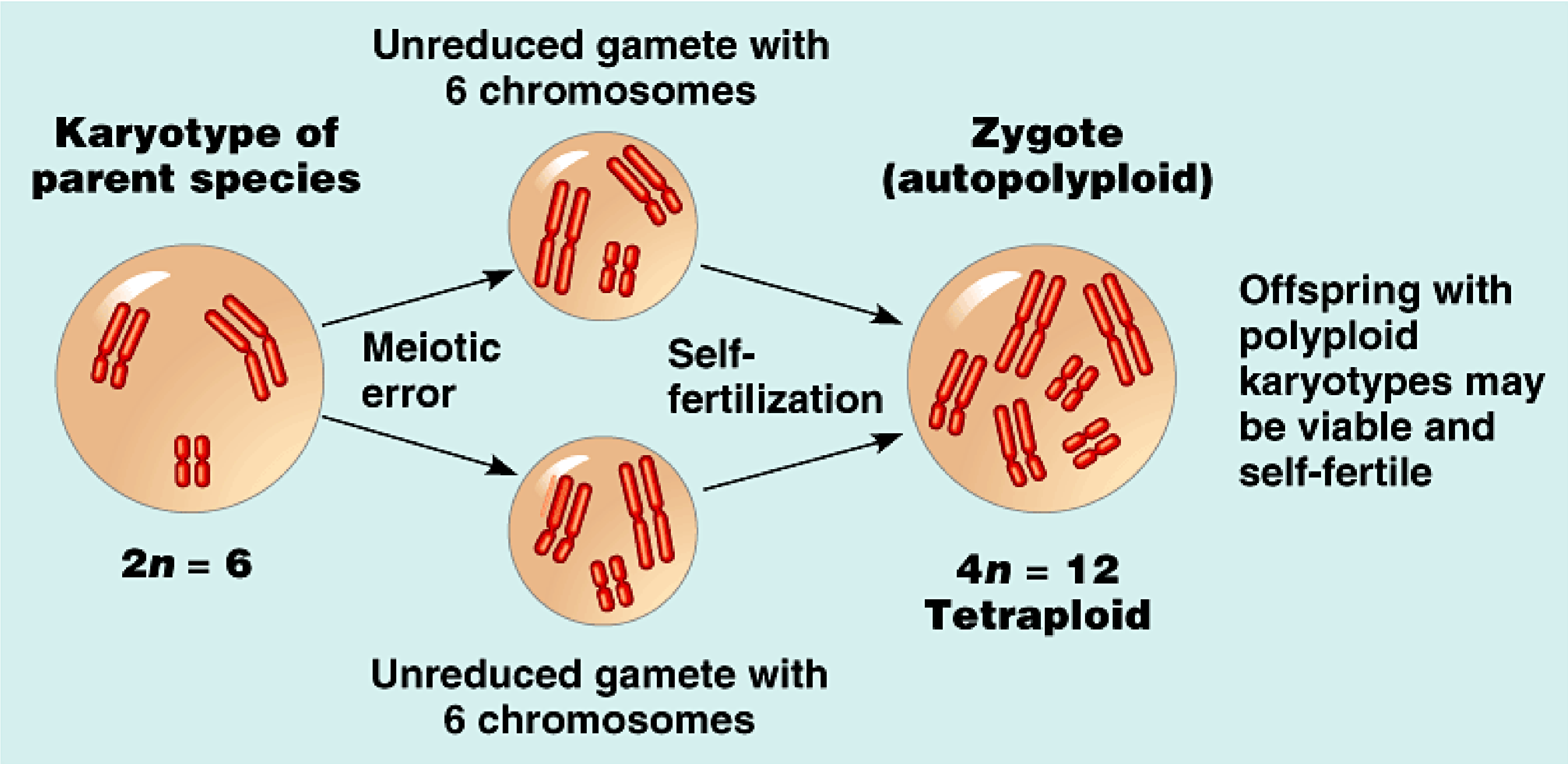
Occurs without any separation of the ancestral geographic range.

May occur after the establishment of a stable polymorphism.

Most common with plant polyploids, doubling chromosome numbers, instant species



Sympatric speciation by autopolyploidy in plants, doubling of chromosomes.



Reproductive Isolating mechanisms

- Any behavioral, structural or biochemical traits that prevent individuals of different species from reproducing successfully together
- There are two types of isolating mechanisms
  - Prezygotic isolating mechanisms
  - Postzygotic isolating mechanisms.

Reproductive Barriers Between Species

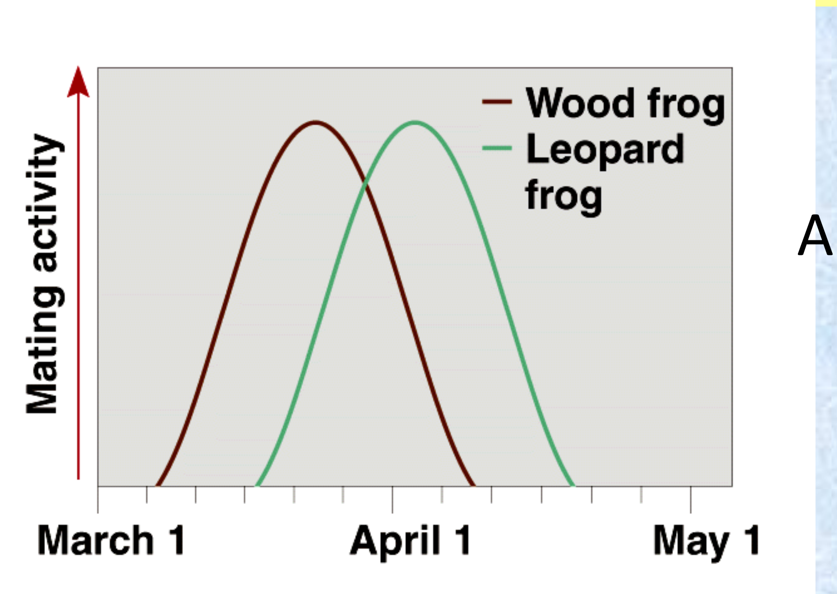
PREZYGOTIC BARRIERS: Prevent mating or fertilization

Temporal isolation:	Mating or flowering occurs at different times for different species.
Habitat isolation:	Species breed in different habitats.
Behavioral isolation:	There is little or no sexual attraction between individuals of different species.
Mechanical isolation:	Structural differences between species (in animal sex organs or plant flowers, for example) prevent copulation or pollen transfer.
Gametic isolation:	Male and/or female gametes die before uniting with gametes of other species, or the gametes fail to unite.

Temporal Isolation

Wood frog
Rana sylvatica

Northern leopard frog
Rana pipiens



Also have different calls

Temporal Isolation

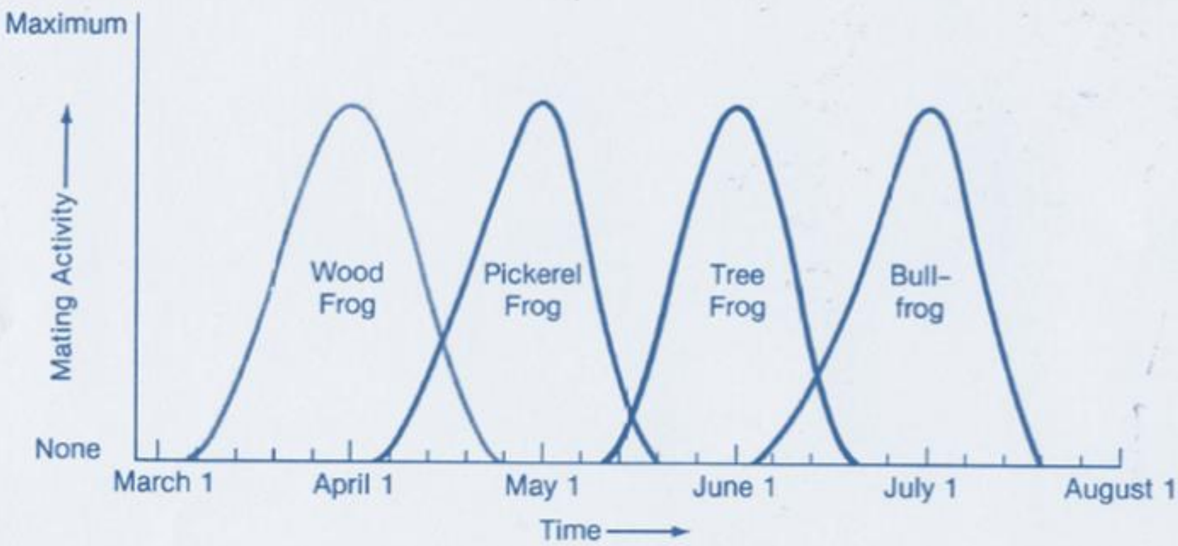


Figure 43-3 TEMPORAL ISOLATION IN BREEDING OF AMPHIBIANS.
Four kinds of frogs are seen to have maximal reproductive behavior at different times; this helps to ensure that interbreeding is reduced or absent.

Frogs breeding in the North American spring and summer

Scarcely-overlapping windows of time when each species reproduces

Species-specific vocalizations

Habitat (Ecological) Isolation

- Species occupy separate habitats or niches and do not encounter oneanother to
- Do not reproduce due to some geographic or ecological barrier.

Example – ground squirrel species occupy different habitats.

Woodchucks live in fields at low elevation

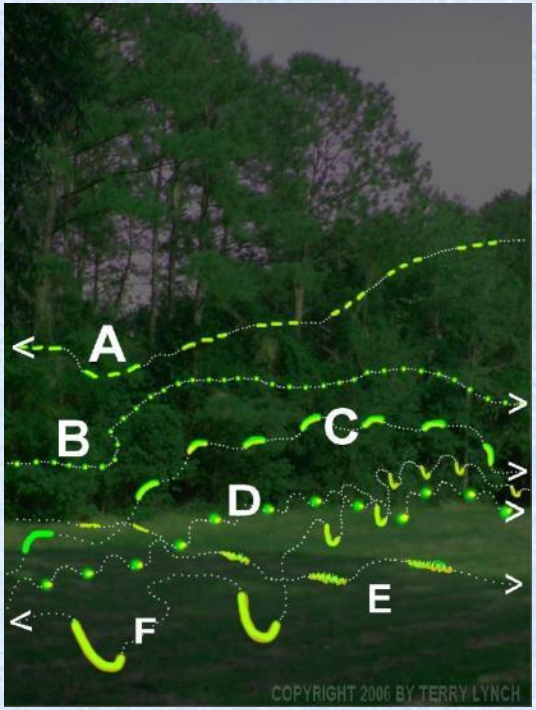
Marmots live in the Rocky Mountains at high elevations

Behavioral Isolation

Species specific mating rituals

male jumping spiders Courtship dance to attract females.

fireflies flash patterns for each species



Behavioral isolation
Even if they breed at the same time, they will not mate if they are not attracted to one another.

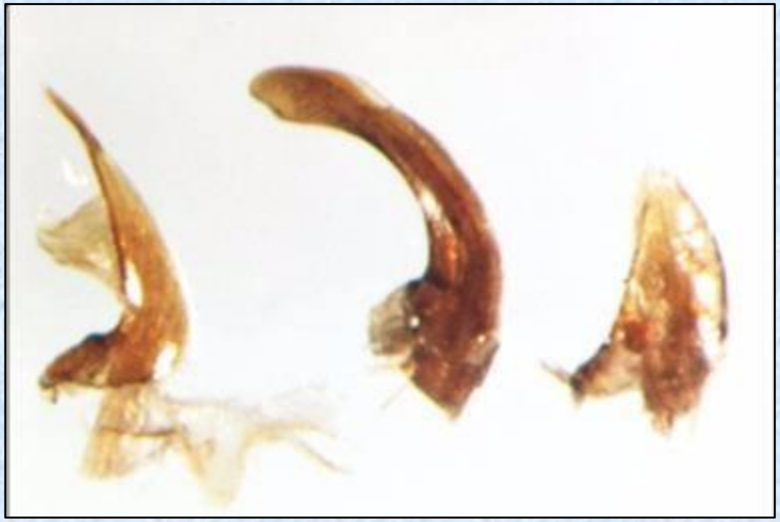
Courtship rituals, like these, are critical for mating within a species, but ineffective for attracting members of other species.

Mechanical Isolation

(a) Honeybee drinking nectar from a foxglove flower

(b) Ruby-throated hummingbird drinking nectar from a trumpet creeper flower

Flower shapes, sizes, position of anthers and stigma

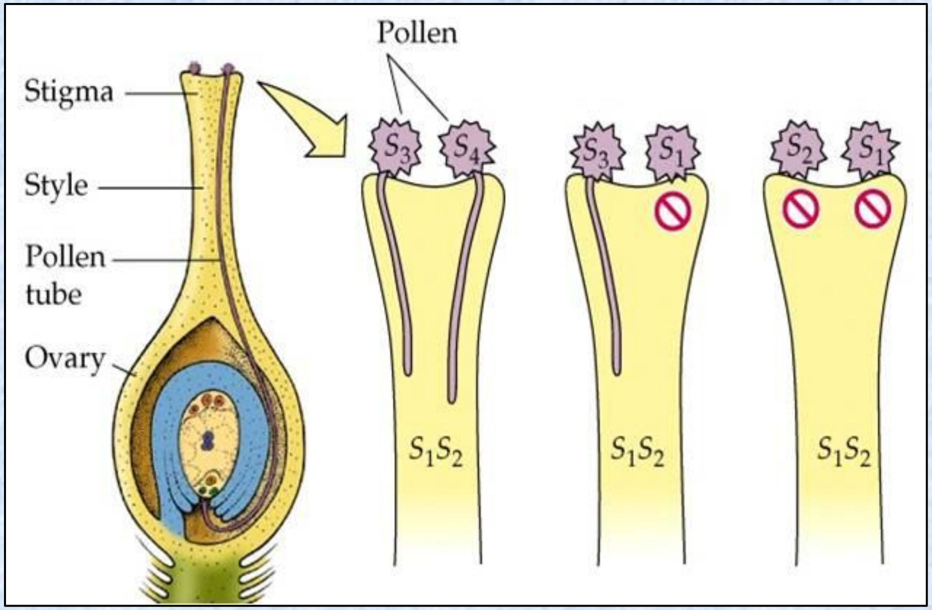


Beetle Genitalia, lock and key fit

Gametic Isolation

Sponges, sedentary organisms

Stigma – Pollen Interactions

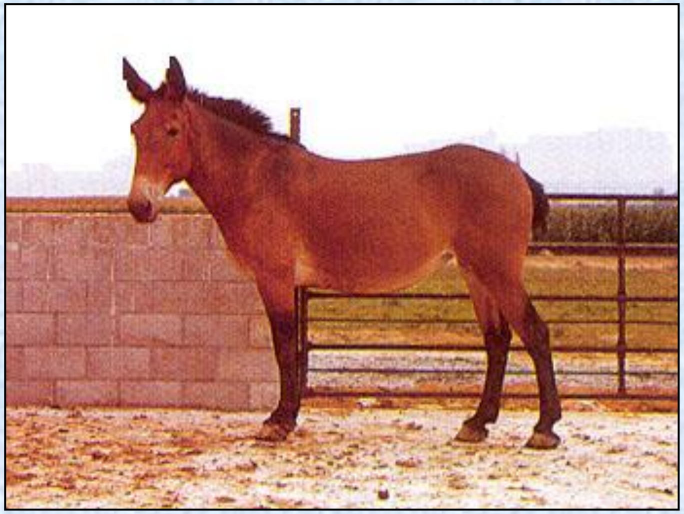


Reproductive Barriers Between Species

POSTZYGOTIC BARRIERS:	Prevent the development of fertile adults
Hybrid inviability:	Hybrid zygotes fail to develop, or the hybrids fail to reach sexual maturity.
Hybrid sterility:	Hybrids fail to produce functional gametes.
Hybrid breakdown:	Offspring of hybrids are weak or infertile.

Hybrid Sterility

A female donkey mated to a male horse produces what?

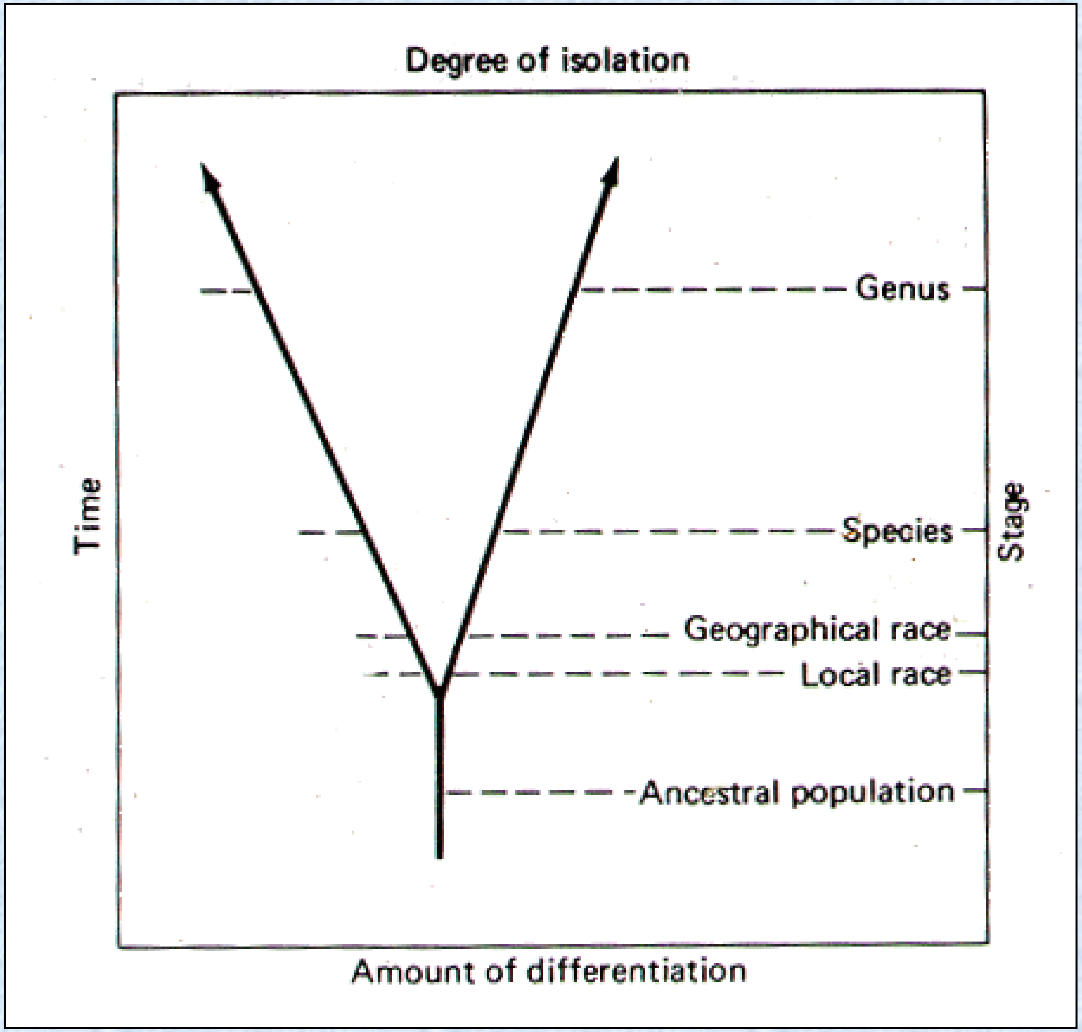


A mule (which is sterile). Hence, donkeys and horses are separate species.

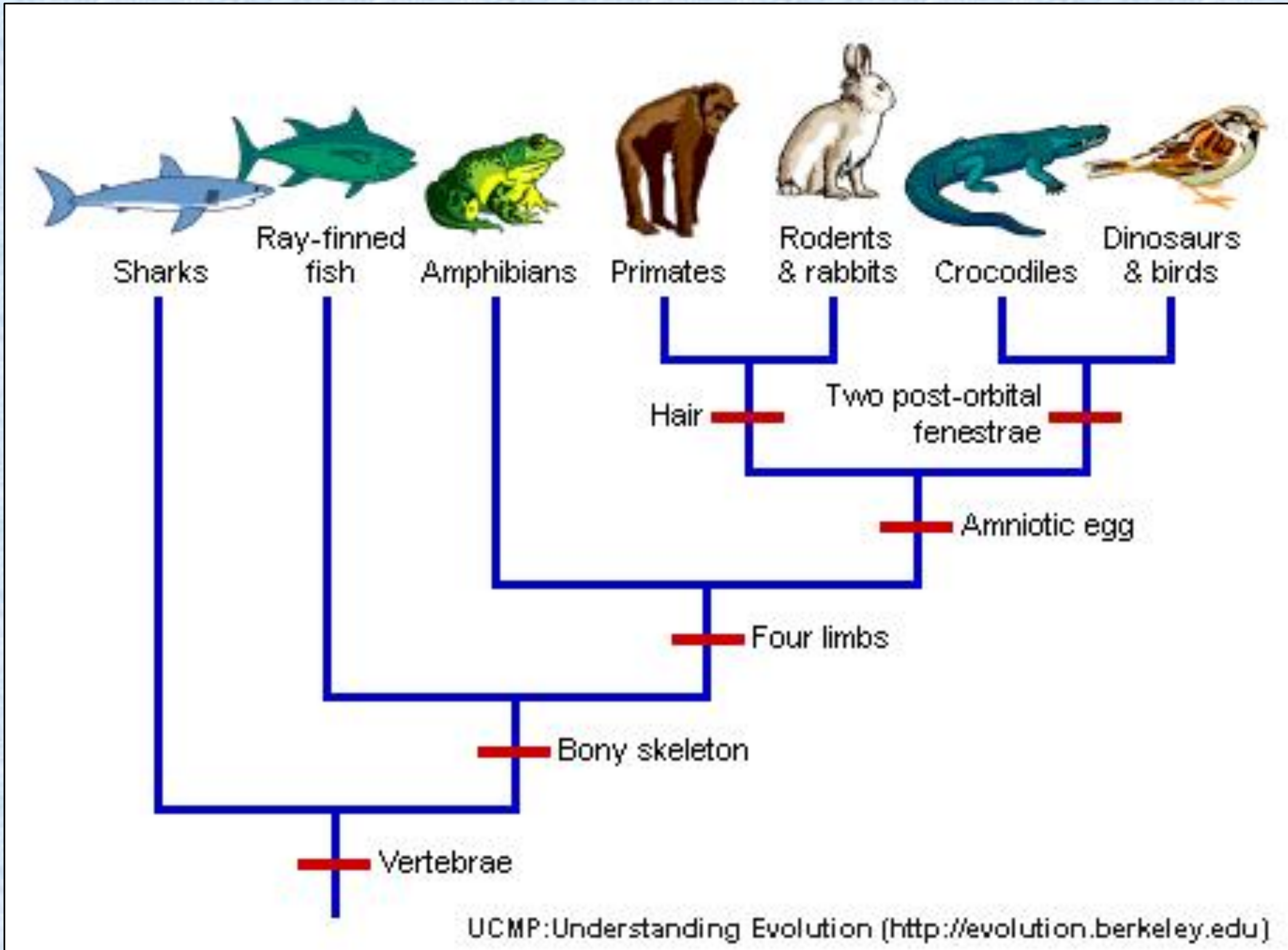
What happens when two allopatric populations or species come back together?

1. Populations mix, become one, gene flow re-established, maybe different varieties.
2. Hybrid zone established, partial mixture in some areas only
3. Reinforcement – selection against hybrids, promotes reproductive isolating mechanisms
4. Complete reproductive isolation – have become separate species

Microevolution – small genetic changes can lead to new species eventually



Macroevolution – big changes over long periods of time



Adaptive radiation – single ancestral species diversifies rapidly, gives rise to many new species

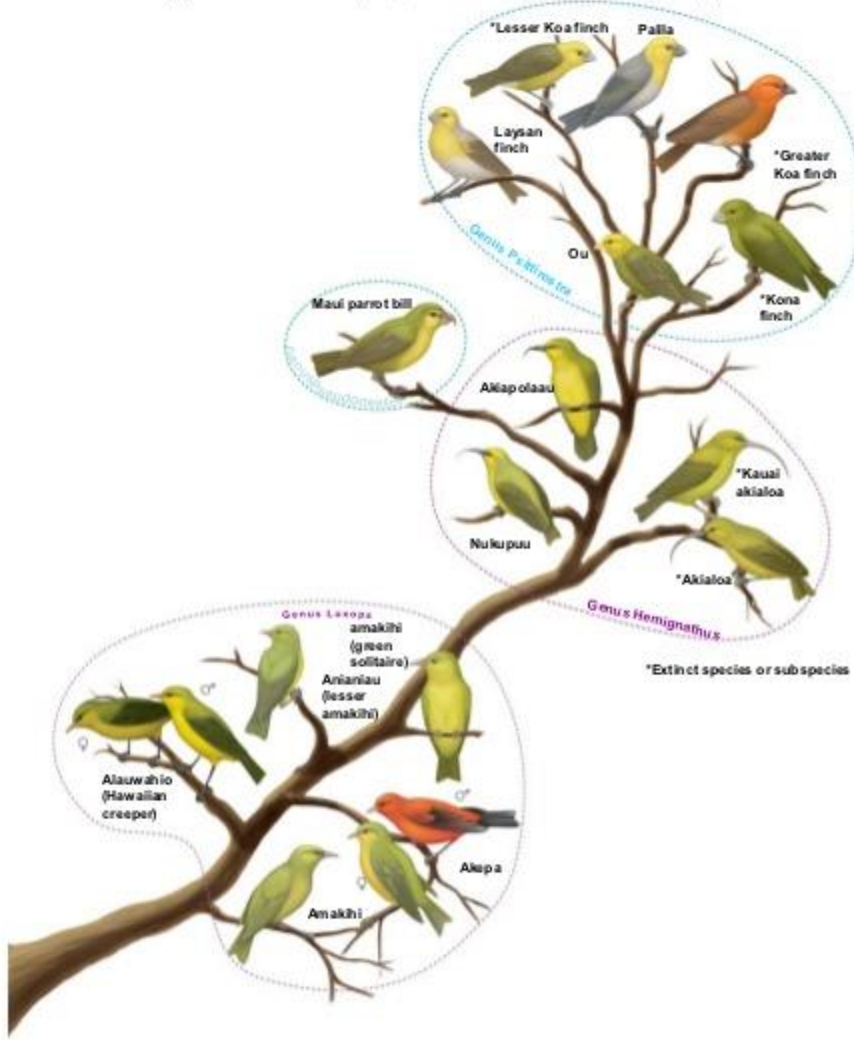
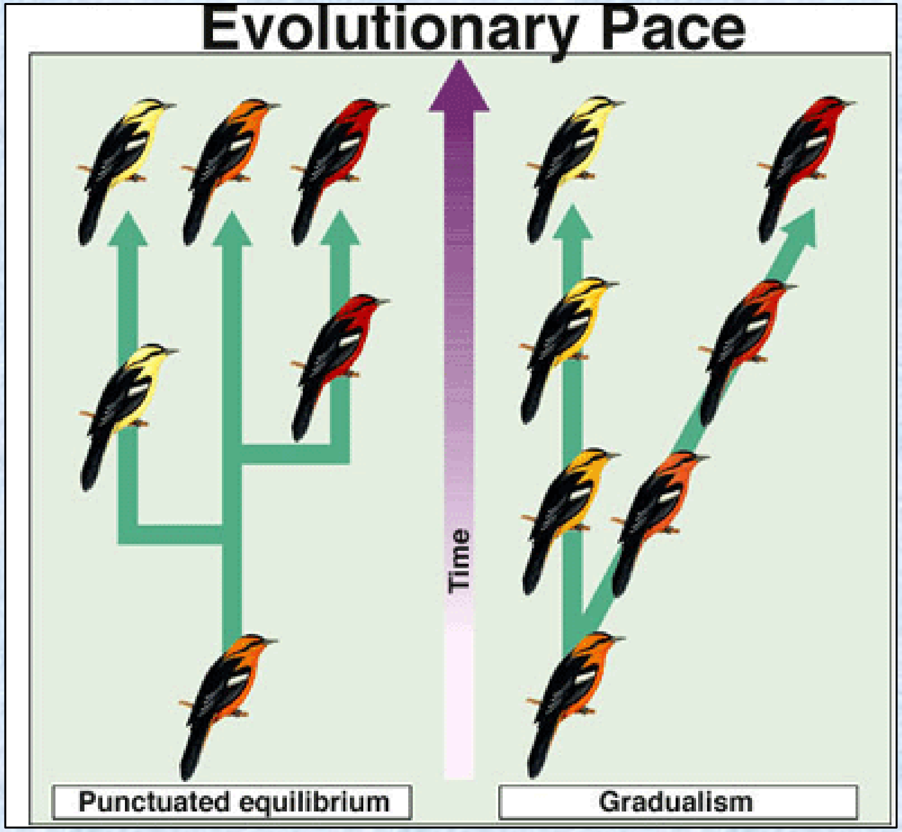


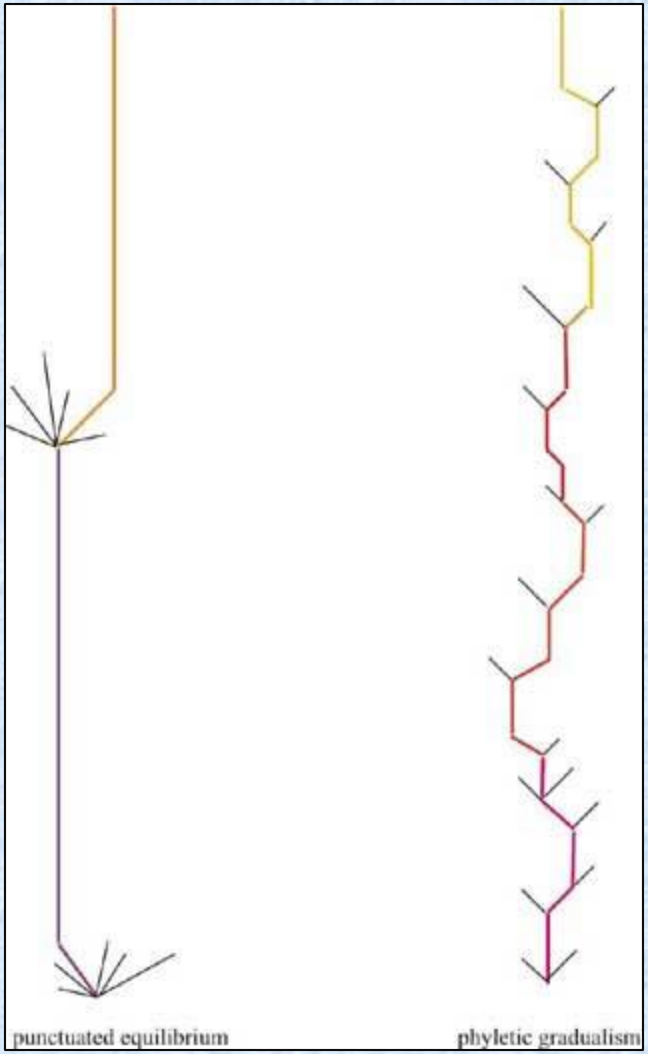
Figure 14.4 Adaptive radiation in Hawaiian honeycreepers

14-16

Pace of Evolution

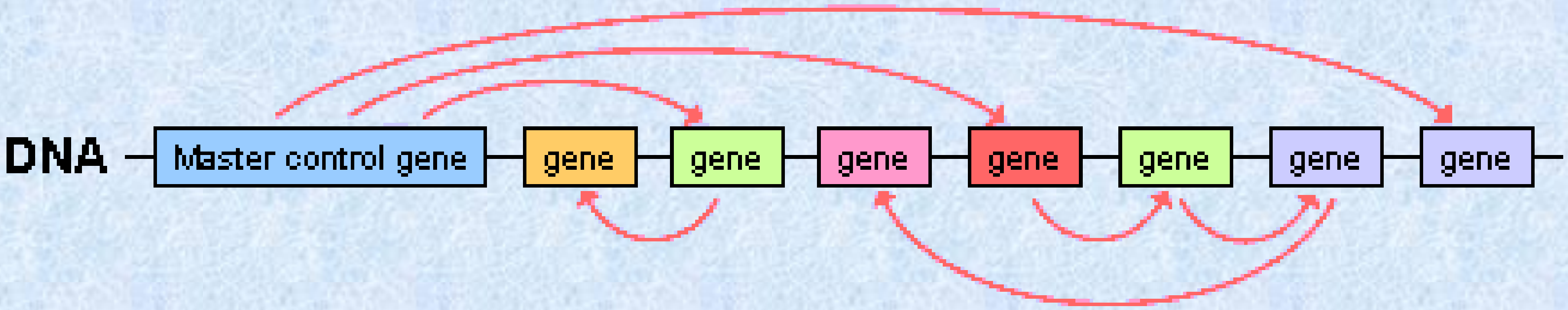
- Gradual change over time, steady
- Punctuated Equilibrium, periods of rapid change





Developmental Genes and Macroevolution

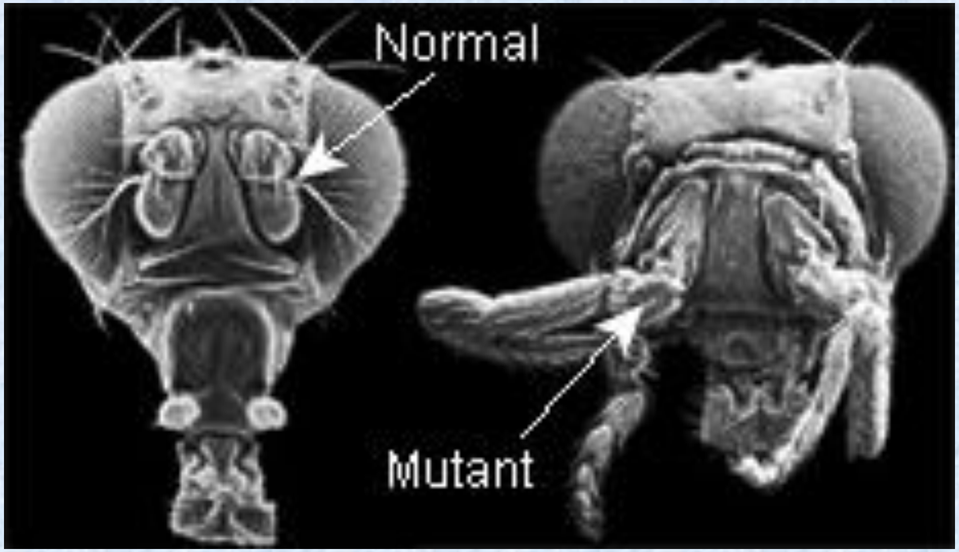
- Homeotic genes control developmental sequence and fates of cells, regulate other genes.
- Animals - *Hox* (for "homeobox"), homeotic genes
- Plants - *MADS*-box genes
- Changes in developmental genes can result in big changes, probably involved in adaptive radiation
- Some ancient, retain same switches



Homeotic Gene Mutation

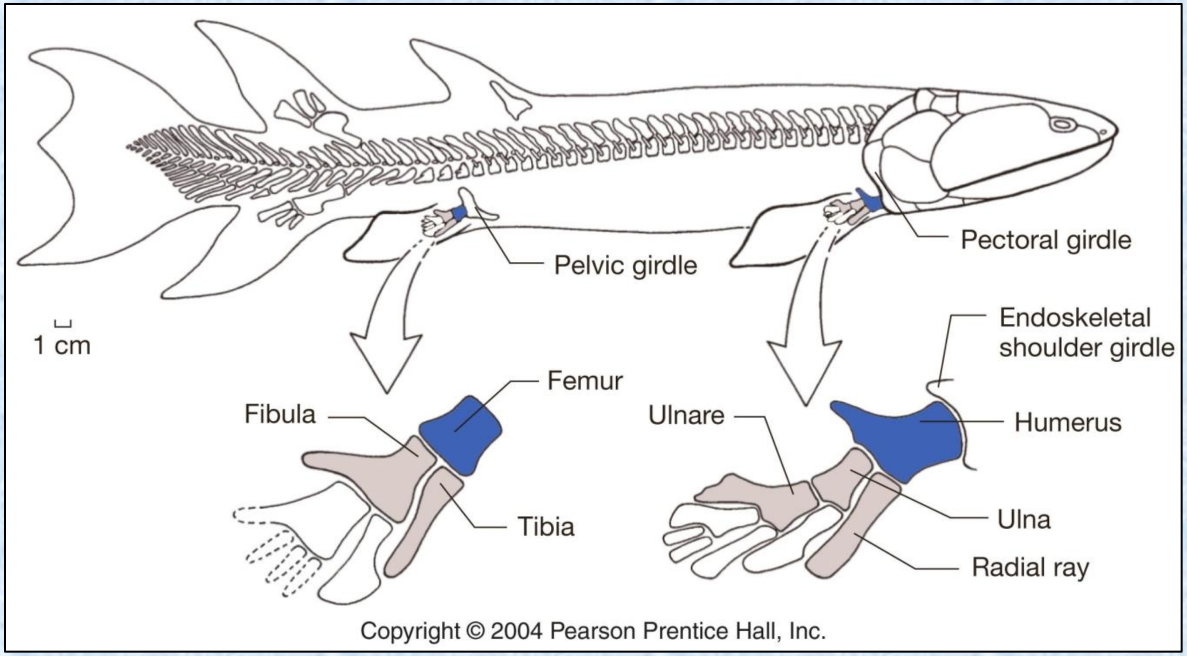
Mutations to *Hox* genes can produce 4-winged fly or put an entire leg where an antenna should sprout out, and produce other equally grotesque transformations.

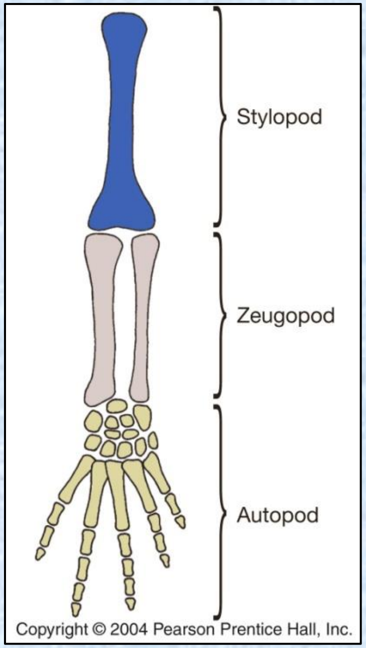
Small changes in such powerful regulatory genes, or changes in the genes turned on by them, could represent a major source of evolutionary change



Developmental Genes and Macroevolution

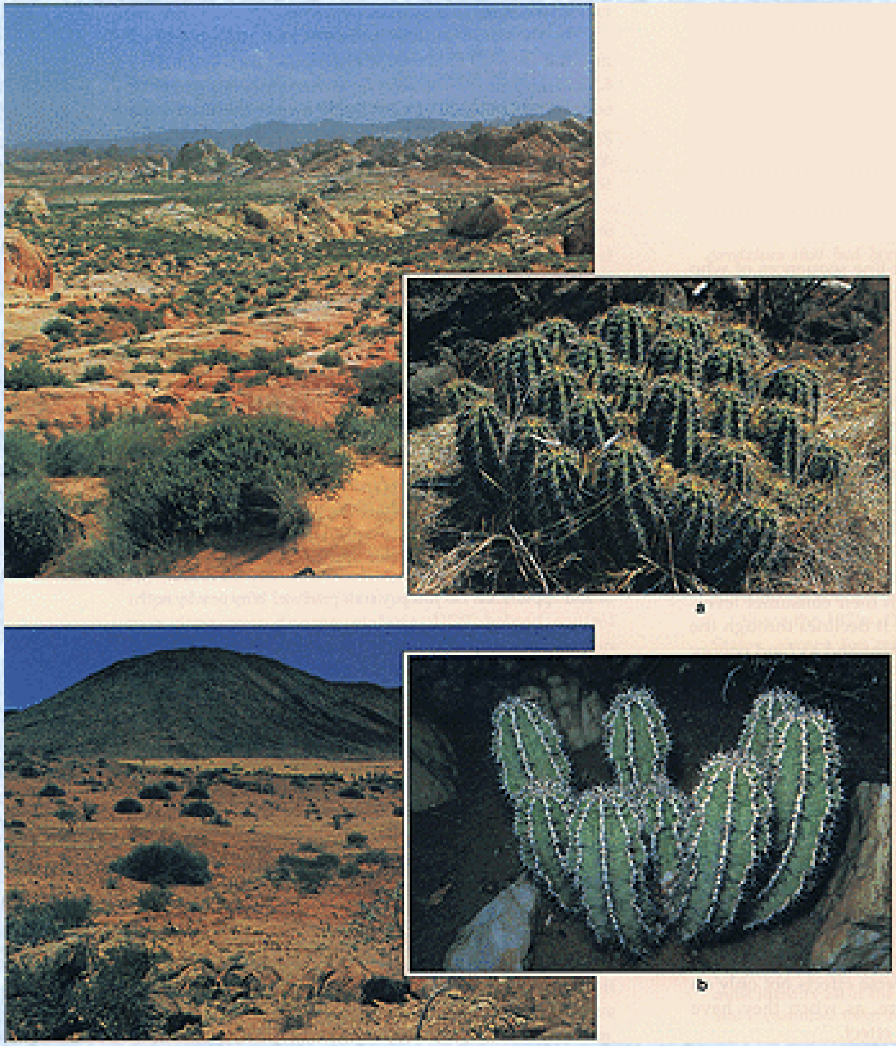
Example - Lobe-finned fish and the tetrapod limb





- *Eusthenopteron,* a lobe-finned fish from the Devonian (409-354 mya)
- Small changes in developmental genes can account for differences in size and shape in tetrapods

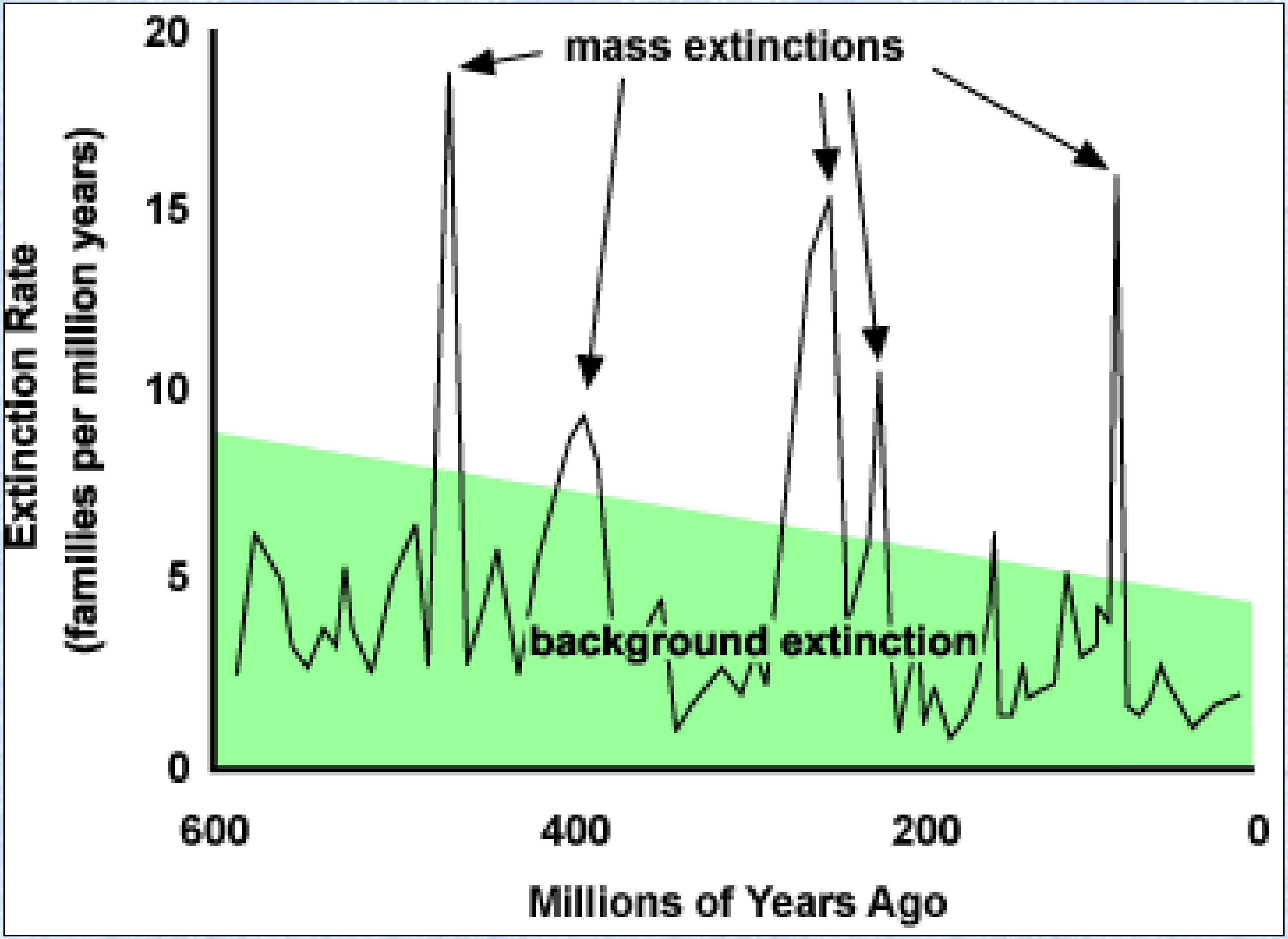
Convergent evolution – when unrelated taxa evolve similar appearance due to similar climate or other pressures



Cactaceae in North American deserts

Euphorbiaceae in southern African deserts

Mass Extinctions – periods when many species or higher groups go extinct in a short time



End