Evolution

Impacts, Issues
Measuring Time

- Evidence of events that happened millions of years ago – such as meteor impacts – lead to inferences about evolution of life on Earth

Early Beliefs, Confounding Discoveries

- Belief systems are influenced by the extent of our knowledge
- Beliefs that are inconsistent with systematic observations of the natural world tend to change over time

Naturalists and Biogeography

- Aristotle was one of first **naturalists** – people who observe life from a scientific perspective

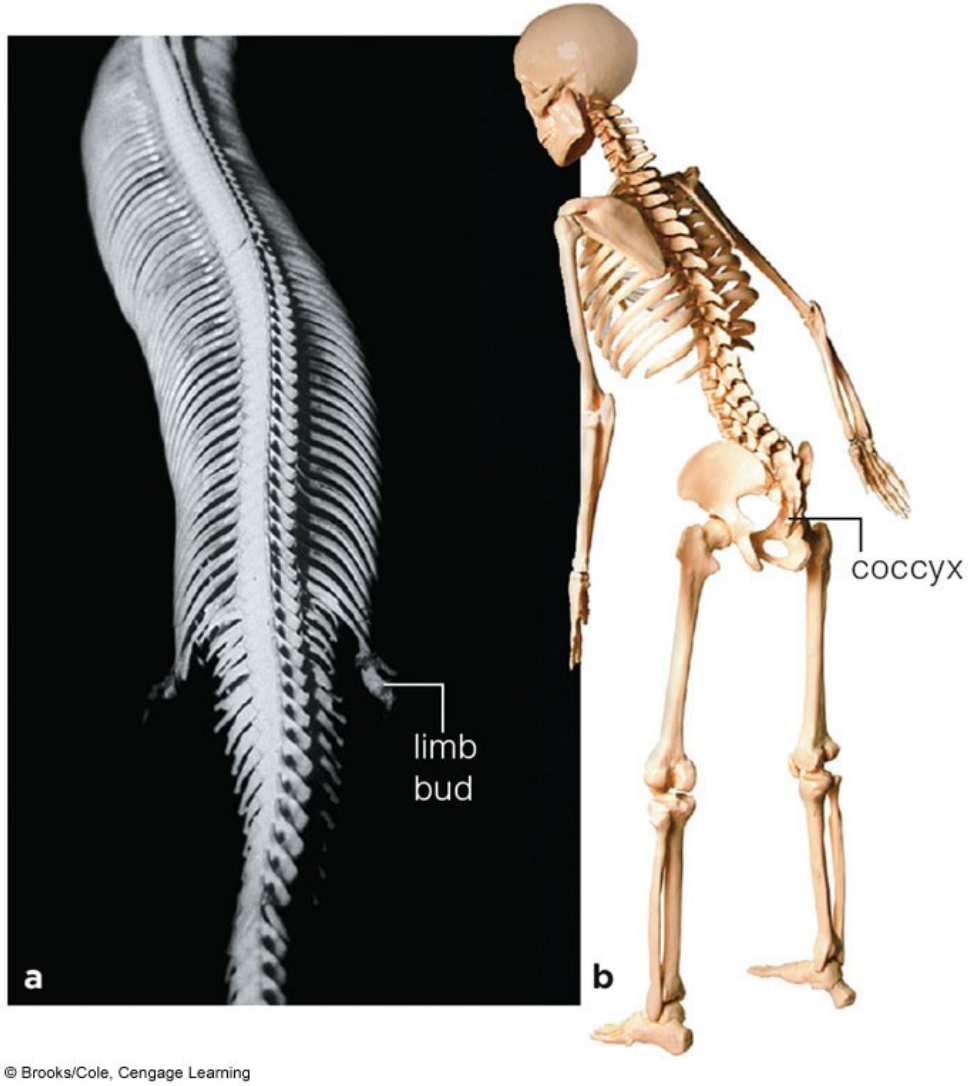
- In the late 1800s, Alfred Wallace and others were pioneers in **biogeography** – the study of patterns in the observation of species

Patterns in Biogeography

Comparative Morphology

- **Comparative morphologists** study body plans and structures among groups of organisms
  - Some organisms are outwardly similar, but different internally; others differ outwardly, but have similar internal structures
  - Some organisms have vestigial parts with no apparent function

Vestigial Body Parts

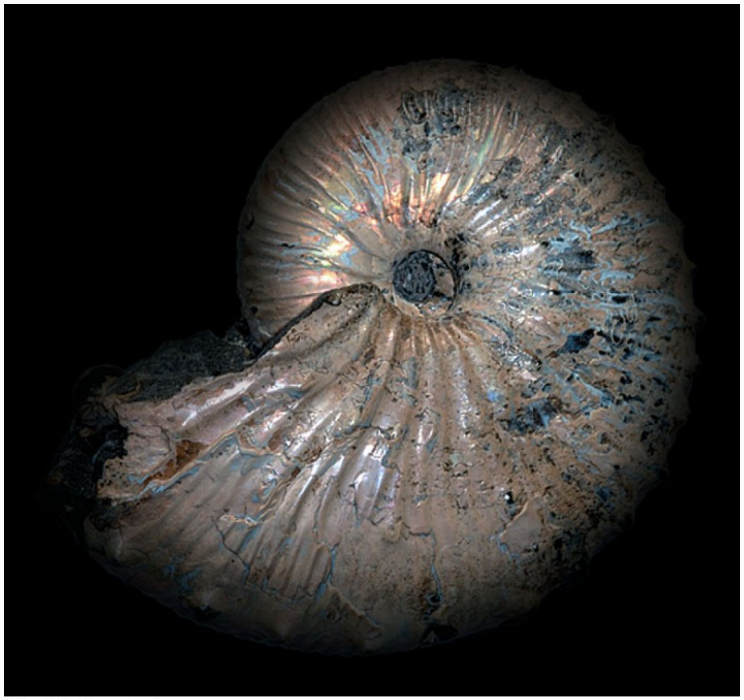


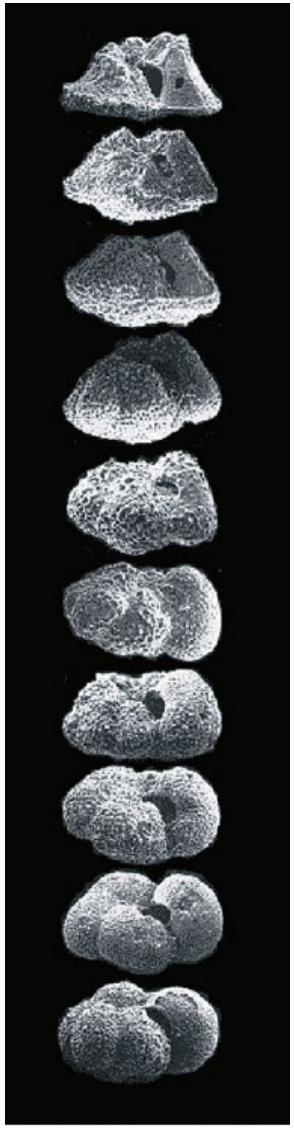
Geology

- Geologists found identical sequences of rock layers in different parts of the world
  - Different layers held different **fossils** – evidence of earlier forms of life

- Cumulative findings from biogeography, comparative morphology, and geology led to new ways of thinking about the natural world

Fossils





A Flurry of New Theories

- By the 1800s, many scholars realized that life on Earth had changed over time, and began to think about what could have caused the changes

nd Old Beliefs

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- Jean-Baptiste Lamarck proposed that individuals changed in response to their environment, and passed those changes on to their descendents - theory of inheritance of acquired characteristics

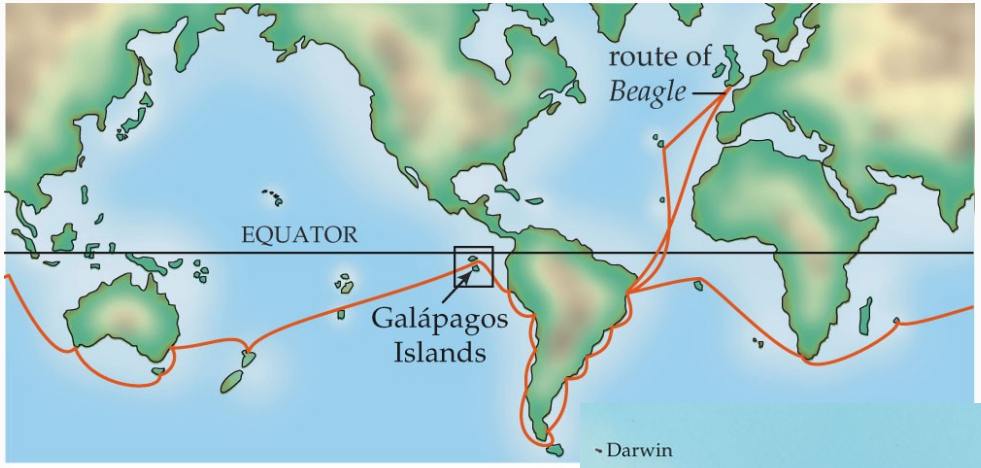
Reconsidering Old Beliefs

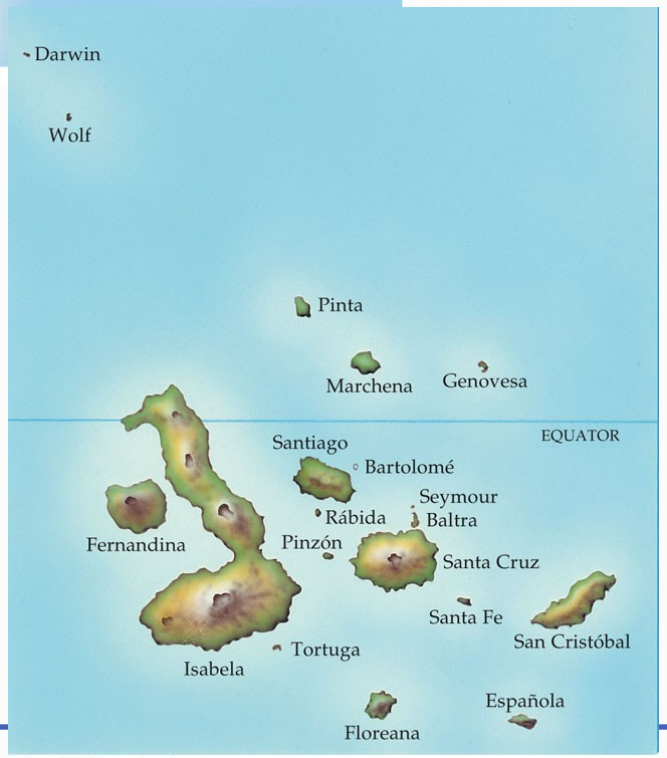
- **Theory of uniformity**
  - Lyell's book, *Principles of Geology*, proposed that gradual, repetitive geological processes shaped the Earth over great spans of time
  - Lyell's insights shaped Charles Darwin's thinking during his five-year voyage on the *Beagle*

Voyage of the *Beagle*

- Darwin observed unusual fossils and diverse species in a range of habitats

Beagle and The Galapagos Islands





Key Concepts
Emergence of Evolutionary Thought

- *Long ago, naturalists started to catalog previously unknown species and think about the global distribution of all species*

- *They discovered similarities and differences among major groups, including those represented as fossils in layers of sedimentary rock*

Darwin and Natural Selection

- Darwin's observations of species in different parts of the world helped him understand a driving force of evolution – natural selection

A Key Insight – Variation in Traits

- Darwin's observations:
  - Populations can produce more individuals than their environment can support
  - Some versions of a trait might enhance an individual's ability to survive and reproduce in its particular environment
  - *Example:* Finches in the Galapagos Islands

Finches in the Galapagos Islands

Natural Selection

- **Natural selection**
  - Differential survival and reproduction among individuals of a population that vary in details of shared, inherited traits

- **Adaptive trait**
  - Any trait that enhances an individual's **fitness** (ability to survive and reproduce in a particular environment)

Great Minds Think Alike

- Darwin's insights into evolution were made possible by contributions of scientists who preceded him
- Alfred Wallace independently developed the idea of evolution by natural selection

Alfred Wallace

- Wallace drew on his own observations of plant and animal species and proposed that natural selection is a driving force of evolution

Main Premises of the Theory of Natural Selection

1. A population tends to grow until it begins to exhaust the resources of its environment

2. Individuals must then compete for resources such as food and shelter from predators

3. Individuals with forms of traits that make them more competitive tend to produce more offspring

Key Concepts
A Theory Takes Form

- *Evidence of evolution, or changes in lines of descent, gradually accumulated*

- *Charles Darwin and Alfred Wallace independently developed a theory of natural selection to explain how heritable traits that define each species evolve*

A summary

1. As the world got “bigger” and more explored with many new discoveries, the theories that were previously accepted were no longer acceptable
2. Many new theories arose
3. Darwin was triggered by some of these theories and formulated his own based on his experience aboard the Beagle
4. Theory of evolution through the mechanism of natural selection
5. Let’s look more closely at the “evidence”!!!

The Evidence

1. The fossil record – organisms found and the earth itself (geologists & biogeographers)
2. Anatomical Record – similarities in structures (comparative morphologists)
3. Molecular Record – traces changes in genome

- Fossils
  - The fossil record will never be complete
    - For example, crabs will appear much more than gelatinous orgs
  - However, substantial enough to help reconstruct patterns and trends in the history of life

More evidence: Drifting Continents, Changing Seas

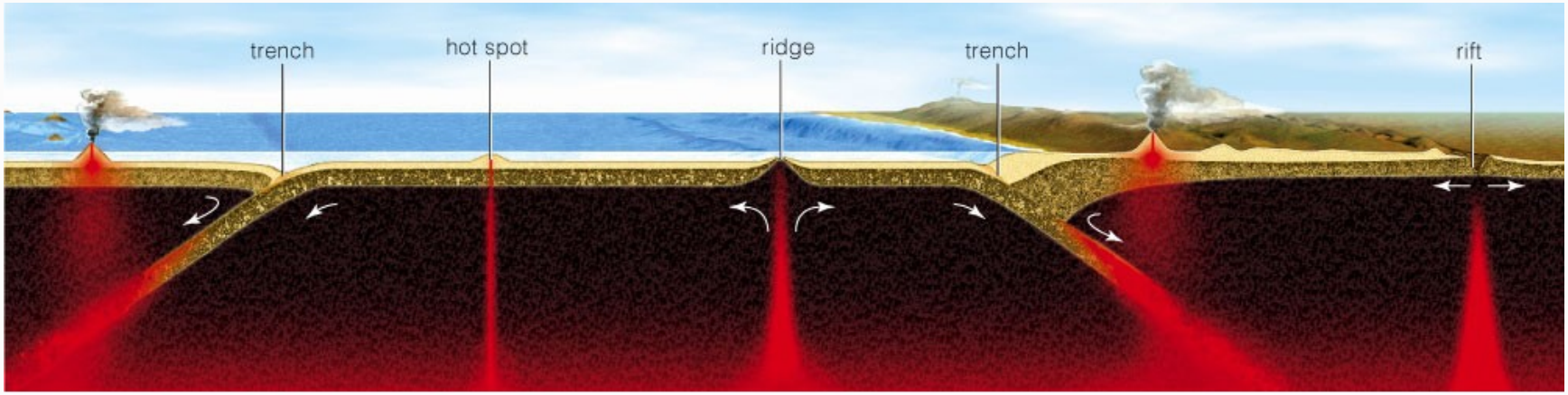
- For billions of years, slow movements of Earth's outer layer and catastrophic events have changed the land, atmosphere, and oceans, with profound effects on the evolution of life

Continental Drift

- **Continental drift**
  - All continents were once part of a supercontinent – **Pangea** – that split and drifted apart
  - *Evidence:* Magnetic rocks

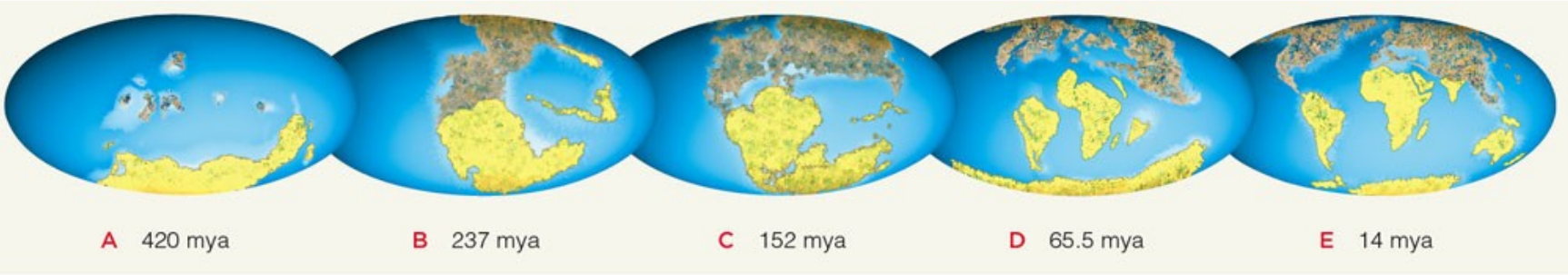
- **Plate tectonics**
  - The mechanisms of continental drift
  - Plate grow from ridges (seafloor spreading) and sink into trenches (subduction zones)

Plate Tectonics



http://www.youtube.com/v/ALwDK7oS750

The Drifting Continents



http://www.youtube.com/v/0hU7QKKjGx8

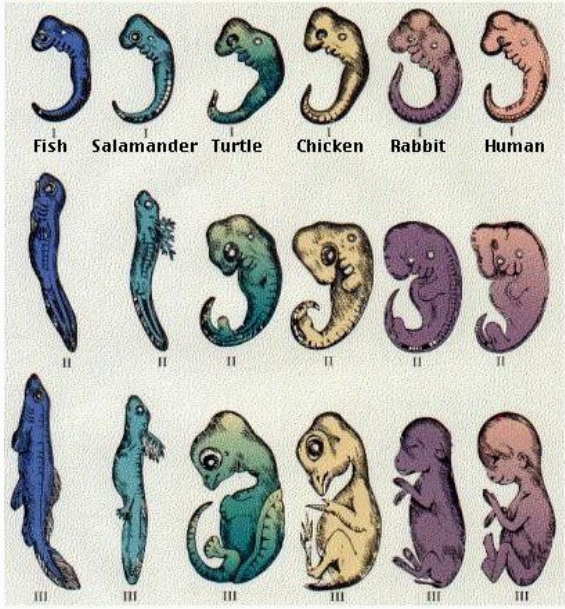
Evidence From Biogeography & Geology

- *Correlating evolutionary theories with geologic history helps explain the distribution of species, past and present*

The Evidence

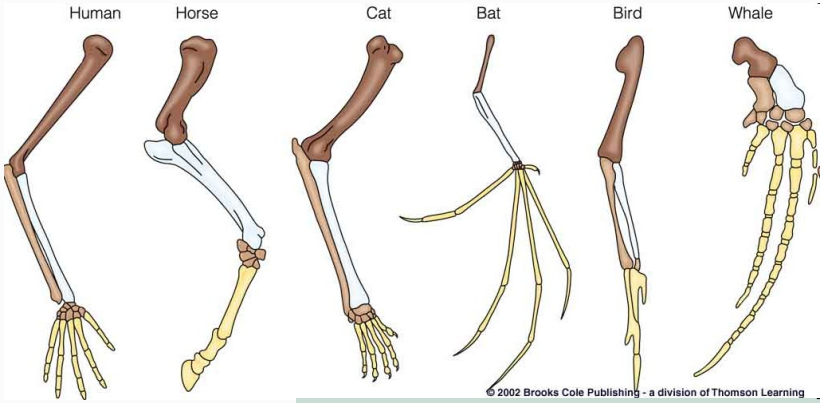
1. The fossil record – organisms found and the earth itself (geologists & biogeographers)
2. Anatomical Record – similarities in structures (comparative morphologists)
3. Molecular Record – traces changes in genome

- For example, all vertebrate embryos share similar characeristics!

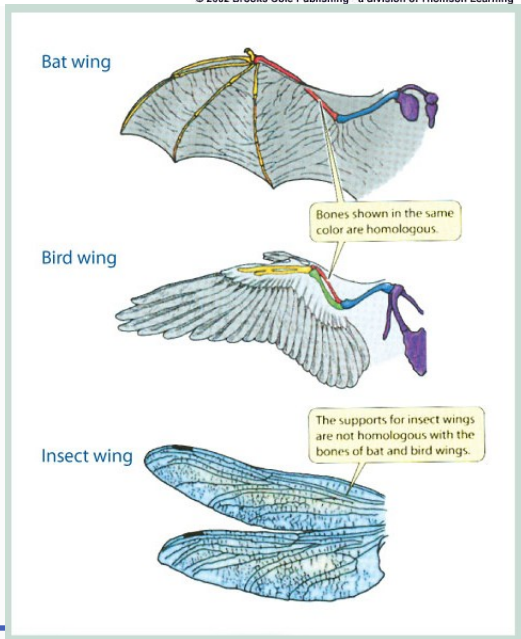


Homologous and analogous structures

- Homologous structures – similar structures although they may serve different functions. Implies a common evolutionary ancestor



- Analogous structures – similar in function but different origins. Implies convergent evolution – result of common environment



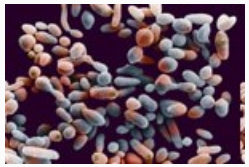
The Evidence

1. The fossil record – organisms found and the earth itself (geologists & biogeographers)
2. Anatomical Record – similarities in structures (comparative morphologists)
3. Molecular Record – traces changes in genome

98%

90%

85%



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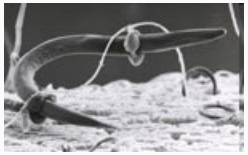

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Taxonomy

- **Taxonomy**
  - The science of naming and classifying species
- We group species based on what we know about their evolutionary relationships

Linnaean Classification

- Carolus Linneaus ranked organisms into ever more inclusive categories (**taxa**)
  - Species
  - Genus
  - Family
  - Order
  - Class
  - Phylum
  - Kingdom
  - Domain

Naming Species

- In the Linnaean system, each species is given a unique, two-part scientific name
  - *Example:* the dog rose, *Rosa canina*
- The first part is the genus name
- The second part is the species name

Linnaean Classification





DOMAIN	Eukarya	Eukarya	Eukarya	Eukarya	Eukarya
KINGDOM	Plantae	Plantae	Plantae	Plantae	Plantae
PHYLUM	Magnoliophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta	Magnoliophyta
CLASS	Magnoliopsida	Magnoliopsida	Magnoliopsida	Magnoliopsida	Magnoliopsida
ORDER	Apiales	Rosales	Rosales	Rosales	Rosales
FAMILY	Apiaceae	Cannabaceae	Rosaceae	Rosaceae	Rosaceae
GENUS	*Daucus*	*Cannabis*	*Malus*	*Rosa*	*Rosa*
SPECIES	*carota*	*sativa*	*domesticus*	*acicularis*	*canina*
COMMON NAME	carrot	marijuana	apple	arctic rose	dog rose

http://www.youtube.com/v/GF-HrAVCggk

Mechanisms of Evolution – Microevolution and Macroevolution

- Populations evolve, individuals don't!
- Population
  - Individuals of the same species in the same area
  - Generally the same number and kinds of genes for the same traits
- Gene pool
  - All the genes of a population

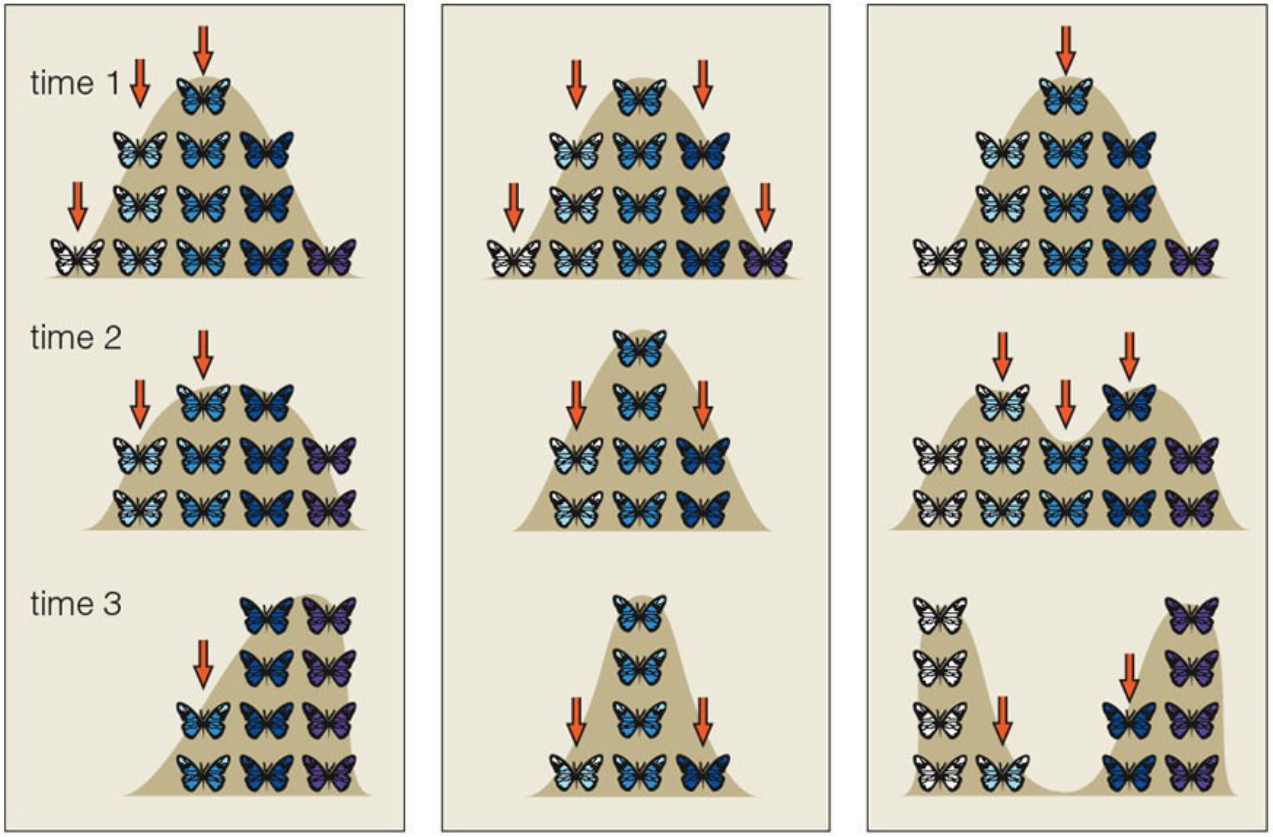
Microevolution

- Changes in allele frequencies of a population
  - Mutation
  - Natural selection
  - Genetic drift
  - Gene flow

Natural Selection

- Natural selection
  - Differential survival and reproduction among individuals of a population that show variations in details of their shared traits (alleles)
- Allele frequencies
  - Maintained by stabilizing selection
  - Shifted by directional or disruptive selection

Modes of Natural Selection



Directional selection	Stabilizing selection	Disruptive selection
Extreme form at one end of the range of phenotypes favored	Intermediate form within the range of phenotypes favored	Extreme forms at both ends of the range of phenotypes favored

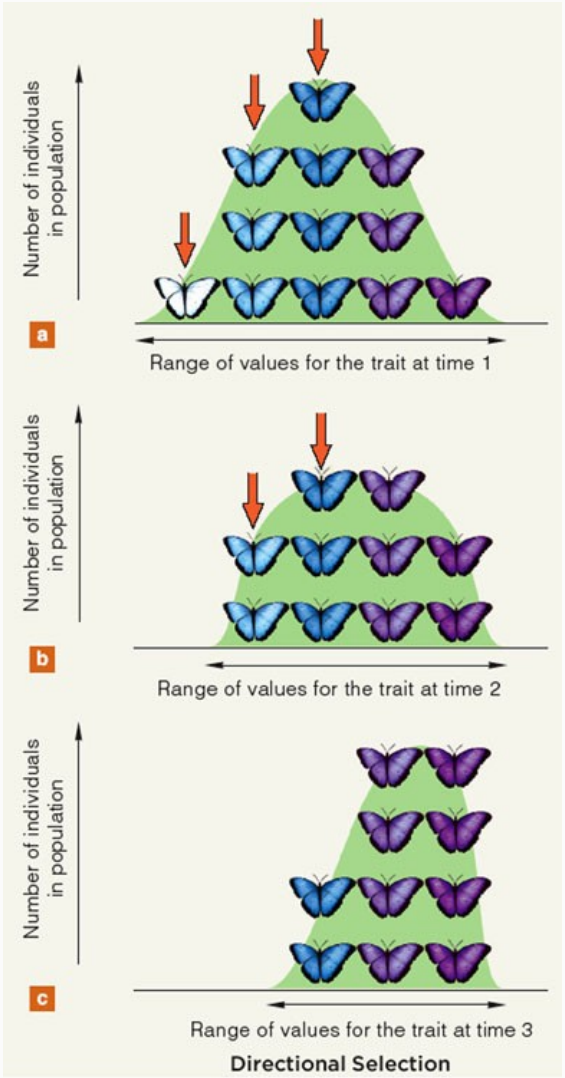
Directional Selection

- Shifts range of variation in traits in one direction
  - Individuals at one end of the range are favored; those at the other end are not

- *Examples:*
  - Peppered moth
  - Antibiotic resistance

http://www.youtube.com/watch?v=LyRA807djLc

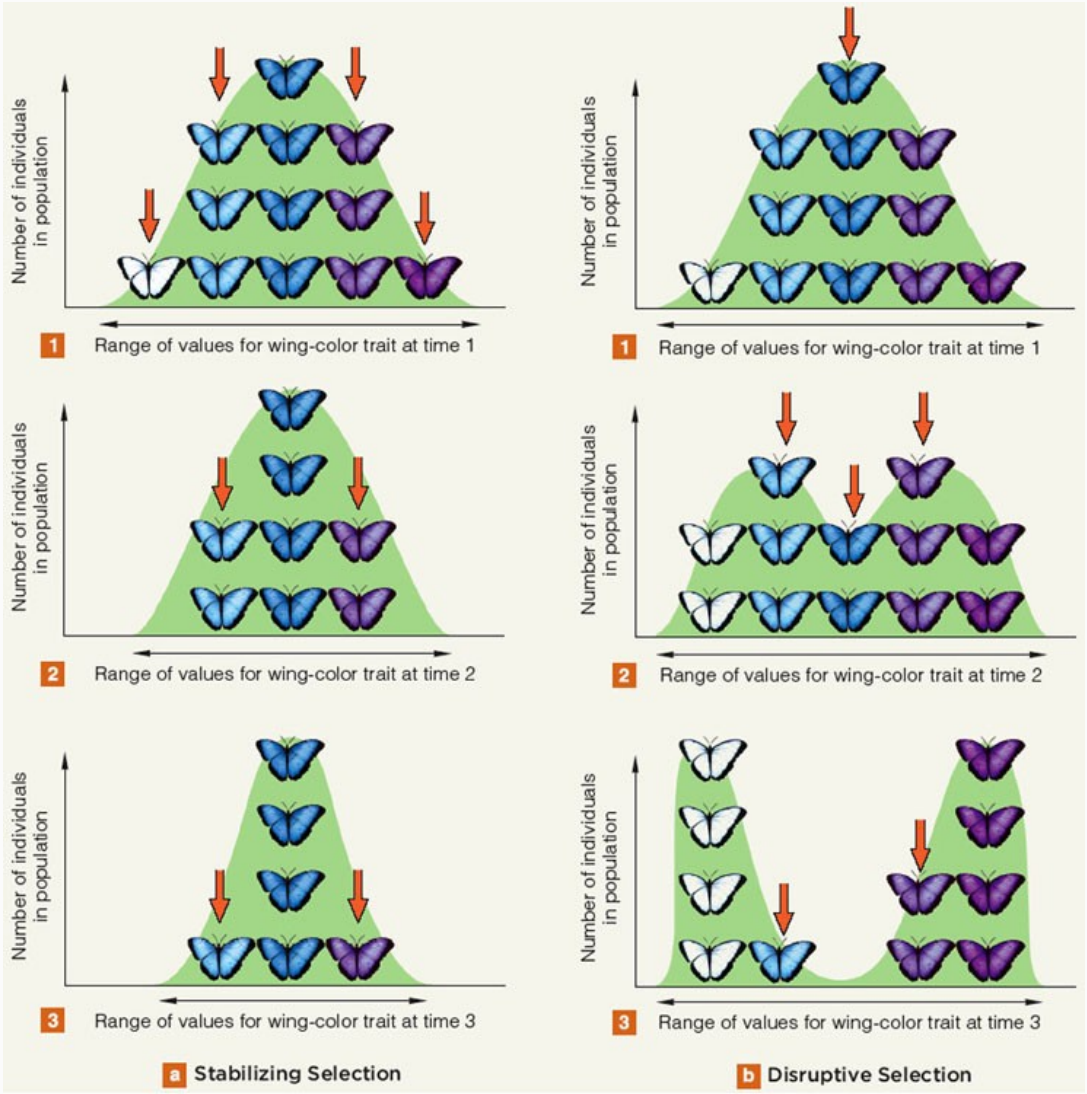
Directional Selection



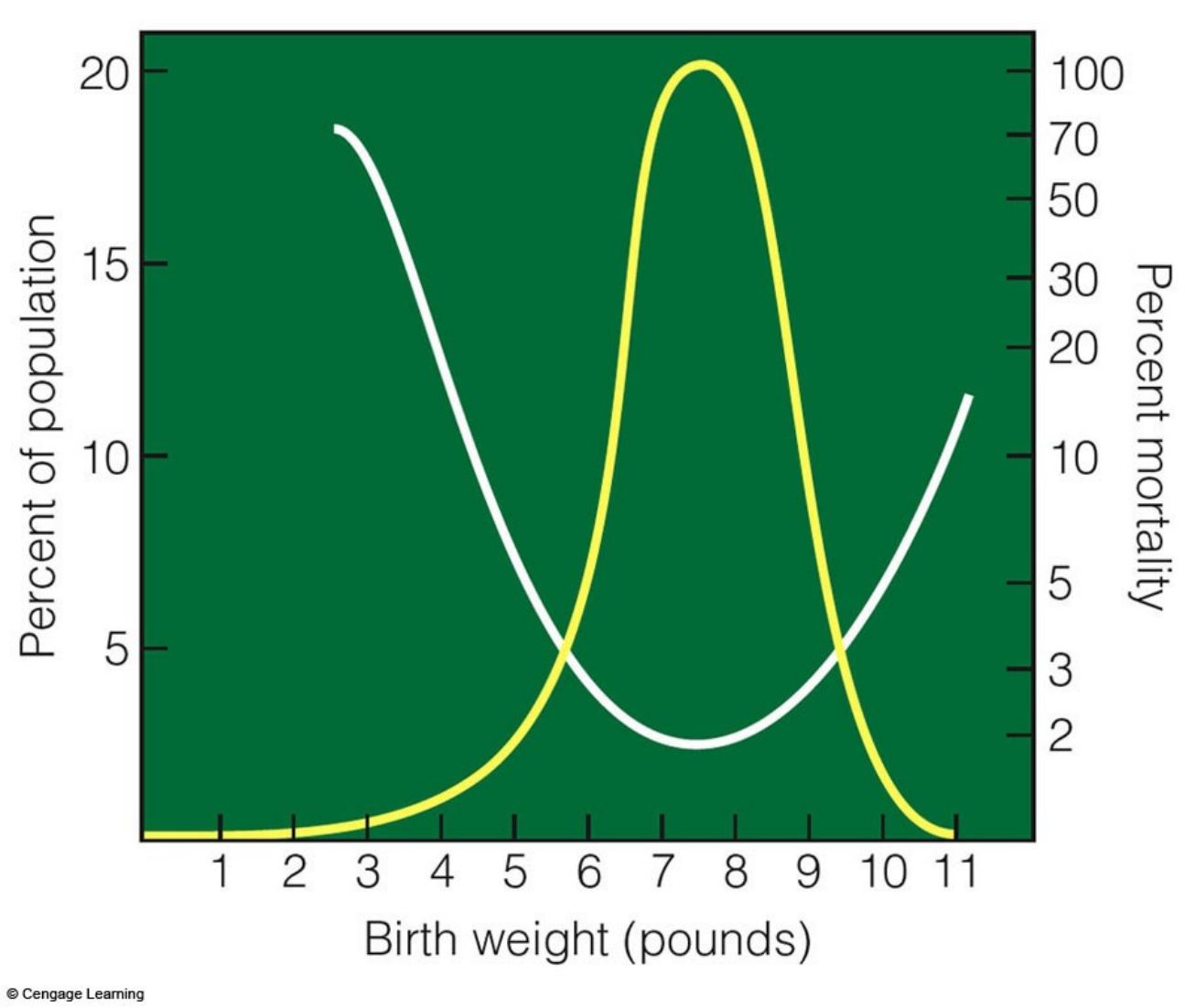
Selection For or Against Extreme Phenotypes

- Stabilizing Selection
  - Works against both extremes in the range of phenotypic variation
  - Favors intermediate forms
- Disruptive selection
  - Favors forms at extremes of the range

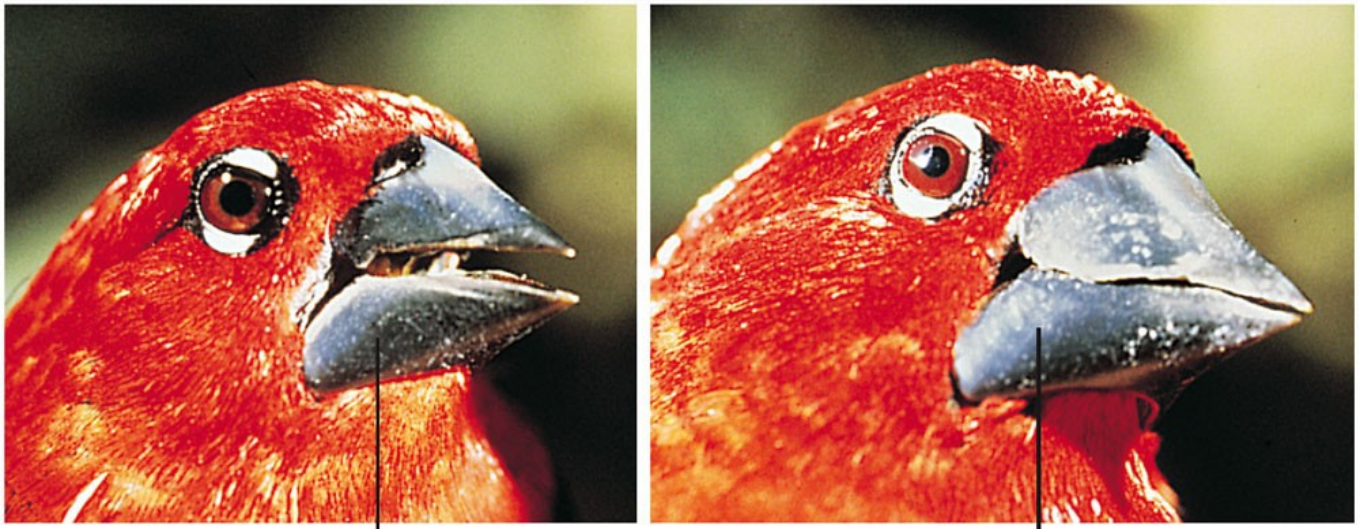
Stabilizing and Disruptive Selection

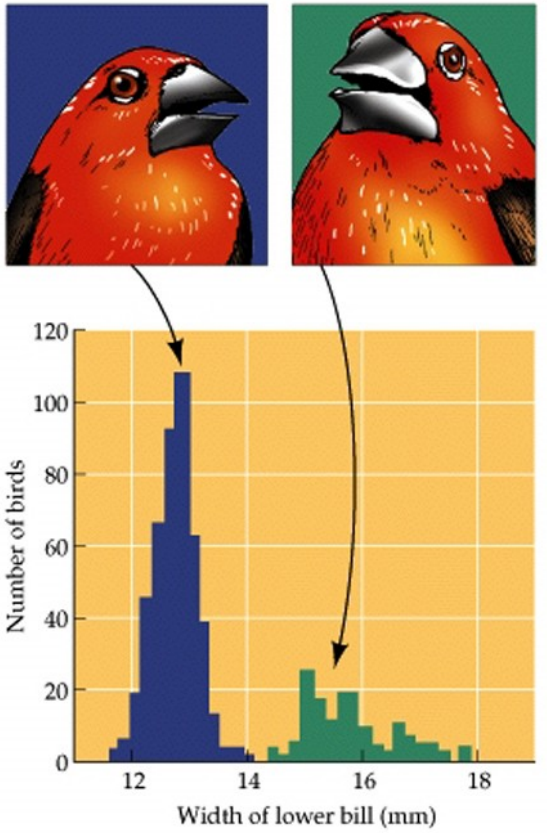


Stabilizing Selection: Birth Weight



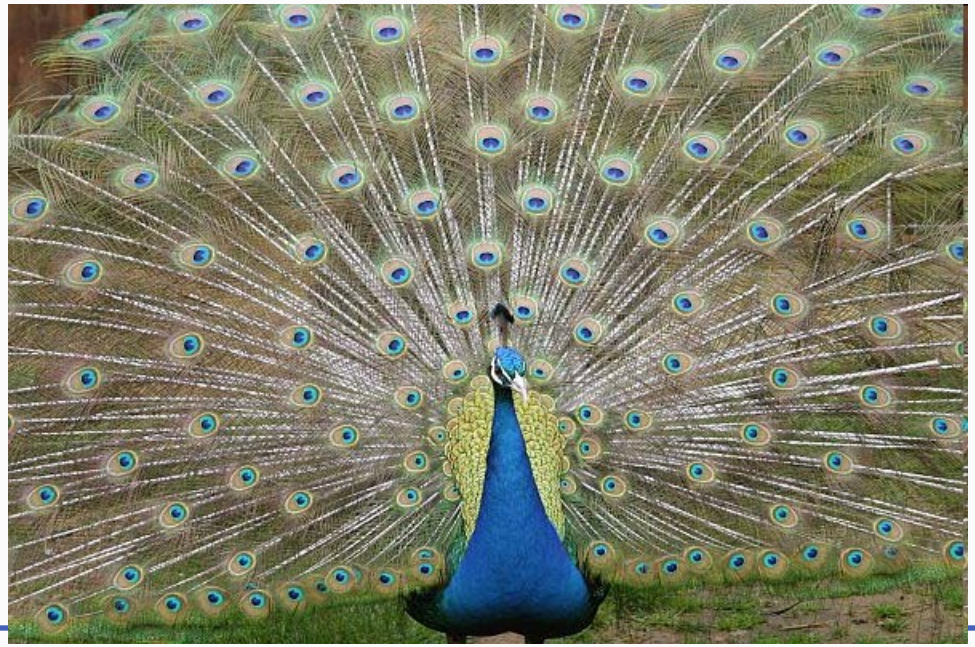
Disruptive Selection: Finch Bill Size





Sexual Selection – a form of natural selection

- A female or a male acts as an agent of selection on its own species
- Leads to trait forms that favor reproductive success



Genetic Drift

- Genetic drift
  - Random change in a population's allele frequencies over time, due to chance
  - It's not always natural selection!!!
  - Can lead to loss of genetic diversity

- Most pronounced in small or inbred populations
  - Bottleneck: Drastic reduction in population
  - Founder effect: Small founding group

Gene Flow

- Gene flow
  - Movement of alleles into or out of a population by immigration or emigration
  - Helps keep populations of same species similar

- Counters processes that cause populations to diverge (mutation, natural selection, genetic drift)

Gene Flow Between Oak Populations

Key Concepts:
MICROEVOLUTION

- *Populations evolve*
- *Individuals of a population differ in which alleles they inherit, and thus in phenotypes*
- *Over generations, any allele may increase or decrease in frequency in a population*
- *Such shifts occur by the microevolutionary processes of mutation, natural selection, genetic drift, and gene flow*

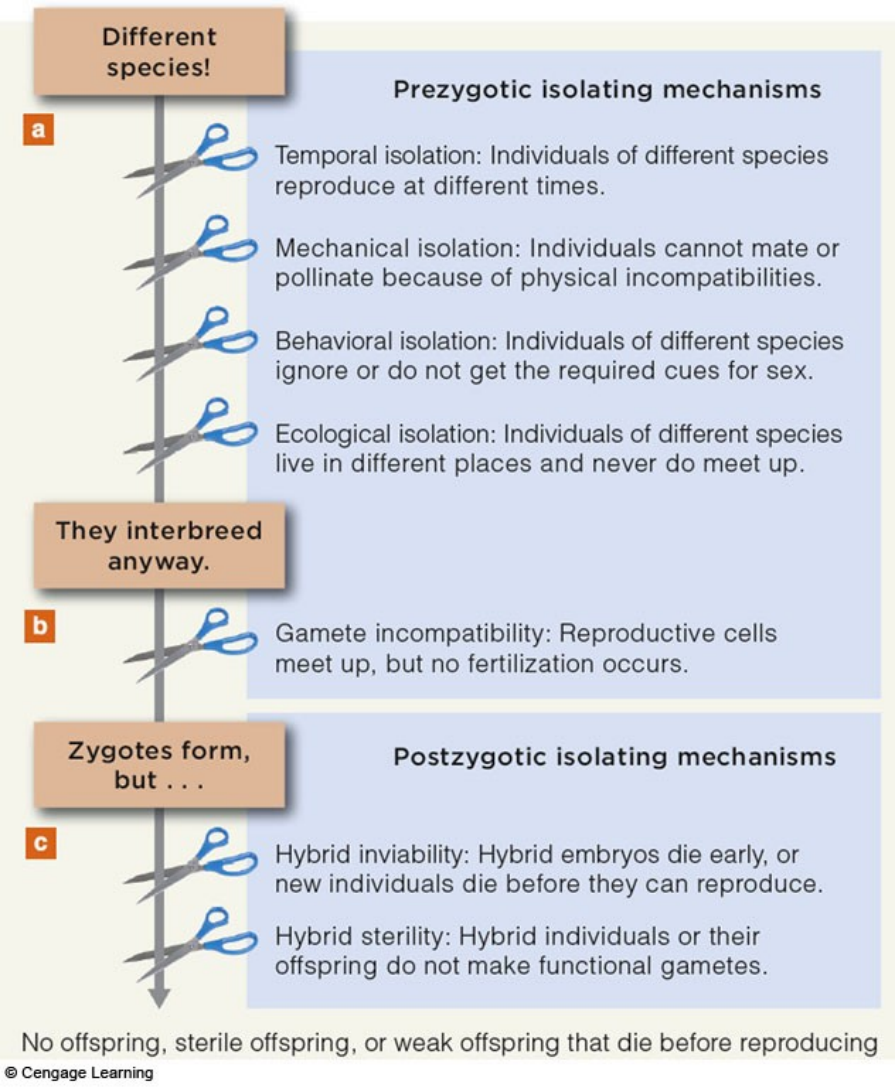
Reproductive Isolation

- Individuals of a sexually reproducing species can produce fertile offspring, but are reproductively isolated
- Reproductive isolating mechanisms evolve when gene flow between populations stops
- Divergences may lead to new species

Reproductive Isolating Mechanisms

- Prezygotic isolating mechanisms
  - Temporal isolation
  - Mechanical isolation
  - Behavioral isolation
  - Ecological isolation
  - Gamete incompatibility
- Postzygotic isolating mechanisms
  - Hybrid sterility or inviability

Reproductive Isolating Mechanisms



Key Concepts:
HOW SPECIES ARISE

- *Sexually reproducing species consist of one or more populations of individuals that interbreed successfully under natural conditions, produce fertile offspring, and are reproductively isolated from other species*

- *The origin of new species varies in details and duration*

Key Concepts: HOW SPECIES ARISE *(cont.)*

- *Typically, speciation starts after gene flow ends between parts of a population*
- *Microevolutionary events occur independently, lead to genetic divergence of subpopulations*
- *Such divergences are reinforced as reproductive isolation mechanisms evolve*

Macroevolution

- Large-scale patterns of evolution
  - One species giving rise to others
  - Origin of major groups
  - Major extinctions

- Two models:
  - Gradualism – evolution occurs very slowly, but gradually
  - Punctuated equilibrium – species experience long periods of little or no evolutionary change, interrupted by bursts of evolution

Gradualism vs. punctuated equilibrium