Darwin's Theory of Evolution

13.1 A Sea Voyage Helped Darwin Frame His Theory of Evolution (1 of 3)

- Charles Darwin is best known for his book *On the Origin of Species by Means of Natural Selection*, commonly referred to as *The Origin of Species*, which launched the era of evolutionary biology.

13.1 A Sea Voyage Helped Darwin Frame His Theory of Evolution (2 of 3)

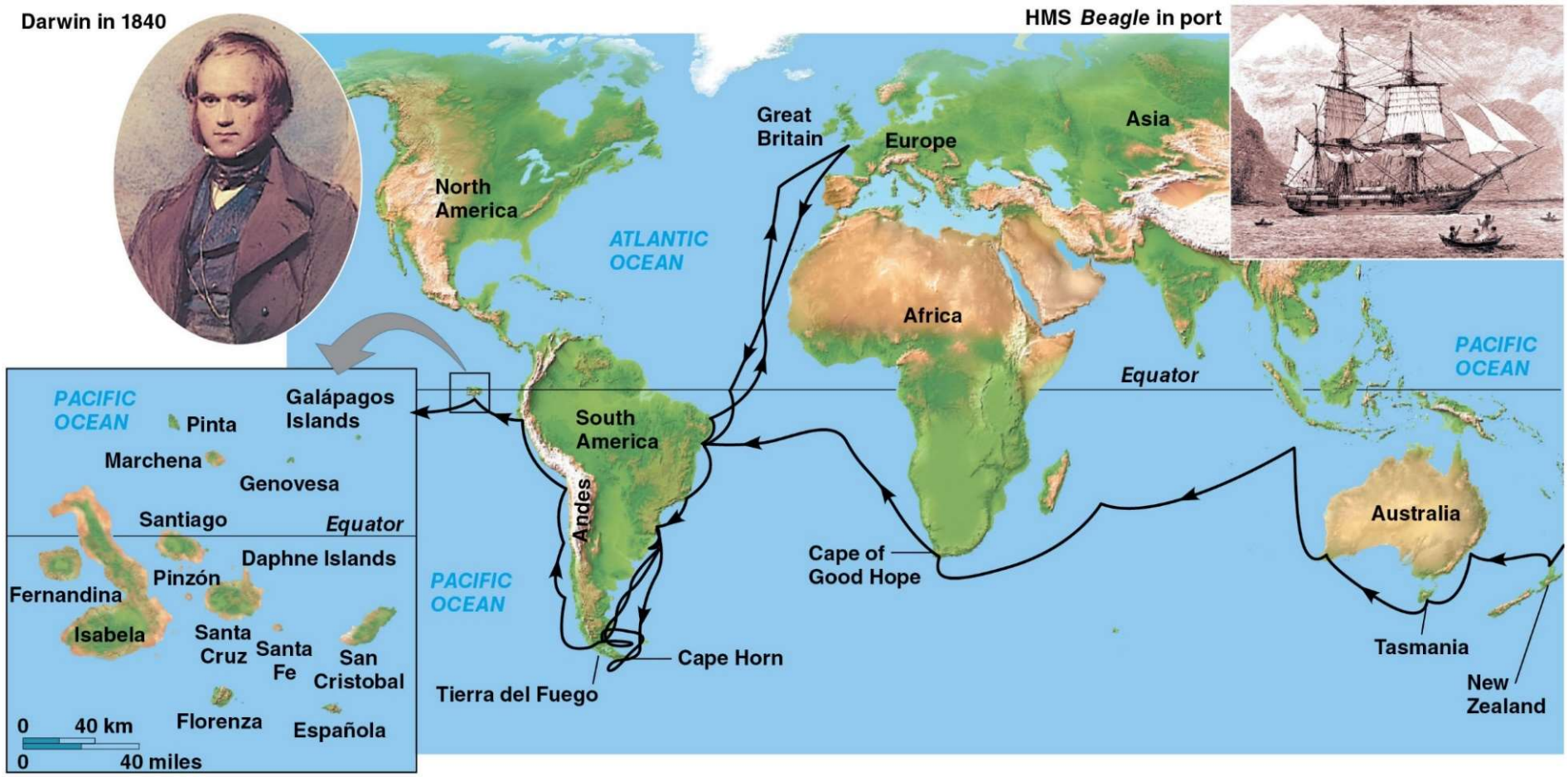
- Darwin's theory differed greatly from the long-held notion of a young Earth inhabited by unchanging species.
- Darwin called his theory descent with modification, which explains that
  - all of life is connected by common ancestry and
  - descendants have accumulated **adaptations** to changing environments over vast spans of time.

13.1 A Sea Voyage Helped Darwin Frame His Theory of Evolution (3 of 3)

- Consequently, scientists regard Darwin's concept of **evolution** by means of **natural selection** as a **theory**, a widely accepted explanatory idea that
  - is broader in scope than a hypothesis,
  - generates new hypotheses, and
  - is supported by a large body of evidence.

Checkpoint question What was Darwin's phrase for evolution? What does it mean?

Figure 13.1a



13.2 The Study of Fossils Provides Strong Evidence for Evolution

- **Fossils**
  - are the imprints or remains of organisms that lived in the past,
  - document differences between past and present organisms, and
  - reveal that many species have become extinct.
- The fossil record reveals the historical sequence in which organisms have evolved.

13.3 Scientific Thinking: Fossils of Transitional Forms Support Darwin's Theory of Evolution (1 of 3)

- Many fossils link early extinct species with species living today.
- Thousands of fossil discoveries shed light on the evolutionary origins of many groups of organisms.

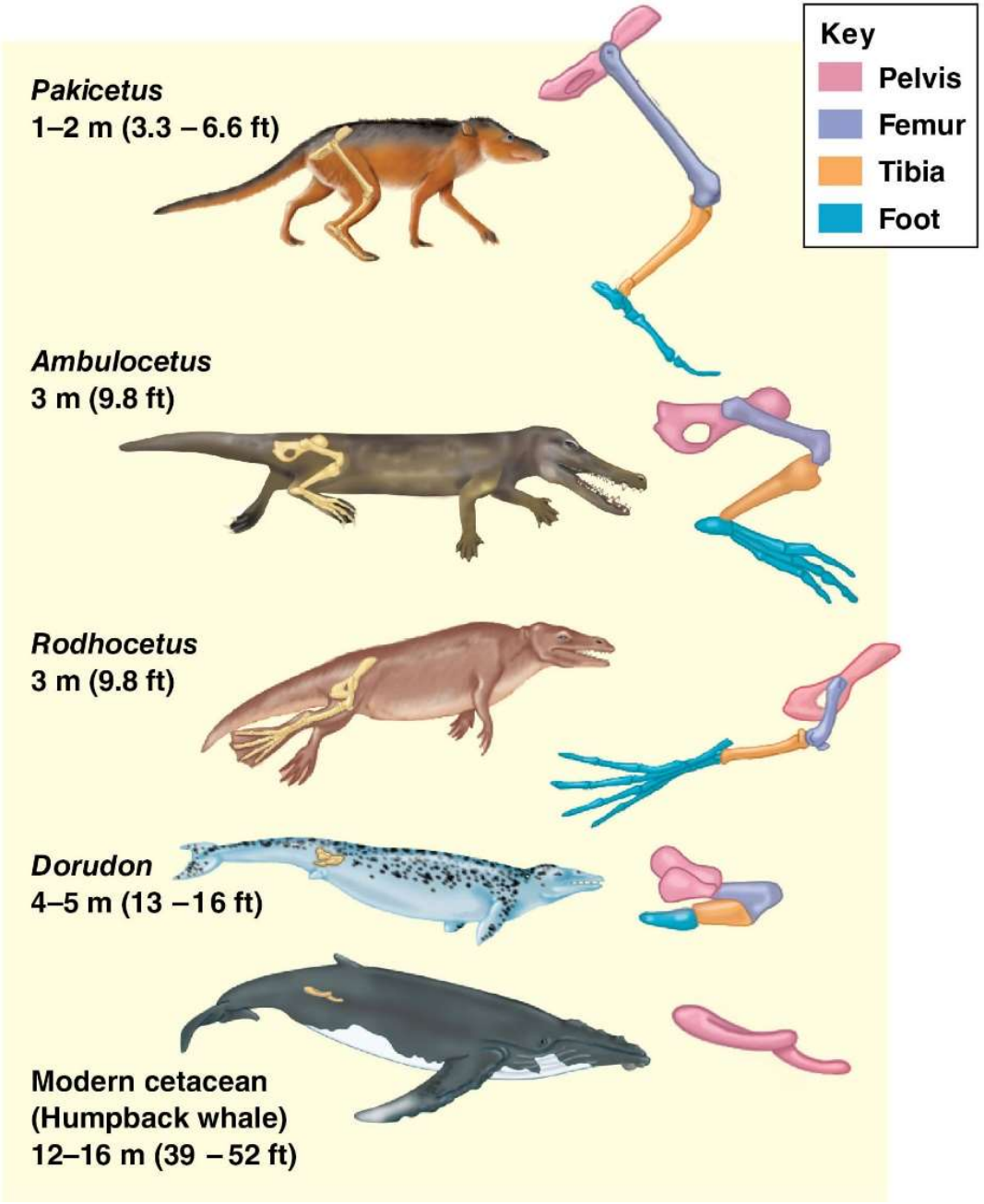
13.3 Scientific Thinking: Fossils of Transitional Forms Support Darwin's Theory of Evolution (2 of 3)

- Beginning in the late 1970s, paleontologists unearthed transitional fossils and thought that whales arose from a wolf-like carnivore.
- But molecular biologists found a close relationship between whales and hippopotamuses and hypothesized that whales and hippos were both descendants of a cloven-hoofed ancestor.

13.3 Scientific Thinking: Fossils of Transitional Forms Support Darwin's Theory of Evolution (3 of 3)

- Two fossils discovered in 2001 provided the answer.
  - Both *Pakicetus* and *Rodhocetus* had the distinctive ankle bone of a cloven-hoofed mammal.
  - Thus, as is often the case in science, scientists are becoming more certain about the evolutionary origin of whales.

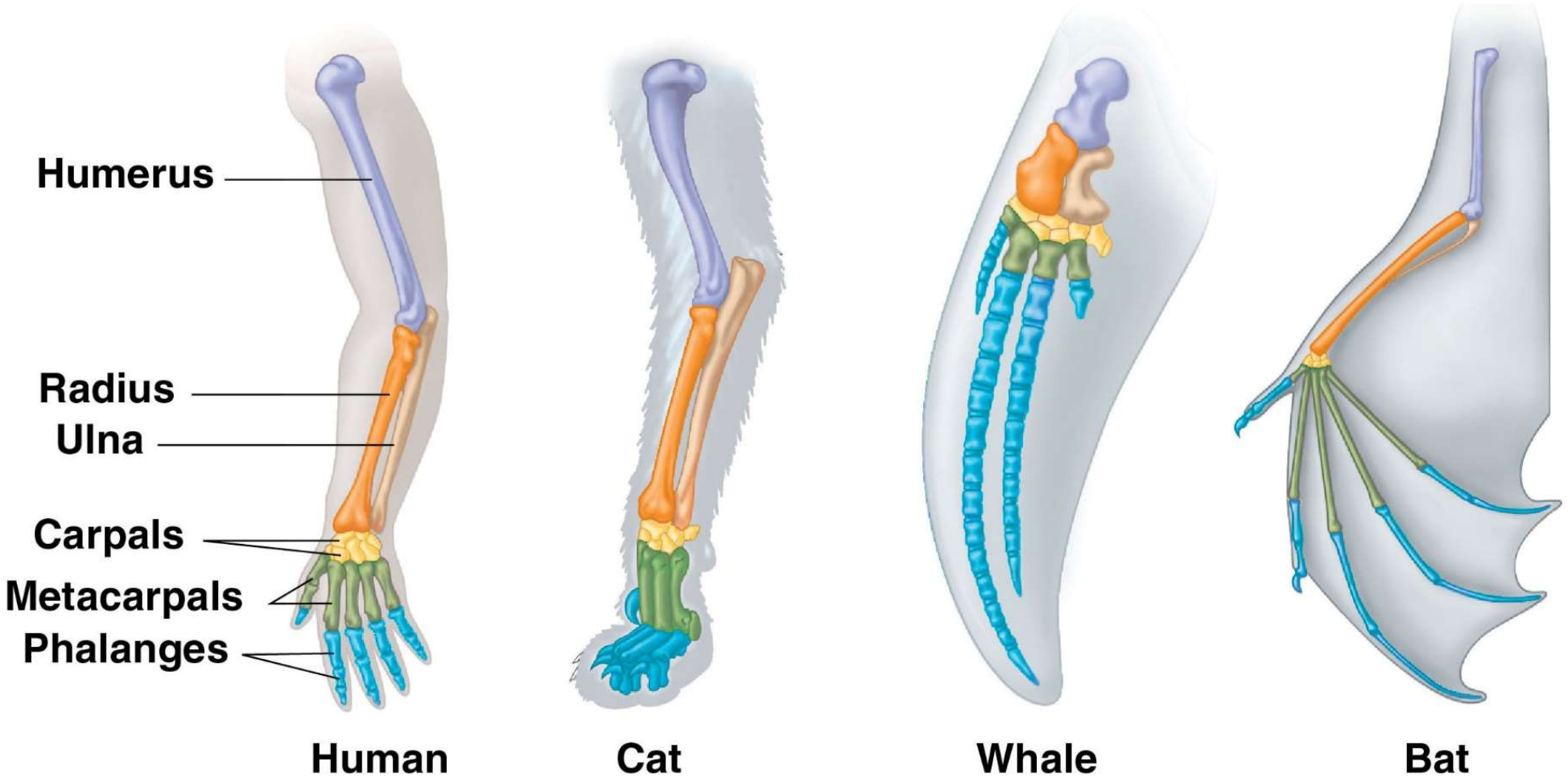
Figure 13.3



13.4 Homologies Provide Strong Evidence for Evolution (1 of 2)

- Evolution is a process of descent with modification.
  - Evolution is a remodeling process.
  - Related species can have characteristics that have an underlying similarity yet function differently.
  - Similarity resulting from common ancestry is known as **homology**.
- Structural and molecular homologies reveal evolutionary relationships.

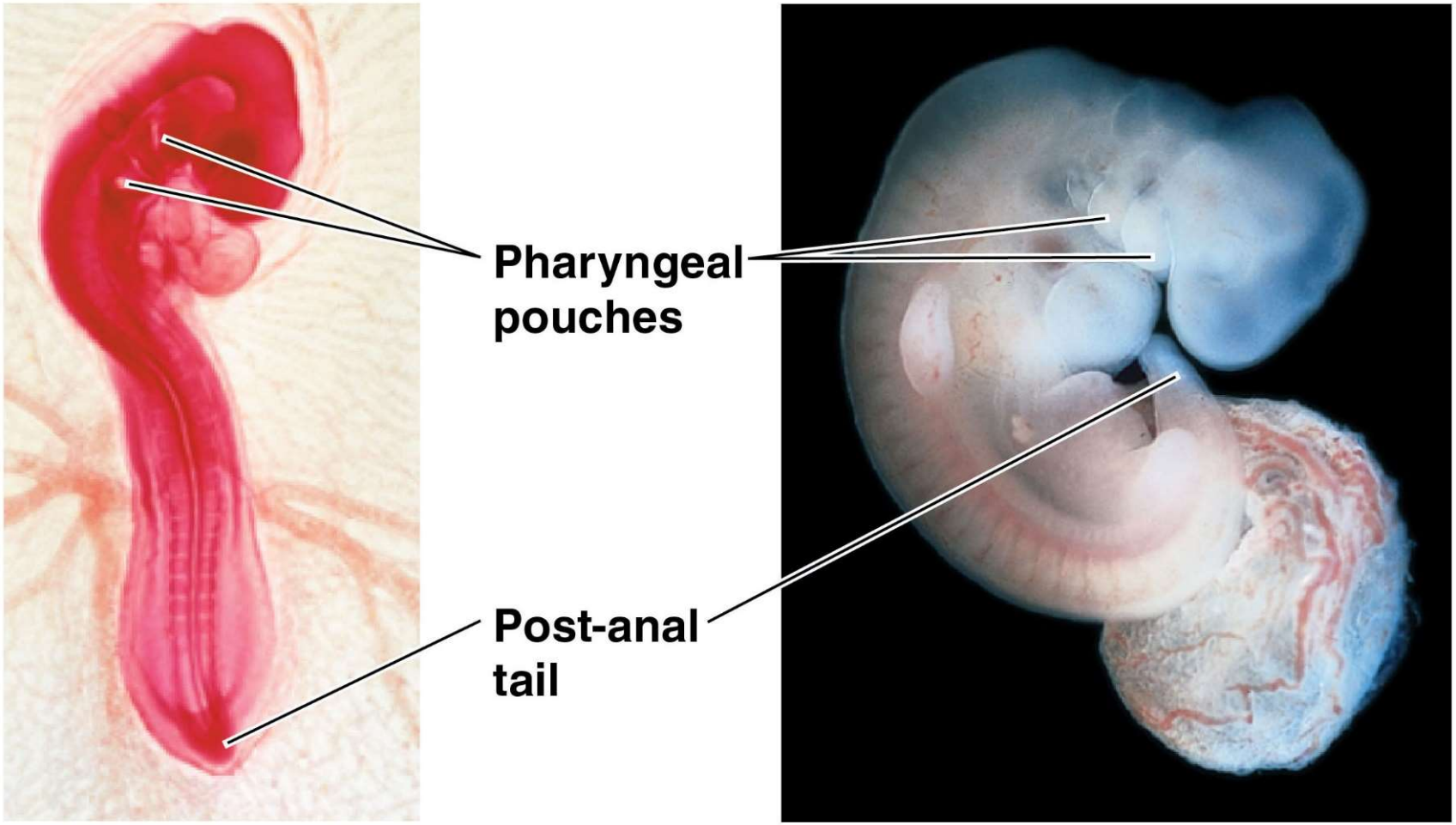
Figure 13.4a



13.4 Homologies Provide Strong Evidence for Evolution (2 of 2)

- An understanding of homology helps explain why early stages of development in different animal species reveal similarities not visible in adult organisms.
- Some of the most interesting homologies are **vestigial structures**, remnants of features that served important functions in the organism's ancestors.

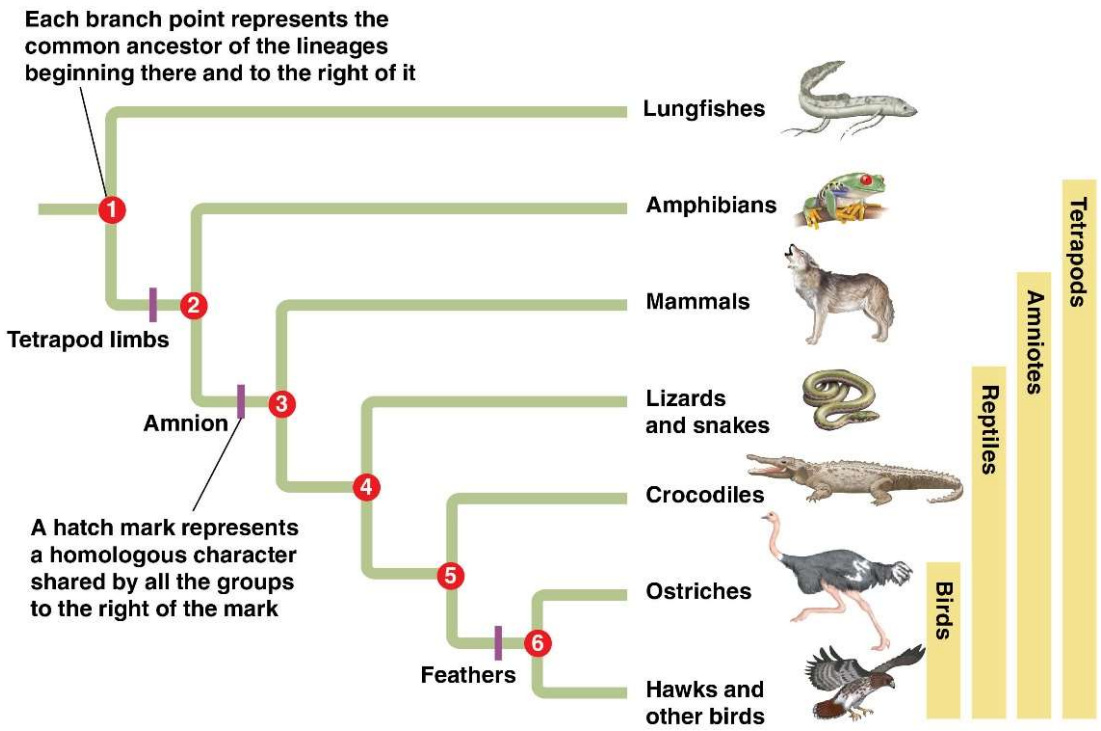
Figure 13.4b



13.5 Homologies Indicate Patterns of Descent That Can Be Shown on an Evolutionary Tree (1 of 2)

- Today, biologists represent patterns of descent with an **evolutionary tree**, often turned sideways.
- Homologous structures can be used to determine the branching sequence of an evolutionary tree.
- These homologies can include
  - anatomical structure and/or
  - molecular structure.

13.5 Homologies Indicate Patterns of Descent That Can Be Shown on an Evolutionary Tree (2 of 2)



Look for the most recent common ancestor of these groups. Crocodiles are more closely related to birds because they share a more recent common ancestor with birds (ancestor ❺) than with lizards (ancestor ❹).

Checkpoint question Refer to the evolutionary tree in Figure 13.5 above. Are crocodiles more closely related to lizards or birds?

13.6 Darwin Proposed Natural Selection as the Mechanism of Evolution (1 of 2)

- Darwin's greatest contribution to biology was his explanation of *how* life evolves.
- Insights into how incremental change occurs could be seen in examples of **artificial selection**.
- Darwin reasoned that if artificial selection can bring about so much change in a relatively short period of time, then natural selection could modify species considerably over hundreds or thousands of generations.

13.6 Darwin Proposed Natural Selection as the Mechanism of Evolution (2 of 2)

- It is important to emphasize three key points about evolution by natural selection.
  1. Although natural selection occurs through interactions between individual organisms and the environment, individuals do not evolve. Rather, it is the population, the group of organisms, that evolves over time.
  2. Natural selection can amplify or diminish only heritable traits.
  3. Evolution is not goal directed; it does not lead to perfectly adapted organisms.

13.7 Scientists Can Observe Natural Selection in Action (1 of 2)

- Biologists have documented evolutionary change in thousands of scientific studies.
- An unsettling example of natural selection in action is the evolution of pesticide resistance in hundreds of insect species.

13.7 Scientists Can Observe Natural Selection in Action (2 of 2)

- These examples of evolutionary adaptation reveal two important points about natural selection.
  1. Natural selection is more of an editing process than a creative mechanism.
  2. Natural selection is contingent on time and place, favoring those heritable traits in a varying population that fit the current, local environment.

Checkpoint question In what sense is natural selection more an editing process than a creative process?

Natural selection cannot create beneficial traits on demand but instead "edits" variation in a population by selecting for individuals with those traits that are best suited to the current environment.

The Evolution of Populations

13.8 Mutation and Sexual Reproduction Produce the Genetic Variation That Makes Evolution Possible (1 of 3)

- Organisms typically show individual variation.
- **Mutations** are the ultimate source of the genetic variation that serves as raw material for evolution.
- In organisms that reproduce sexually, most of the genetic variation in a population results from the unique combination of alleles that each individual inherits.

13.8 Mutation and Sexual Reproduction Produce the Genetic Variation That Makes Evolution Possible (2 of 3)

- Fresh assortments of existing alleles arise every generation from three random components of sexual reproduction:
  1. crossing over,
  2. independent orientation of homologous chromosomes at metaphase I of meiosis, and
  3. random fertilization.

13.8 Mutation and Sexual Reproduction Produce the Genetic Variation That Makes Evolution Possible (3 of 3)

Checkpoint question What is the ultimate (original) source of genetic variation? What is the source of most genetic variation in a population that reproduces sexually?

Mutation; unique combinations of alleles resulting from sexual reproduction

13.9 Evolution Occurs Within Populations

- A **population** is a group of individuals of the same species that live in the same area and interbreed.
- A **gene pool** consists of all copies of every type of allele, at every locus, in all members of the population.
- **Microevolution** is a change in the frequencies of alleles in a population's gene pool and evolution occurring on its smallest scale.

Checkpoint question Why can't an individual evolve?

Evolution involves changes in the genetic makeup of a population over time. An individual's genetic makeup rarely changes during its lifetime.

13.10 The Hardy-Weinberg Equation Can Test Whether a Population Is Evolving (1 of 3)

- The **Hardy-Weinberg equilibrium** states that allele and genotype frequencies will remain constant if
  - a population is large,
  - mating is random, and
  - there is no mutation, gene flow, or natural selection.
- The Hardy-Weinberg equation can be used to test whether evolution is occurring in a population.

13.10 The Hardy-Weinberg Equation Can Test Whether a Population Is Evolving (2 of 3)

- To test the Hardy-Weinberg principle, let's look at two generations of our imaginary iguana population.
  - **Figure 13.10B** shows the frequencies of alleles in the gene pool of the original population.
  - From these genotype frequencies, we can calculate the frequency of each allele in the population.

13.10 The Hardy-Weinberg Equation Can Test Whether a Population Is Evolving (3 of 3)

- **Figure 13.10C** shows a Punnett square that uses these gamete allele frequencies and the rule of multiplication to calculate the frequencies of the three genotypes in the next generation.
  - Because the genotype frequencies are the same as in the parent population, the allele frequencies *p* and *q* are also the same.
  - Thus, the gene pool of this population is in a state of equilibrium—Hardy-Weinberg equilibrium.

13.11 Connection: The Hardy-Weinberg Equation Is Useful in Public Health Science

- Public health scientists use the Hardy-Weinberg equation to estimate how many people carry alleles for certain inherited diseases.
- About one out of 10,000 babies born in the United States has phenylketonuria (PKU), an inherited inability to break down the amino acid phenylalanine.
- The health problems associated with PKU can be prevented by strict adherence to a diet that limits the intake of phenylalanine.

Mechanisms of Microevolution

13.12 Natural Selection, Genetic Drift, and Gene Flow Can Cause Microevolution (1 of 2)

- The three main causes of evolutionary change are
  1. natural selection,
  2. genetic drift, and
  3. gene flow.

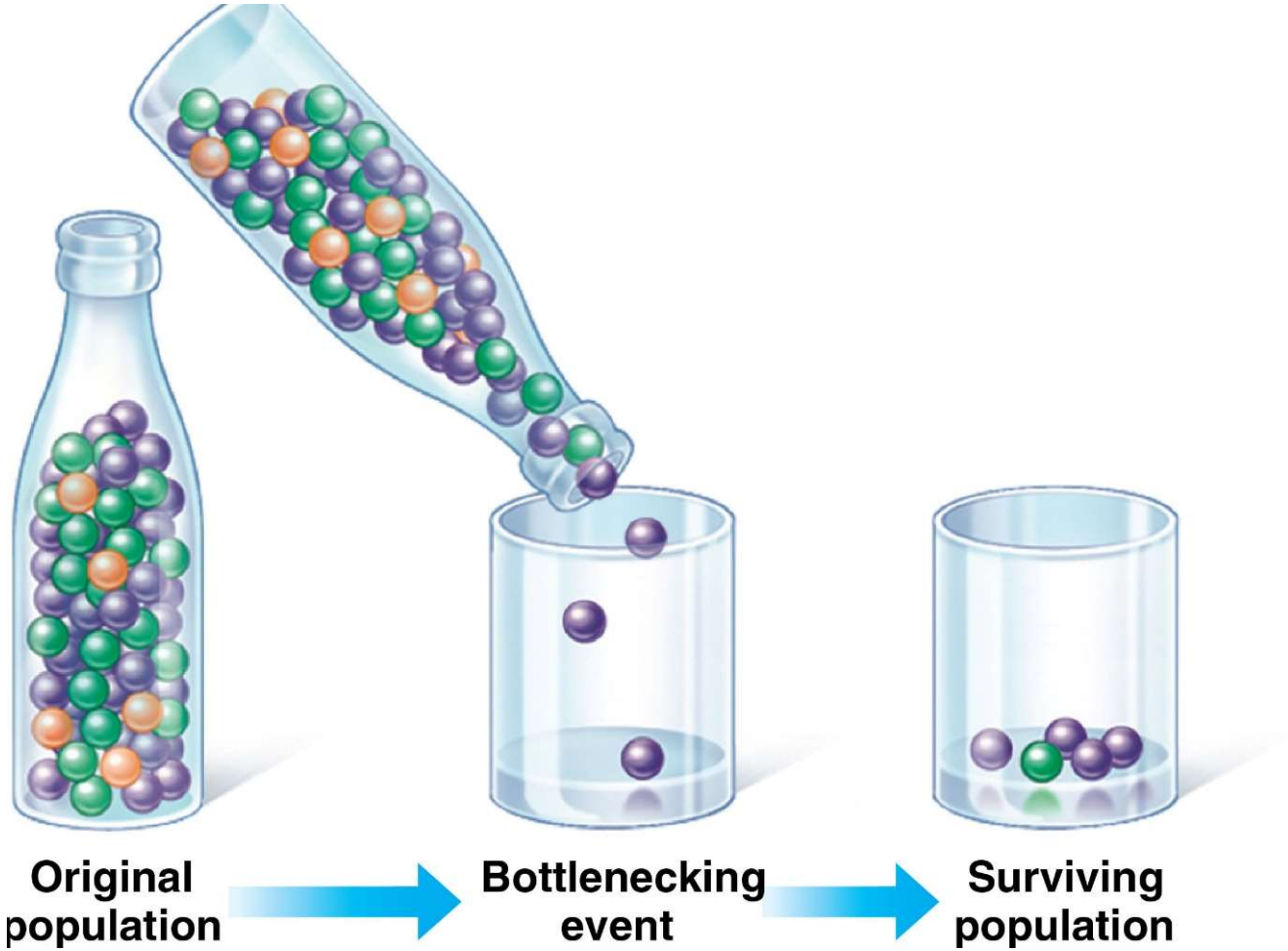
13.12 Natural Selection, Genetic Drift, and Gene Flow Can Cause Microevolution (2 of 2)

The introduction of alleles that may not be beneficial in a particular habitat prevents the population living there from becoming fully adapted to its local conditions.

- The bottleneck effect and founder effect lead to genetic drift.
  - The **bottleneck effect** leads to a loss of genetic diversity when a population is greatly reduced.
  - Genetic drift is also likely when a few individuals colonize an island or other new habitat, producing what is called the **founder effect**.

Checkpoint question How might gene flow between populations living in different habitats actually interfere with each population's adaptation to its local environment?

Figure 13.12a_3



13.13 Natural Selection Is the Only Mechanism That Consistently Leads to Adaptive Evolution (1 of 2)

- Only natural selection consistently leads to adaptive evolution—evolution that results in a better fit between organisms and their environment.
- **Relative fitness** is the contribution an individual makes to the gene pool of the next generation relative to the contributions of other individuals.
- As a result of natural selection, favorable traits increase in a population.

13.13 Natural Selection Is the Only Mechanism That Consistently Leads to Adaptive Evolution (2 of 2)

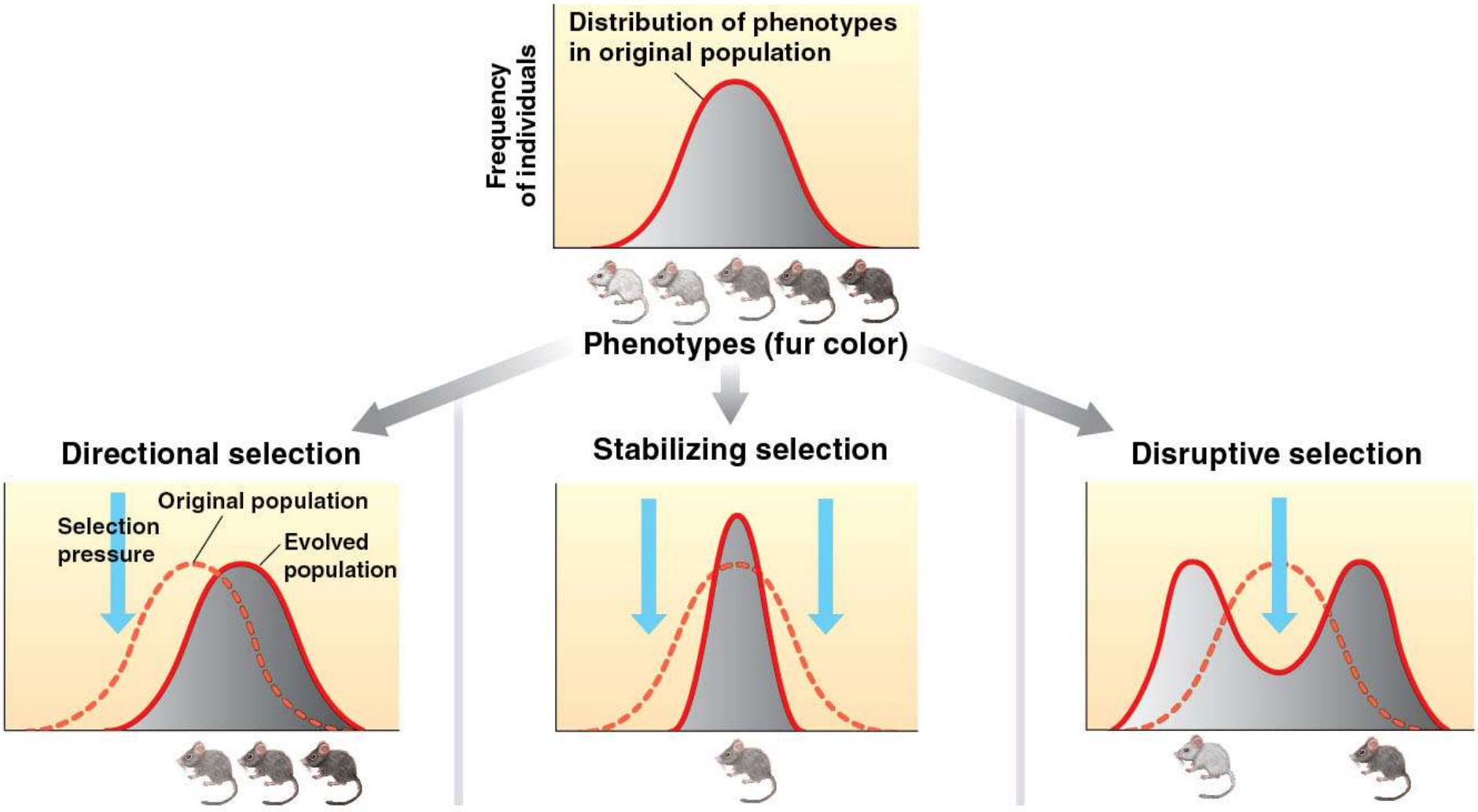
Checkpoint question Explain how the phrase "survival of the fittest" differs from the biological definition of relative fitness.

Survival alone does not guarantee reproductive success. An organism's relative fitness is determined by its number of fertile offspring and thus its relative contribution to the gene pool of the next generation.

13.14 Visualizing the Concept: Natural Selection Can Alter Variation in a Population in Three Ways (1 of 2)

- Natural selection can affect the distribution of phenotypes in a population.
  - **Stabilizing selection** favors intermediate phenotypes.
  - **Directional selection** shifts the overall makeup of the population by acting against individuals at one of the phenotypic extremes.
  - **Disruptive selection** typically occurs when environmental conditions vary in a way that favors individuals at *both* ends of a phenotypic range over individuals with intermediate phenotypes.

Figure 13.14



13.14 Visualizing The Concept: Natural Selection Can Alter Variation in a Population in Three Ways (2 of 2)

Checkpoint question What type of selection probably resulted in the color variations evident in the garter snakes seen above? Disruptive selection

13.15 Sexual Selection May Lead to Phenotypic Differences Between Males and Females (1 of 3)

- **Sexual selection** is a form of natural selection in which individuals with certain characteristics are more likely than other individuals to obtain mates.
- Secondary sex characteristics can give individuals an advantage in mating.

13.15 Sexual Selection May Lead to Phenotypic Differences Between Males and Females (2 of 3)

- In some species, intrasexual selection occurs, in which individuals compete directly with members of the same sex for mates.
- In a more common type of sexual selection, called intersexual selection (between sexes) or mate choice, individuals of one sex (usually females) are choosy in selecting their mates.

13.15 Sexual Selection May Lead to Phenotypic Differences Between Males and Females (3 of 3)

Checkpoint question Males with the most elaborate ornamentation may garner the most mates. How might choosing such a mate be advantageous to a female?

An elaborate display may signal good health and therefore good genes, which in turn could be passed along to the female's offspring.

13.16 Evolution Connection: The Evolution of Drug-Resistant Microorganisms Is a Serious Public Health Concern (1 of 2)

- In the same way that pesticides select for resistant insects, antibiotics select for resistant bacteria.
- We contribute to the problem of antibiotic resistance when
  - doctors overprescribe antibiotics,
  - patients prematurely stop taking antibiotics, and
  - livestock producers add antibiotics to animal feed as a growth promoter and to prevent illness.

13.16 Evolution Connection: The Evolution of Drug-Resistant Microorganisms Is a Serious Public Health Concern (2 of 2)

- In 2013, the Centers for Disease Control (CDC) reported that drug-resistant microorganisms infect more than 2 million people and cause 23,000 deaths in the United States each year.
- The CDC identified 15 microorganisms that pose urgent or serious threats to public health.

Checkpoint question Explain why the following statement is incorrect: "Antibiotics have created resistant bacteria."

The use of antibiotics did not cause bacteria to make new alleles. Rather, antibiotic use has increased the frequency of alleles for resistance that were already naturally present in bacterial populations.

13.17 Diploidy and Balancing Selection Preserve Genetic Variation (1 of 2)

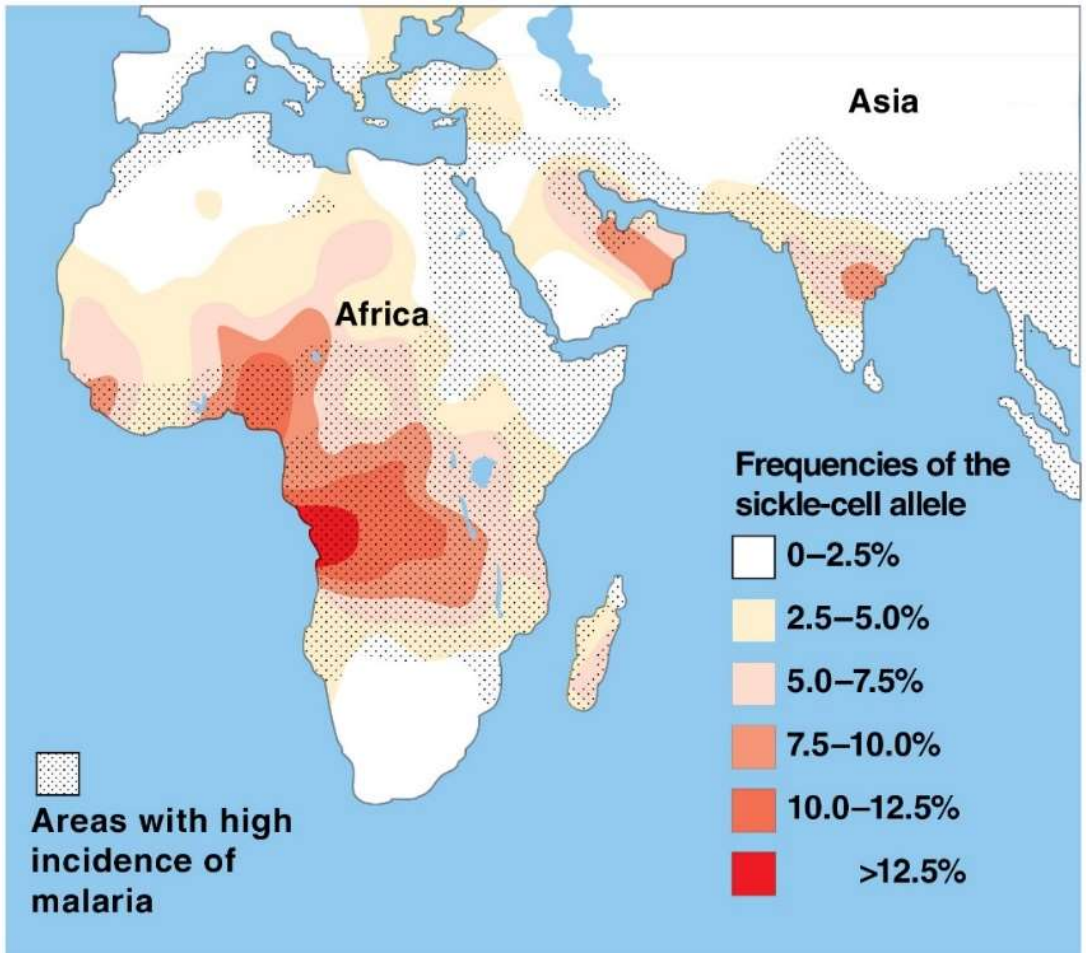
- Diploidy preserves variation by "hiding" recessive alleles.
  - **Balancing selection** occurs when natural selection maintains stable frequencies of two or more phenotypic forms in a population.
  - **Heterozygote advantage** is a type of balancing selection in which heterozygous individuals have greater reproductive success than either type of homozygote, with the result that two or more alleles for a gene are maintained in the population.

13.17 Diploidy and Balancing Selection Preserve Genetic Variation (2 of 2)

Checkpoint question Why would natural selection tend to reduce genetic variation more in populations of haploid organisms than in populations of diploid organisms?

All alleles in a haploid organism are phenotypically expressed and are hence screened by natural selection.

Figure 13.17



Adapted from A.C. Allison, Abnormal hemoglobins and erythrovute enzyme-deficiency traits, Genetic variation in human populations, G.A. Harrison, ed. Oxford, *Elsevier Science* (1961).

13.18 Natural Selection Cannot Fashion Perfect Organisms (1 of 2)

- The evolution of organisms is constrained.
  1. *Selection can act only on existing variations*. New, advantageous alleles do not arise on demand.
  2. *Evolution is limited by historical constraints.* Evolution co-opts existing structures and adapts them to new situations.
  3. *Adaptations are often compromises*. The same structure often performs many functions.
  4. *Chance, natural selection, and the environment interact*. Environments often change unpredictably.

13.18 Natural Selection Cannot Fashion Perfect Organisms (2 of 2)

Checkpoint question Humans owe much of their physical versatility and athleticism to their flexible limbs and joints. But we are prone to sprains, torn ligaments, and dislocations. Why?