Chapter 5
Evolution of Biodiversity

Biodiversity

What is biodiversity?

How does evolution occur?

What is an ecological niche?

Earth is Home to a Tremendous Diversity of Species

Ecosystem diversity—the variety of ecosystems within a given region

Ecosystem Diversity

- Walk across a grassy pasture
- Cross a fence into a forest
- Traverse a stream on a series of rocks

Ecosystem Diversity

Within a few hundred yards, you've moved through at least three ecosystems.

Species Diversity

How many species did you see?

Many . . .

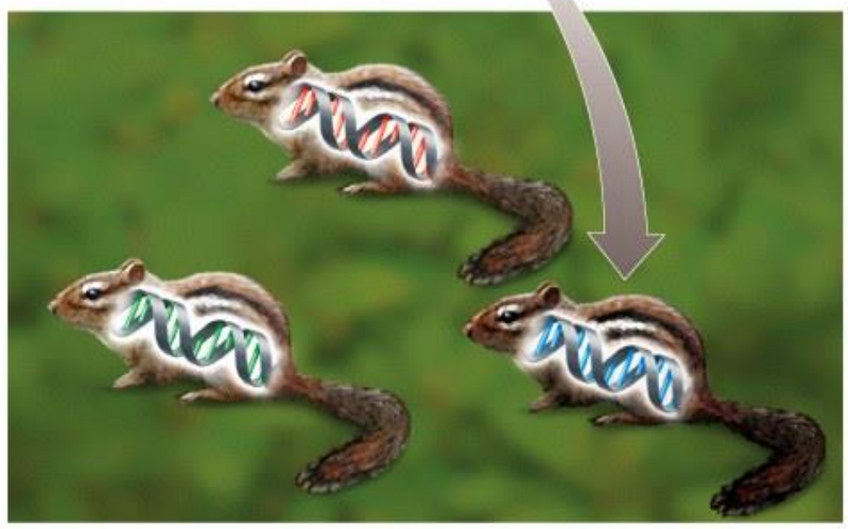
- In the pasture, you saw cows and a horse.
- A rabbit darted from under a bush.
- Grasses and weeds covered the ground.

Genetic Diversity

- The cows were all of the same species, but different breeds, because they have different assortments of genes.
- The cows were genetically diverse as breeds and individuals.

(a) Ecosystem diversity

(b) Species diversity



(c) Genetic diversity

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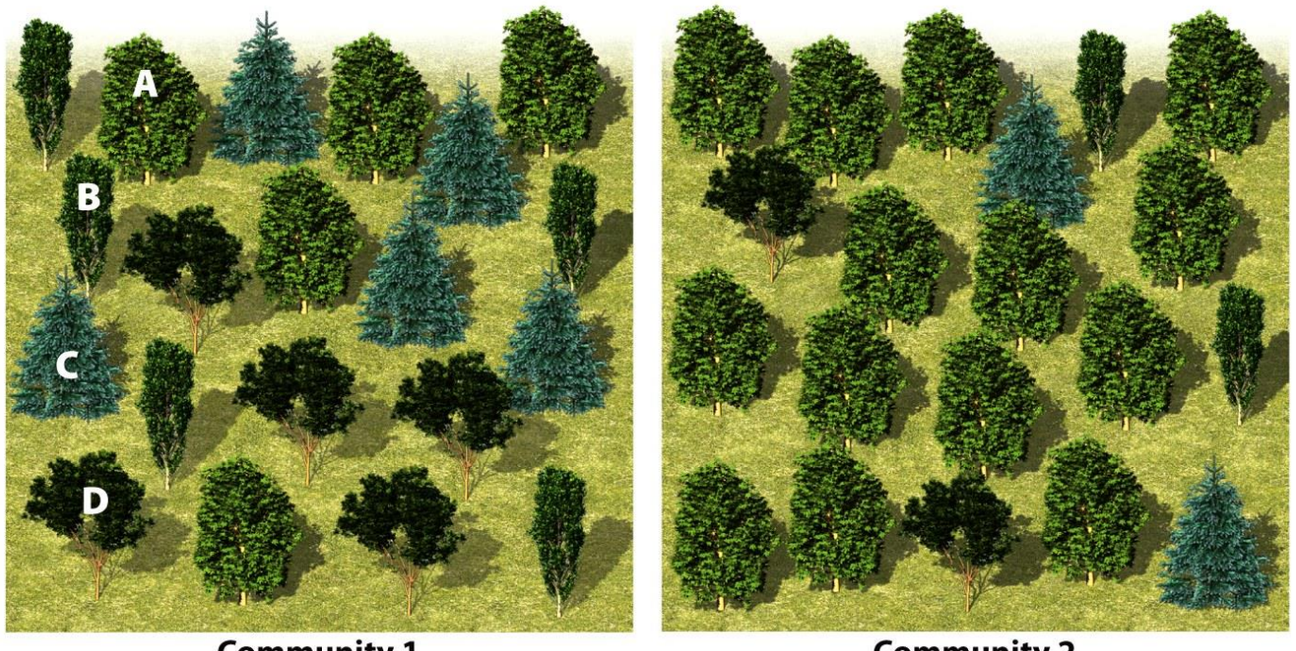
Species: Number and Distribution

- Species differ in distribution.
- How many species are present and how are they distributed in an ecosystem?

- **Species richness**—the number of species in a given area
- **Species evenness**—the measure of whether a particular ecosystem is numerically dominated by one species or are all represented by similar numbers of individuals



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Evolution results in biodiversity

Evolution is how the genetic composition of a species changes over time.

Evolution is the mechanism underlying biodiversity

- **Microevolution**—evolution below the species level
- **Macroevolution**—Evolution that gives rise to new species or larger groups, such as new genera, family, class, or phyla

Creating Genetic Biodiversity

- **Genes**—physical locations on chromosomes within each cell of an organism
- These code for **inherited traits,** which may or may not be expressed in a physical organism.

Creating Genetic Biodiversity

- **Genotype**—the complete set of genes in an individual. All the genes within an organism are also collectively called the **genome.**

Creating Genetic Biodiversity

- **Mutation**—a random change in the genetic code
- These happen in an unpredictable manner. Most such changes are disadvantageous for the organism.

Genetic Biodiversity

Phenotype—the set of traits actually physically or biochemically expressed in an individual

Genetic Biodiversity

- A brown-eyed person has the phenotype of brown eyes.
- But he or she may or may not carry in the genotype the form of genes for blue eyes as well.

Threats to Biodiversity

Extinction Rates

- The gradual process of species becoming extinct is known as background extinction
- Mass extinction is an event in which a large percentage of all living species become extinct in a relatively short period of tim

Threats to Biodiversity

Factors that Threaten Biodiversity

- The current high rate of extinction is due to the activities of a single species—*Homo sapiens*.
  - Humans are changing conditions on Earth faster than new traits can evolve to cope with the new conditions.

Threats to Biodiversity

Overexploitation

- Overexploitation, or excessive use, of species that have economic value is a factor increasing the current rate of extinction.
  - Bison
  - Passenger pigeons
    - Ocelot
  - Rhinoceros

Threats to Biodiversity

Habitat Loss

- If a habitat is destroyed or disrupted, the native species might have to relocate or they will die.

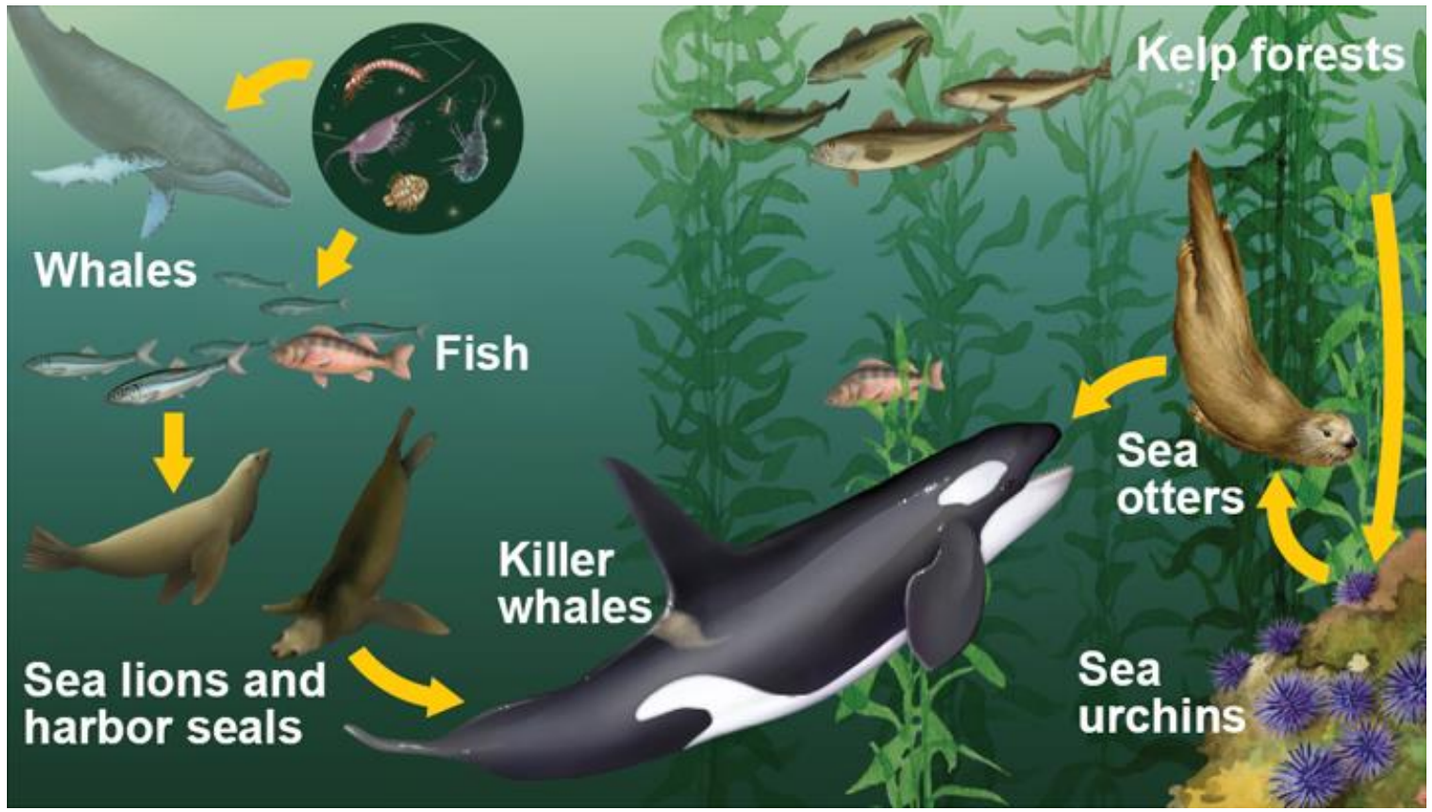
Destruction of Habitat

- The destruction of habitat, such as the clearing of tropical rain forests, has a direct impact on global biodiversity.

Threats to Biodiversity

Disruption of Habitat

- The declining population of one species can affect an entire ecosystem.



Threats to Biodiversity

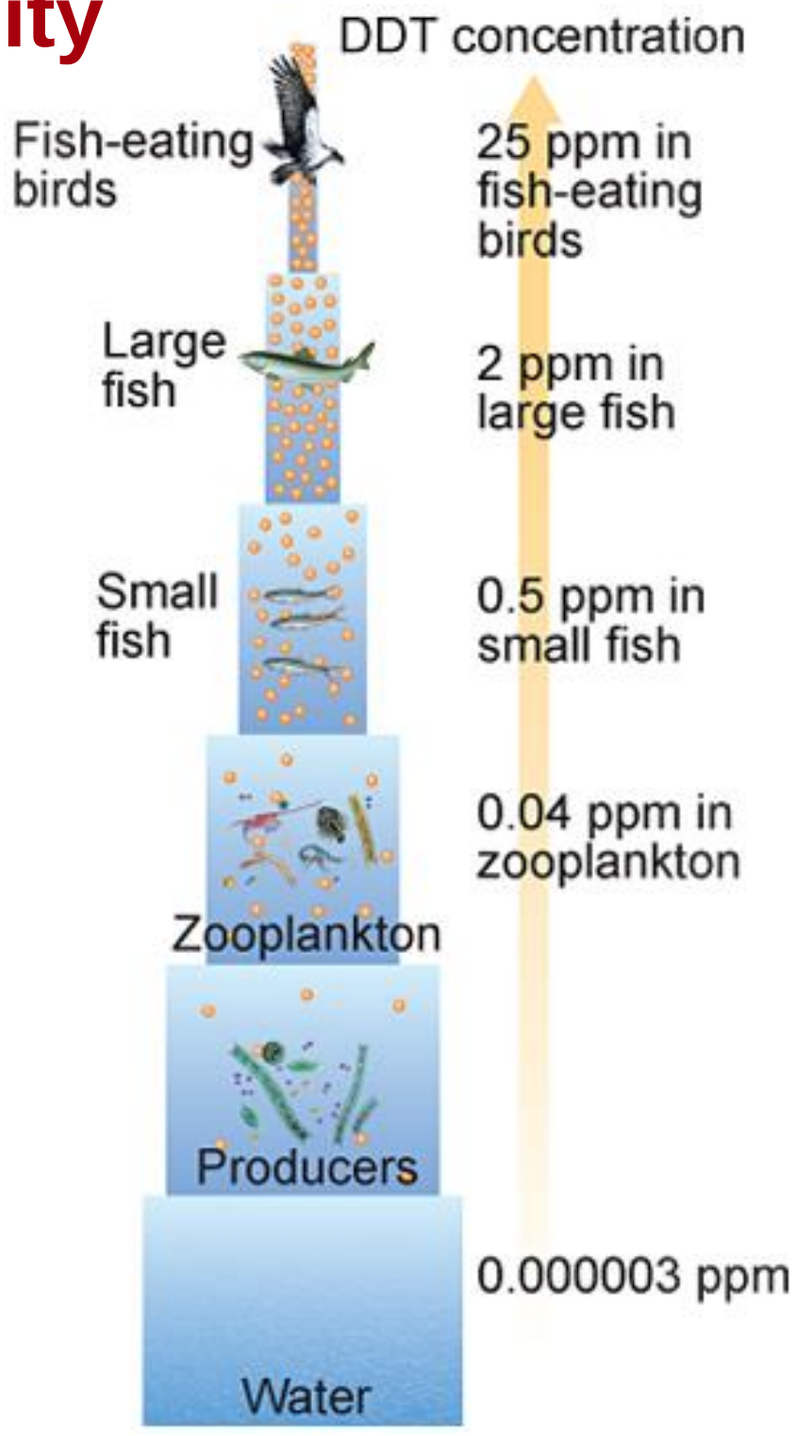
Fragmentation of Habitat

- The separation of an ecosystem into small pieces of land is called habitat fragmentation.
- The smaller the parcel of land, the fewer species it can support.
- Fragmentation reduces the opportunities for individuals in one area to reproduce with individuals from another area.
- Carving the large ecosystem into small parcels increases the number of edges—creating edge effects.

Threats to Biodiversity

Pollution

- Pollution and atmospheric changes threaten biodiversity and global stability.
- Biological magnification is the increasing concentration of toxic substances in organisms as trophic levels increase in a food chain or food we[illegible].



Threats to Biodiversity

Acid Precipitation

- Sulfur and nitrogen compounds react with water and other substances in the air to form sulfuric acid and nitric acid.
- Acid precipitation removes calcium, potassium, and other nutrients from the soil, depriving plants of these nutrients.

Assessing Water Quality

Threats to Biodiversity

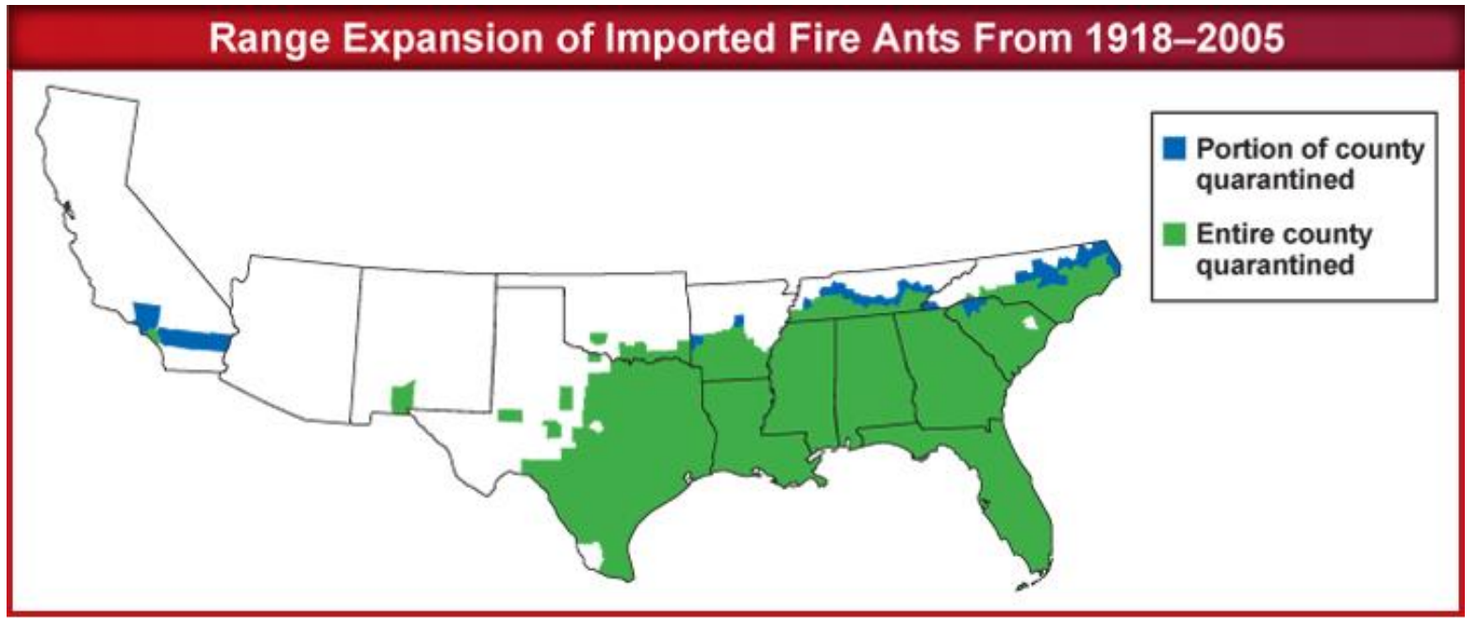
Eutrophication

- Eutrophication occurs when substances rich in nitrogen and phosphorus flow into waterways, causing extensive algae growth.
- The algae use up the oxygen supply during their rapid growth and after their deaths during the decaying process.
- Other organisms in the water suffocate.

Threats to Biodiversity

Introduced Species

- Nonnative species that are either intentionally or unintentionally transported to a new habitat are known as introduced species.

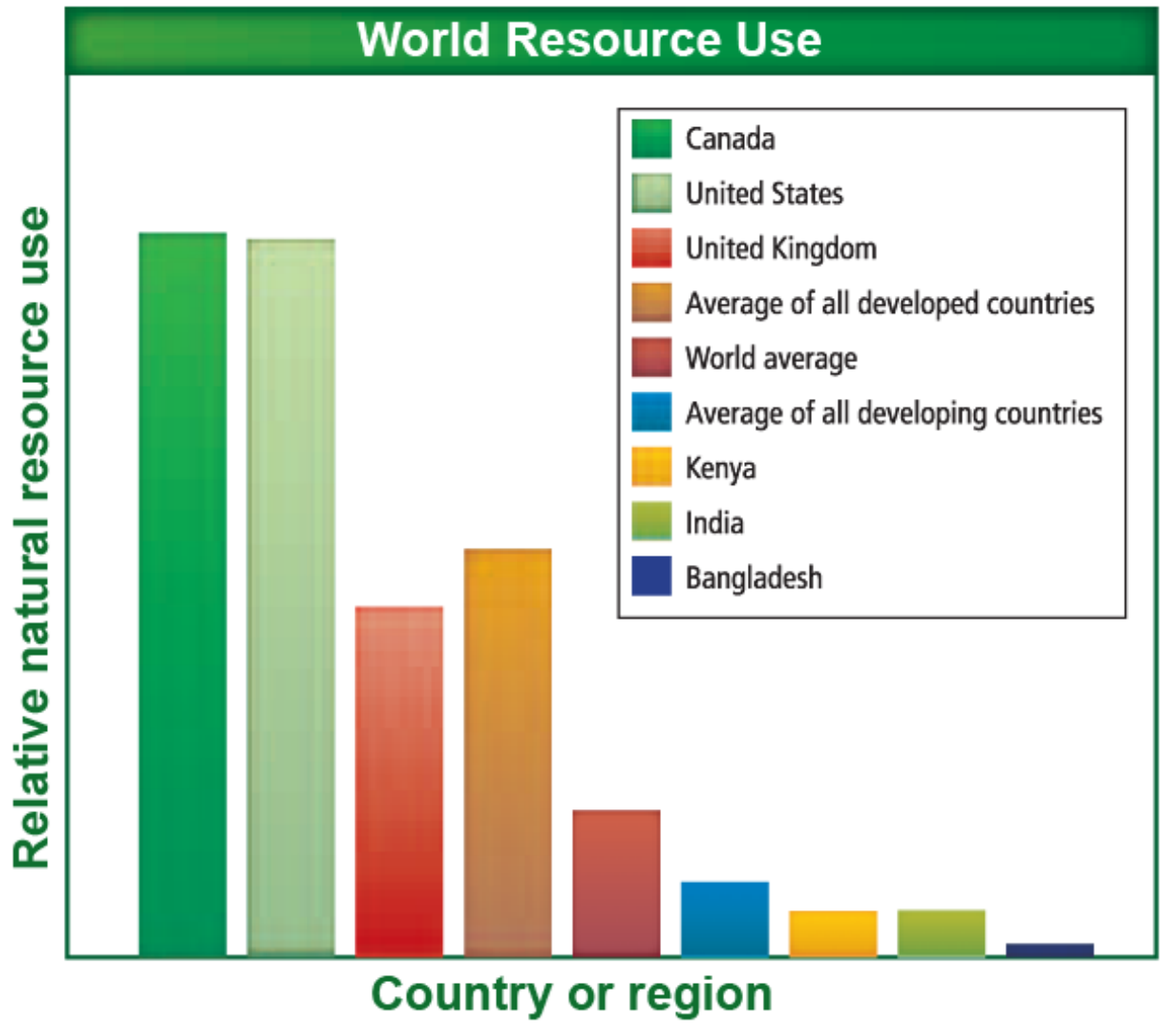


- Introduced species often reproduce in large numbers because of a lack of predators, and become invasive species in their new habitat.

Conserving Biodiversity

Natural Resources

- The consumption rate of natural resources is not evenly distributed.



Conserving Biodiversity

- Resources that are replaced by natural processes faster than they are consumed are called renewable resources.
- Resources that are found on Earth in limited amounts or those that are replaced by natural processes over extremely long periods of time are called nonrenewable resources.

Conserving Biodiversity

- Sustainable use means using resources at a rate in which they can be replaced or recycled while preserving the long-term environmental health of the biosphere.

Conserving Biodiversity

Protecting Biodiversity

- Currently, about seven percent of the world's land is set aside as some type of reserve.
  - The United Nations supports a system of Biosphere Reserves and World Heritage sites.

Conserving Biodiversity

Biodiversity Hotspots

- At least 1500 species of vascular plants are endemic.

- The region must have lost at least 70 percent of its original habitat.

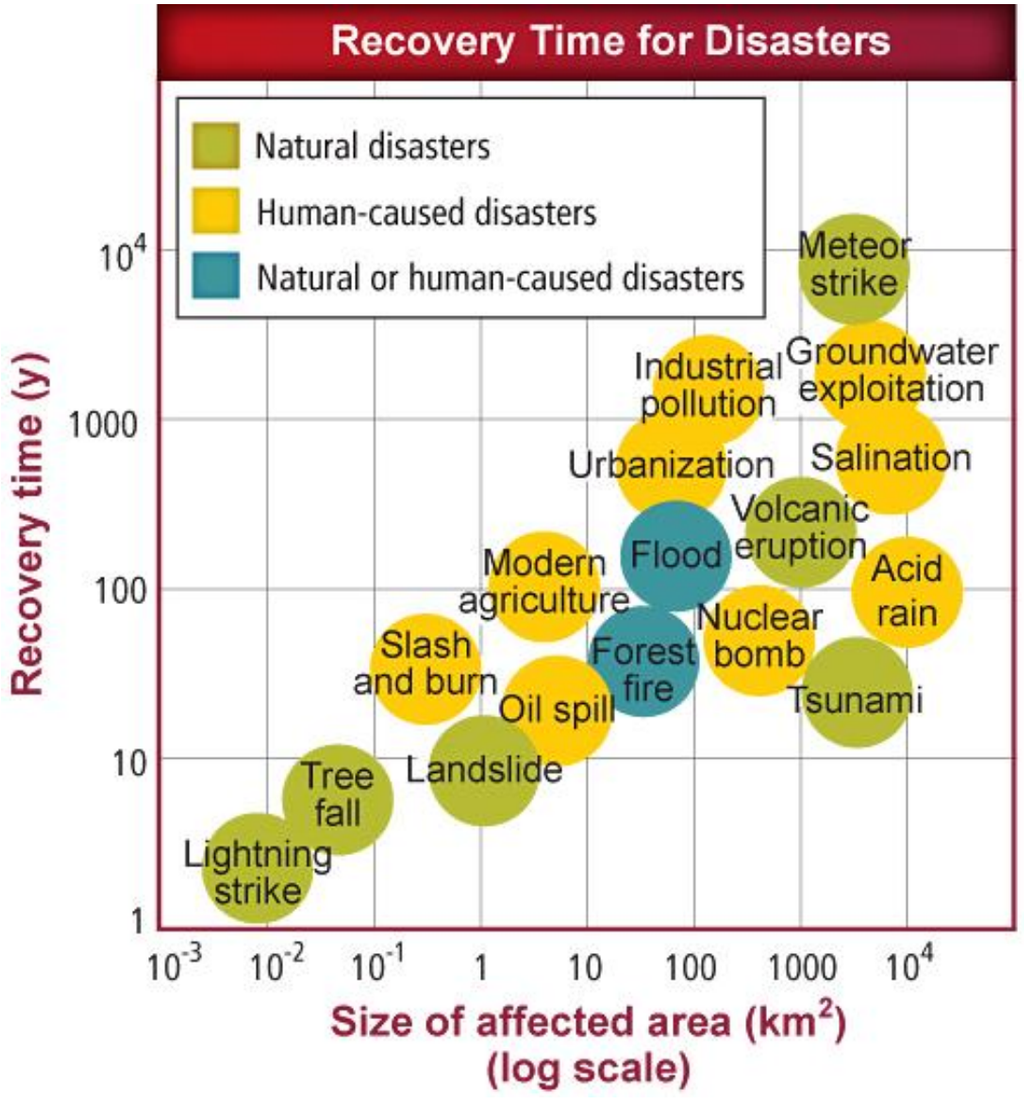
- These hot spots originally covered 15.7 percent of Earth’s surface, however, only about a tenth of that habitat remains.

Conserving Biodiversity

Corridors Between Habitat Fragments

- Improve the survival of biodiversity by providing corridors, or passageways, between habitat fragments
- Creates a larger piece of land that can sustain a wider variety of species and a wider variety of genetic variation

Conserving Biodiversity



Restoring Ecosystems

- The larger the affected area, the longer it takes for the biological community to recover.

Conserving Biodiversity

Bioremediation

The use of living organisms, such as prokaryotes, fungi, or plants, to detoxify a polluted area is called bioremediation

Conserving Biodiversity

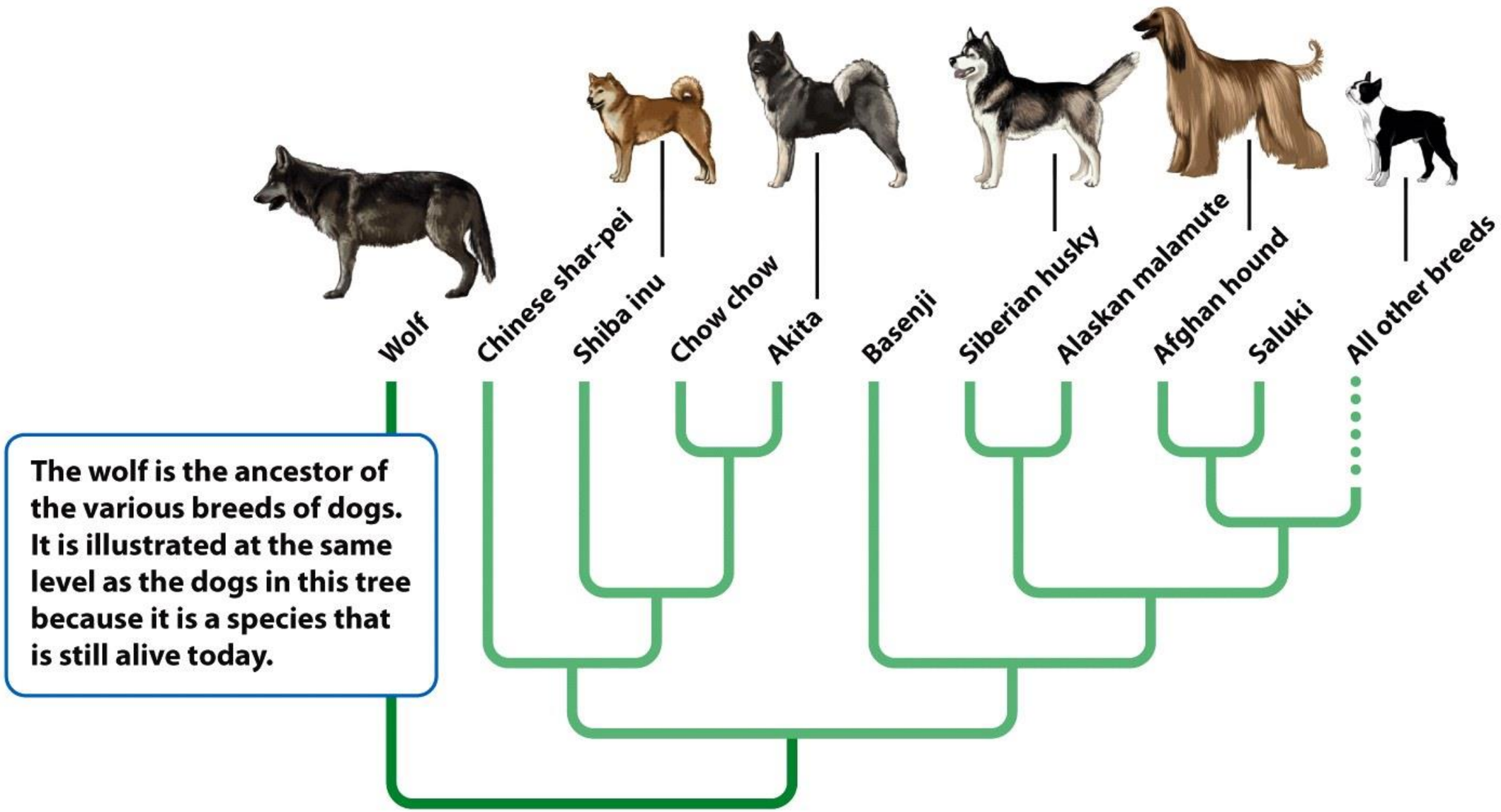
Biological Augmentation

- Adding natural predators to a degraded ecosystem is called biological augmentation

Evolution by Artificial and Natural Selection

Evolution by Artificial Selection

- Evolution by artificial selection—when humans determine which individuals breed
- Good examples are the more than 400 modern breeds of dogs, and 800 breeds of domestic cattle.



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Evolution by Natural Selection

Evolution by natural selection—the environment determines which individuals are most likely to survive and reproduce.

Darwin's theory of evolution by natural selection

- Individuals produce an excess of offspring
- Not all offspring can survive
- Individuals differ in their traits
- Differences in traits can be passed on from parents to offspring
- Differences in traits are associated with differences in the ability to survive and reproduce

Darwin's Theory of Evolution by Natural Selection

Natural selection can be explained in five points. Now, we'll examine each point, and see if you agree with them, one by one.

Darwin's Theory of Evolution by Natural Selection: Point #1

1. Individuals vary.

Darwin's Theory of Evolution by Natural Selection: Point #2

2. Some of this variation is inherited.

Darwin's Theory of Evolution by Natural Selection: Point #3

3. Some inherited variation confers advantages on the individual such as making them faster, stronger, smarter, or otherwise better adapted to survive.

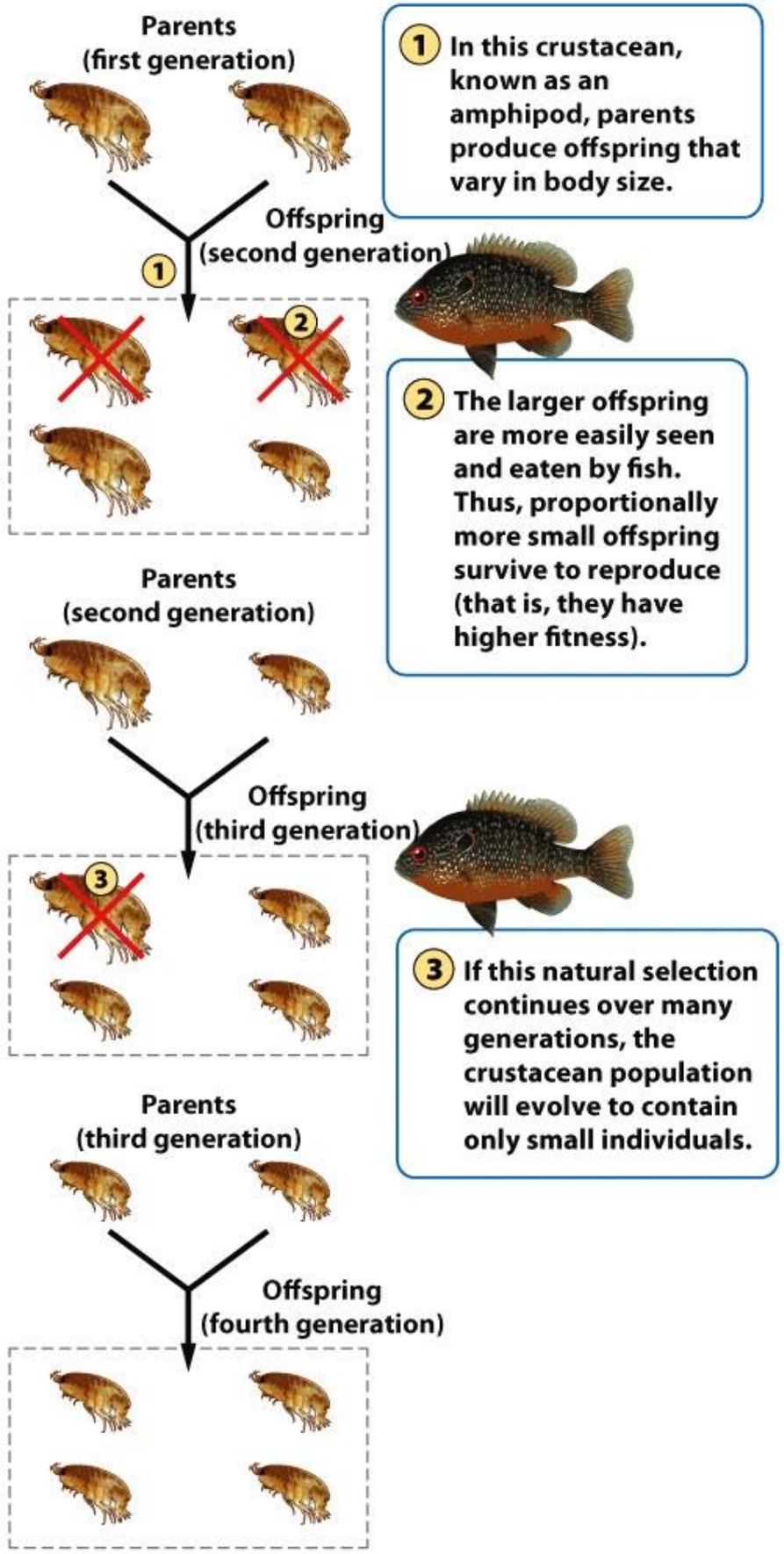
Darwin's Theory of Evolution by Natural Selection: Point #4

4. Those individuals who are better adapted to the environment are more likely to survive and reproduce, passing on their inherited advantage.

Darwin's Theory of Evolution by Natural Selection: Point #5

5. Individuals who successfully reproduce transmit forms of their specific genes to the next generation, and offspring will benefit from the advantage offered by the genes: over generations, these genes will become much more frequently found in the species.

The next slide demonstrates an example of the evolution by natural selection of body size in amphipods, as an inherited advantage.



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Evolution by Random Processes [Reviewer's note: too many points on one slide! – four slides are used instead]

- Mutation—occur randomly and can add to the genetic variation of a population
- Genetic drift—change in the genetic composition of a population over time as a result of random mating
- Bottleneck effect—a reduction in the genetic diversity of a population caused by a reduction in its size
- Founder effect—a change in a population descended from a small number of colonizing individuals

Evolution by Random Processes: Mutation

- **Mutation**—occurs randomly and can add to the genetic variation of a population
- Most mutations have very little or no effect (neutral mutation) or decrease the likelihood of an individual reproducing (deleterious mutations)

Evolution by Random Processes: Genetic drift

Genetic drift—change in the genetic composition of a population over time as a result of random mating

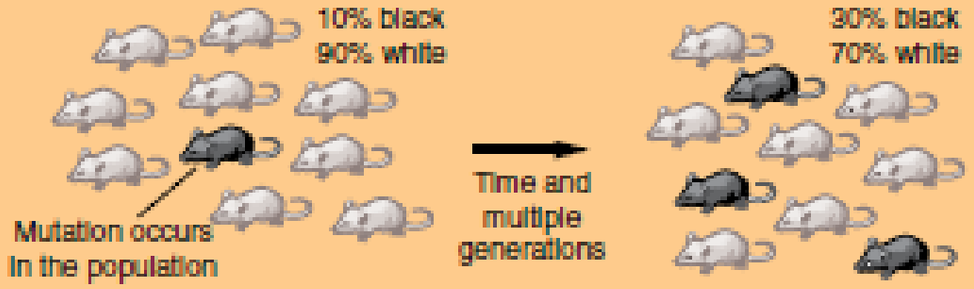
Evolution by Random Processes: Bottleneck effect

Bottleneck effect—a reduction in the genetic diversity of a population caused by a reduction in number of organisms

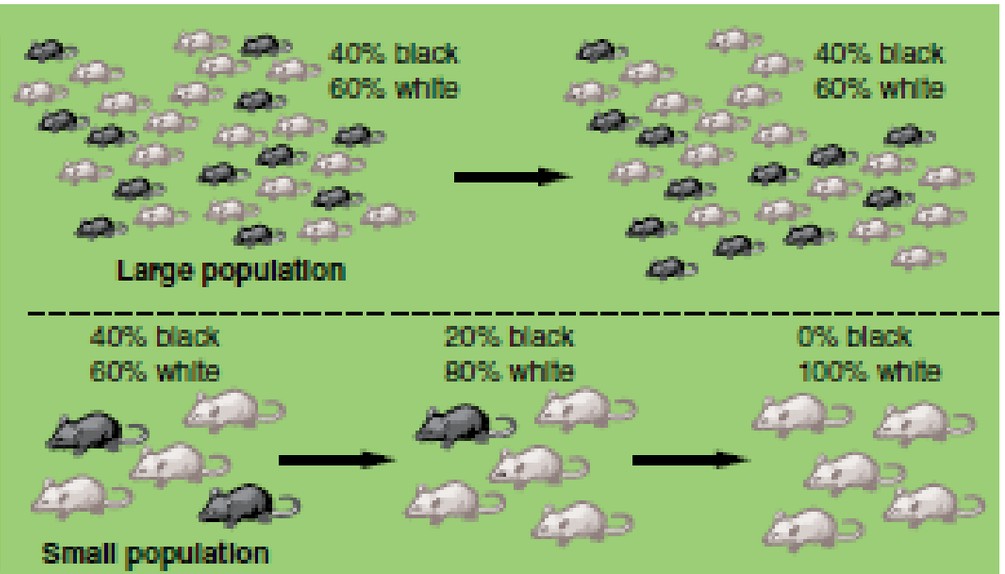
Evolution by Random Processes: Founder Effect

Founder effect—a change in a population descended from a small number of colonizing individuals

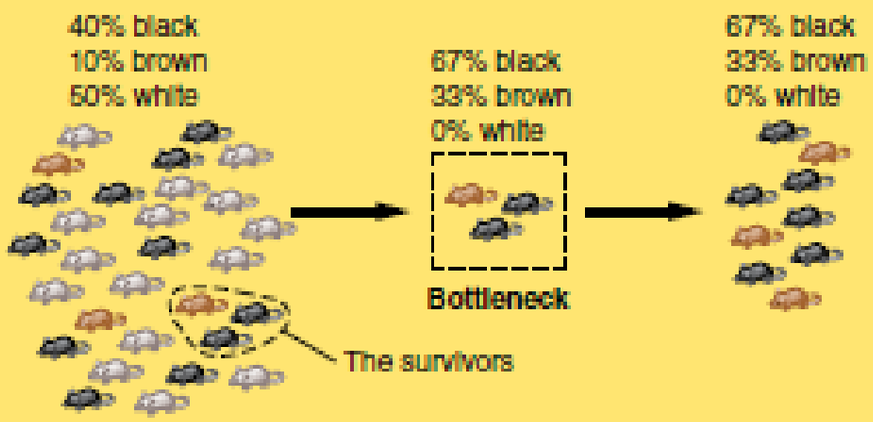
(a) Mutation
A mutation can arise in a population and, if it is not lost, may increase in frequency over time.



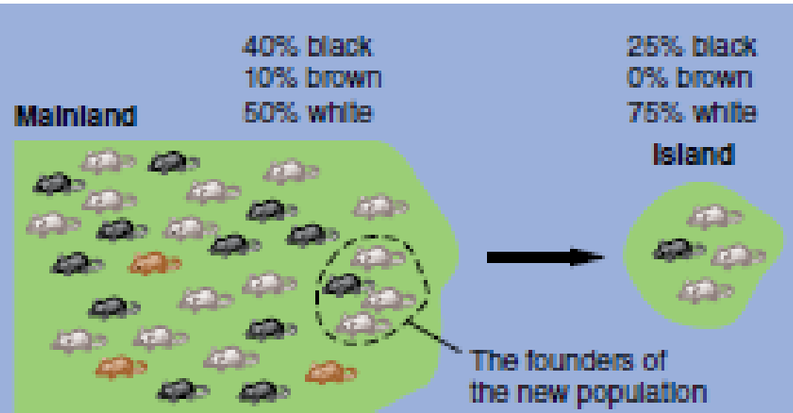
(b) Genetic drift
In a large population, the genetic composition tends to remain the same over time.
In a small population, however, some genotypes can be lost by chance and the genetic composition can change over time.



(c) Bottleneck effect
If a population experiences a drastic decrease in size (goes through a "bottleneck"), some genotypes will be lost, and the genetic composition of the survivors will differ from the composition of the original group.



(d) Founder effect
If a few individuals from a mainland population colonize an island, the genotypes on the island will represent only a subset of the genotypes present in the mainland population. As with the bottleneck effect, some genotypes will not be present in the new population.



Speciation and Extinction Determine Biodiversity: Two Forms of Speciation

- **Allopatric** speciation—new species are created by geographic or reproductive isolation
- **Sympatric** speciation—one species evolves into two species without being geographically isolated

Speciation and Extinction Determine Biodiversity

Allopatric speciation—new species are created by geographic or reproductive isolation

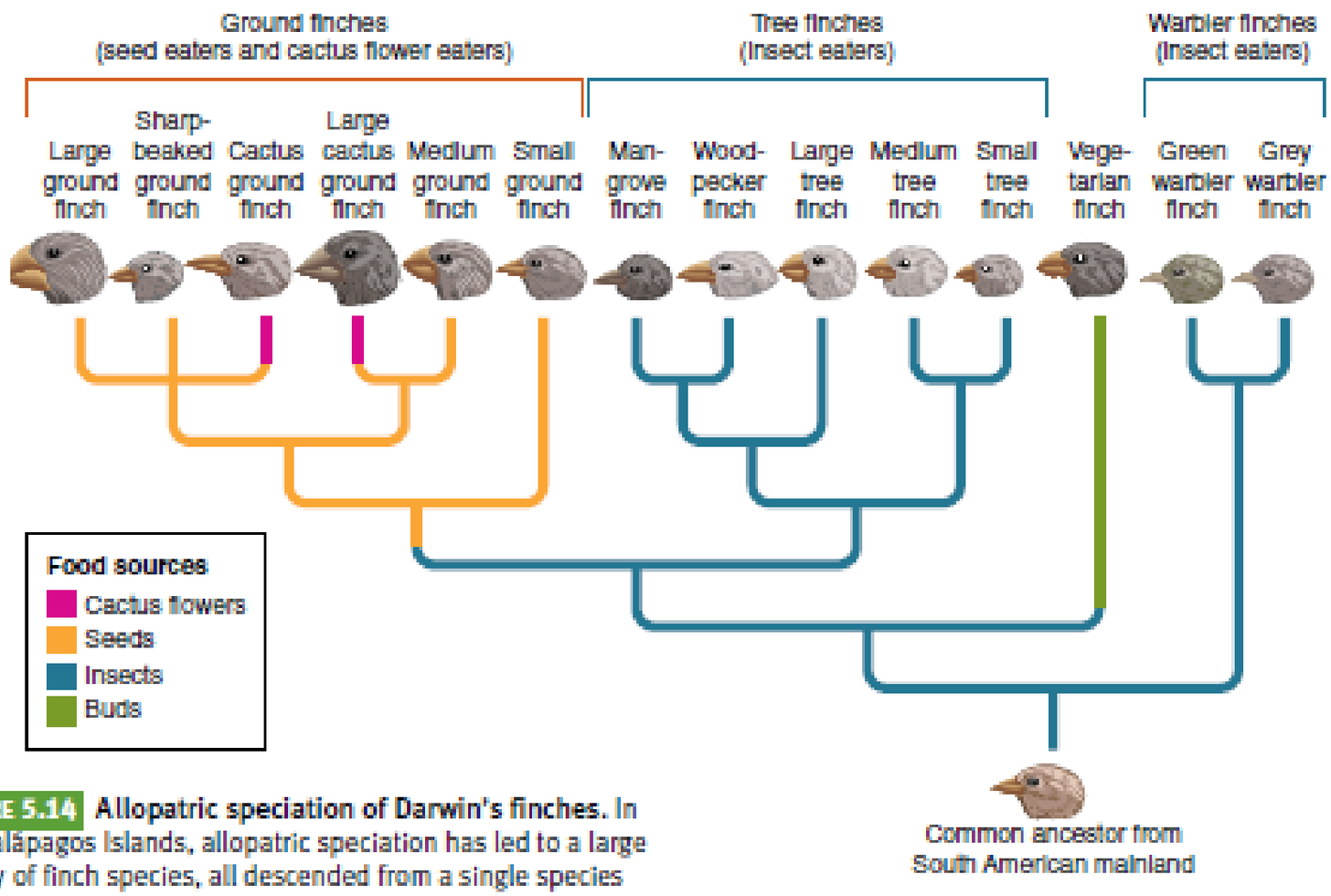


FIGURE 5.14 **Allopatric speciation of Darwin's finches.** In the Galápagos Islands, allopatric speciation has led to a large variety of finch species, all descended from a single species that colonized the islands from the South American mainland.

Sympatric speciation—evolution of one species into two species in the absence of geographic isolation, usually through **polyploidy**, which is an increase in the number of sets of chromosomes

(a) Einkorn wheat (b) Durum wheat (c) Common wheat

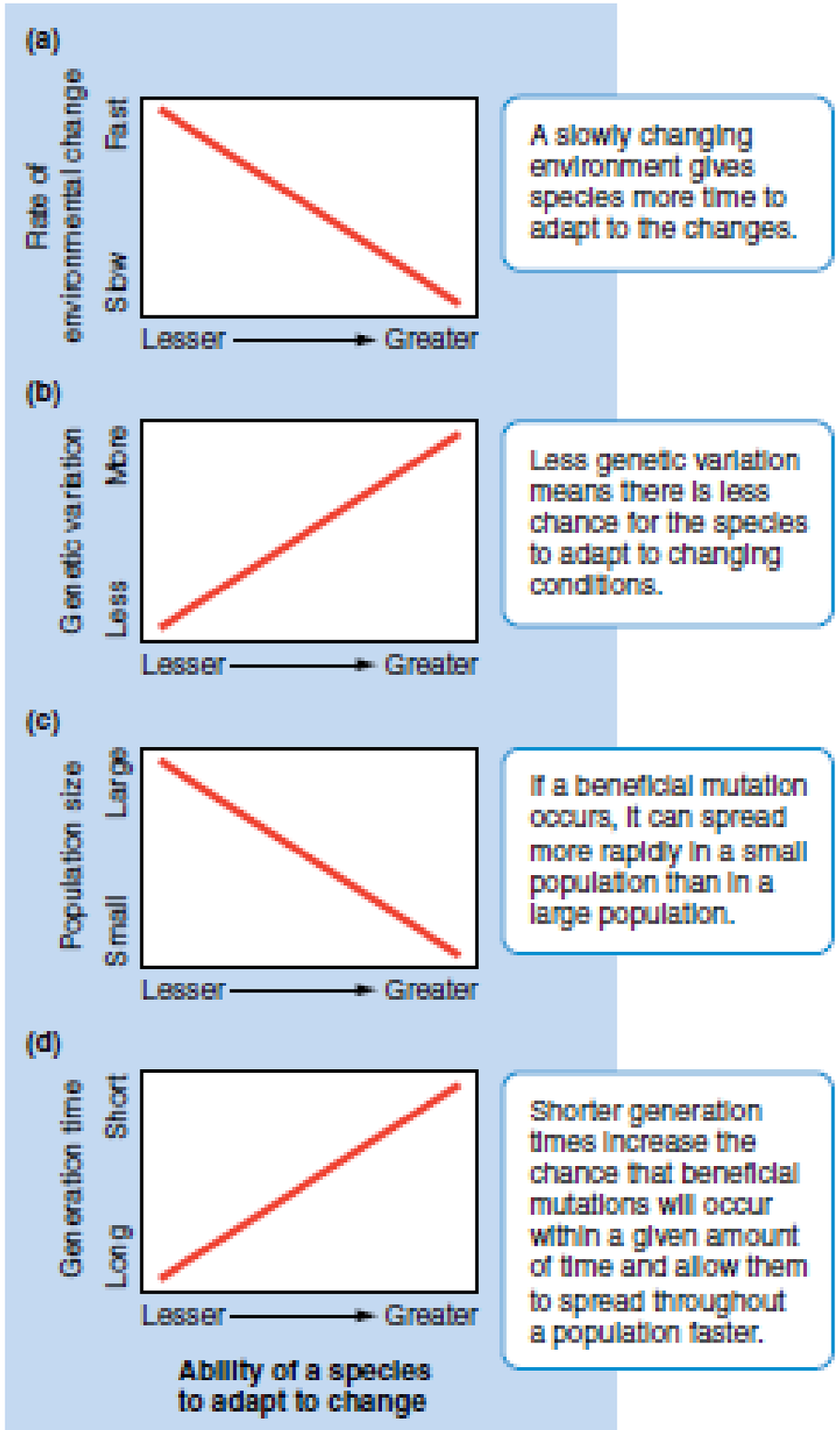
The Pace of Evolution

The rate at which a species evolves is dependent on a combination of four factors:

Factors Affecting the Pace of Evolution

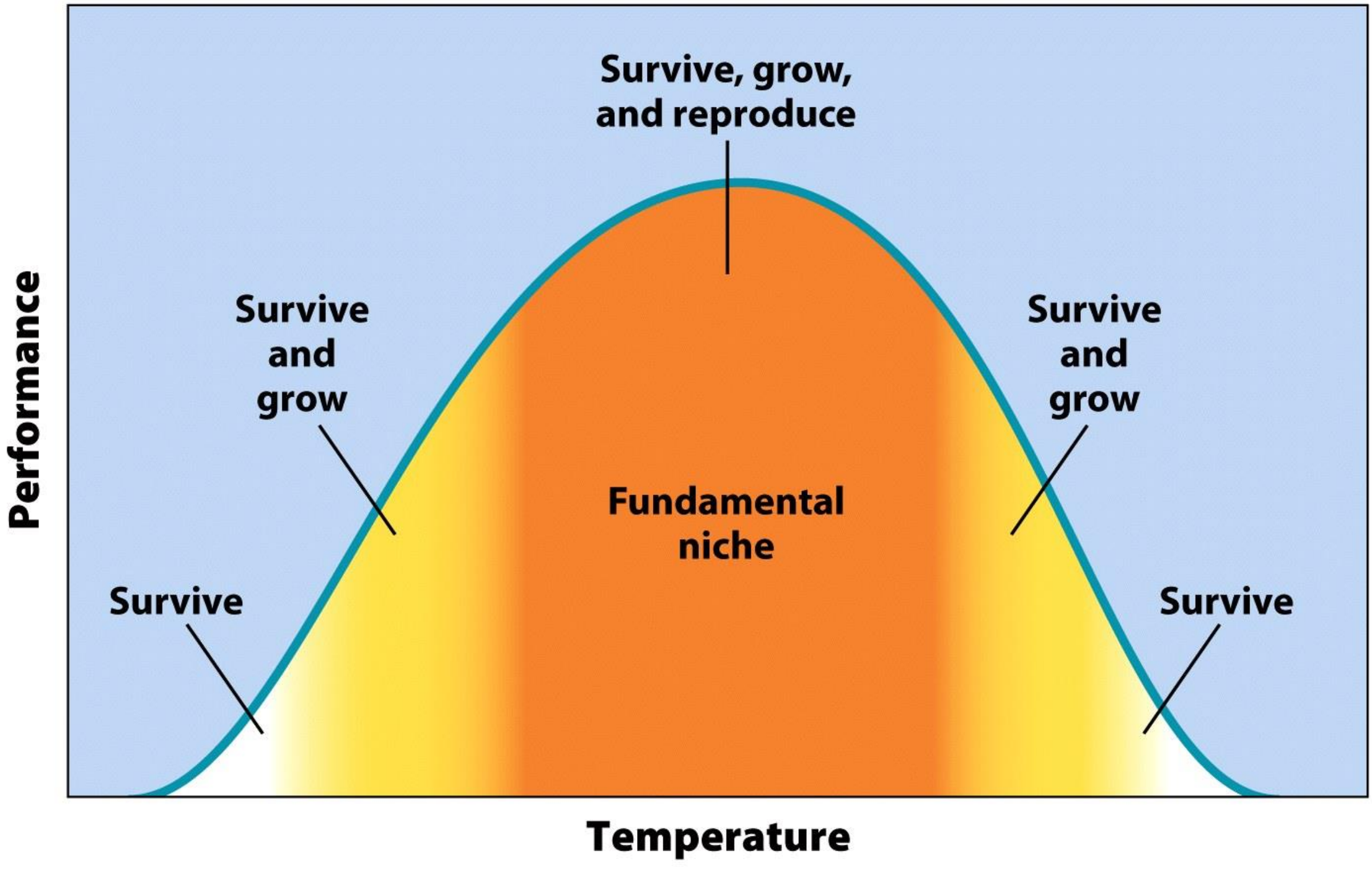
- The *rate* of environmental change
- The *amount* of genetic variation in the species
- The *size* of the population involved
- How *fast* the species reproduces (generation time)

The Pace of Evolution



Evolution Shapes Ecological Niches and Determines Species Distributions

Range of tolerance—all species perform best under certain environmental conditions. These abiotic conditions are known as the range of tolerance for that particular species.



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The Niche

The concept of “**niche**” is a useful one in ecology and can be discussed in several ways, including the following:

Niches

- **Realized niche**—the range of abiotic and biotic conditions under which a species lives. This determines the species distribution, or areas of the world where it lives.
- **Niche generalist**—species that live under a wide range of conditions
- **Niche specialist**—species that live only in specific habitats

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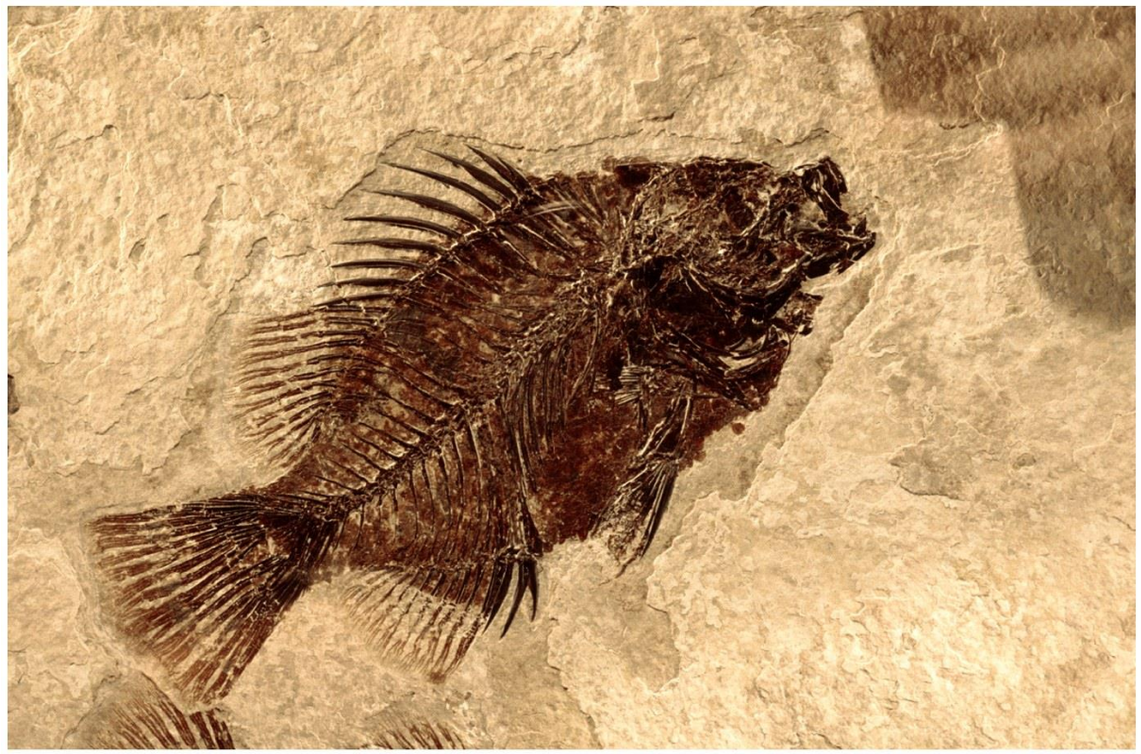
The Fossil Record

Fossils—the organic remains of organisms have been preserved by being replaced by minerals in rock. Much of what we know about evolution comes from the fossil record.



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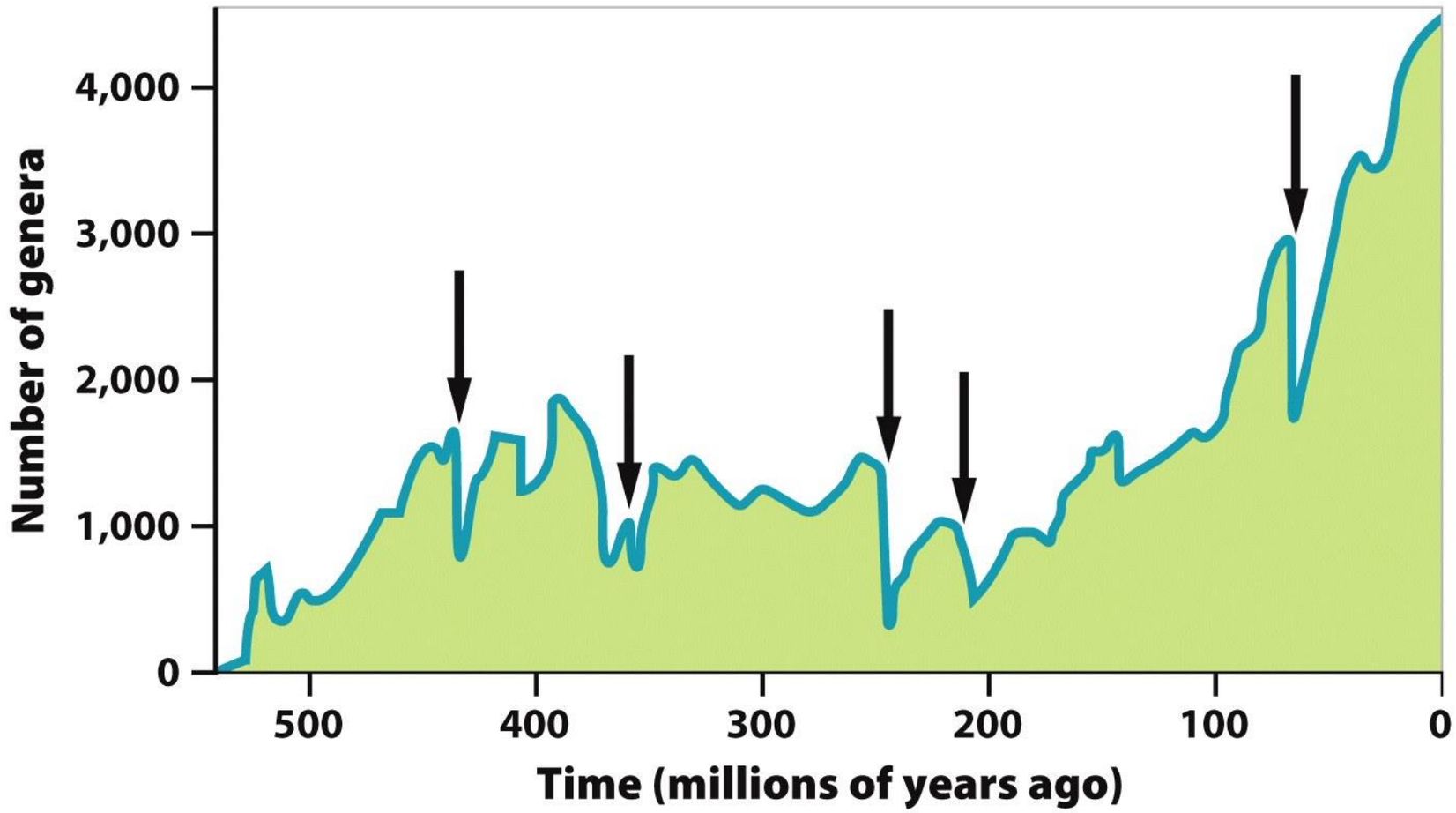
The Five Global Mass Extinctions

Mass extinction—when large numbers of species went extinct over a relatively short period of geological time.



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What Caused the First Five Mass Extinctions?

- Causes can be guessed at, but are not known for certain
- Effect was on a massive scale
- In the oldest example, 251 million years ago, 90% of marine and 70% or land species became extinct

The Sixth Mass Extinction

- Scientists feel that we are in our **sixth mass extinction**, occurring in the last two decades.
- Estimates of possible extinction rates vary widely, from 2% to 25% by 2020.
- **In contrast to previous mass extinctions, scientists agree that this one is caused by humans.**

Review Questions

- What are three forms of biodiversity?
- What is the difference between species richness and species evenness?
- Distinguish macroevolution form microevolution. What is the result of each process?
- What are genes? What is meant by “genotype”?

Review Questions

- What is a mutation? How does it affect evolution?
- List the five main steps in Natural selection.
- List the four random processes involved in natural selection.
- What is the difference between sympatric and allopatric speciation?

Review Questions

- What factors determine the rate of evolution of a species?
- What is meant by “range of tolerance”?
- Distinguish a niche generalist from a niche specialist.
- How are fossils created?

Review Questions

- How many global mass extinctions have there been in Earth's history?
- What distinguishes the current global mass extinction from previous mass extinctions?