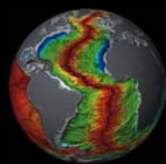
Evolution 2
Speciation



Evolution

- The evolution of life is directly connected to the evolution of earth.
- Evidence:
  - Fossils
  - Geology
  - Biogeography
    - Similarities in rock types
    - Glaciation
    - Fossil distributions

Plate tectonics

Alfred Wegener (1880-1930)

1915 – he suggested that 300 mya all of the continents formed a supercontinent that he called "Pangea".

Plate tectonics

His theory was based on several observations:

1. The fit of the continents.
2. Similarity of rock types across Atlantic.
3. Glacial "tracks".
4. Fossil distributions.

Plate Tectonics

Plate Tectonics
Continental Margins

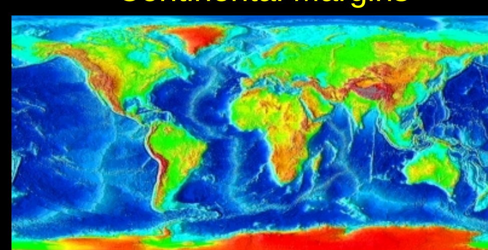


Plate Tectonics
Continental Margins

South America

Africa

Plate Tectonics

Near perfect fit when continents are joined by continental margins.

Plate Tectonics

Matching rock assemblages across the Atlantic Ocean.

Plate Tectonics

Glacial striations reveal ancient continental connections.

Grooves carved by glaciers (shown by arrows) provided evidence for continental drift. This diagram assumes the continents were in their present-day locations.

Plate Tectonics

Glacial striations reveal ancient continental connections.

The distribution of glacial features can be best explained if the continents were part of Pangaea.

Plate Tectonics

Glacial Striations

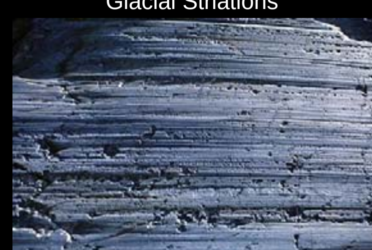


Plate Tectonics

Glacial Striations

Plate Tectonics

Glacial Striations

Plate Tectonics

Overlapping Fossil assemblages

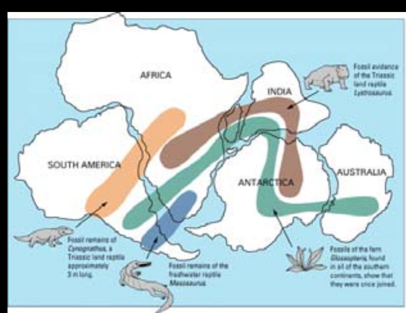


Plate tectonics

New evidence supporting Wegener:

1. Sea floor spreading
2. Magnetic sea floor patterns
3. Sea floor age patterns

Plate Tectonics

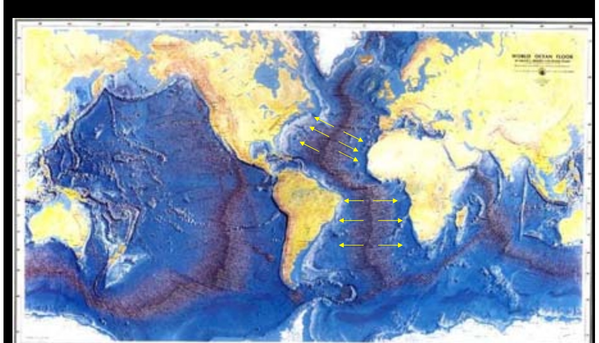


Plate Tectonics

Evidence of sea floor spreading

The planet experience periodic reversals in the poles.

Rock reflect direction of magnetism when they are created.

Sea floor reveals a mirror image of rock magnetism.

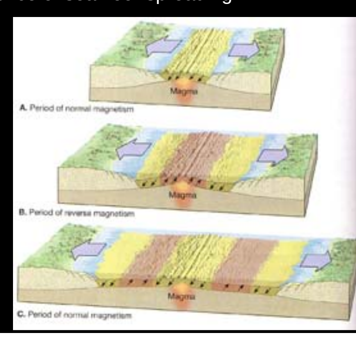


Plate Tectonics

Evidence of sea floor spreading

The planet experience periodic reversals in the poles.

Rock reflect direction of magnetism when they are created.

Sea floor reveals a mirror image of rock magnetism.

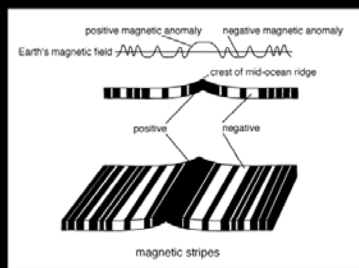
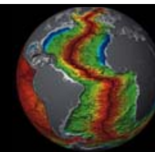
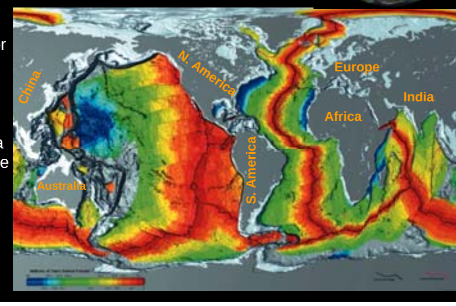


Plate Tectonics



Sea floor spreading

Age of seafloor increases at equal rates relative to oceanic rifts. The oldest sea floor is near the continents.



Evolution

Focus on how life changed after it began

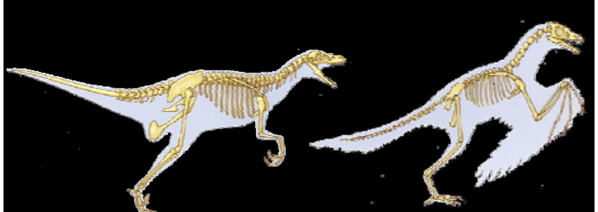
<u>Evidence</u>

- Fossils – evidence of ancient life
- Biogeography – continental movement
- Comparative Morphology – homologous structures
- Patterns of Development – similarities
- Comparative Biochemistry – cellular, molecular
- Current Observations – speciation, selection

Evidence of Evolution

<u>Fossils</u> – buried remains and impressions of organisms that lived in the past

- stratified layers of sedimentary rock are a historical record of life
- the fossil record provides a uniformly good documentation of the life of the past
- relative and absolute dating methods



Dromaeosaurus *Archaeopteryx*

Evidence of Evolution

<u>Biogeography</u> – involves continental movement

- Theory of Continental Drift
- Plate Tectonics
- Distributions of fossils and descendants

Evidence of Evolution

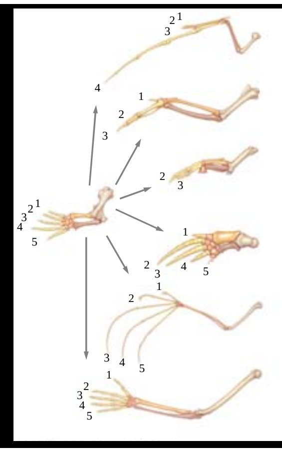
Comparative Morphology – evidence of descent with modification

- juvenile hoatzin and *Archaeopteryx*
- forelimbs
- vestigial structures
- transitional forms

Homologous Bones

Radius

Stem Reptile



PTEROSAUR

CHICKEN

PENGUIN

PORPOISE

BAT

HUMAN

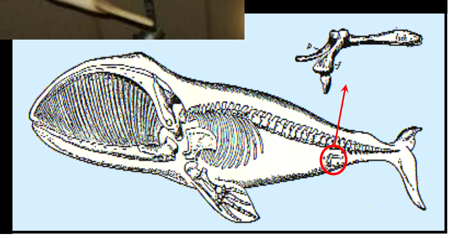
Figure 17.9 from page 266 of your text

Homologous Structures

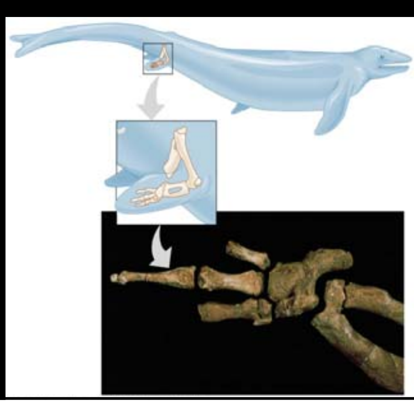
Radius

Vestigial Structures

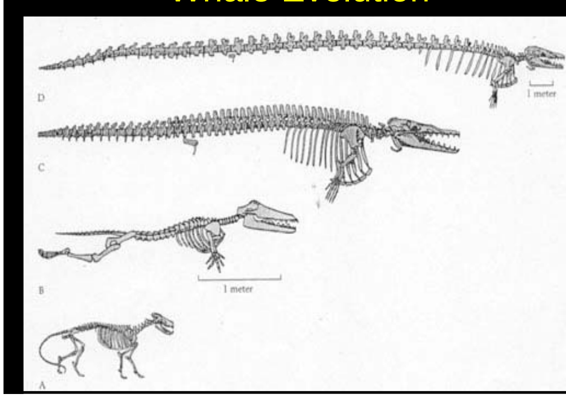
whale hind limbs



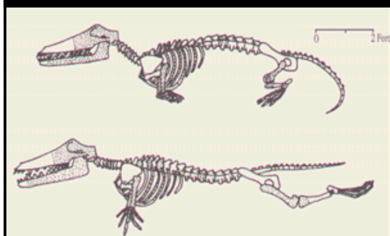
Vestigial Structures – Indicate Relatedness



Whale Evolution



Whale Evolution – Transitional Species

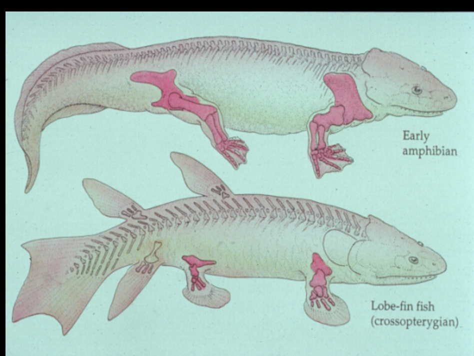


Ambulocetus lived both on land and in water. It is believed that this is a linking species between modern whales and terrestrial whale ancestors.

Transition – Fish to Tetrapod

Latimeria menadoensis
coelacanth

Transition – Fish to Tetrapod

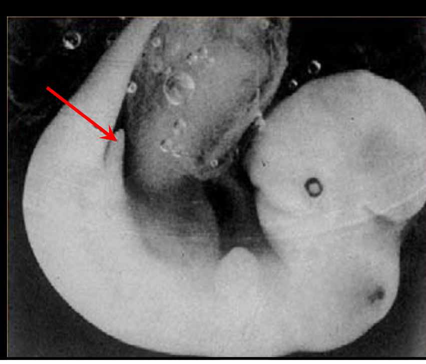


Evidence of Evolution

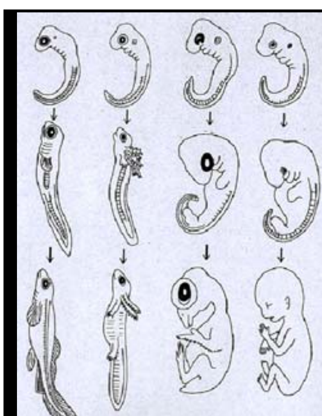
Patterns of Development – during some stages of development, organisms exhibit ancestral features in whole or incomplete form.

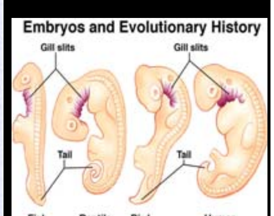
- whale hind limb buds in the embryo
- vertebrate embryo similarities

Whale Embryo Hind Limb Bud



Vertebrate Embryo Similarities





Evidence of Evolution

Comparative Biochemistry – at the cellular and molecular level living things are remarkably similar to each other

- plant and animal cells have mostly same organelles
- cytochrome c similarities
- nucleic acid hybridization

Cytochrome c Comparisons

Figure 17.14 from page 270 of your text

=identical sequences

=identical for 2

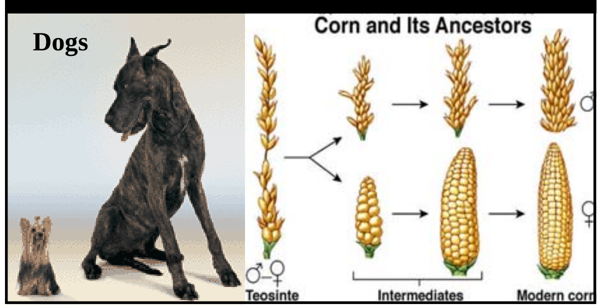
Top row=yeast
Middle row=wheat
Bottom row=primate

Evidence of Evolution

Current Observations – speciation, selection

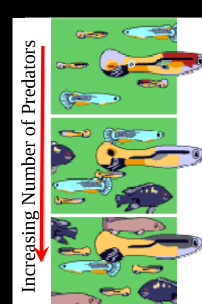
- artificial selection (breeding)
- natural selection
- experiments
- speciation

Artificial Selection



Natural Selection

Experimental Evidence



Female guppies prefer to mate with brightly colored males. John Endler transplanted predators in a stream without predators and strong selection quickly produced males with a duller coloration.

Species and Populations

- The biological species concept defines a species as groups of actually, or potentially, interbreeding natural populations of organisms that are reproductively isolated from other such groups.
- A population is defined as a unit of a species comprising those organisms that are actually interbreeding.

Biological Species Concept

"Species are groups of interbreeding natural populations that are reproductively isolated from other such groups."

Ernst Mayr

Morphology & Species

- Morphological traits may not be useful in distinguishing species
  - Members of same species may appear different because of environmental conditions
  - Morphology can vary with age and sex
  - Different species can appear identical

Variable Morphology

Grown in water

Grown on land

Arrangements of Populations Within a Species

- **Allopatric** populations: when the geographic ranges of 2 populations do not overlap we say the populations are allopatric (geographic isolation).
- **Parapatric** populations: populations abut
- **Sympatric** populations: populations overlap in space

Reproductive Isolation

- Cornerstone of the biological species concept.
- Speciation is the attainment of reproductive isolation.
- Reproductive isolation arises as a by-product of genetic change.

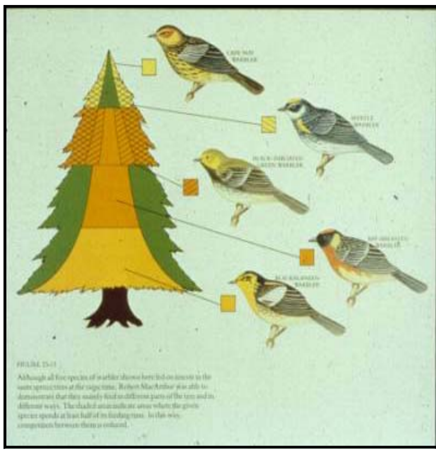
Reproductive Isolating Mechanisms

- Prezygotic isolation
  - Mating or zygote formation is prevented
- Postzygotic isolation
  - Takes effect after hybrid zygotes form
  - Zygotes may die early, be weak, or be sterile

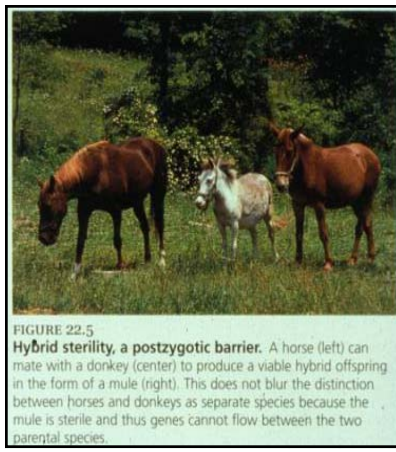
Mechanisms of Reproductive Isolation

A. Pre–zygotic
1. Spatial isolation
2. Ecological isolation
3. Temporal isolation
4. Behavioral isolation
5. Mechanical isolation
6. Gametic isolation

B. Post–zygotic
1. Hybrid inviability
2. Hybrid sterility
3. Hybrid breakdown



Ecological Isolation

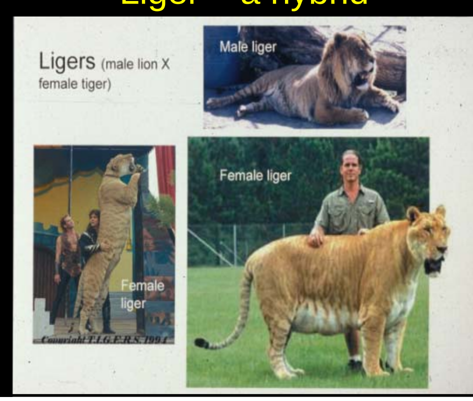


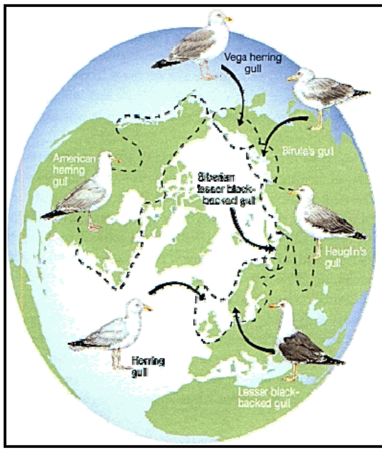
Hybrid Sterility: A Postzygotic Barrier

Tiglon – a hybrid

Male Tiger X Female Lion

Liger – a hybrid



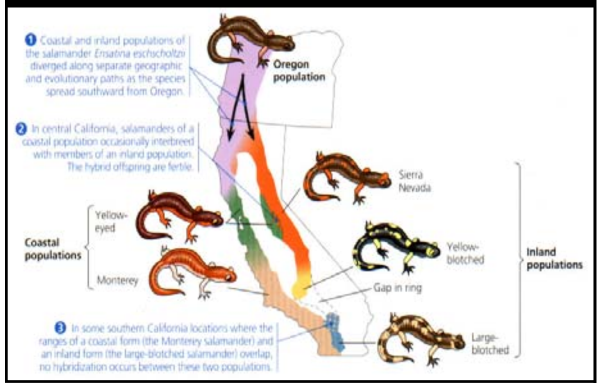


Ring Species in Gulls

Can hybridize except for 2 species at endpoint of ring

Speciation in Progress

Ensatina eschscholtzii



A Lineage

Lineage – a group of organisms related by descent from a common ancestor - A temporal view.

4 Fates of a Lineage

1. Populations can appear the same phenotypically over time. We call this **stasis.** Examples: crocodilians, beetles, horseshoe crabs.
2. The populations may change over time, either due to natural selection or because of chance effects (e.g., genetic drift or founder effects), but these changes are all **anagenetic** effects. They don't lead to any separation of one lineage from another. Examples: peppered moths over the last 100 years, horses.
3. When changes do lead to separation of a lineage from other lineages, we call these changes **cladogenetic** because new clades arise that are genetically separated from other lineages. When gene flow stops between two populations or two lineages, the lineages are reproductively isolated from one another. Example: mammals.
4. There is a fourth possible outcome for changes within populations – **extinction**. Example: dinosaurs.

Stasis

crocodilians

Stasis

Leaf Beetles

Recent

30 Million Years Old from amber

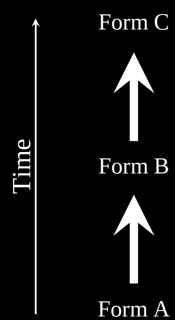
Stasis

Horseshoe Crabs

4 Fates of a Lineage

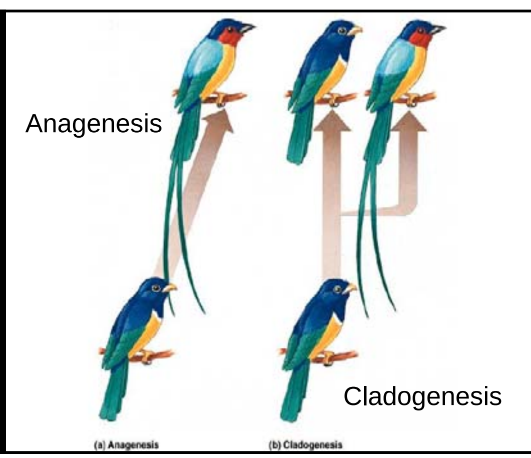
1. Populations can appear the same phenotypically over time. We call this **stasis.** Examples: crocodilians, beetles, horseshoe crabs.
2. The populations may change over time, either due to natural selection or because of chance effects (e.g., genetic drift or founder effects), but these changes are all **anagenetic** effects. They don't lead to any separation of one lineage from another. Examples: peppered moths over the last 100 years, horses.
3. When changes do lead to separation of a lineage from other lineages, we call these changes **cladogenetic** because new clades arise that are genetically separated from other lineages. When gene flow stops between two populations or two lineages, the lineages are reproductively isolated from one another. Example: mammals.
4. There is a fourth possible outcome for changes within populations – **extinction**. Example: dinosaurs.

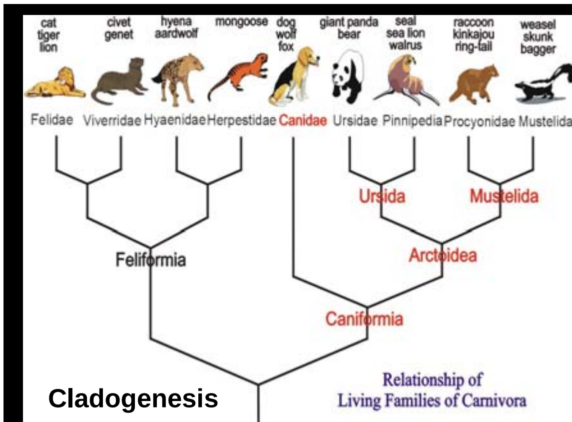
Anagenesis



4 Fates of a Lineage

1. Populations can appear the same phenotypically over time. We call this **stasis.** Examples: crocodilians, beetles, horseshoe crabs.
2. The populations may change over time, either due to natural selection or because of chance effects (e.g., genetic drift or founder effects), but these changes are all **anagenetic** effects. They don't lead to any separation of one lineage from another. Examples: peppered moths over the last 100 years, horses.
3. When changes do lead to separation of a lineage from other lineages, we call these changes **cladogenetic** because new clades arise that are genetically separated from other lineages. When gene flow stops between two populations or two lineages, the lineages are reproductively isolated from one another. Example: mammals.
4. There is a fourth possible outcome for changes within populations – **extinction**. Example: dinosaurs.





Patterns of Change in a Lineage

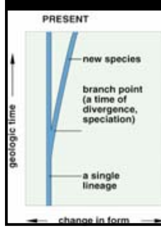
- Cladogenesis
  - Branching pattern
  - Lineage splits, isolated populations diverge
- Anagenesis (phyletic evolution)
  - No branching
  - Changes occur within single lineage
  - Gene flow throughout process

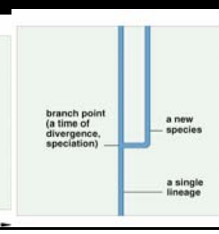
Evolutionary Tree Diagrams

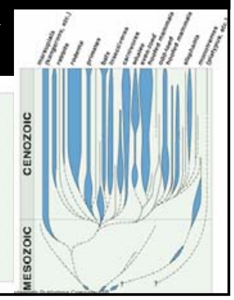
Many branchings of the same lineage. Adaptive radiation has taken place.

Species formed through gradual change.

Rapid change in traits. Traits of new species did not change much after.







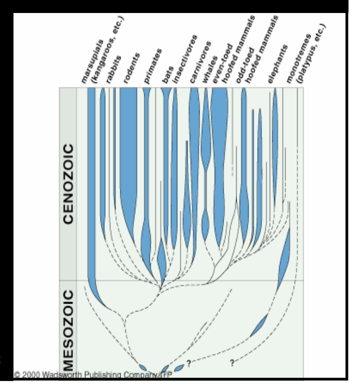
Adaptive Radiation

- Burst of divergence
- Single lineage gives rise to many new species
- New species fill vacant adaptive zone
- Adaptive zone is "way of life"

Adaptive Radiation of Mammals

Burst of divergences giving rise to many new species.

Figure 17.26 from page 279 of your text



4 Fates of a Lineage

1. Populations can appear the same phenotypically over time. We call this **stasis.** Examples: crocodilians, beetles, horseshoe crabs.
2. The populations may change over time, either due to natural selection or because of chance effects (e.g., genetic drift or founder effects), but these changes are all **anagenetic** effects. They don't lead to any separation of one lineage from another. Examples: peppered moths over the last 100 years, horses.
3. When changes do lead to separation of a lineage from other lineages, we call these changes **cladogenetic** because new clades arise that are genetically separated from other lineages. When gene flow stops between two populations or two lineages, the lineages are reproductively isolated from one another. Example: mammals.
4. There is a fourth possible outcome for changes within populations – **extinction**. Example: dinosaurs.

Extinction

- Irrevocable loss of a species
- Mass extinctions have played a major role in evolutionary history
- Fossil record shows 20 or more large-scale extinctions
- Reduced diversity is followed by adaptive radiation

Dodo Bird

The dodo bird inhabited the island of Mauritius in the Indian Ocean, where it lived undisturbed for so long that it lost its need and ability to fly. It lived and nested on the ground and ate fruits that had fallen from trees.

The combination of human exploitation and introduced species to the habitat eventually led to their demise with extinction in 1681.

Moa

A mere 1,000 years ago, giant flightless birds called moas inhabited the islands of New Zealand. There were more than a dozen species of moa and the largest of these may have weighed more than 200 kilograms and stood 2 to 3 meters high.

Human beings did not colonize New Zealand until about 1,000 years ago when the first Polynesians arrived. These new arrivals hunted the moas and it seems unlikely that any of the species survived into the time of the first contact with Europeans in 1770.

Tasmanian Wolf (Thylacine)

This remarkable animal looked like a wolf with tiger stripes on its back and tail, but it was more closely related to kangaroos than to either tigers or wolves. The Tasmanian tiger-wolf was a marsupial; it had a pouch for its young just like a kangaroo. Marsupials are found almost exclusively in Australia and certain surrounding islands such as Tasmania. The population was decimated by an unknown disease in the early 1900s. Determined extinct in 1936.

Caribbean Monk Seal

The Caribbean Monk seal is probably extinct. Caribbean Monk seals were sometimes spotted with a green-flecked back, probably caused by an algal growth. The pups were born in December and had a woolly coat. The last time a Caribbean Monk seal was sighted was in the early 1950s.

Stellar's Sea Cow

When the sea cow was discovered in Alaska, it was already rare; there were perhaps 1,000 to 2,000 individuals. Bering's crew killed many of the remaining sea cows for their meat and hides, as their ship was stranded in Alaska and they were forced to remain there. Subsequent expeditions to the area killed the rest. The Steller's sea cow probably was extinct by 1768.

Passenger Pigeon

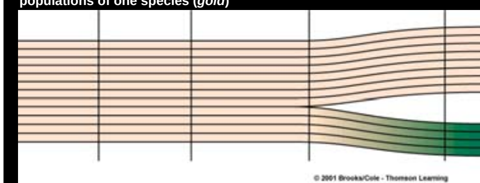
The passenger pigeon became extinct in 1914, after the last individual, Martha, died in captivity in the Cincinnati Zoo. The passenger pigeon was one of the most abundant bird species on Earth. It was driven to extinction by uncontrolled commercial hunting for their meat which was desired by Euroamerican settlers.

Quagga

The last Quagga, a mare at an Amsterdam zoo, died in 1883. It went extinct in the wild in the 1870s. Quaggas lived in desert environments in Africa. These social animals were closely related to the modern-day zebras and horses. Quaggas were herbivores who ate grasses. They were nomadic and spent most of their time grazing.

Genetic Change and Speciation

- Any structural, functional, behavioral difference that brings about reproductive isolation
- Genetic divergence
  - Geographic barrier



Speciation & Natural Selection

- Natural selection *can* lead to speciation
- Speciation can also occur as a result of other microevolutionary processes
  - Genetic drift
  - Mutation

Genetic Divergence

- Gradual accumulation of differences in the gene pools of populations.
- Natural selection, genetic drift, and mutation can contribute to divergence.
- Gene flow counters divergence

Mechanisms of Speciation

- Allopatric speciation
- Sympatric speciation
- Parapatric speciation

Allopatric Speciation

- Speciation in geographically isolated populations.
- Probably most common mechanism.
- Some sort of barrier arises and prevents gene flow.
- Effectiveness of barrier varies with species.

Extensive Divergence Prevents Inbreeding

- Species separated by geographic barriers will diverge genetically.
- If divergence is great enough it will prevent inbreeding even if the barrier later disappears.

Vicariance & Dispersal

Vicariance:

- Populations can be separated by some geographic change, like a river or a mountain range.

Dispersal:

- Subpopulations can leave a population for a new habitat – migration to an island.

Allopatric Speciation in Wrasses

- Isthmus of Panama arose and separated wrasses in Atlantic and Pacific.
- Since separation, genes for certain enzymes have diverged in structure.
- Divergence may be evidence of speciation in progress.

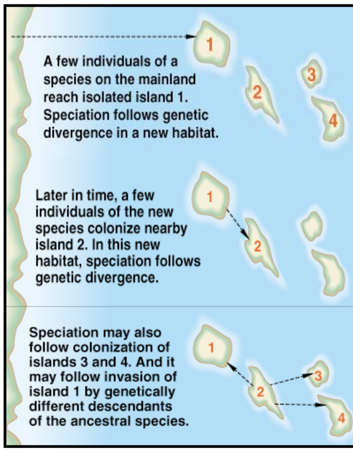
Rainbow wrasses

Allopatric Speciation

Grand Canyon, Arizona

Archipelagos

- Island chains distant from continents.
  - Galapagos Islands
  - Hawaiian Islands
- Colonization of islands followed by genetic divergence sets the stage for speciation.



Allopatric Speciation on an Isolated Archipelago

Physical barrier prevents gene flow between populations of species

Figure 17.20 from page 275 of your text

Hawaiian Islands

- Volcanic origins, variety of habitats.
- Adaptive radiations:
  - Honeycreepers - In absence of other bird species, they radiated to fill numerous niches.
  - Fruit flies (*Drosophila*) - 40% of fruit fly species are found in Hawaii

Allopatric Speciation in Hawaiian Honeycreepers

- New arrival in species
  - Poor habitats on an isolated Archipelago
  - Start of allopatric speciation

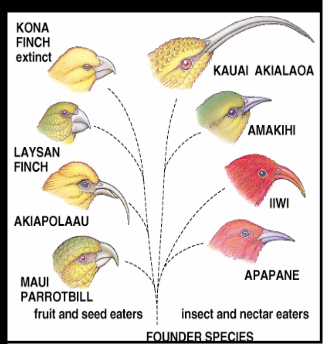


Figure 17.7 from page 265 of your

Allopatric Speciation in Hawaiian Drosophila

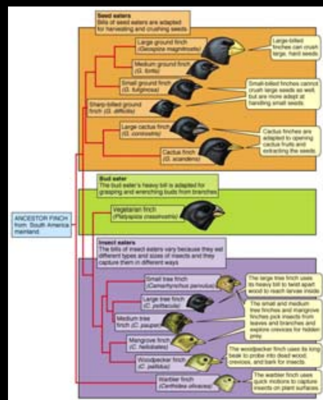
Galapagos Islands

Galapagos Islands

Darwin's finches

•Example of dispersal allopatric speciation.

•Example of adaptive radiation.



Speciation without a Barrier

- Sympatric speciation
  - Species forms within the home range of the parent species.
- Parapatric speciation
  - Neighboring populations become distinct species while maintaining contact along a common border.

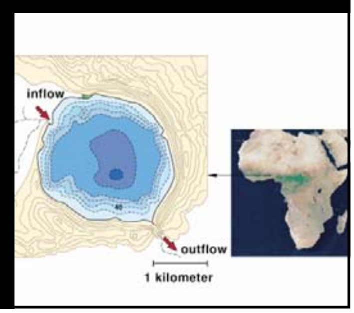
Sympatric Speciation in African Cichlids

- Studied fish species in two lakes
  - Species in each lake are most likely descended from single ancestor.
- No barriers within either lake.
- Some ecological separation but species in each lake breed in sympatry.

Sympatric Speciation

Map of Lake Barombi Mbo in Cameroon, West Africa

Nine kinds of cichlids evolved in this isolated crater lake

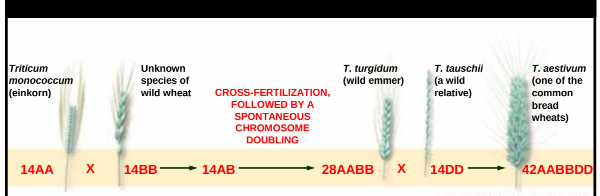


Parapatric Speciation

Adjacent populations evolve into distinct species while maintaining contact along a common border

HYBRID ZONE

Possible Evolution of Wheat



Barriers to Gene Flow

- Whether or not a physical barrier deters gene flow depends upon:
  - Organism's mode of dispersal or locomotion
  - Duration of time organism can move

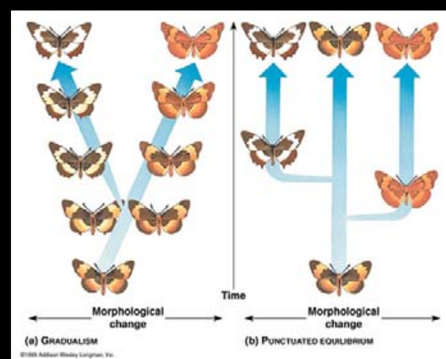
Gradual Model

- Speciation model in which species emerge through many small morphological changes that accumulate over a long time period
- Fits well with evidence from certain lineages in fossil record

Punctuation Model

- Speciation model in which most changes in morphology are compressed into brief period near onset of divergence
- Supported by fossil evidence in some lineages

Punctuation Model



Evolutionary Rates

- These two models illustrate that evolution does not proceed at a constant rate.
- Evolutionary rates may be lineage dependant, environmentally dependant or a combination of both.

We're All Related

- All species are related by descent
- Share genetic connections that extend back in time to the prototypical cell