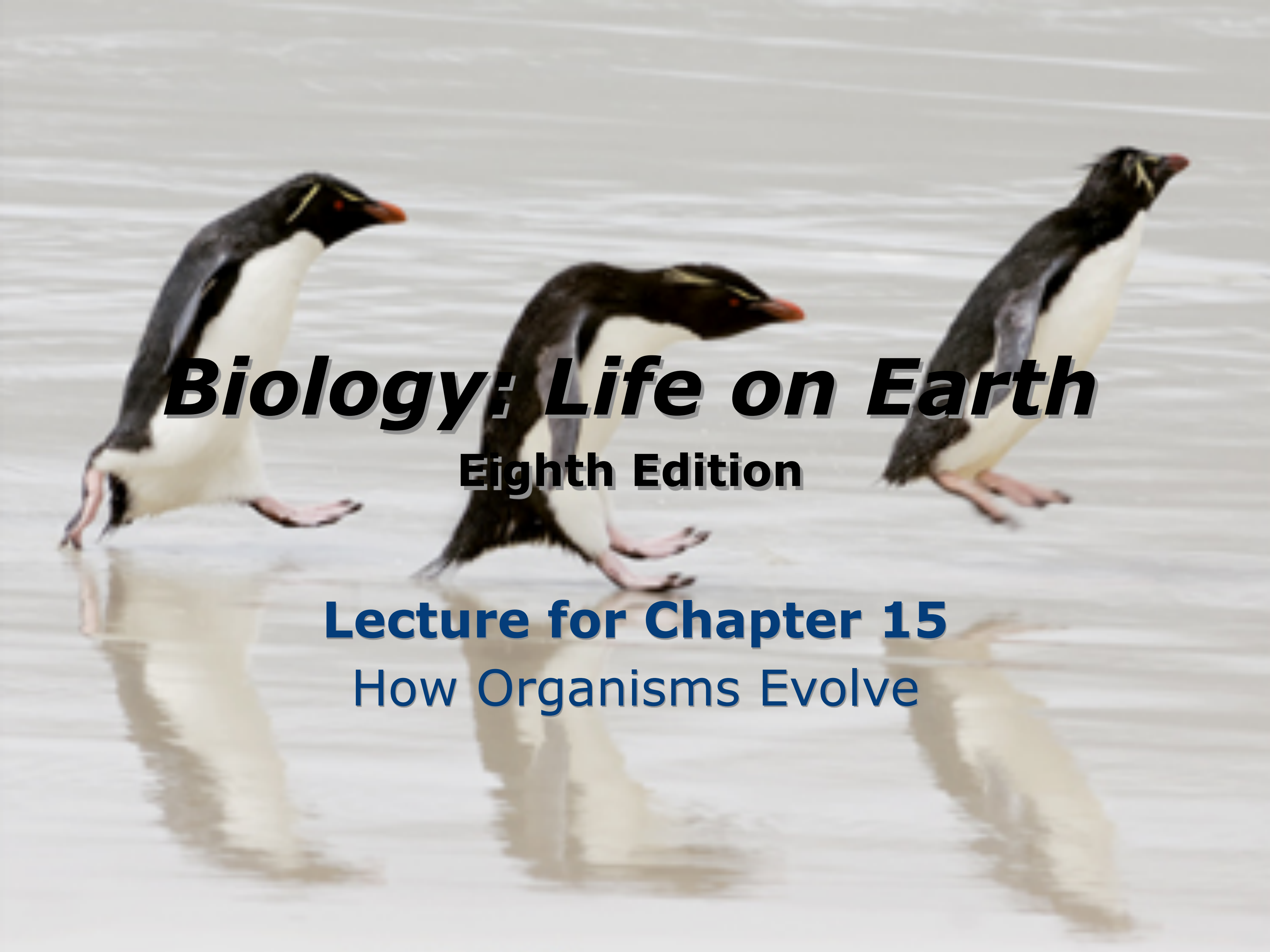

Biology: Life on Earth

Eighth Edition

Lecture for Chapter 15

How Organisms Evolve

Chapter 15 Opener Biology: Life on Earth, 8/e

Chapter 15 Outline

Section 15.1 Outline

- **15.1 How Are Populations, Genes, and Evolution Related?**
  - Genes and the Environment Interact to Determine Traits
  - The Gene Pool Is the Sum of the Genes in a Population
  - Evolution Is the Change Over Time of Allele Frequencies Within a Population
  - The Equilibrium Population Is a Hypothetical Population That Does Not Evolve

Determination of Traits

- All cells contain DNA
- A **gene** is a segment of DNA found at a specific place on a chromosome

Determination of Traits

- In diploid individuals, each gene consists of two **alleles** (its genotype)
  - Individuals whose alleles are the same are **homozygous** for that gene
  - Individuals whose alleles are different are **heterozygous** for that gene

Determination of Traits

- For example, coat color is determined by 2 alleles in hamsters:
  - The dominant allele encodes for an enzyme that catalyzes black pigment formation
  - The recessive allele encodes for an enzyme that catalyzes brown pigment

Determination of Traits

- Hamsters with at least one dominant allele (homozygous dominant or heterozygous) produce black pigment
- Hamsters with two recessive alleles (homozygous recessive) produce brown pigment

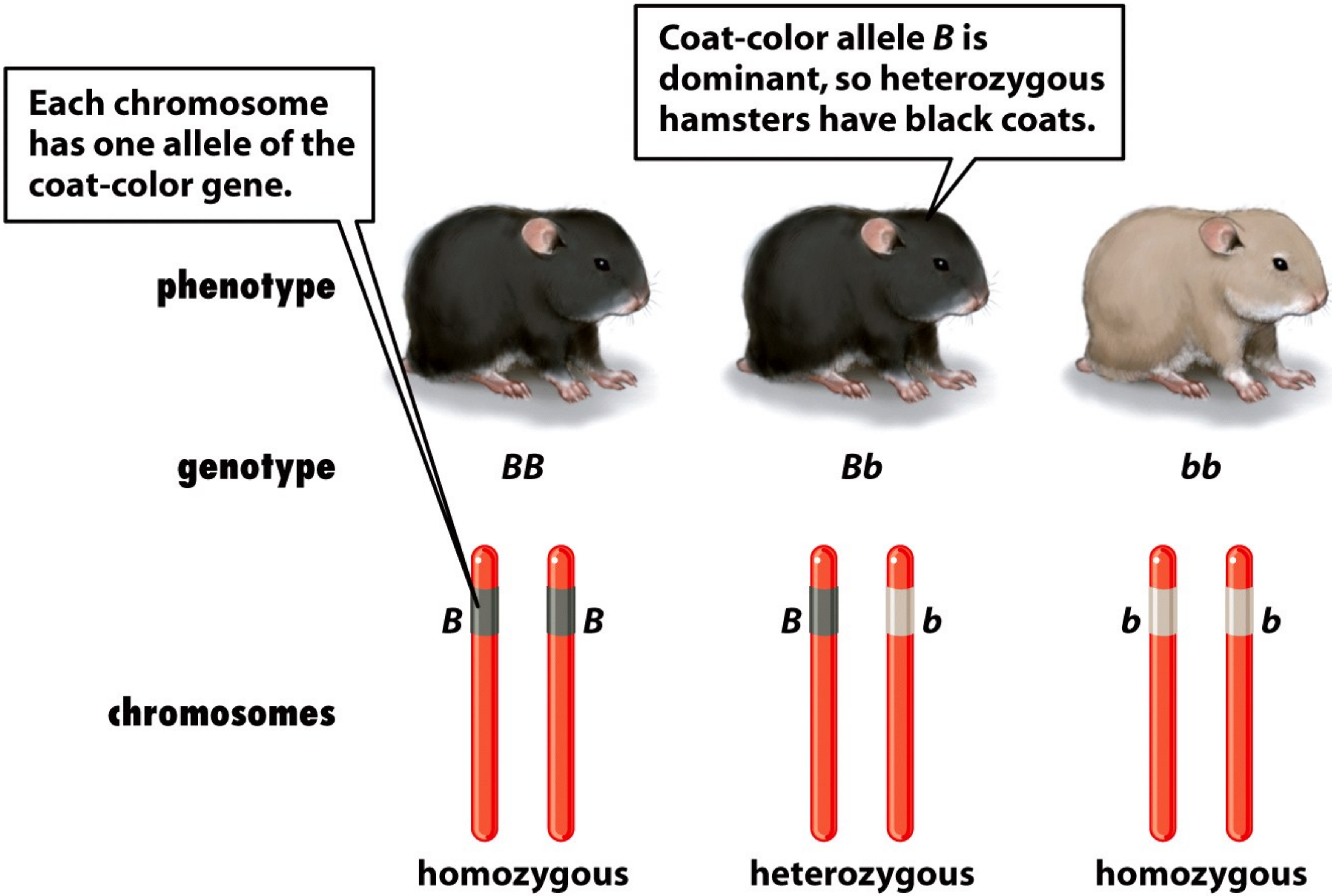

Figure 15-1 Biology: Life on Earth, 8/e

Determination of Traits

- An individual's genotype also interacts with the environment to determine its physical appearance and behavioral traits (phenotype)

Determination of Traits

- The changes an individual experiences as it grows and develops are not evolutionary changes
- Evolutionary changes:
  - Occur from generation to generation
  - Cause descendants to differ from their ancestors
  - Occur at the population level

The Gene Pool

- A **population** is a group of organisms of the same species living in a given area
- The sum of all genes in a population at any one time is the population's **gene pool**
- A gene pool consists of all alleles of all genes in all individuals of a population
- **Allele frequency**: each allele has a frequency (proportion) in a population

The Gene Pool

- For example, coat color in hamsters:
  - A population of 25 hamsters contains 50 alleles of the coat color gene (hamsters are diploid)
  - If 20 of those 50 alleles code for black coats, then the frequency of the black allele is 0.40 or 40% [20/50 = 0.40]

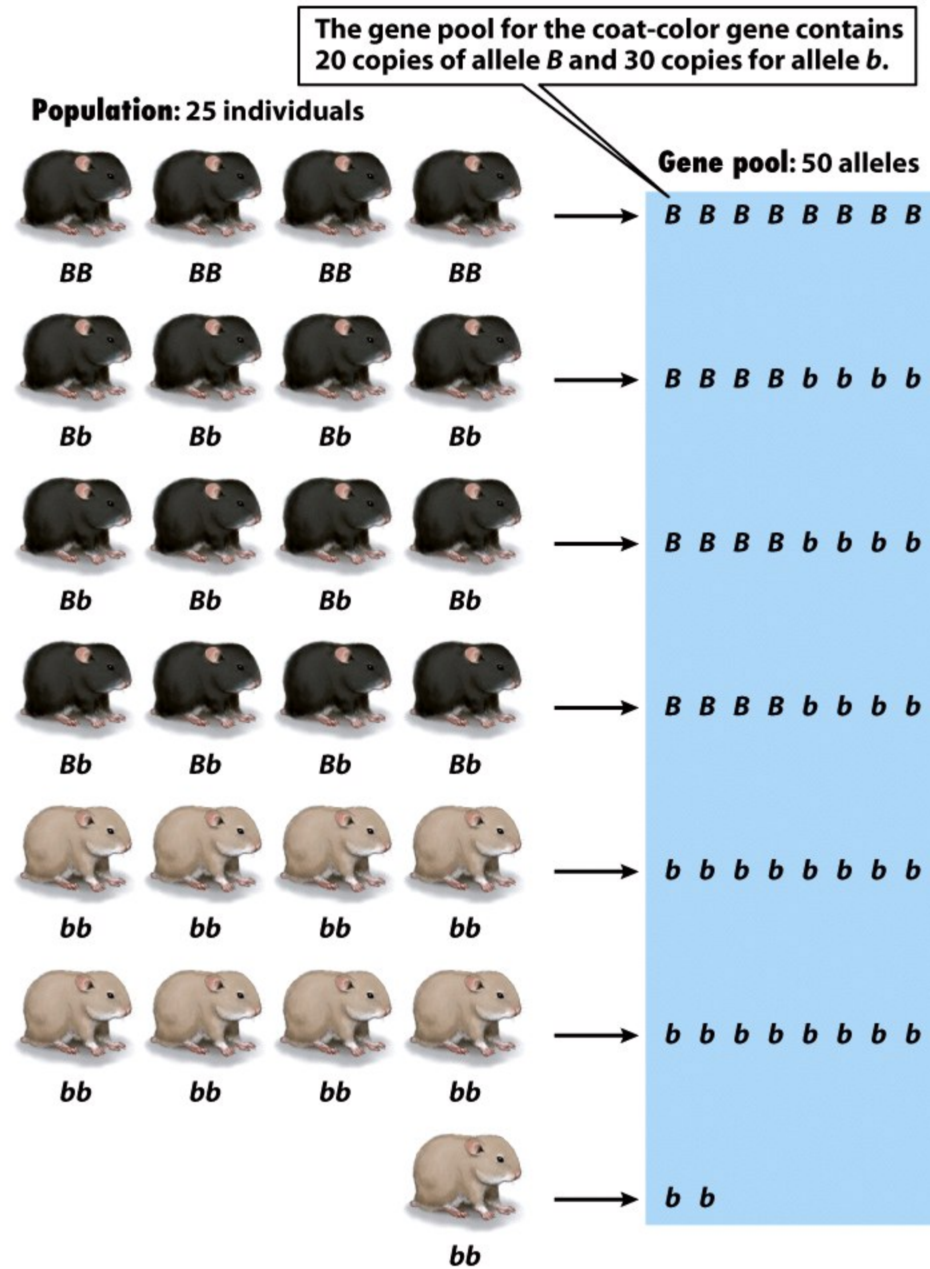

Figure 15-2 Biology: Life on Earth, 8/e

Evolution

- Evolution is the change of allele frequencies in a population's gene pool over time
  - If allele frequencies change from one generation to the next, the population is evolving
  - If allele frequencies do not change from generation to generation, the population is NOT evolving

The Hardy-Weinberg Principle

- A mathematical model (1908) proposed independently by
  - Godfrey H. Hardy (English mathematician)
  - Wilhelm Weinberg (German physician)

The Equilibrium Population

- The Hardy-Weinberg principle demonstrates that, under certain conditions, the frequencies of alleles and genotypes in a sexually reproducing population remain constant from one generation to the next
- An **equilibrium population** is an idealized population in which allele frequencies do not change from generation to generation

The Equilibrium Population

- How is an equilibrium population maintained?

The Equilibrium Population

- An equilibrium can be maintained as long as the following five conditions are satisfied:
  1. No mutation
  2. No gene flow between populations
  3. Population must be very large
  4. Mating must be random
  5. No natural selection

The Equilibrium Population

- Violation of one or more of these five conditions may allow changes in allele frequencies

Section 15.2 Outline

- **15.2 What Causes Evolution?**
  - Mutations Are the Source of Genetic Variability
  - Gene Flow Between Populations Changes Allele Frequencies
  - Allele Frequencies May Drift in Small Populations
  - Mating Within a Population Is Almost Never Random
  - All Genotypes Are Not Equally Beneficial

Causes of Evolution

- Five factors contribute to evolutionary change:
  1. Mutation
  2. Gene flow
  3. Small population size
  4. Nonrandom mating
  5. Natural selection

Source of Genetic Variability

- **Mutations** are rare changes in the base sequence of DNA in a gene
  - Usually have little or no immediate effect
  - Are the source of new alleles
  - Can be passed to offspring only if they occur in cells that give rise to gametes
  - Can be beneficial, harmful, or neutral
  - Arise spontaneously, not as a result of, or in anticipation of, environmental necessity

Mutations Are Not Goal Directed

- A mutation does not arise as the result of, or in anticipation of, environmental events

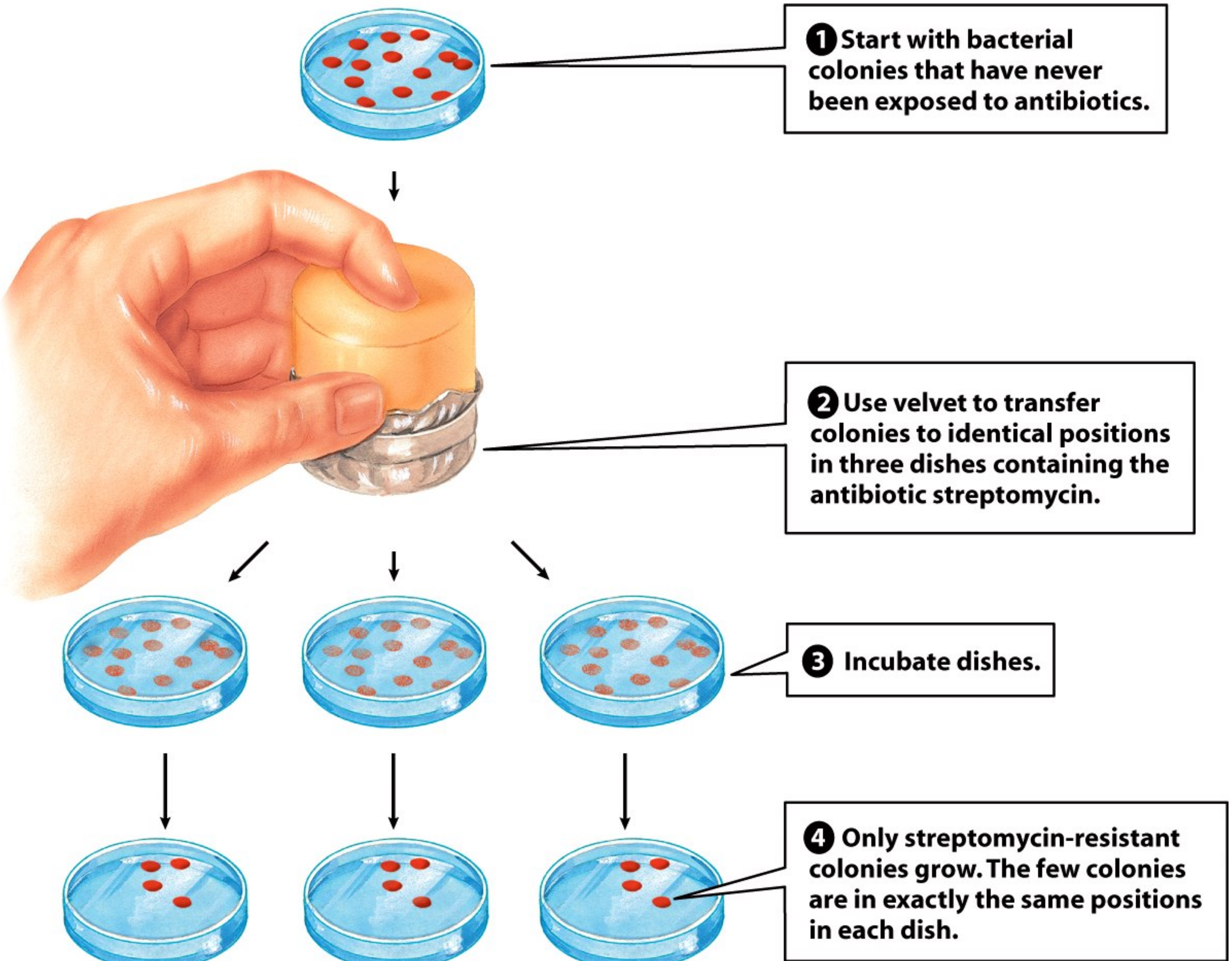

Figure 15-3 Biology: Life on Earth, 8/e

Gene Flow

- **Gene flow** is the movement of alleles from one population to another
  - Immigration adds alleles to a population
  - Emigration removes alleles from a population
- Alleles can move between populations even if organisms do not
  - Plants release seeds and pollen

Figure 15-4 Biology: Life on Earth, 8/e

Gene Flow

- The main evolutionary effect of gene flow is to reduce the differences in the gene pools of different populations of the same species

Allele Frequencies Drift

- **Genetic drift** is the random change in allele frequencies over time, brought about by chance alone
  - Has minor impact in very large populations
  - Occurs more rapidly and has bigger effect on small populations

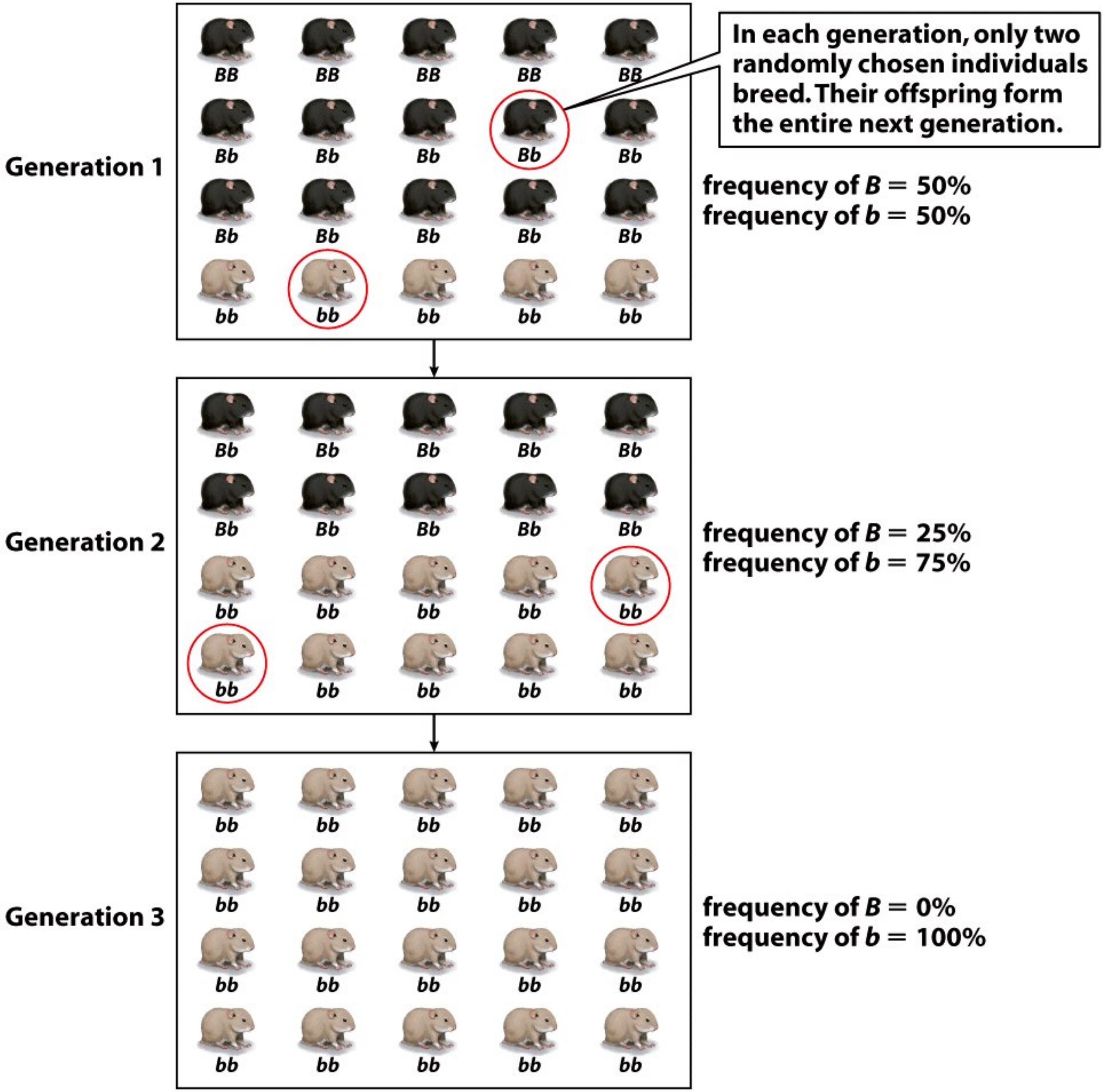

Figure 15-5 Biology: Life on Earth, 8/e

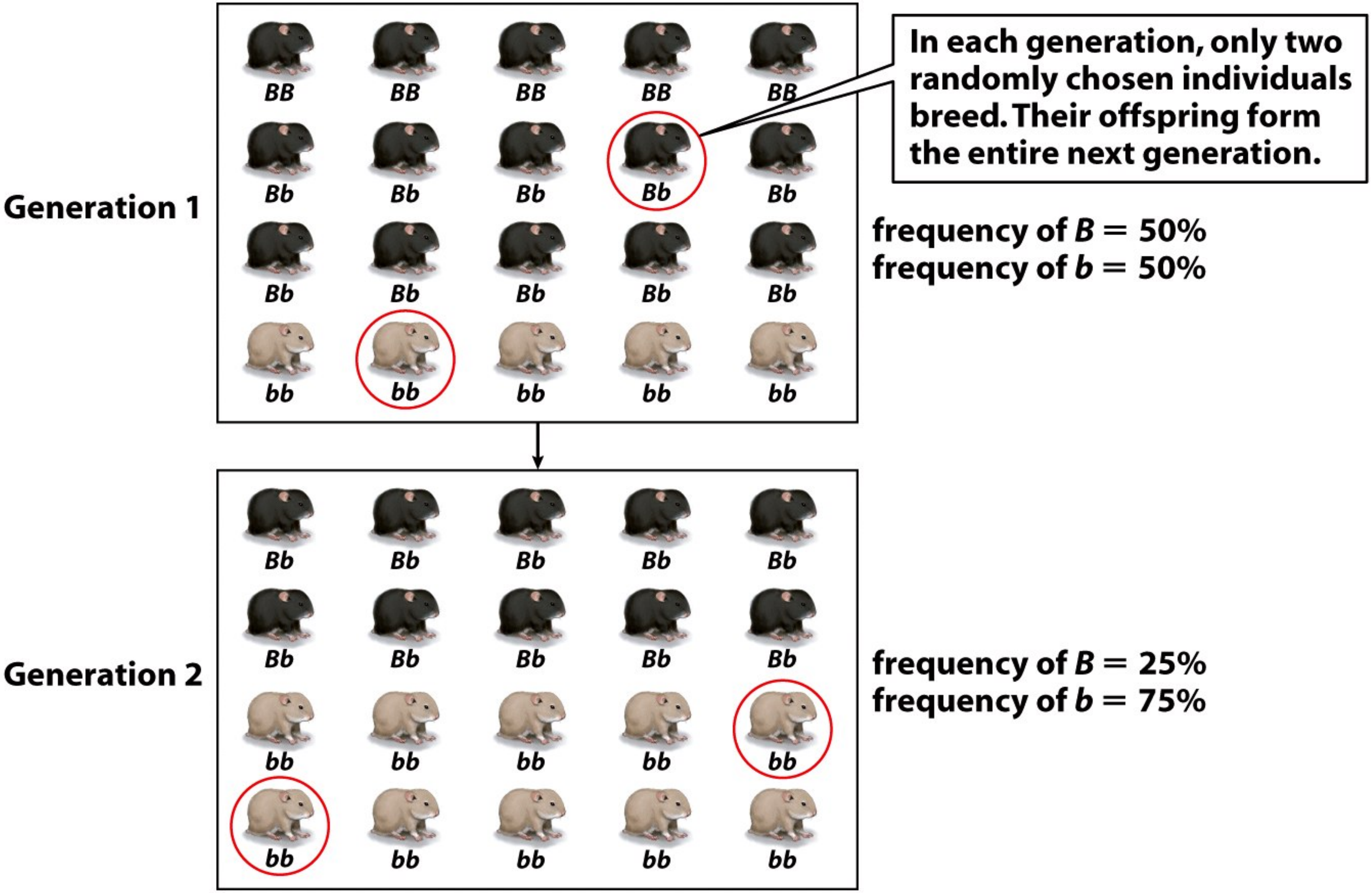

Figure 15-5 part 1 Biology: Life on Earth, 8/e

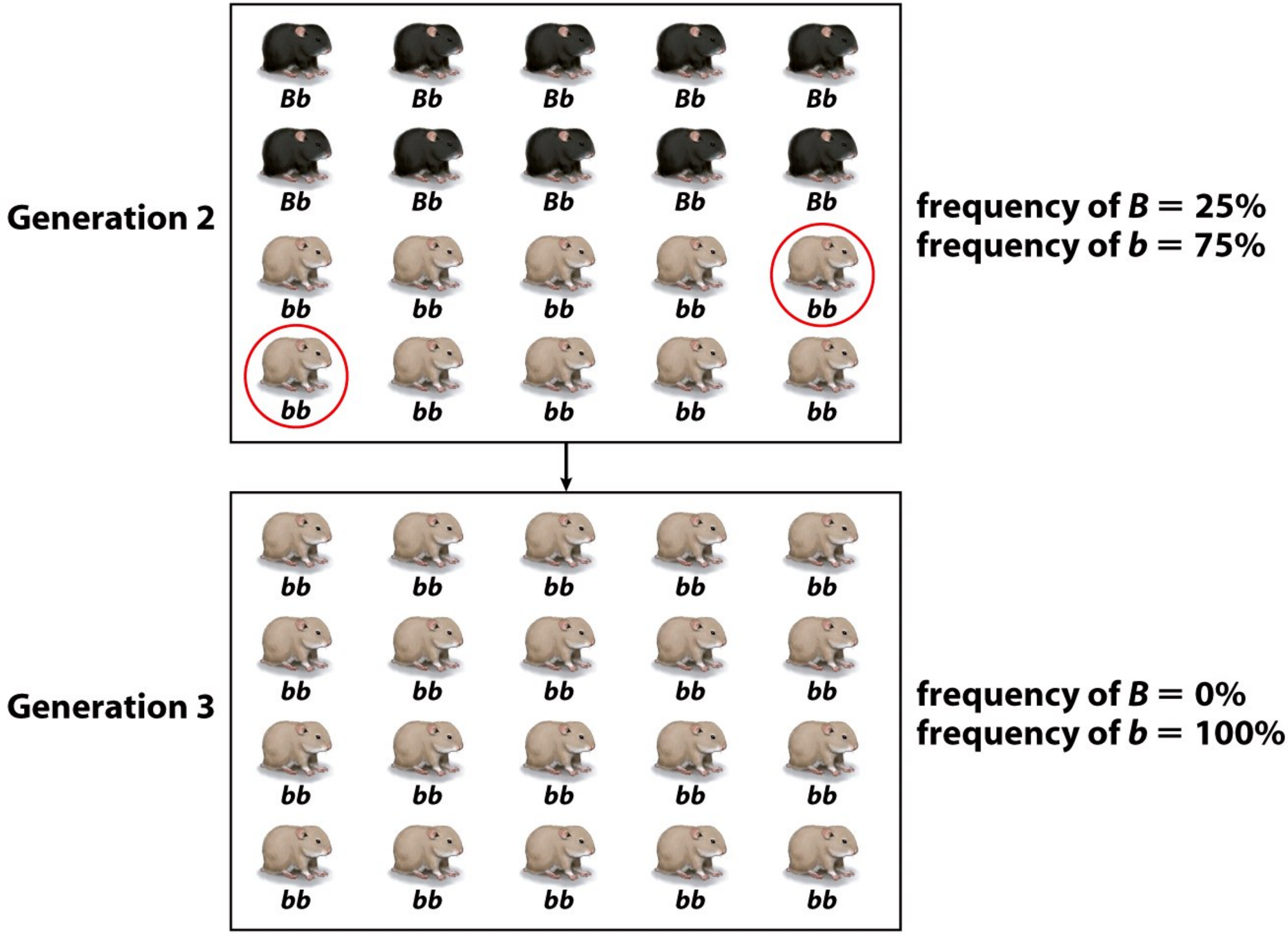

Figure 15-5 part 2 Biology: Life on Earth, 8/e

Population Size Matters

- Population size affects genetic drift

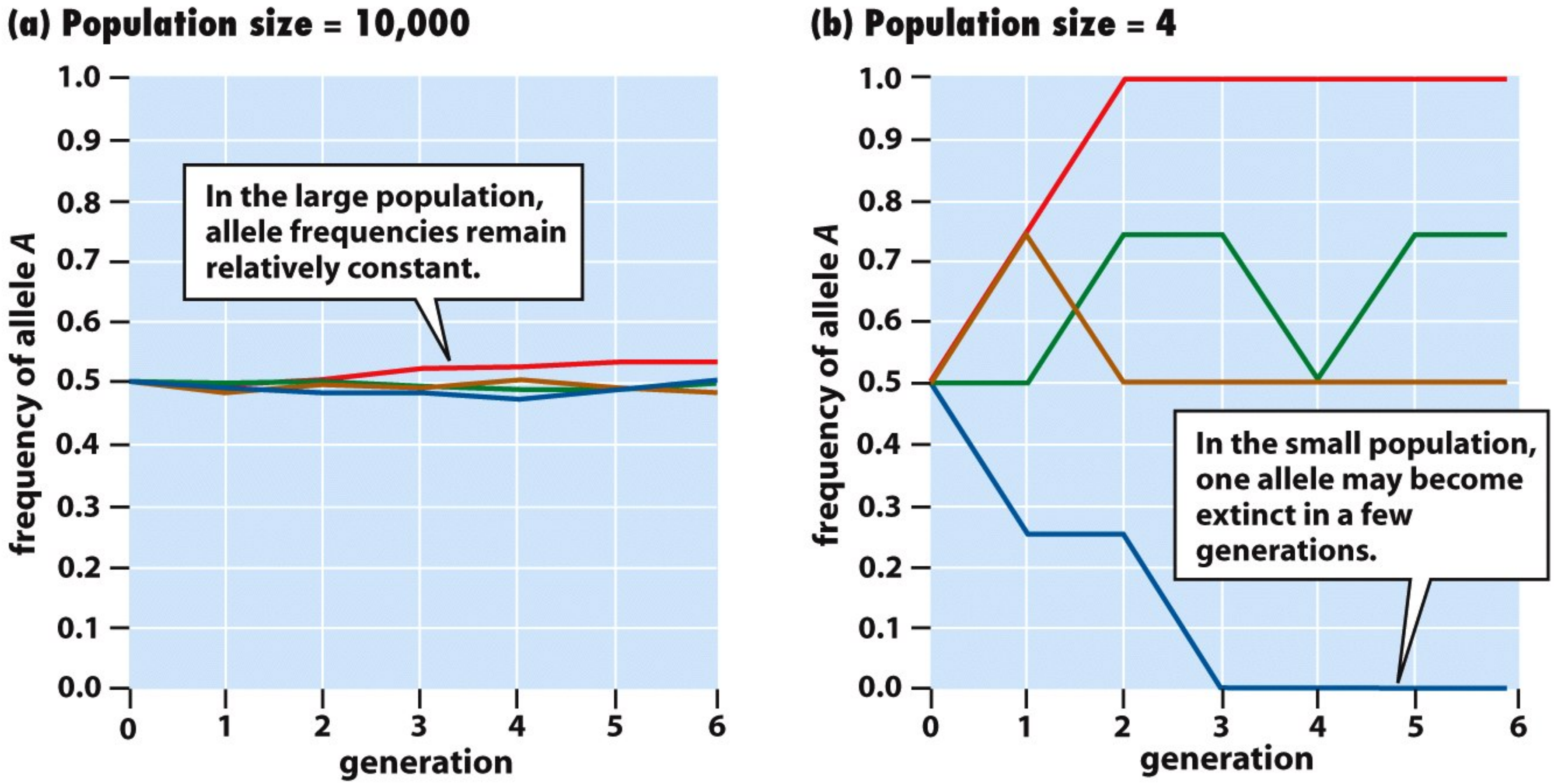

Figure 15-6 Biology: Life on Earth, 8/e

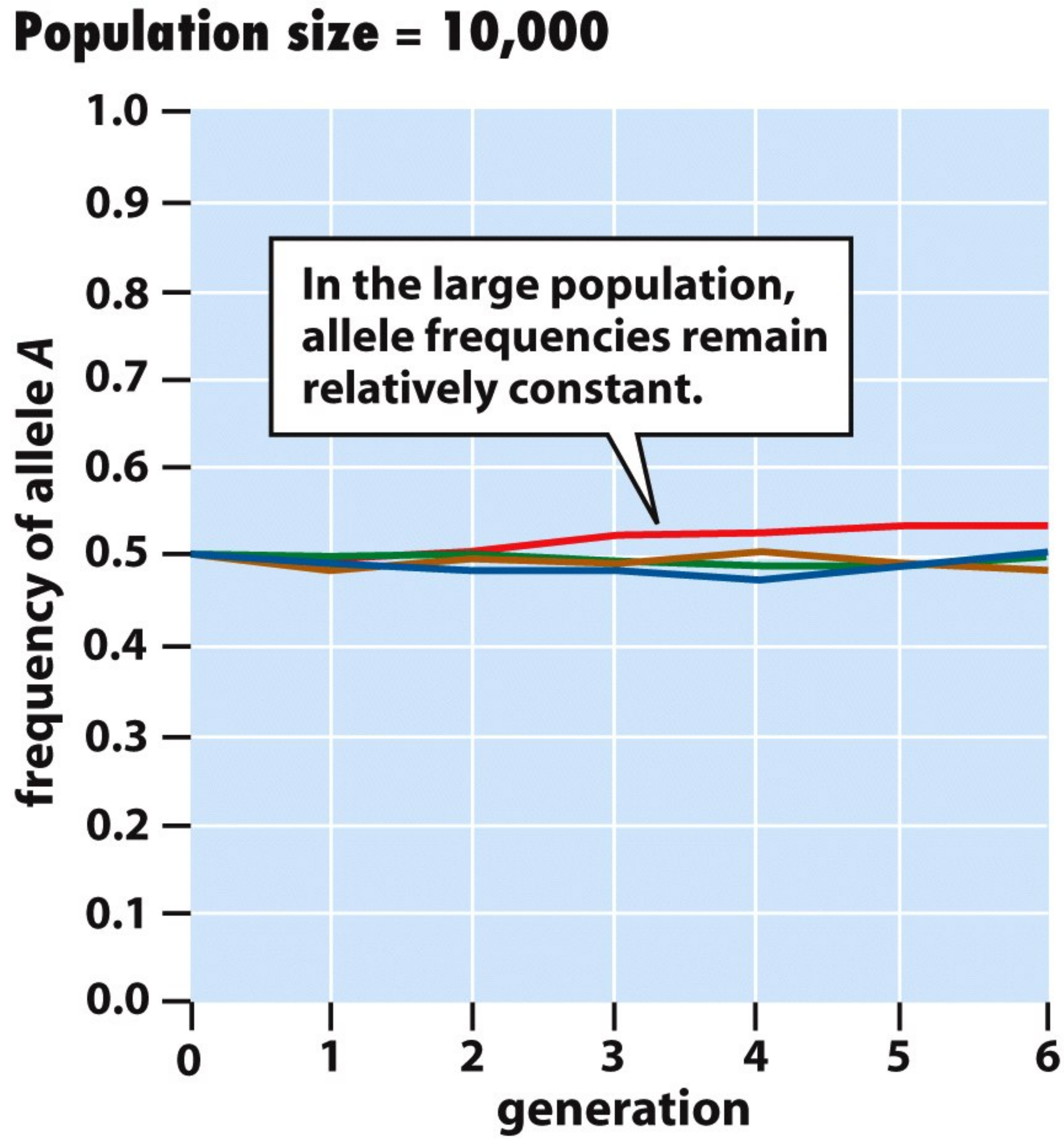

Figure 15-6a Biology: Life on Earth, 8/e

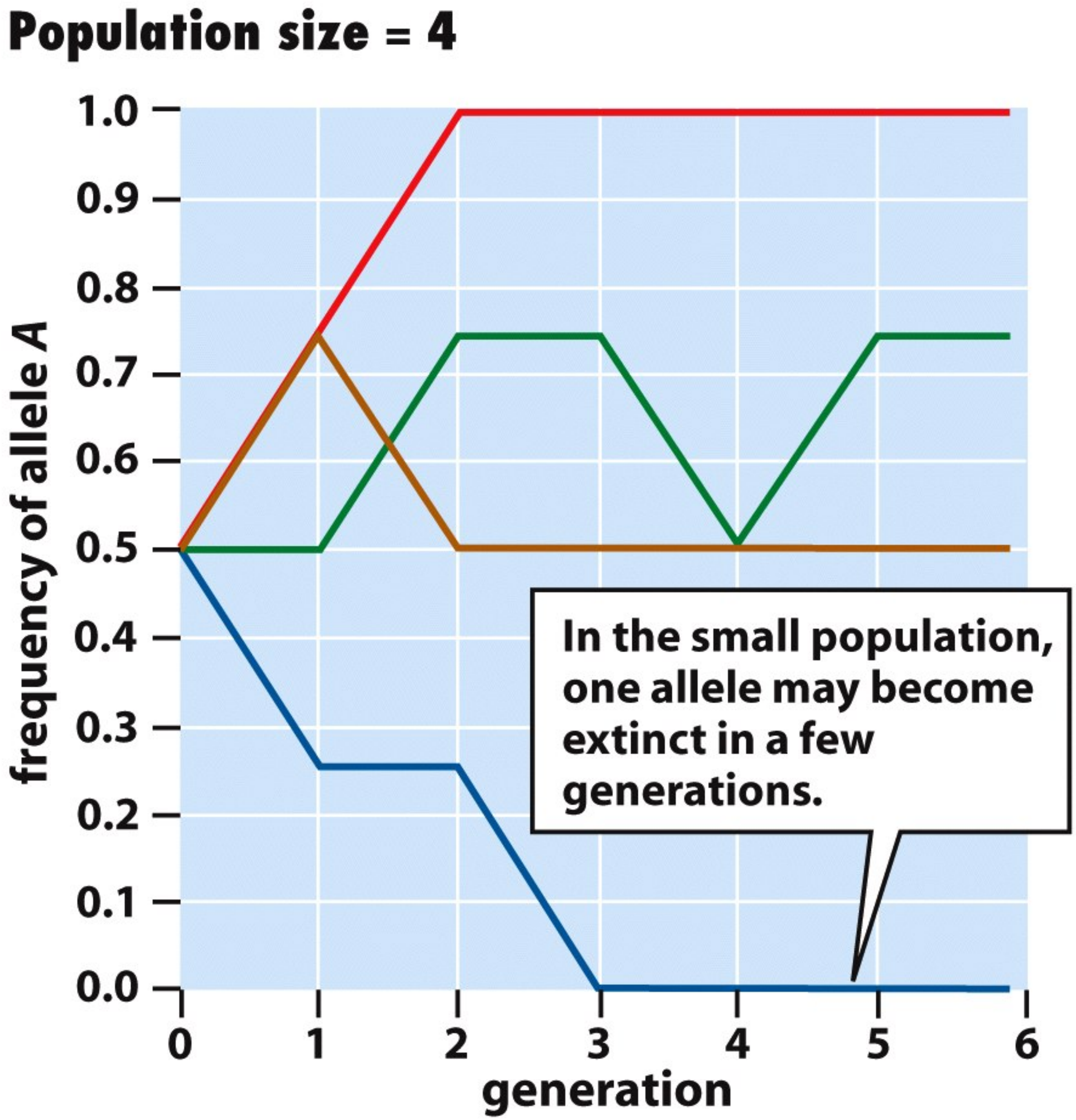

Figure 15-6b Biology: Life on Earth, 8/e

Causes of Genetic Drift

- There are two causes of genetic drift
  - Population bottleneck
  - Founder effect

Population Bottleneck

- A **population bottleneck** is a drastic reduction in population size brought about by a natural catastrophe or over-hunting
- A population bottleneck can change allele frequencies and reduce genetic variation

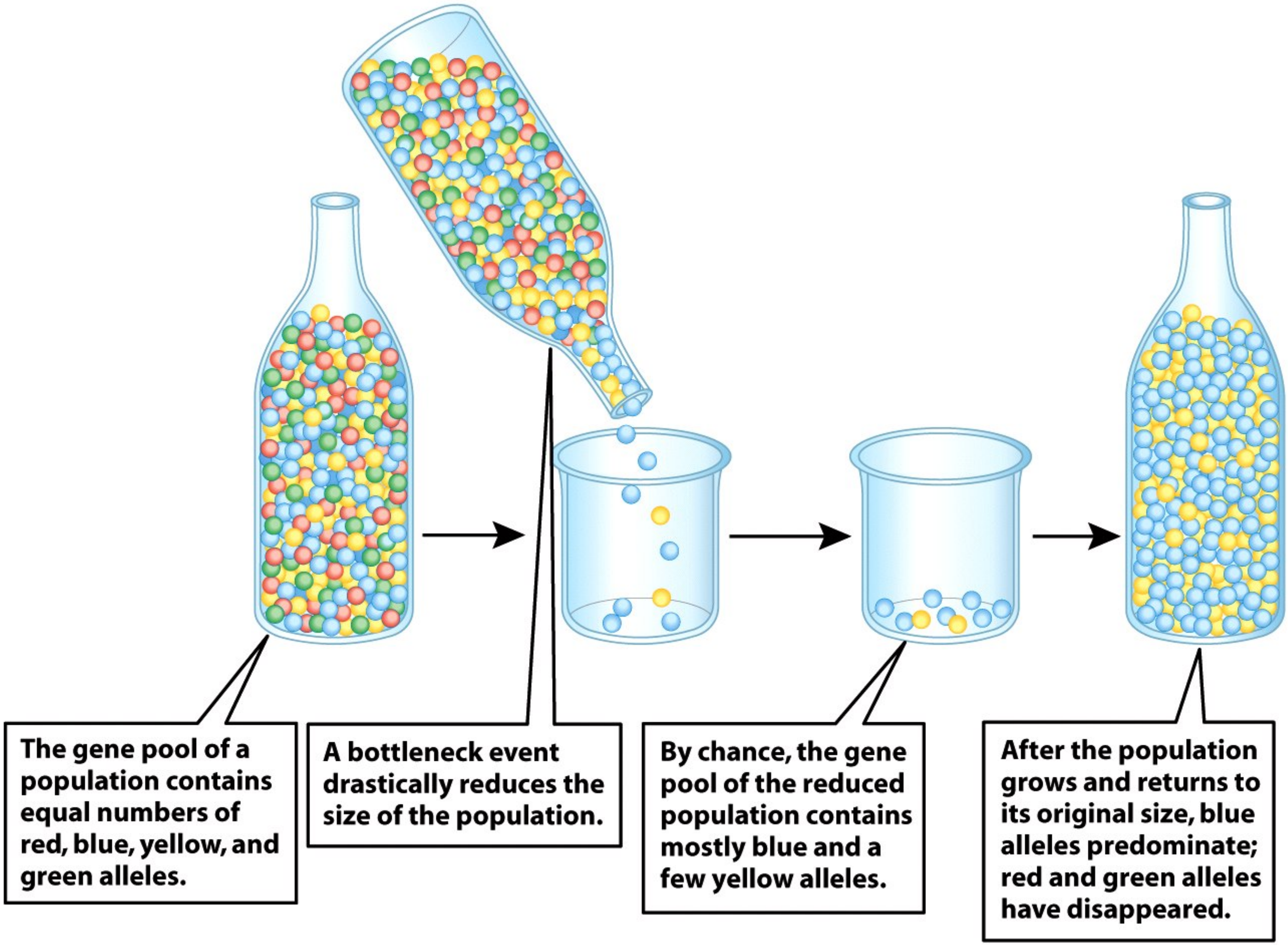

Figure 15-7a Biology: Life on Earth, 8/e

Population Bottleneck

- Northern elephant seal
  - Hunted almost to extinction in the 1800s
  - By 1890s, only 20 individuals remained
  - Hunting ban allowed population to increase to 30,000
  - Biochemical analysis shows that present-day northern elephant seals are almost genetically identical

Figure 15-7b Biology: Life on Earth, 8/e

Founder Effect

- The **founder effect** occurs when a small number of individuals leave a large population and establish a new isolated population

Isolated Founding Populations

- By chance, allele frequencies of founders may differ from those of original population
- Over time, new population may exhibit allele frequencies that differ from original population

Figure 15-8 Biology: Life on Earth, 8/e

Mating Is Almost Never Random

- Nonrandom mating can change the distribution of genotypes in a population
- Organisms within a population rarely mate randomly

Mating Is Almost Never Random

- Most animals are likely to mate with nearby members of their species
- Certain animals, such as snow geese, exhibit **assortative mating**, where there is a preference for mates that are similar in appearance

Figure 15-9 Biology: Life on Earth, 8/e

All Genotypes Are Not Equal

- Natural selection favors certain alleles at the expense of others (e.g. evolution of penicillin-resistant bacteria)…

All Genotypes Are Not Equal

- First widespread use of penicillin occurred during World War II
- Penicillin killed almost all infection-causing bacteria
- Penicillin did not affect bacteria possessing a rare allele that destroyed penicillin on contact
- Bacteria carrying the rare allele survived and reproduced

All Genotypes Are Not Equal

- Natural selection does not cause genetic changes in individuals
  - Penicillin resistance allele arose spontaneously (before exposure to penicillin)
  - Presence of penicillin caused bacteria possessing the rare allele to be favored (have greater reproductive success) over bacteria lacking the allele

All Genotypes Are Not Equal

- Natural selection acts on individuals, yet changes populations
  - Penicillin (the agent of natural selection) acted on individual bacteria
  - The bacterial population evolved as its allele frequencies changed

All Genotypes Are Not Equal

- Evolution is change in allele frequencies of a population, owing to unequal reproductive success among organisms bearing different alleles
  - Penicillin-resistant bacteria had greater **fitness** (reproductive success) than non-resistant bacteria

All Genotypes Are Not Equal

- Evolutionary changes are not “good” or “progressive” in any absolute sense
  - Penicillin-resistant bacteria were favored only because of presence of penicillin
  - Long neck of male giraffe was favored only because it confers a distinct advantage in combat to establish dominance

All Genotypes Are Not Equal

- Evolution is a compromise between opposing pressures…

(a) **(b)**

Figure 15-10 Biology: Life on Earth, 8/e

Figure 15-10a Biology: Life on Earth, 8/e

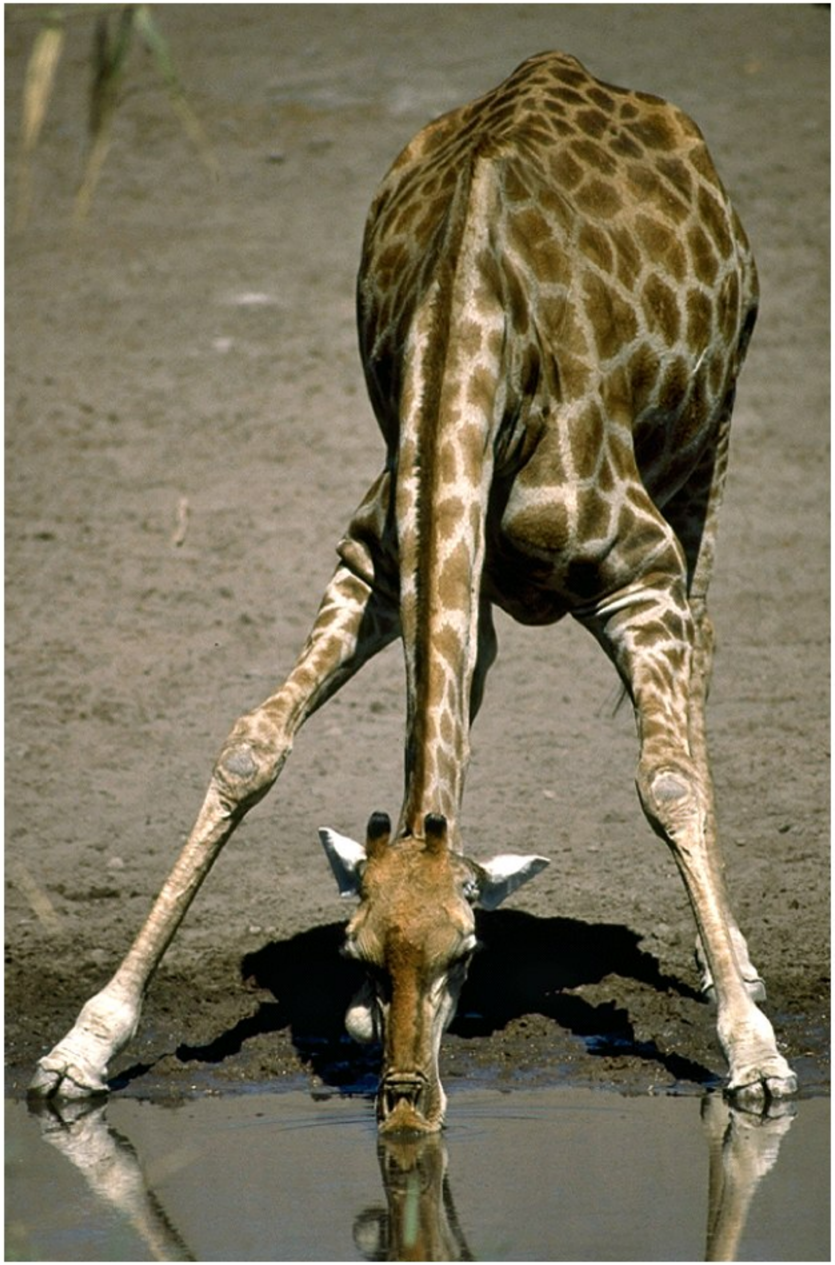

Figure 15-10b Biology: Life on Earth, 8/e

Table 15-1 Causes of Evolution

Process	Consequence
Mutation	Creates new alleles; increases variability
Gene flow	Increases similarity of different populations
Genetic drift	Causes random change of allele frequencies; can eliminate alleles
Nonrandom mating	Changes genotype frequencies but not allele frequencies
Natural and sexual selection	Increases frequency of favored alleles; can produce adaptations

Table 15-1 Biology: Life on Earth, 8/e

Section 15.3 Outline

- **15.3 How Does Natural Selection Work?**
  - Natural Selection Stems from Unequal Reproduction
  - Natural Selection Acts on Phenotypes
  - Some Phenotypes Reproduce More Successfully Than Others
  - Selection Can Influence Populations in Three Ways

Natural Selection

- Natural selection is often associated with the phrase "survival of the fittest"
- The fittest individuals are those that not only survive, but are able to leave the most offspring behind

Natural Selection

- The selection on phenotypes affects genotypes present in the population
  - If environmental conditions favored tall pea plants, then tall pea plants would leave more offspring
  - These offspring would carry tall alleles

Success of Phenotypes

- Successful phenotypes are those that have the best adaptations to their present environment
  - **Adaptations** are characteristics that help an individual survive and reproduce
- Adaptations arise from the interactions of organisms with both the nonliving and living parts of their environments

The Environment

- Nonliving (abiotic) components include:
  - Climate
  - Availability of water
  - Concentration of minerals in the soil
- Living (biotic) components include:
  - Other organisms

The Environment

- Interactions with other organisms include:
  - Competition
  - Coevolution
  - Sexual selection

Agents of Selection

- **Competition** is an interaction among individuals who attempt to utilize a limited resource
  - May be between individuals of same species or different species
  - Most intense among members of the same species

Agents of Selection

- **Coevolution** is the evolution of adaptations in two species due to their extensive interaction
  - e.g. predator-prey relationships
- **Predation** is an interaction in which one organism (the predator) kills and eats another organism (the prey)

Agents of Selection

- Coevolution between predators and prey is akin to a "biological arms race"
  - Wolf predation selects against slow, careless deer
  - Alert, swift deer select against slow, clumsy wolves

Sexual Selection

- **Sexual selection** is a type of natural selection that favors traits that help an organism acquire a mate
- Traits that help males acquire mates include:
  - Conspicuous features (bright colors, long feathers or fins, elaborate antlers)
  - Bizarre courtship behaviors
  - Loud, complex courting songs
- Traits derived by sexual selection make males more vulnerable to predators

Sexual Selection

- Male-male competition for access to females
  - Favors evolution of features that provide an advantage in fights or ritual displays of aggression

Figure 15-11 Biology: Life on Earth, 8/e

Sexual Selection

- Female mate choice
  - Male structures, colors, and displays that do not enhance survival might provide an outward sign of a male's health and vigor

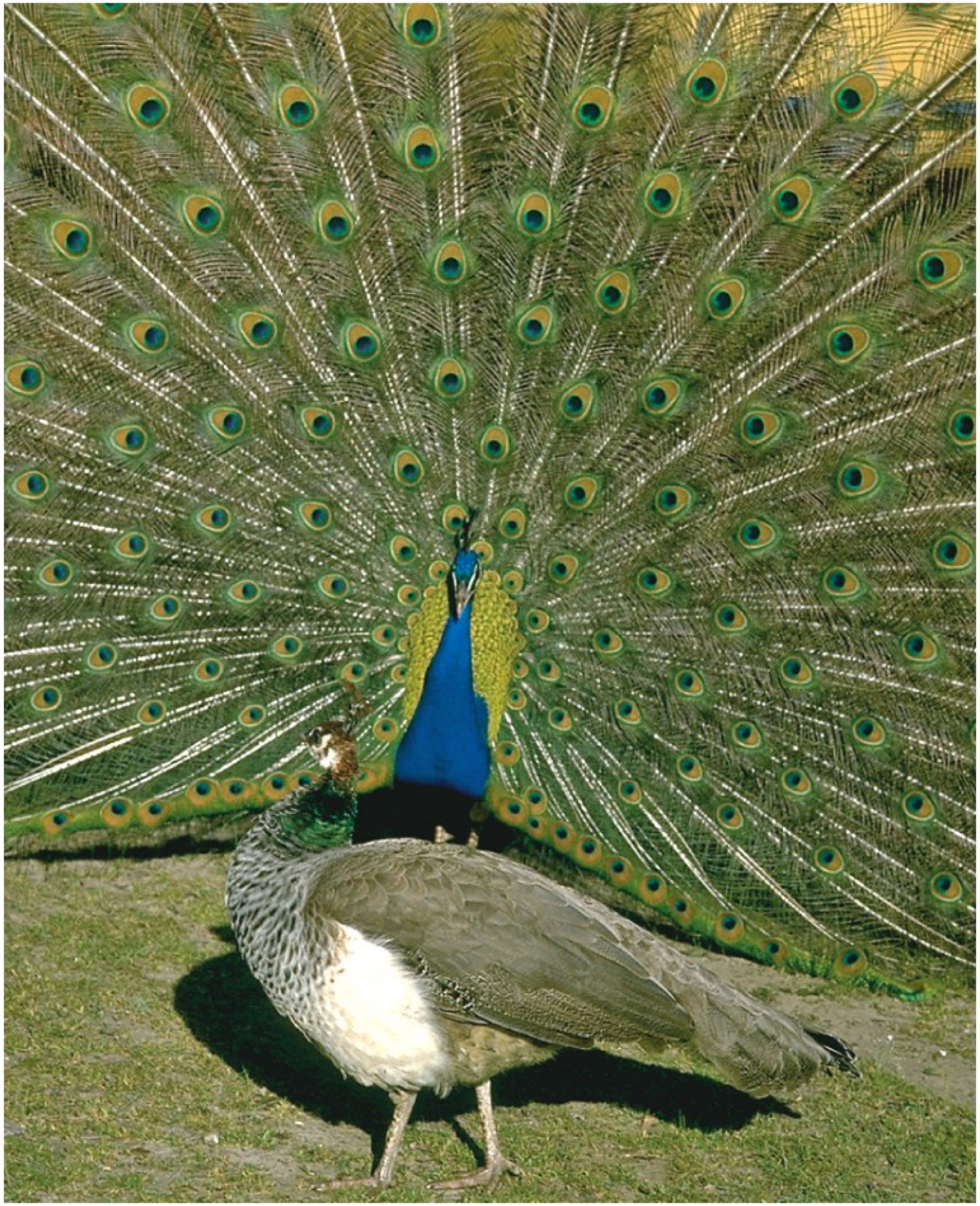

Figure 15-12 Biology: Life on Earth, 8/e

Selection Influences Populations

- Natural selection and sexual selection can affect populations in three ways:
  - Directional selection
  - Stabilizing selection
  - Disruptive selection

Directional Selection

- **Directional selection** occurs when environmental conditions change in a consistent direction
- Average phenotype shifts in a consistent direction
  - One of the extreme phenotypes is favored
  - Both intermediate and opposite extreme phenotypes are selected against
  - e.g. pesticide resistance, antibiotic resistance

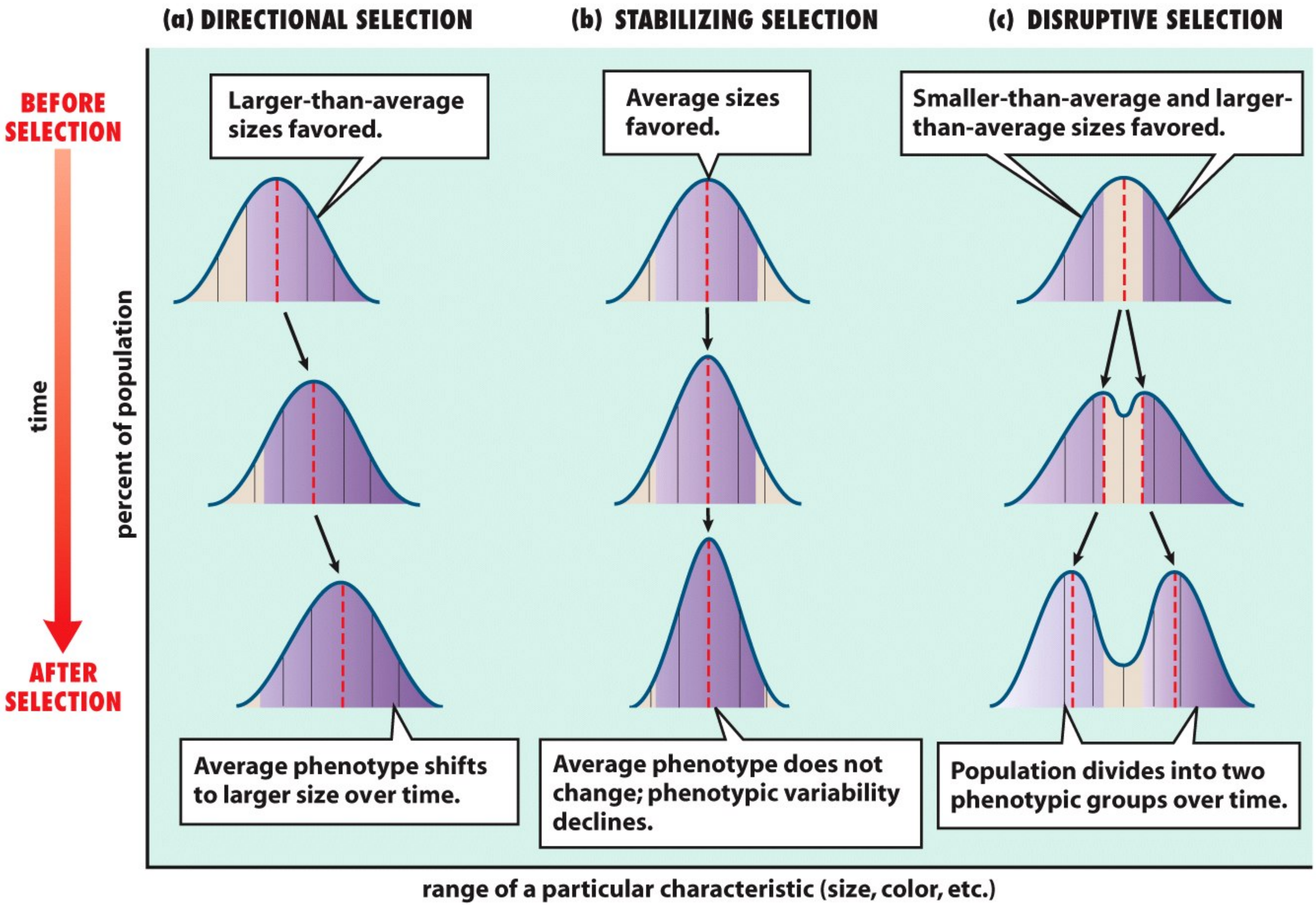

Figure 15-13 Biology: Life on Earth, 8/e

Stabilizing Selection

- **Stabilizing selection** when environmental conditions are relatively constant
- Phenotypic variability declines
  - Intermediate phenotype is favored
  - Both extreme phenotypes are selected against
- e.g. body size in *Aristelliger* lizards
  - Smallest lizards have a difficulty defending territory
  - Largest lizards more likely to be eaten by owls

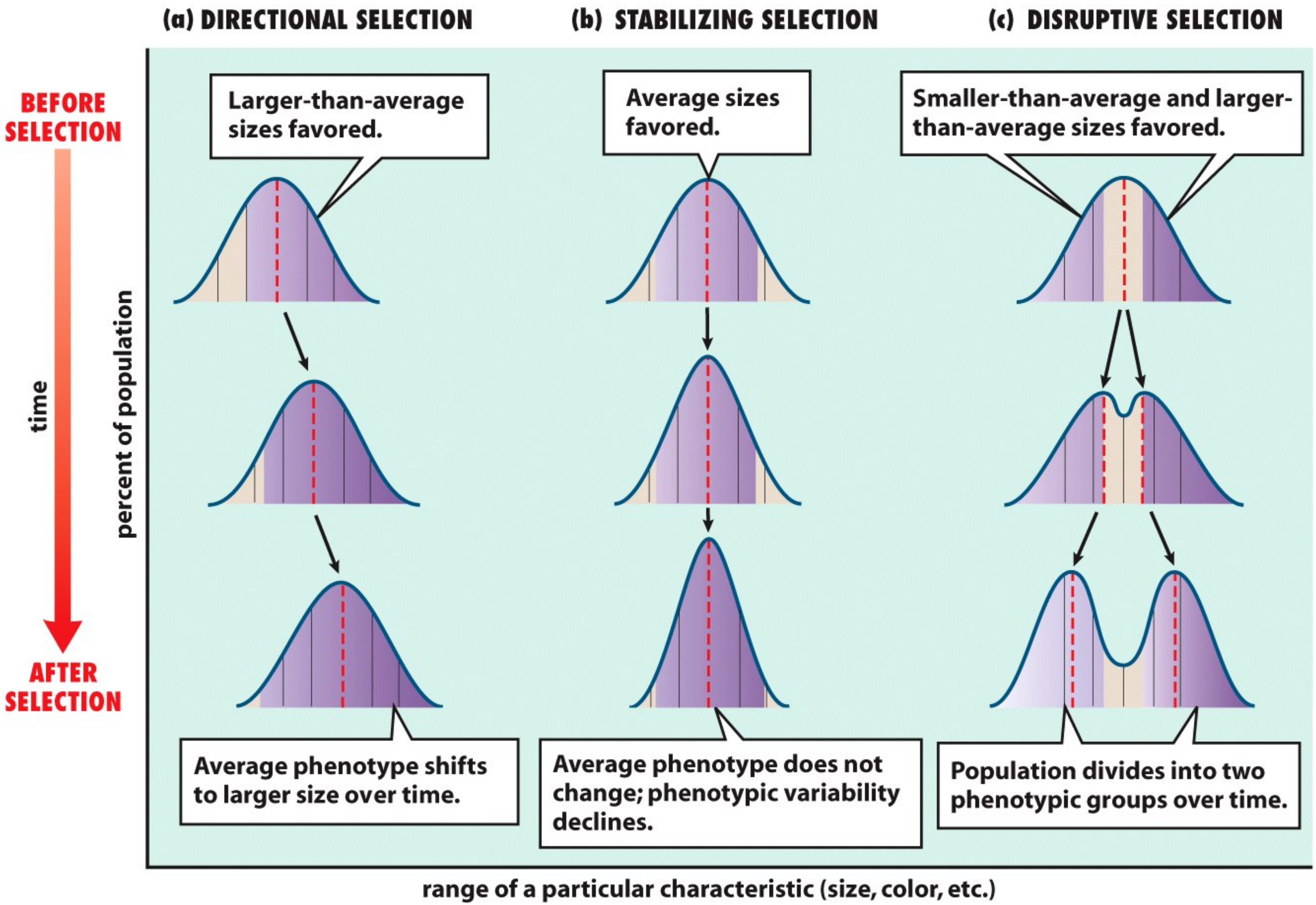

Figure 15-13 Biology: Life on Earth, 8/e

Disruptive Selection

- **Disruptive selection** occurs when an environment has more than one type of useful resource
- Population divides into two phenotypic groups over time
  - Both extreme phenotypes are favored
  - Intermediate phenotype is selected against
- e.g. beak size in black-bellied seedcrackers
  - Birds with large beaks eat hard seeds
  - Birds with small beaks eat soft seeds

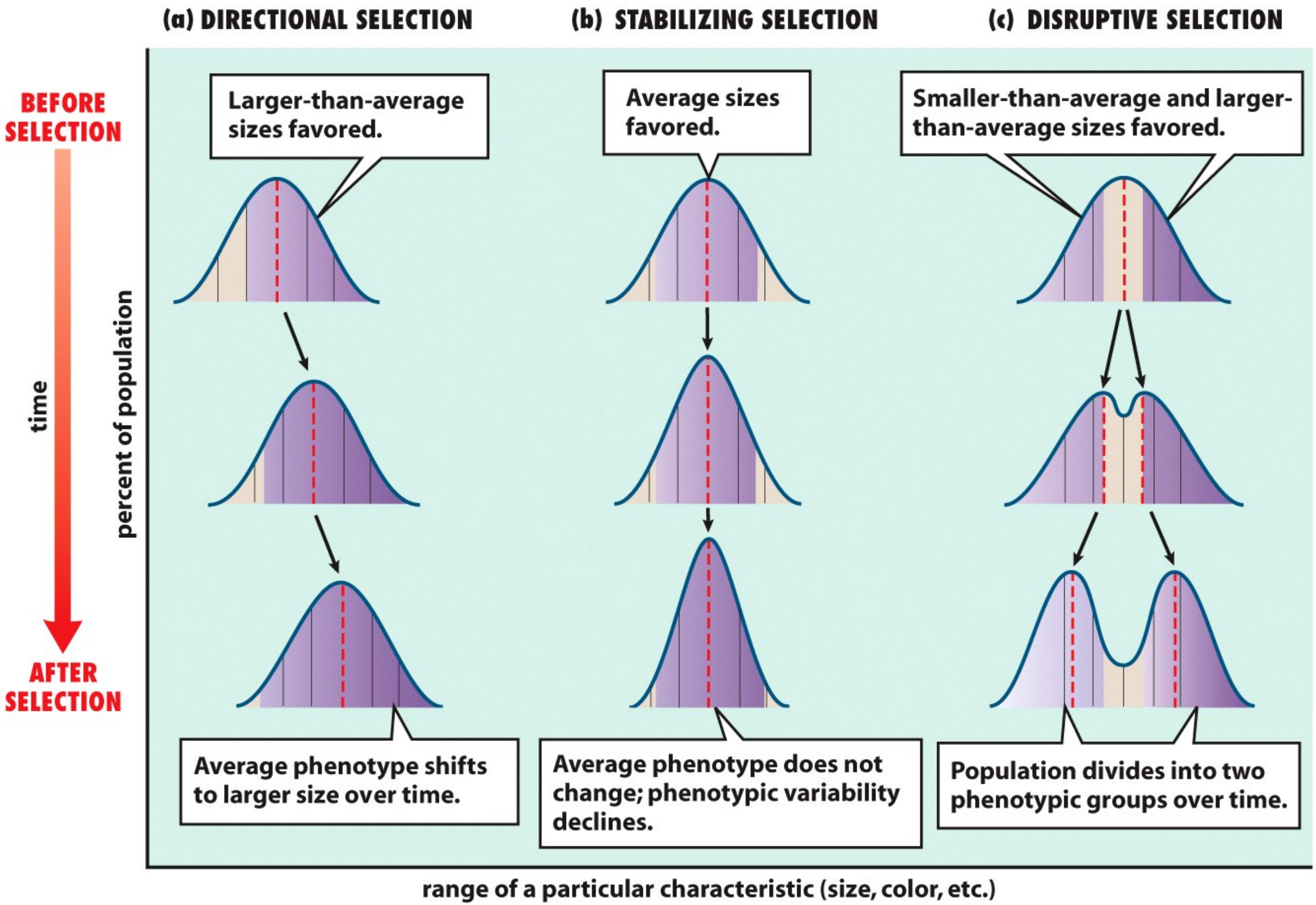

Figure 15-13 Biology: Life on Earth, 8/e

Figure 15-14 Biology: Life on Earth, 8/e

Balanced Polymorphism

- **Balanced polymorphism** is the prolonged maintenance of two or more alleles in a population
- Balanced polymorphism often occurs when environmental conditions favor heterozygotes
  - e.g. normal and sickle-cell hemoglobin alleles in malaria-prone regions of Africa