Refer to pages 4T-5T of the Teacher Guide for an explanation of the National Science Education Standards correlations.

Section	Objectives	Activities/Features
Section 15.1 **Natural Selection and the Evidence for Evolution** National Science Education Standards UCP.1-5; A.1, A.2; C.3, C.4, C.6; F.4; G.1, G.3 (2 sessions, 1 block)	1. **Summarize** Darwin's theory of natural selection. 2. **Explain** how the structural and physiological adaptations of organisms relate to natural selection. 3. **Distinguish** among the types of evidence for evolution.	**MiniLab 15-1:** Camouflage Provides an Adaptive Advantage, p. 406 **Problem-Solving Lab 15-1,** p. 407
Section 15.2 **Mechanisms of Evolution** National Science Education Standards UCP.1-5; A.1, A.2; C.1-4, C.6; F.4; G.1-3 (3 sessions, 2 blocks)	4. **Summarize** the effects of the different types of natural selection on gene pools. 5. **Relate** changes in genetic equilibrium to mechanisms of speciation. 6. **Explain** the role of natural selection in convergent and divergent evolution.	**MiniLab 15-2:** Detecting a Variation, p. 415 **Internet BioLab:** Natural Selection and Allelic Frequency, p. 422 **Math Connection:** Mathematics and Evolution, p. 424

Need Materials? Contact Carolina Biological Supply Company at 1-800-334-5551 or at **http://www.carolina.com**

MATERIALS LIST

BioLab
p. 422 colored pencils (2), paper bag, graph paper, pinto beans, white navy beans

MiniLabs
p. 406 hole punch, paper, white and black
p. 415 ruler, unshelled peanuts (30)

Alternative Lab
p. 414 culture of *Bacillus subtilis,* 3 tubes of nutrient agar, tube of streptomycin agar, inoculation loop, petri dishes (2), Bunsen burner, wax pencil, test tube

Quick Demos
p. 402 photographs of automobile model
p. 418 overhead projector

Key to Teaching Strategies

- **L1** Level 1 activities should be appropriate for students with learning difficulties.
- **L2** Level 2 activities should be within the ability range of all students.
- **L3** Level 3 activities are designed for above-average students.
- **ELL** ELL activities should be within the ability range of English Language Learners.
- **COOP LEARN** Cooperative Learning activities are designed for small group work.
- **P** These strategies represent student products that can be placed into a best-work portfolio.
- These strategies are useful in a block scheduling format.

Teacher Classroom Resources

Section	Reproducible Masters	Transparencies
Section 15.1 **Natural Selection and the Evidence for Evolution**	**Reinforcement and Study Guide,** pp. 65-66 L2 **Concept Mapping,** p. 15 L3 ELL **Critical Thinking/Problem Solving,** p. 15 L3 **BioLab and MiniLab Worksheets,** p. 71 L2 **Laboratory Manual,** pp. 103-108 L2 **Content Mastery,** pp. 73-74, 76 L1	Section Focus Transparency 37 L1 ELL
Section 15.2 **Mechanisms of Evolution**	**Reinforcement and Study Guide,** pp. 67-68 L2 **Critical Thinking/Problem Solving,** p. 15 L3 **BioLab and MiniLab Worksheets,** pp. 72-74 L2 **Content Mastery,** pp. 73, 75-76 L1	Section Focus Transparency 38 L1 ELL Basic Concepts Transparency 21 L2 ELL Basic Concepts Transparency 22 L2 ELL Reteaching Skills Transparency 24 L1 ELL

Assessment Resources

Chapter Assessment, pp. 85-90
MindJogger Videoquizzes
Performance Assessment in the Biology Classroom
Alternate Assessment in the Science Classroom
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 15 quiz

Additional Resources

Spanish Resources ELL
English/Spanish Audiocassettes ELL
Cooperative Learning in the Science Classroom COOP LEARN
Lesson Plans/Block Scheduling

NATIONAL GEOGRAPHIC Teacher's Corner

Products Available From National Geographic Society
To order the following products, call National Geographic Society at 1-800-368-2728:
Book
National Geographic Atlas of World History

Index to National Geographic Magazine
The following articles may be used for research relating to this chapter:
"The Dawn of Humans: Redrawing Our Family Tree?" by Lee Berger, August 1998.
"Dinosaurs Take Wing," by Jennifer Ackerman, July 1998.
"A Curious Kinship: Apes and Humans," by Eugene Linden, May 1992.

GLENCOE TECHNOLOGY

The following multimedia resources are available from Glencoe.

Biology: The Dynamics of Life

CD-ROM ELL
Video: *Galapagos*
Video: *Adapted for Survival*
Exploration: *The Record of Life*
Exploration: *Selection Pressure*

Videodisc Program
Geographic Isolation
Adapted for Survival

The Infinite Voyage
The Great Dinosaur Hunt

The Secret of Life Series
It's in the Genes: *Evolution*
Camouflage: *Caterpillars*
Camouflage: *Spider*
Horse Evolution
Patterns of Descent
Gone Before You Know It: *The Biodiversity Crisis*

Getting Started Demo

Kinesthetic Blindfold a student volunteer. Then place a couple of small, familiar objects, such as a stapler and a pen, on a desk and ask the volunteer to identify the objects. Point out to the class that some organisms that live in dark caves successfully use senses other than sight to monitor their environments. L1 ELL

Theme Development

The **unity within diversity** theme is apparent in this chapter. The theme of **evolution** is also evident. The theory of evolution can explain the diversity of organisms.

0:00 Out of Time?

If time does not permit teaching the entire chapter, use the BioDigest at the end of the unit as an overview.

Chapter

15 The Theory of Evolution

What You'll Learn

- You will analyze the theory of evolution.
- You will compare and contrast the processes of evolution.

Why It's Important

Evolution is a key concept for understanding biology. Evolution explains the diversity of species and predicts changes.

Getting Started

Identifying Variation

All populations have variations. *Hypothesize the most common eye color in your class. Now test this hypothesis.*

interNET CONNECTION To find out more about evolution, visit the Glencoe Science Web Site. **www.glencoe.com/sec/science**

This crayfish (above) and cricket (inset) live in dark caves and are blind. They have sighted relatives that live where there is light. Both the cave-dwelling species and their relatives are adapted to different environments. As populations adapt to new or changing environments, individuals in the population that are adapted successfully survive.

Section

15.1 Natural Selection and the Evidence for Evolution

You need only to look around you to see the diversity of organisms on Earth. About 150 years ago, Charles Darwin, who had studied an enormous variety of life forms, proposed an idea to explain how organisms probably change over time. Biologists still base their work on this idea because it explains the living world they study.

An Asian leopard and a cheetah (inset)

Section Preview

Objectives

Summarize Darwin's theory of natural selection.

Explain how the structural and physiological adaptations of organisms relate to natural selection.

Distinguish among the types of evidence for evolution.

Vocabulary

artificial selection
natural selection
mimicry
camouflage
homologous structure
analogous structure
vestigial structure
embryo

Charles Darwin and Natural Selection

The modern theory of evolution is a fundamental concept in biology. Recall that evolution is the change in populations over time. Learning the principles of evolution makes it easier to understand modern biology. One place to start is by learning about the ideas of English scientist Charles Darwin (1809–1882)—ideas supported by fossil evidence.

Fossils shape ideas about evolution

Biologists have used fossils in their work since the eighteenth century. In fact, fossil evidence formed the basis of the early evolutionary concepts. Scientists wondered how fossils formed, why many fossil species were extinct, and what kinds of relationships might exist between the extinct and the modern species.

When geologists provided evidence indicating that Earth was much older than many people had originally thought, biologists began to suspect that life slowly changes over time, or evolves. Many explanations about how species evolve have been proposed, but the ideas first published by Charles Darwin are the basis of modern evolutionary theory.

Darwin on HMS *Beagle*

It took Darwin years to develop his theory of evolution. He began in 1831 at age 21 when he took a job as

Prepare

Key Concepts

Students will study Charles Darwin's concept of natural selection. They will also learn about scientific evidence that supports the theory of evolution.

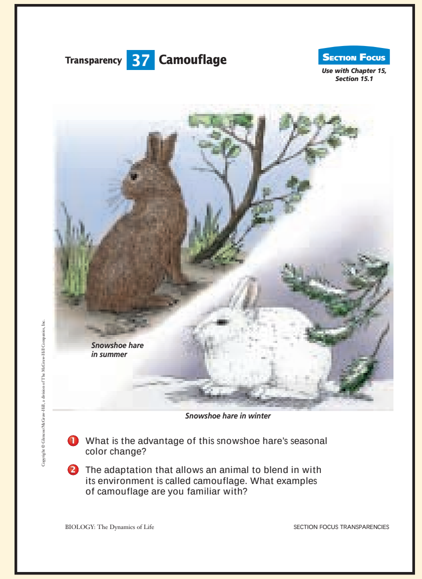
Planning

- Collect photos of automobiles for the Quick Demo.
- Purchase pinto beans for the Project.
- Obtain black and white construction paper and paper punches for MiniLab 15-1.
- Obtain bird bones (chicken, turkey, quail) for the Display.
- Gather photos of a variety of organisms for the Activity.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 37** on the overhead projector and have students answer the accompanying questions. L1 ELL



Multiple Learning Styles

Look for the following logos for strategies that emphasize different learning modalities.

Kinesthetic Getting Started Demo, p. 400; Visual Learning, p. 413

Visual-Spatial Reteach, p. 421

Interpersonal Project, pp. 408, 417; Activity, p. 411

Intrapersonal Reteach, p. 410

Linguistic Portfolio, pp. 402, 406, 407; Meeting Individual Needs, pp. 403, 419; Biology Journal, pp. 405, 413, 416; Extension, p. 421

Logical-Mathematical Project, p. 404; Portfolio, p. 410; Tech Prep, p. 412; Reinforcement, p. 416

Naturalist Meeting Individual Needs, p. 409

Assessment Planner

Portfolio Assessment
- **Portfolio, TWE,** pp. 402, 406, 407, 410, 420
- **Assessment, TWE,** pp. 411, 419
- **MiniLab, TWE,** p. 415

Performance Assessment
- **Assessment, TWE,** pp. 403, 408
- **MiniLabs, SE,** pp. 406, 415
- **Alternative Lab, TWE,** pp. 414-415
- **BioLab, SE,** pp. 422–423

Knowledge Assessment
- **MiniLab, TWE,** p. 406
- **Problem-Solving Lab, TWE,** p. 407
- **Alternative Lab, TWE,** p. 415
- **BioLab, TWE,** p. 423
- **Section Assessments, SE,** pp. 411, 421
- **Chapter Assessment, SE,** pp. 425-427

Skill Assessment
- **Assessment, TWE,** p. 421

2 Teach

Quick Demo

Use a photo series of an automobile model that shows how that model has changed over time. Alternatively, show a picture of an early automobile and one of a modern automobile. Have students explain how automobiles are the same and how they have changed over time. Then, point out that organisms also change over time. Ask students to distinguish between the two kinds of evolution. *The changes in automobiles or a specific automobile model occur faster than changes in organisms.*

Concept Development

A significant influence on Darwin's thinking was the book *The Principles of Geology* by Charles Lyell. This book proposed that Earth is very old and that the forces that have produced changes on Earth's surface in the past are the same ones that continue to operate today. Discuss how Darwin was influenced by other ideas of his day.

Visual Learning

Figure 15.1 Have the students examine the photos of the finch, tortoise, and iguana. Discuss each organism, asking students to identify its adaptations.

Resource Manager

Section Focus Transparency 37 and Master L1 ELL
Laboratory Manual, pp. 103-104 L2

a naturalist on the English ship HMS *Beagle*, which sailed to South America and the South Pacific on a five-year scientific journey.

As the ship's naturalist, Darwin studied and collected biological specimens at every port along the route. As you might imagine, these specimens were quite diverse. Studying the specimens made Darwin curious about possible relationships among species. His studies provided the foundation for his theory of evolution by natural selection.

Darwin in the Galapagos

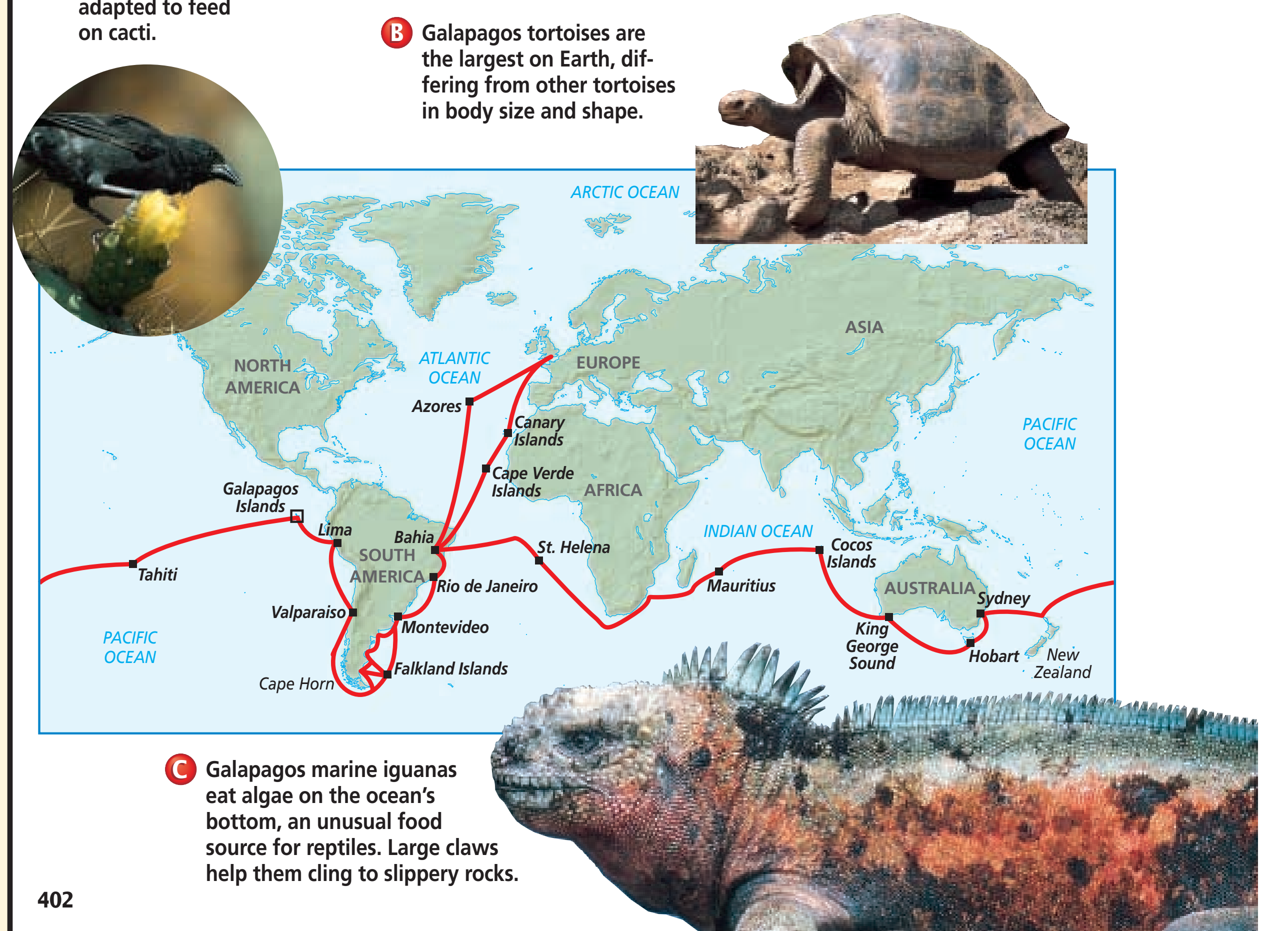
The Galapagos (guh LAHP uh gus) Islands are a group of small islands near the equator, about 1000 km off the west coast of South America. The observations that Darwin made and the specimens that he collected there were especially important to him.

On the Galapagos Islands, Darwin studied many species of animals and plants, ***Figure 15.1***, that are unique to the islands, but similar to species elsewhere. These observations led Darwin to consider the possibility that species can change over time. However, after returning to England, he could not at first explain how such changes occur.

Darwin continues his studies

For the next 22 years, Darwin worked to find an explanation for how species change over time. He read, studied, collected specimens, and conducted experiments.

Figure 15.1
The five-year voyage of HMS *Beagle* took Darwin around the world. Animal species in the Galapagos Islands have unique adaptations.



A The beak of this Galapagos finch is adapted to feed on cacti.

B Galapagos tortoises are the largest on Earth, differing from other tortoises in body size and shape.

C Galapagos marine iguanas eat algae on the ocean's bottom, an unusual food source for reptiles. Large claws help them cling to slippery rocks.

Finally, English economist Thomas Malthus proposed an idea that Darwin modified and used in his explanation. Malthus's idea was that the human population grows faster than Earth's food supply. How did this help Darwin? He knew that many species produce large numbers of offspring. He also knew that such species had not overrun Earth. He realized that individuals struggle to survive. There are many kinds of struggles, such as competing for food and space, escaping from predators, finding mates, and locating shelter. Only some individuals survive the struggle and produce offspring. Which individuals survive?

Darwin gained insight into the mechanism that determined which organisms survive in nature from his pigeon-breeding experiments. Darwin observed that the traits of individuals vary in populations—even in a population of pigeons. Sometimes variations are inherited. By breeding pigeons with desirable variations, Darwin produced offspring with these variations. Breeding organisms with specific traits in order to produce offspring with identical traits is called **artificial selection.** Darwin hypothesized that there was a force in nature that worked like artificial selection.

Darwin explains natural selection

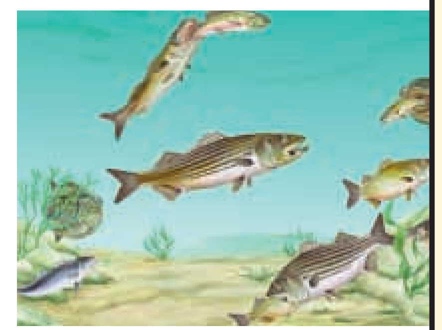
Using his collections and observations, Darwin identified the process of natural selection, the steps of which you can see summarized in ***Figure 15.2.*** **Natural selection** is a mechanism for change in populations. It occurs when organisms with certain variations survive, reproduce, and pass their variations to the next generation. Organisms without these variations are less likely to survive and reproduce. As a result, each generation consists largely of offspring from parents with these variations that aid survival.

Figure 15.2
Darwin proposed the idea of natural selection to explain how species change over time.

A In nature, organisms produce more offspring than can survive. Fishes, for example, can sometimes lay millions of eggs.

B In any population, individuals have variations. Fishes, for example, may differ in color, size, and speed.

C Individuals with certain useful variations, such as speed, survive in their environment, passing those variations to the next generation.



D Over time, offspring with certain variations make up most of the population and may look entirely different from their ancestors.

Concept Development

Before Darwin developed his theory of evolution by natural selection, French biologist Jean-Baptiste de Lamarck (1744-1829) proposed a different mechanism for evolutionary change. Lamarck's idea rested on two assumptions: (1) the more an organism uses a part of its body, the more that part develops, and (2) the physical characteristics that an organism develops in this way can be passed to offspring. Discuss Lamarck's hypothesis with students, asking them to list its weaknesses.

Visual Learning

Figure 15.2 shows the four principal ideas of natural selection. Discuss each principle to reinforce the ideas. Provide other examples of natural selection, using alternative organisms and habitats, to review the concept.

Assessment

Performance Assessment in the Biology Classroom, p. 23, *Investigating Variations in Populations.* Have students carry out this activity to explore what variations occur in a population. L2

Portfolio

Change over Time

Linguistic Have students make a collage showing how television, music, food, clothing, and movies have changed over time. Then, ask them to describe changes in nature, such as weather and tide. Help them compare these types of changes to those in organisms over time. L1 P ELL

Meeting Individual Needs

English Language Learners

Linguistic Review the meanings of the words *fit, fitter,* and *fittest*. Help students form sentences using the three words. Then have them rearrange the words *the, selects, nature,* and *fittest* to form a sentence that summarizes Darwin's concept of natural selection. L1 ELL

Different Viewpoints in Biology

Provide students with a set of class data, such as the data they gathered in this chapter's Getting Started. Ask different students to interpret the data to show how the same information can be interpreted differently. L2

Visual Learning

Figure 15.3 illustrates the probable evolution of the common mole-rat from a member of the rodent family Bathyergidae. After students have studied each step of the illustration, ask them to list the steps that may have occurred during the evolution of the sightless, cave-dwelling fish genus *Amblyopsis*, and the blind, burrowing snake genus *Typhlops*.

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Video: *The Galapagos* Disc 2
Video: *Adapted for Survival* Disc 2

Darwin was not the only one to recognize the significance of natural selection for populations. As a result of his studies on islands near Indonesia in the Pacific Ocean, Alfred Russell Wallace, another British naturalist, had reached a similar conclusion. After Wallace wrote Darwin to share his ideas about natural selection, Darwin and Wallace had their similar ideas jointly presented to the scientific community. However, it was Darwin who published the first book about evolution called *On the Origin of Species by Natural Selection* in 1859. The ideas detailed in Darwin's book are today a basic unifying theme of biology.

Interpreting evidence after Darwin

Volumes of scientific data have been gathered as evidence for evolution since Darwin's time. Much of this evidence is subject to interpretation by different scientists. One of the problems is that evolutionary processes are difficult for humans to observe directly. The short scale of human life spans makes it difficult to comprehend evolutionary processes that occur over millions of years. For some people the theory of evolution is contradictory to their faith, and they offer other interpretations of the data. Many biologists, however, have suggested that the amount of scientific evidence supporting the theory of evolution is overwhelming. Almost all of today's biologists accept the theory of evolution by natural selection. However, biologists are also now more aware of genetics. Evolution is more commonly defined by modern biologists as any change in the gene pool of a population.

Adaptations: Evidence for Evolution

Have you noticed that some plants have thorns and some plants don't? Have you noticed that some animals have distinctive coloring but others don't? Have you ever wondered how such variations arose? Recall that an adaptation is any variation that aids an organism's chances of survival in its environment. Thorns are an adaptation of some plants and distinctive colorings are an adaptation of some animals. Darwin's theory of evolution explains how adaptations may develop in species.

Structural adaptations arise over time

According to Darwin's theory, adaptations in species develop over many generations. Learning about adaptations in mole-rats can help you understand how natural selection has affected them. Mole-rats that live underground in darkness are blind. These blind mole-rats have many adaptations that enable them to live successfully underground. Look at *Figure 15.3* to see how these modern mole-rat adaptations might have evolved over millions of years from characteristics of their ancestors.

The structural adaptations of common mole-rats include large teeth and claws. These are body parts that help mole-rats survive in their environment by, for example, enabling them to dig better tunnels. Structural adaptations such as the teeth and claws of mole-rats are often used to defend against predators. Some adaptations of other organisms that keep predators from approaching include a rose's thorns or a porcupine's quills.

Some other structural adaptations are subtle. **Mimicry** is a structural adaptation that enables one species to resemble another species. In one form of mimicry, a harmless species has adaptations that result in a physical resemblance to a harmful species. Predators that avoid the harmful species also avoid the similar-looking, harmless species. See if you can tell

Figure 15.3
Darwin's ideas about natural selection can explain some adaptations of mole-rats.

A The ancestors of today's common mole-rats probably resembled African rock rats.

B Some ancestral rats may have avoided predators better than others because of variations such as the size of teeth and claws.

C Ancestral rats that survived passed their variations to offspring. After many generations, most of the population's individuals would have these adaptations.

D Over time, natural selection produced modern mole-rats. Their blindness may have evolved because vision had no survival advantage for them.

Enrichment

Using Figure 15.3 as a model, have the students illustrate or describe possible evolutionary sequences of one of the following: (1) the evolution of long necks in giraffes from short-necked ancestors, (2) the evolution of whales from terrestrial carnivores, (3) the evolution of flight in birds from bipedal dinosaurs, (4) the evolution of high-speed running in cheetahs from slower movements of their ancestors.

GLENCOE TECHNOLOGY

VIDEOTAPE
The Secret of Life
It's in the Genes: Evolution

Resource Manager

Concept Mapping, p. 15 L3 ELL
Laboratory Manual, pp. 105-108 L2

PROJECT

Variation in Beans

Logical-Mathematical Students can study the effects of individual variations by planting a pinto bean garden. Have them wash their hands after handling bean seeds. Obtain some pinto bean seeds and ask the students to measure and observe them, placing the seeds into categories, such as short, long, wide, thin, etc. Have them write hypotheses that predict how each category of bean seed will grow. Then plant 3 or 4 beans from each category. Students should observe the plants each day, recording their observations. Have them write a brief summary after 4-5 weeks of plant growth. L1 ELL

BIOLOGY JOURNAL

Evidence for Natural Selection

Linguistic Have students describe the main evidence Darwin used in formulating his concept of natural selection. Next, have them select an organism and, in their own words, use the main ideas of the concept of natural selection to explain the evolution of the organism. L3

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

MiniLab 15-1

Purpose
Students will model how a camouflage adaptation can aid an organism's survival.

Process Skills
observe and infer, form a hypothesis

Teaching Strategies
- Have students do this activity after studying camouflage.
- Explain that students will simulate how natural selection might operate on a population of insects that vary in color.

Expected Results
Most groups will have picked up more white dots than black dots.

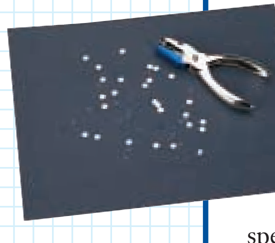
Analysis
1. white dots
2. Light-colored insects may be seen and preyed on more easily than dark-colored insects. Therefore, dark-colored insects have a higher survival rate.
3. Over time, an insect population might become dark-colored because light-colored insects were eliminated from the population.

Assessment
Knowledge Have students research and write a summary about insect adaptations that aid survival in specific environments. Use the Performance Task Assessment List for Writing in Science in **PASC**, p. 87. L2

Resource Manager
BioLab and MiniLab Worksheets, p. 71 L1

MiniLab 15-1 Formulating Models

Camouflage Provides an Adaptive Advantage
Camouflage is a structural adaptation that allows organisms to blend with their surroundings. In this activity, you'll discover how natural selection can result in camouflage adaptations in organisms.



Procedure
1. Working with a partner, punch 100 dots from a sheet of white paper with a paper hole punch. Repeat with a sheet of black paper. These dots will represent black and white insects.
2. Scatter both white and black dots on a sheet of black paper.
3. Decide whether you or your partner will role-play a bird.
4. The "bird" looks away from the paper, then turns back, and immediately picks up the first dot he or she sees.
5. Repeat step 4 for one minute.

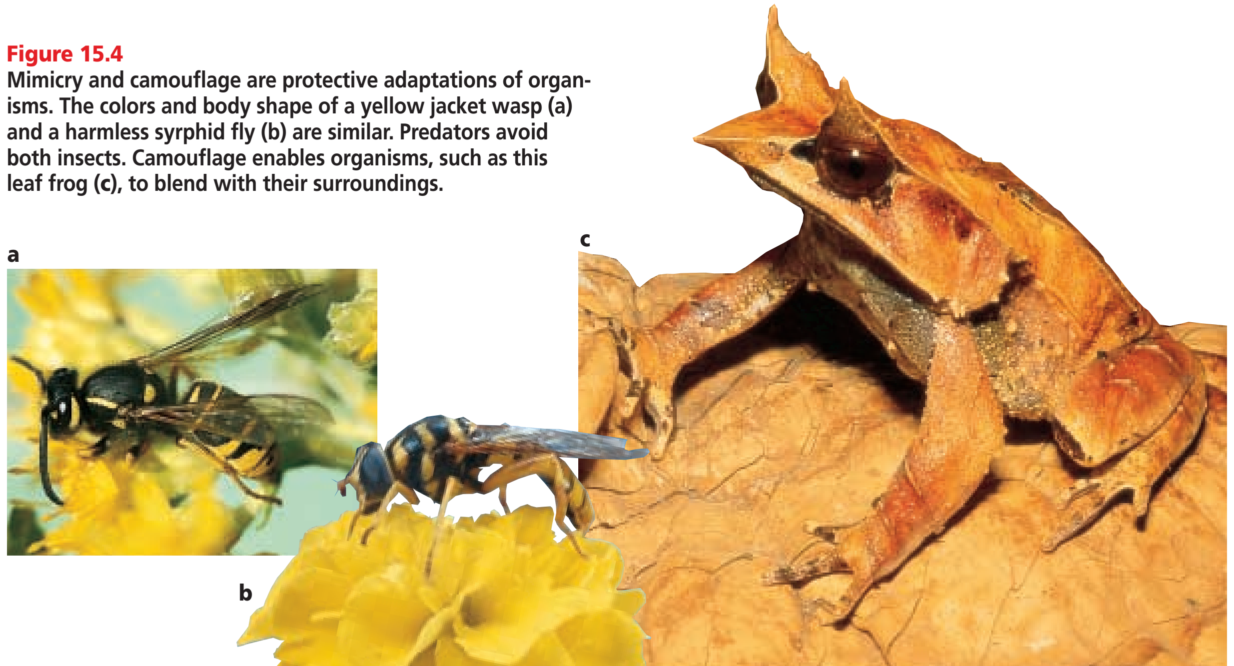
Analysis
1. What color dots were most often collected?
2. How does color affect the survival rate of insects?
3. What might happen over many generations to a similar population in nature?

the difference between a harmless fly and the wasp it mimics when you look at *Figure 15.4.*

In another form of mimicry, two or more harmful species resemble each other. For example, yellow jacket hornets, honeybees, and many other species of wasps all have harmful stings and similar coloration and behavior. Predators may learn quickly to avoid any organism with their general appearance.

Another subtle adaptation is **camouflage** (KAM uh flahj), an adaptation that enables species to blend with their surroundings, as shown in *Figure 15.4.* Because well-camouflaged organisms are not easily found by predators, they survive to reproduce. Try the *MiniLab* to experience how camouflage can help an organism survive. Then use the *Problem-Solving Lab* on the next page to analyze data from an English study of camouflaged peppered moths.

Figure 15.4
Mimicry and camouflage are protective adaptations of organisms. The colors and body shape of a yellow jacket wasp (a) and a harmless syrphid fly (b) are similar. Predators avoid both insects. Camouflage enables organisms, such as this leaf frog (c), to blend with their surroundings.



Physiological adaptations can develop rapidly

In general, most structural adaptations develop over millions of years. However, there are some adaptations that evolve much more rapidly. For example, do you know that some of the medicines developed during the twentieth century to fight bacterial diseases are no longer effective? When the antibiotic drug penicillin was discovered about 50 years ago, it was called a wonder drug because it killed many types of disease-causing bacteria and saved many lives. Today, penicillin no longer affects as many species of bacteria because some species have evolved physiological (fihz ee uh LAHJ ih kul) adaptations to prevent being killed by penicillin. Look at *Figure 15.5* to see how resistance develops in bacteria.

Physiological adaptations are changes in an organism's metabolic processes. In addition to species of bacteria, scientists have observed these adaptations in species of insects and weeds that are pests. After years of exposure to specific pesticides, many species of insects and weeds have become resistant to these chemicals that used to kill them.

Problem-Solving Lab 15-1 Interpreting Data


Biston betularia

How can natural selection be observed? In some organisms that have a short life cycle, biologists have observed the evolution of adaptations to rapid environmental changes. In the early 1950s, English biologist H. B. Kettlewell studied camouflage adaptations in a population of light- and dark-colored peppered moths, *Biston betularia*. The moths rested on the trunks of trees that grew in both the country and the city.

Moths are usually speckled gray-brown, and dark moths, which occur occasionally, are black. Birds pluck the moths from the trees for food. Urban industrial pollution had blackened the bark of city trees with soot. In the photo, you see a city tree with dark bark similar to the color of one of the moths.

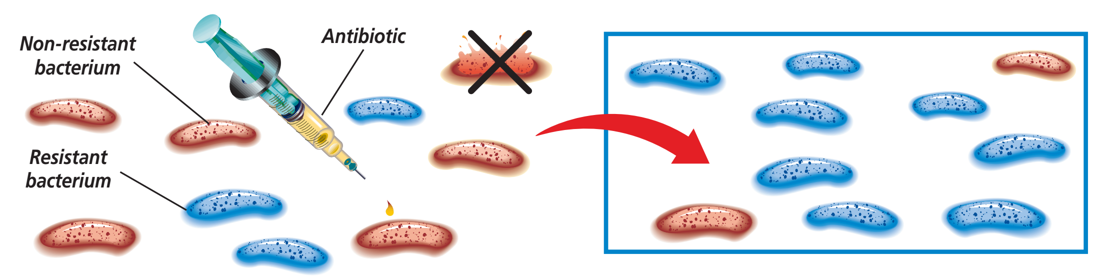
Analysis
Kettlewell raised more than 3000 caterpillars to provide adult moths. He marked the wings of the moths these caterpillars produced so he would recapture only his moths. In a series of trials in the country and the city, he released and recaptured the moths. The number of moths recaptured in a trial indicates how well the moths survived in the environment. Examine the table below.

Table 15.1 Comparison of country and city moths

Location		Numbers of light moths	Numbers of dark moths
Country	Released	496	488
	Recaptured	62	34
City	Released	137	493
	Recaptured	18	136

Thinking Critically
Calculate the percentage of moths recaptured in each experiment and explain any differences in survival rates in the country and the city moths in terms of natural selection.

Figure 15.5
The development of bacterial resistance to antibiotics is direct evidence for evolution.



A The bacteria in a population vary in their ability to resist antibiotics.

B When the population is exposed to an antibiotic, only the resistant bacteria survive.

C The resistant bacteria live and produce more resistant bacteria.

Problem Solving Lab 15-1

Purpose
Students will analyze data from a natural selection study.

Process Skills
use a table, form a hypothesis

Background
A dark variety of peppered moth was first observed in English cities in 1848. It was hard to see on the dark tree trunks near polluted areas. Over the next 100 years, near the cities, scientists observed greater numbers of dark moths relative to light moths. In the 1950s, English scientist H. B. Kettlewell tested the hypothesis that natural selection accounted for the difference.

Teaching Strategies
- Remind students that these data are from an experiment used to support the theory of evolution by natural selection.

Thinking Critically
country/light moths = 12.5%; country/dark moths = 0.7%; city/light moths = 13.0%; city/dark moths = 27.6%
The differences in survival rates are due to camouflage. There was natural selection for the dark variation in the city where pollution killed the lichen on trees, and natural selection for the light variation in the country where lichens were present.

Assessment
Knowledge Have students predict the effect on a peppered moth population if reddish-green lichens invaded a forest. Use the Performance Task Assessment List for Formulating a Hypothesis in **PASC**, p. 21. L1

Portfolio

Camouflage and Mimicry
Linguistic Have the students write about an organism that has camouflage or mimicry adaptations. The report should include the organism's name, details about its environment and predators, and a description of its camouflage or mimicry adaptations. L3 P

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Camouflage: Caterpillars

Camouflage: Spider

Portfolio

Breeds of Dogs
Linguistic Have students prepare a short report about a dog breed of their choice, describing its characteristics, the reasons why it was originally bred, the details about its breeding, and the characteristics of closely related breeds. Students should include a picture of the breed in their report. L1

Assessment

Performance Assessment in the Biology Classroom, p. 35, *Model for Sexual Reproduction.* Have students do this activity to reinforce the idea that natural selection occurs if some individuals inherit certain traits that equip them to cope better with the environment. L1 ELL

Visual Learning

Use **Figure 15.6** to illustrate that, although the fossil record provides evidence for evolution, a relatively complete sequence of fossils, such as those that exist for camels and horses, is rare. Relate this fact to students' previous knowledge of problems in fossil preservation, dating, and interpretation.

GLENCOE TECHNOLOGY

CD-ROM
Biology: The Dynamics of Life
Explorations: *The Record of Life*
Disc 2

VIDEODISC
The Secret of Life
Horse Evolution

The Infinite Voyage *The Great Dinosaur Hunt, New Dinosaur Discoveries and Their Link with Today* (Ch. 10)
8 min.

Other Evidence for Evolution

The development of physiological resistance in species of bacteria, insects, and plants is direct evidence of evolution. However, most of the evidence for evolution is indirect, coming from sources such as fossils and studies of anatomy, embryology, and biochemistry.

Fossils

Fossils are an important source of evolutionary evidence because they provide a record of early life and evolutionary history. For example, paleontologists conclude from fossils that the ancestors of whales were probably land-dwelling, doglike animals.

Although the fossil record provides evidence that evolution occurred, the record is incomplete. Working with an incomplete fossil record is something like trying to put together a jigsaw puzzle with missing pieces. But, after the puzzle is together, even with missing pieces, you will probably still understand the overall picture. It's the same with fossils. Although paleontologists do not have intermediate forms of most species, they can often still understand the overall picture of how a species evolved.

Fossils are found throughout the world. As the fossil record becomes more complete, the sequences of evolution become more clear. For example, in ***Figure 15.6*** you can see how paleontologists sequenced the possible forms that led to today's camel after piecing together fossil skulls, teeth, and limb bones.

Anatomy

Structural features with a common evolutionary origin are called **homologous structures.** Homologous structures can be similar in arrangement, in function, or in both. For example, look at the forelimb bones of the animals shown in ***Figure 15.7.*** Although the bones of each forelimb are modified for their function, the basic arrangement of the bones in each limb is similar. Evolutionary biologists view homologous structures as evidence that organisms evolved from a common ancestor. It would be unlikely for so many animals to have similar structures if each species arose separately.

The structural or functional similarity of a body feature doesn't always mean that two species are closely related. In ***Figure 15.8,*** you can compare the wing of a butterfly with the wing of a bird. Bird and butterfly wings are not similar in structure, but they are similar in function. The wings of birds and insects evolved independently of each other in two distantly related groups of ancestors. The body parts of organisms that do not have a common evolutionary origin but are similar in function are called **analogous structures.**

Although analogous structures don't shed light on evolutionary relationships, they do provide evidence of evolution. For example, insect and bird wings probably evolved separately when their different ancestors adapted independently to similar ways of life.

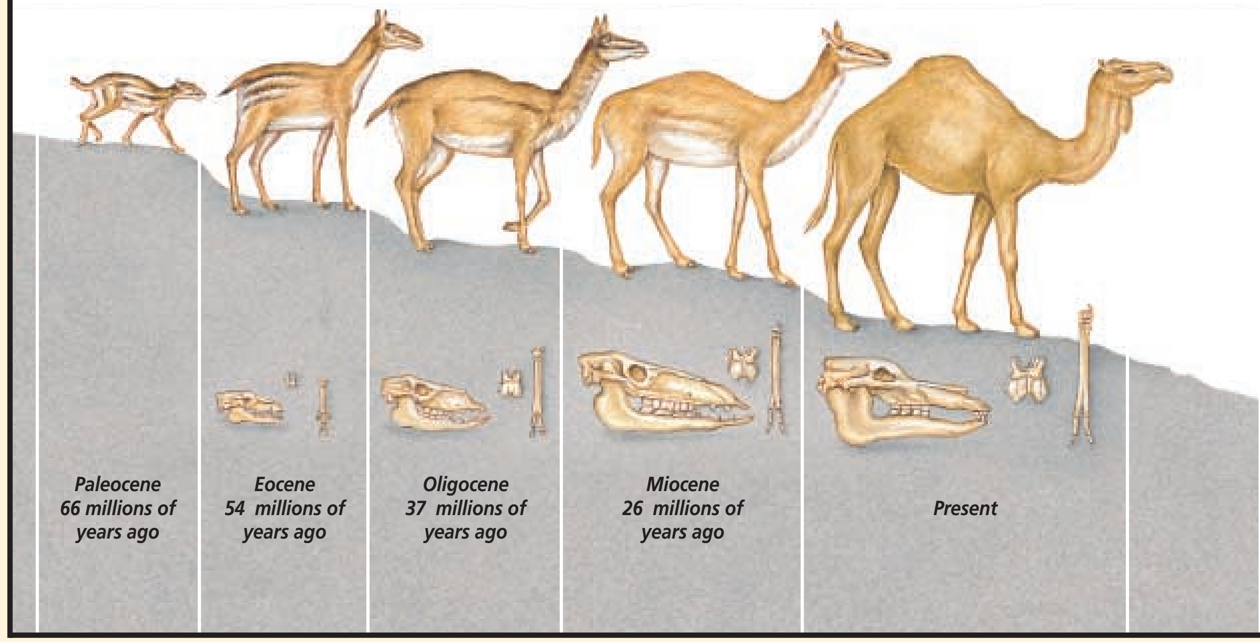


Figure 15.6
Paleontologists have used fossils to trace the evolution of the modern camel. About 66 million years ago the ancestors of camels were as small as rabbits.

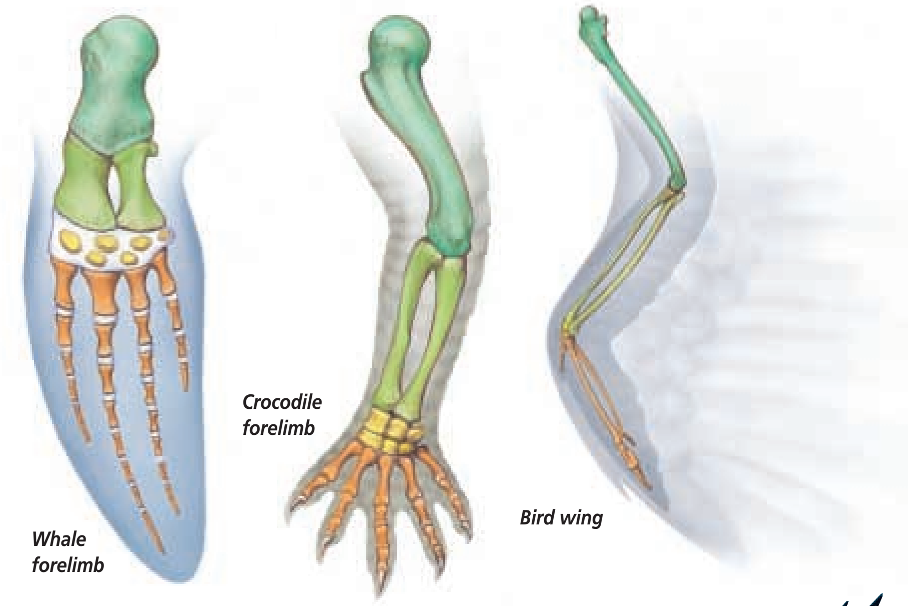


Figure 15.7
The forelimbs of crocodiles, whales, and birds are homologous structures. The bones of each are modified for their function.

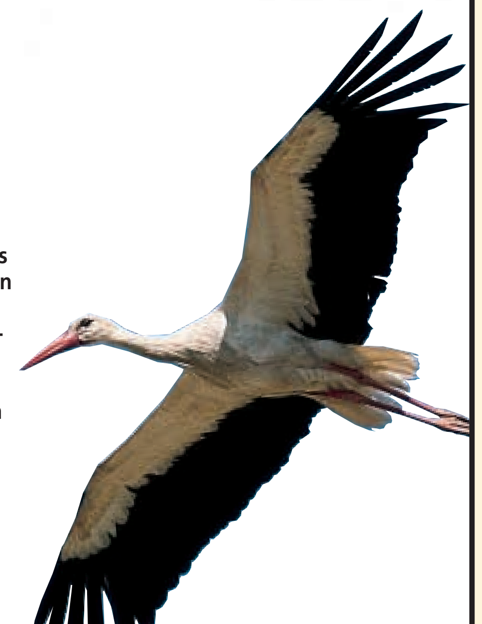


Figure 15.8
Insect and bird wings are similar in function but not in structure. Bones are the framework of bird wings, whereas a tough material called chitin composes insect wings.

Display

Obtain samples of different bird wings (turkey, chicken, duck, or guinea hen) from a supermarket. Display the wings and have students identify the homologous structures. Discuss the structure and function of a bird's wing. Ask students if their observations support the idea that the organisms are closely related.

Tying to Previous Knowledge

Point out that the theory of evolution predicts that organisms with similar physical characteristics will also have similar DNA. Briefly review the structure and function of DNA. Remind students that DNA makes up the genes of an organism that are part of the organism's chromosomes.

GLENCOE TECHNOLOGY

VIDEODISC
The Infinite Voyage:
The Great Dinosaur Hunt: Where the Great Hunt Began (Ch. 1), 4 min.

The Great American Bone Rush (Ch. 3), 2 min.

PROJECT

Evolving Bacteria

Interpersonal Have student groups research for a class presentation a bacterium that has evolved quickly to develop resistance to antibiotics. Possible bacteria include those that cause staph and strep infections, TB, and childhood ear infections. Students should identify the bacterium, the disease it causes, how it is transmitted, and the data that suggest the bacterium is resistant to antibiotic treatment. Students can make visuals—graphs, data tables, and time lines—to illustrate their presentations. L2 COOP LEARN

MEETING INDIVIDUAL NEEDS

Learning Disabled

Naturalist The fossil records of some organisms, such as camels, horses, elephants, and the extinct titanotheres, are relatively complete and show evolutionary change. Give students illustrations of the fossil sequence of one of these organisms, and point out the organism's major characteristics in each stage of the sequence. Have them summarize the organism's major changes during its evolution. L1 ELL

Visual Learning

Figure 15.9 Ask students what the function of the vestigial wings may have been. *Flight in ancestral species*

Different Viewpoints in Biology

The use of embryological evidence to support the common ancestry of organisms has both proponents and opponents. Some people interpret this kind of data to indicate that all organisms are related, and others do not.

3 Assess

Check for Understanding

Linguistic Have students describe how each of the following concepts relates to natural selection: overproduction, favorable variations, population change over time. L1

Reteach

Intrapersonal Have students identify five of an organism's traits, such as its hair color or size. Ask them to name five variations for each trait and state how each variation would affect the organism in its environment. L1

GLENCOE TECHNOLOGY

VIDEODISC
The Infinite Voyage
The Great Dinosaur Hunt, Newborns: Examining Dinosaur Eggs (Ch. 7)
8 min. 30 sec.

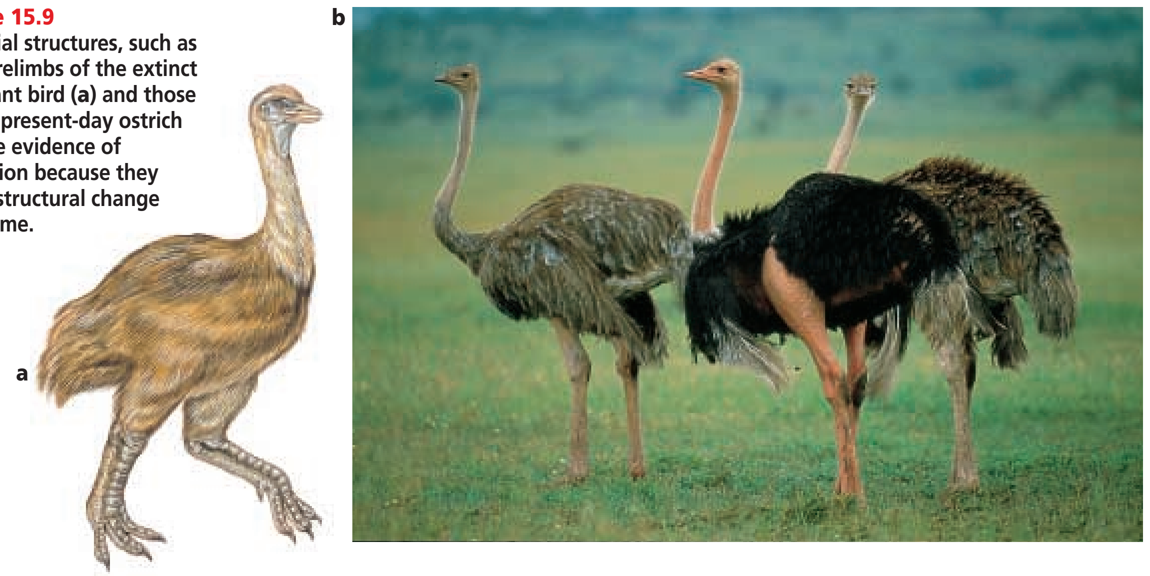


Figure 15.9
Vestigial structures, such as the forelimbs of the extinct elephant bird (a) and those of the present-day ostrich (b), are evidence of evolution because they show structural change over time.

Word Origin

vestigial
From the Latin word *vestigium*, meaning "sign." The forelimbs of ostriches are vestigial structures.

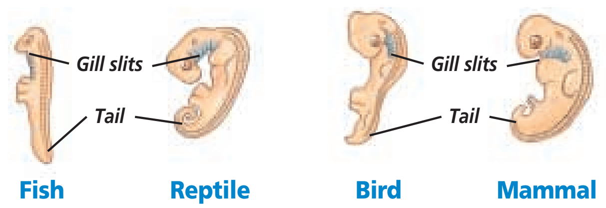
Another type of body feature that suggests evolutionary relationship is a **vestigial structure** (veh STIHJ ee ul)—a body structure that has no function in a present-day organism but was probably useful to an ancestor. A structure becomes vestigial when the species no longer needs the feature. Although the structure has no function, it is still inherited as part of the body plan for the species.

Many organisms have structures with no apparent function. The eyes of blind mole-rats and cave fish are vestigial structures because they have no function. In ***Figure 15.9***, you see two flightless birds—an extinct elephant bird and an African ostrich—with extremely reduced forelimbs. Their ancestors probably foraged on land for food and nested on the ground. As a result, over time, the ancestral birds probably became quite large and unable to fly, features evident in fossils of the elephant bird and present in the African ostrich.

Embryology

It's very easy to see the difference between an adult bird and an adult mammal, but can you distinguish between them by looking at their embryos? An **embryo** is the earliest stage of growth and development of both plants and animals. The embryos of a fish, a reptile, a bird, and a mammal are shown in ***Figure 15.10.*** You can see a tail and gill slits in all the embryos. You know that reptiles, birds, and mammals do not have gills when they are mature. As development continues, the differences in the embryos will increase until you can distinguish among them. However, the similarities among the young embryos suggest evolution from a distant, common ancestor.

Figure 15.10
Comparing embryos can reveal their evolutionary relationships. The presence of gill slits and tails in early vertebrate embryos shows that they may share a common ancestor.



Biochemistry

Biochemistry also provides evidence for evolution. It reveals information about relationships between individuals and species. Comparisons of the DNA or RNA of different species produce biochemical evidence for evolution. Today, many scientists use the results of biochemical studies to help determine the evolutionary relationships of species.

Since Darwin's time, scientists have constructed evolutionary diagrams that show levels of relationships among species. In the 1970s, some biologists began to use RNA and DNA nucleotide sequences to construct evolutionary diagrams. The evolutionary diagram you see in ***Figure 15.11*** was constructed using the results of biochemical analysis and other data, including anatomical data. Notice that it divides all species into three domains: the Archaea, the Eubacteria, and the Eukaryota—an idea that underlies one of the most recently developed classification systems for organisms.

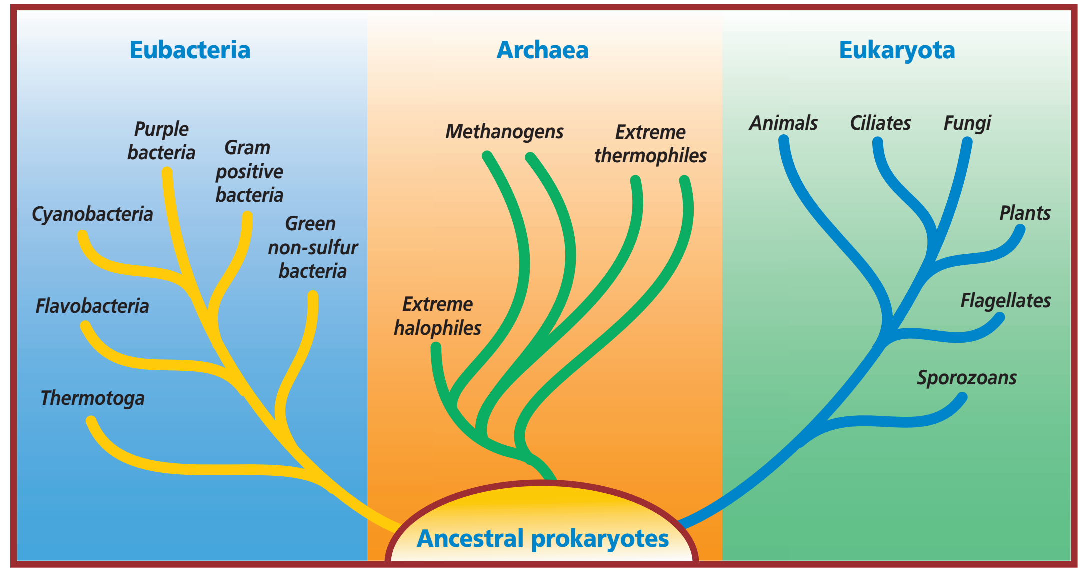


Figure 15.11
This evolutionary diagram is based on comparisons of organisms' RNA and supported by other data.

Section Assessment

Understanding Main Ideas

1. Briefly explain Darwin's ideas about natural selection.
2. Some snakes have vestigial legs. Why is this considered evidence for evolution?
3. Explain how mimicry and camouflage help species survive.
4. How do homologous structures provide evidence for evolution?

Thinking Critically

5. A parasite that lives in red blood cells causes the disease called malaria. In recent years, new strains of the parasite have appeared that are resistant to the drugs used to treat the disease. Explain how this could be an example of natural selection occurring.

Skill Review

6. **Sequencing** Fossils indicate that whales evolved from ancestors that had legs. Using your knowledge of natural selection, sequence the steps that may have occurred during the evolution of whales from their terrestrial, doglike ancestors. For more help, refer to *Organizing Information* in the **Skill Handbook**.

Extension

Have students answer the problem: Anteaters, toothless mammals that live in South American rain forests, feed on termites. If the termites they normally feed on are replaced by termites that are too large to swallow whole, how might the anteaters change over time?

Assessment

Portfolio Ask the students to research an organism and describe five of its adaptations. Then, have them select a new environment for the organism and predict how natural selection would affect the organism there. L2 P

4 Close

Activity

Interpersonal Divide the class into groups and show photos of different organisms. Have groups brainstorm a list of the organisms' adaptations and three explanations for each adaptation. L1 COOP LEARN

Resource Manager

Reinforcement and Study Guide, pp. 65-66 L2
Content Mastery, p. 74 L1

Portfolio

Evolution

Logical-Mathematical Have students describe how each statement that follows supports the theory of evolution.

- An insecticide does not kill an aphid species.
- The feet of geckos enable them to climb vertically on trees and rocks.
- Human, rabbit, chicken, and lizard embryos have gill slits during their early developmental stages.
- About 20% of human DNA is identical to mouse DNA, and 98% of human DNA is identical to chimpanzee DNA.
- The fossil record shows that camels were once the size of rabbits. L3 P

Section Assessment

1. Organisms produce many offspring with variations, some of which enable longer survival than others. Variations with a survival advantage are widespread among descendants.
2. They suggest that snake ancestors had functional legs and today's snakes may have evolved from them.
3. They reduce a species' visibility to predators or mimic the appearance of an organism that predators avoid.
4. They suggest common ancestry.
5. Some parasites had a variation that made them resistant to drugs. They survived and passed this variation to their offspring.
6. Ancestral whales were forced to live in water. Individuals with variations that had survival advantages in water reproduced, passing on these variations. Over time the variations became common in the population.

Section 15.2

Prepare

Key Concepts

Students will learn about gene pools and how natural selection affects them. Then they will study factors that may contribute to speciation. Finally, specific examples of different patterns of evolution will enhance the students' understanding of the theory of evolution.

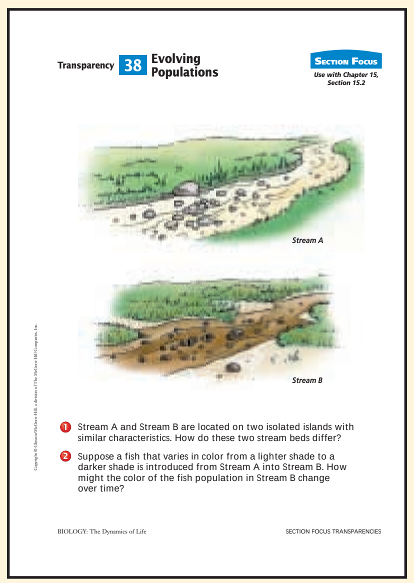
Planning

- Purchase beans for the Visual Learning and BioLab, unshelled peanuts for MiniLab 15-2, and carnations for the Tech Prep.
- Gather equipment for the Alternative Lab.

1 Focus

Bellringer

Before presenting the lesson, display **Section Focus Transparency 38** on the overhead projector and have students answer the accompanying questions. L1 ELL



SECTION PREVIEW

Objectives

Summarize the effects of the different types of natural selection on gene pools.

Relate changes in genetic equilibrium to mechanisms of speciation.

Explain the role of natural selection in convergent and divergent evolution.

Vocabulary

gene pool
allelic frequency
genetic equilibrium
genetic drift
stabilizing selection
directional selection
disruptive selection
speciation
geographic isolation
reproductive isolation
polyploid
gradualism
punctuated equilibrium
adaptive radiation
divergent evolution
convergent evolution

Section 15.2 Mechanisms of Evolution

You may recognize the birds shown here as meadowlarks. These birds range throughout much of the United States. Meadowlarks look so similar that it's often difficult to tell them apart. But if you listen, you'll hear a melodious bubbling sound from the Western meadowlark, whereas the Eastern meadowlark produces a clear whistle. Although they are closely related and occupy the same ranges in parts of the central United States, these different meadowlarks do not normally interbreed and are classified as distinct species.

Western meadowlark—*Sturnella neglecta*

Eastern meadowlark—*Sturnella magna*

Population Genetics and Evolution

When Charles Darwin developed his theory of natural selection in the 1800s, he did so without knowing about genes. Since Darwin's time, scientists have learned a great deal about genes and modified Darwin's ideas accordingly. At first, genetic information was used to explain the variation among individuals of a population. Then, studies of the complex behavior of genes in populations of plants and animals developed into the field of study called population genetics. The principles of today's modern theory of evolution are rooted in population genetics and other related fields of study and are expressed in genetic terms.

Populations, not individuals, evolve

Can individuals evolve? That is, can an organism respond to natural selection by acquiring or losing characteristics? Recall that genes determine most of an individual's features, such as tooth shape or flower color. If an organism has a feature—a variation called a phenotype in genetic terms—that is poorly adapted to its environment, the organism may be unable to survive and reproduce. However, within its lifetime, it cannot evolve a new phenotype in response to its environment.

Rather, natural selection acts on the range of phenotypes in a population. Recall that a population consists of all the members of a species that live in an area. Each member has the

First generation	Phenotype frequency	Allele frequency
 RR RR RR' RR' RR RR' RR RR'	White = 0 Pink = 0.5 Red = 0.5	*R* = 0.75 *R'* = 0.25
Second generation	**Phenotype frequency**	**Allele frequency**
 RR RR' RR RR' RR R'R' RR RR	White = 0.125 Pink = 0.25 Red = 0.625	*R* = 0.75 *R'* = 0.25

Figure 15.12 Incomplete dominance produces three phenotypes: red flowers (*RR*), white flowers (*R'R'*), and pink flowers (*RR'*). Although the phenotype frequencies of the generations vary, the allelic frequencies for the *R* and *R'* alleles do not vary.

genes that characterize the traits of the species, and these genes exist as pairs of alleles. Just as all of the individuals make up the population, all of the genes of the population's individuals make up the population's genes. Evolution occurs as a population's genes and their frequencies change over time.

How can a population's genes change over time? Picture all of the alleles of the population's genes as being together in a large pool called a **gene pool.** The percentage of any specific allele in the gene pool is called the **allelic frequency.** Scientists calculate the allelic frequency of an allele in the same way that a baseball player calculates a batting average. They refer to a population in which the frequency of alleles remains the same over generations as being in **genetic equilibrium.** In the *Math Connection* at the end of the chapter, you can read about the mathematical description of genetic equilibrium. You can study the effect of natural selection on allelic frequencies in the *BioLab* at the end of the chapter.

Look at the population of snapdragons shown in ***Figure 15.12.*** A pattern of heredity called incomplete dominance, which you learned about earlier, governs flower color in snapdragons. If you know the flower-color genotypes of the snapdragons in a population, you can calculate the allelic frequency for the flower-color alleles. The population of snapdragons is in genetic equilibrium when the frequency of its alleles for flower color is the same in all its generations.

Changes in genetic equilibrium

A population that is in genetic equilibrium is not evolving. Because allelic frequencies remain the same, phenotypes remain the same, too. Any factor that affects the genes in the gene pool can change allelic frequencies, disrupting a population's genetic equilibrium, which results in the process of evolution.

You have learned that one mechanism for genetic change is mutation. Environmental factors, such as radiation or chemicals, cause many mutations, but other mutations occur by

2 Teach

Visual Learning

Kinesthetic **Figure 15.12** Students can use beans to model allelic frequency. Mix red pinto beans, black beans, and white navy beans in a large container. Have students withdraw 20 random beans to represent the gene pool of a population with the genotypes *BB* (black bean), *BB** (white bean), and *B*B** (red bean). Have them calculate the phenotype frequencies by dividing the number of each phenotype by 20, and the allelic frequencies by counting the numbers of each allele and dividing by 40. L1 ELL

The BioLab at the end of the chapter can be used at this point in the lesson. INTERNET BioLab

Quick Demo

Use a world map and explain that many human populations are isolated for geographical, political, or other reasons. Ask students how this might affect these nations' gene pools.

GLENCOE TECHNOLOGY

VIDEOTAPE
The Secret of Life
Gone Before You Know It: The Biodiversity Crisis

CD-ROM
Biology: The Dynamics of Life
Exploration: *Selection Pressure*
Disc 2

Resource Manager

Section Focus Transparency 38 and Master L1 ELL

TechPrep

Logical-Mathematical Have students use a bouquet of carnations (red, pink, and white) to calculate the frequency of alleles that determine flower color. Students should prepare a chart similar to the one in Figure 15.12. L2

Biology Journal

Desert Adaptions

Linguistic Ask students to imagine changes in food, clothing, shelter, and other factors that would be useful if their environment suddenly became desertlike. Have them write a short story about life in the new environment. L1

Genetic Drift

Linguistic Have students write a short summary of how genetic drift may affect small populations. L3

Concept Development

Point out that in small populations that interbreed, such as certain religious groups and royal families, gene pools change quickly because the number of potential mates is limited.

Tying to Previous Knowledge

Review meiosis. Explain how random factors involved in some of the steps of meiosis can contribute to genetic drift.

Using An Analogy

Flip a coin to show how small populations can be affected by genetic drift. If you flip a coin 100 times, the chances of getting 100 heads and 0 tails—or even 80 heads and 20 tails—is unlikely. The result will probably be close to 50-50. But if you flip the coin 10 times, the chance of getting 8 heads and 2 tails—or even 10 heads and 0 tails—is likely to occur. Similarly, the loss of alleles by chance is lower in large populations than in small ones.

Resource Manager

Basic Concepts Transparency 21 and Master L2 ELL

BioLab and MiniLab Worksheets, p. 72 L2

Figure 15.13 Genetic drift can result in an increase of rare alleles in a small population such as in the Amish community of Lancaster County, Pennsylvania.

chance. Of the mutations that affect organisms, many are lethal, and the organisms do not survive. Thus, lethal mutations are quickly eliminated. However, occasionally, a mutation results in a useful variation, and the new gene becomes part of the population's gene pool by the process of natural selection.

Another mechanism that disrupts a population's genetic equilibrium is **genetic drift**—the alteration of allelic frequencies by chance events. Genetic drift can greatly affect small populations that include the descendants of a small number of organisms. This is because the genes of the original ancestors represent only a small fraction of the gene pool of the entire species and are the only genes available to pass on to offspring. The distinctive forms of life that Darwin found in the Galapagos Islands may have resulted from genetic drift.

Genetic drift has been observed in some small human populations that have become isolated due to reasons such as religious practices and belief systems. For example, in Lancaster County, Pennsylvania, there is an Amish population of about 12 000 people who have a unique lifestyle and marry other members of their community. By chance, at least one of the original 30 Amish settlers in this community carried a recessive allele that results in short arms and legs and extra fingers and toes in offspring, ***Figure 15.13.*** Because of the small gene pool, many individuals inherited the recessive allele over time. Today, the frequency of this allele among the Amish is high—1 in 14 rather than 1 in 1000 in the larger population of the United States.

Genetic equilibrium is also disrupted by the movement of individuals in and out of a population. The transport of genes by migrating individuals is called gene flow. When an individual leaves a population, its genes are lost from the gene pool. When individuals enter a population, their genes are added to the pool.

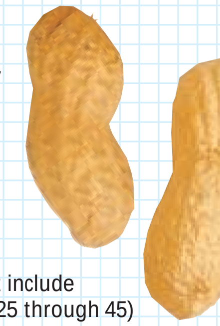
Mutation, genetic drift, and gene flow may significantly affect the evolution of small and isolated gene pools, such as those on islands. However, their effect is often insignificant in larger, less isolated gene pools. Natural selection is usually the most significant factor that causes changes in established gene pools—small or large.

Natural selection acts on variations

As you've learned, traits have variation, as shown in the butterflies pictured in ***Figure 15.14.*** If you measured the thumb lengths of everyone in your class, you'd find average, long, and short thumbs. Try measuring the variations in peanut shells in the *MiniLab* on this page.

Recall that some variations increase or decrease an organism's chance of survival in an environment. These variations can be inherited and are controlled by alleles. Thus, the allelic frequencies in a population's gene pool will change over generations due to the natural selection of variations. There are three different types of natural selection that act on variation: stabilizing, directional, and disruptive.

MiniLab 15-2 Collecting Data



Detecting a Variation Pick almost any trait—height, eye color, leaf width, or seed size—and you can observe how the trait varies in a population. Some variations are an advantage to an organism and some are not.

Procedure

1. Copy the data table shown here, but include the lengths in millimeters (numbers 25 through 45) that are missing from this table.

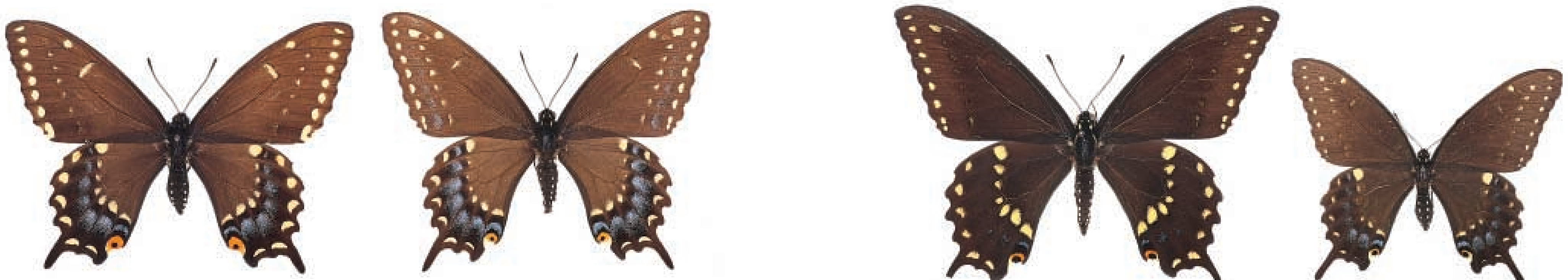
Data Table

Length in mm	20	21	22	23	24	—	46	47	48	49	50
Checks											
My Data—Number of shells											
Class Data—Number of shells											

2. Use a millimeter ruler to measure a peanut shell's length. In the Checks row, check the length you measured.
3. Repeat step 2 for 29 more shells.
4. Count the checks under each length and enter the total in the row marked My Data.
5. Use class totals to complete the row marked Class Data.

Analysis

1. Was there variation among the lengths of peanut shells? Use specific class totals to support your answer.
2. If larger peanut shells were a selective advantage, would this be stabilizing, directional, or disruptive selection? Explain your answer.



Papilio ajax ajax *Papilio ajax ampliata* *Papilio ajax curvifascia* *Papilio ajax ehrmanni*

Figure 15.14 These swallowtail butterflies live in different areas of North America. Despite their slight variations, they can interbreed to produce fertile offspring.

MiniLab 15-2

Purpose

Students will measure and determine that peanut shells vary in length.

Process Skills

collect data, interpret data, make and use tables, make and use graphs, measure in SI

Teaching Strategies

- Have students wash their hands after handling peanuts.
- Unshelled peanuts are available in most large supermarkets.
- Have students pool their data on the chalkboard.
- Tell students that peanut shells contain seeds, and discuss briefly the role of seeds in plant reproduction.

Expected Results

Student data should indicate a wide range in shell length. There should be few shells at either extreme and the majority of shells should fall in the middle range of the measurements.

Analysis

1. yes—student answers will vary
2. Directional selection—larger shells may favor the survival of offspring because they may contain larger, more viable seeds.

Assessment

Portfolio Have students prepare a histogram of the class data. Use the Performance Task Assessment List for Graph from Data in **PASC**, p. 39. L1 P

Alternative Lab

Bacterial Resistance

Purpose

Students will study variation in bacterial resistance to antibiotics. Dispose of used dishes after autoclaving or incinerating.

Materials

culture of *Bacillus subtilis,* 3 tubes of nutrient agar, tube of streptomycin agar, inoculation loop, 2 petri dishes, Bunsen burner, wax pencil, test tube

Procedure

Give the following directions.

1. Wear goggles, aprons, and disposable gloves when working with bacteria.
2. Write *A* and *B* on the halves of one petri dish and *C* and *D* on another.
3. Pour streptomycin agar into dish *A-B.* Place the dish on a pencil, so the liquid flows to one side to solidify. **CAUTION: *Liquid agar is hot.***
4. After the agar solidifies, pour a tube of hot nutrient agar into the dish and cover the dish after it solidifies.
5. Pour the other tubes of agar into the *C-D* dish. Cover the dish after it cools.
6. Sterilize the inoculation loop in the Bunsen burner's flame. Remove the stopper and flame the lip of the bacterial culture.
7. Dip the loop into the culture and remove it. Flame the lip of the container again and replace the stopper.
8. Streak the agar in dish *A-B* with the loop. Do not break the agar surface.
9. Repeat steps 6-8 on the *C-D* dish.
10. Recover the dishes, invert them, and place them in a dark drawer or closet. Do not open the dishes again after you have inoculated and recovered them. Observe them after 24 hours. Dispose of used petri dishes as your teacher instructs.

Expected Results

There should be more bacterial growth in the C-D dish than in the A-B dish.

Analysis

Have students sketch and describe the appearance of both plates.

Assessment

Knowledge What is each dish's purpose? A-B *is experimental;* C-D *is the control.* Explain your observations of the dishes. *Streptomycin accounts for the different number of colonies.* Use the Performance Task Assessment List for Assessing an Experiment in **PASC,** p. 33.

Visual Learning

Figure 15.15 illustrates the three main types of natural selection. Refer to each type and offer students several other examples of each.

Reinforcement

Logical-Mathematical Have students describe the type of natural selection in each of the following examples.

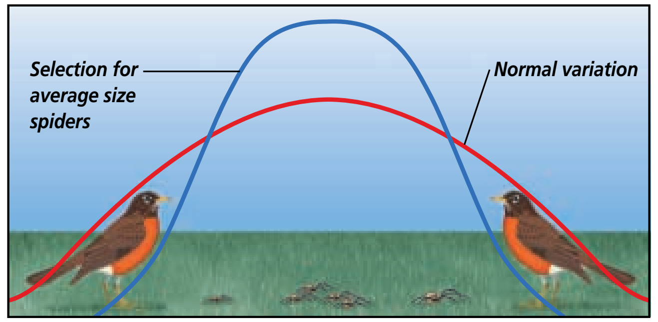
- Members of a population of Amazon tree frogs hop from tree to tree searching for food in the rain forest. They vary in leg length. Events result in massive destruction of the forest's trees. After several generations, only long-legged tree frogs remain alive. *directional selection*
- Different grass plants in a population range in length from 8 cm to 28 cm. The 8-10 cm grass blades receive little sunlight, and the 25-28 cm grass blades are eaten quickly by grazing animals. *stabilizing selection*
- The spines of a sea urchin population's members vary in length. The short-spined sea urchins are camouflaged easily on the seafloor. However, long-spined sea urchins are well defended against predators. *disruptive selection*

Have students illustrate each situation and predict what will happen to the members of each population if natural selection continues to operate. L1

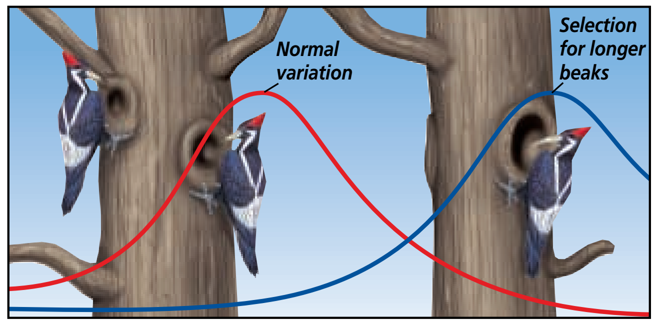
Resource Manager

Basic Concepts Transparency 22 and Master L2 ELL
Critical Thinking/Problem Solving L3

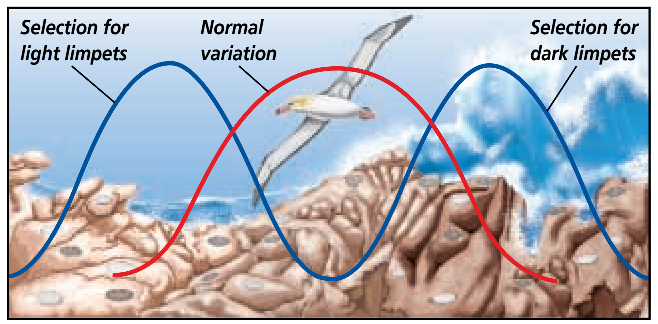
Figure 15.15
Different types of natural selection act over the range of a trait's variation. The red, bell-shaped curve indicates a trait's variation in a population. The blue, bell-shaped curve indicates the effect of a natural selection.



A **Stabilizing selection** **favors average individuals. This type of selection reduces variation in a population.**



B **Directional selection** **favors one of the extreme variations of a trait and can lead to the rapid evolution of a population.**



C **Disruptive selection** **favors both extreme variations of a trait, resulting eventually in no intermediate forms of the trait and leading to the evolution of two new species.**

Stabilizing selection is natural selection that favors average individuals in a population as shown in *Figure 15.15.* Consider a population of spiders in which average size is a survival advantage. Predators in the area might easily see and capture spiders that are larger than average. However, small spiders may find it difficult to find food. Therefore, in this environment, average-sized spiders are more likely to survive—they have a selective advantage, or are "selected for."

Directional selection occurs when natural selection favors one of the extreme variations of a trait. For example, imagine a population of woodpeckers pecking holes in trees to feed on the insects living under the bark. Suppose that a species of insect that lives deep in tree tissues invades the trees in a woodpecker population's territory. Only woodpeckers with long beaks could feed on that insect. Therefore, the long-beaked woodpeckers in the population would have a selective advantage over woodpeckers with very short or average-sized beaks.

Finally, in **disruptive selection,** individuals with either extreme of a trait's variation are selected for. Consider, for example, a population of marine organisms called limpets. The shell color of limpets ranges from white, to tan, to dark brown. As adults, limpets live attached to rocks. On light-colored rocks, white-shelled limpets have an advantage because their bird predators cannot easily see them. On dark-colored rocks, dark-colored limpets have the advantage because they are camouflaged. On the other hand, birds easily see tan-colored limpets on either the light or dark backgrounds. Disruptive selection tends to eliminate the intermediate phenotypes.

Natural selection can significantly alter the genetic equilibrium of a population's gene pool over time. Significant changes in the gene pool can lead to the evolution of a new species over time.

The Evolution of Species

You've just read about how natural processes such as mutation, genetic drift, gene flow, and natural selection can change a population's gene pool over time. But how do the changes in the makeup of a gene pool result in the evolution of new species? Recall that a species is defined as a group of organisms that look alike and can interbreed to produce fertile offspring in nature. The evolution of new species, a process called **speciation** (spee shee AY shun), occurs when members of similar populations no longer interbreed to produce fertile offspring within their natural environment.

Physical barriers can prevent interbreeding

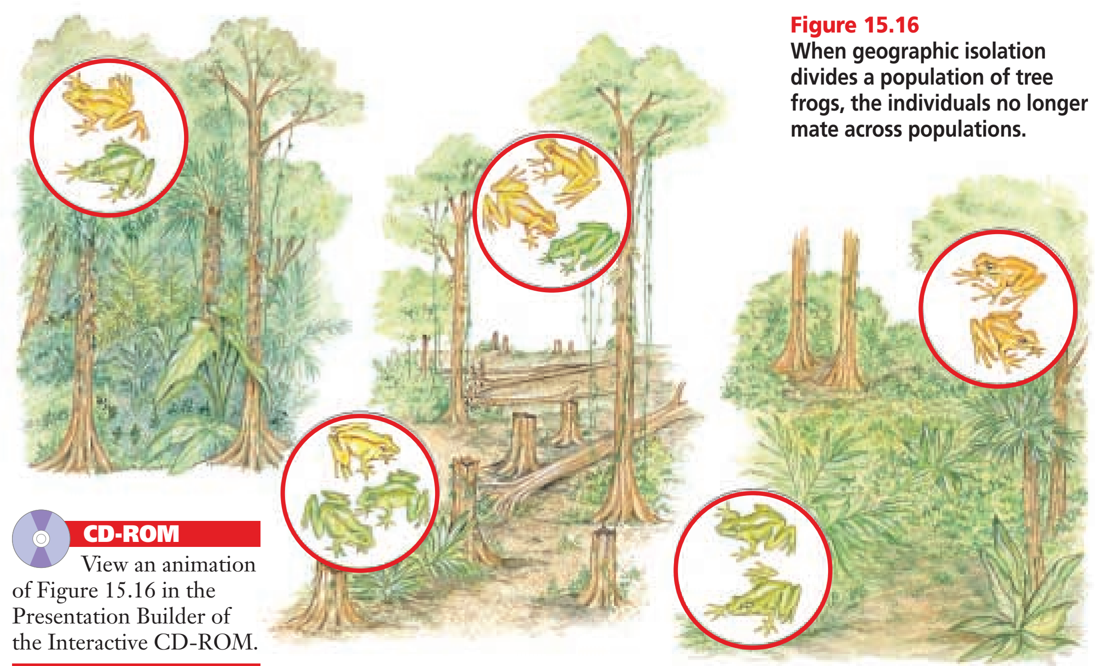
In nature, physical barriers can break large populations into smaller ones. Lava from volcanic eruptions can isolate populations. Sea-level changes along continental shelves can create islands. The water that surrounds an island isolates its populations. **Geographic isolation** occurs whenever a physical barrier divides a population.

A new species can evolve when a population has been geographically isolated. For example, imagine a population of tree frogs living in a rain forest, ***Figure 15.16.*** If small populations of tree frogs were geographically isolated, they would no longer be able to interbreed and exchange genes. Over time, each small population might adapt to its environment through natural selection and develop its own gene pool. Eventually, the gene pools of each population might become so different that new species

Word Origin

speciation
From the Latin word *species,* meaning "kind." Speciation is a process that produces two species from one.

Figure 15.16
When geographic isolation divides a population of tree frogs, the individuals no longer mate across populations.



CD-ROM
View an animation of Figure 15.16 in the Presentation Builder of the Interactive CD-ROM.

Discussion

Remind students that scientists used to classify organisms only on the basis of morphological comparisons. This type of classification is useful but limited. For example, using morphological classification, North American yellow flickers, red-shafted flickers, and their hybrid offspring could be considered three different species.

According to the biological species concept, organisms are classified by whether or not they can naturally interbreed with one another to produce fertile offspring, as the yellow flickers and red-shafted flickers can do. Elicit from students how many species of North American flickers exist based on this biological species definition. *one*

GLENCOE TECHNOLOGY

VIDEODISC
Biology: The Dynamics of Life
Geographic Isolation (Ch. 6)
Disc 1, Side 2, 17 sec.

Biology Journal

Populations and Natural Selection

Linguistic Have students write and illustrate a short story about the effects of natural selection on a specific population. Have them predict what happens to the population if all three types of natural selection occur in it. L2

Internet Address Book

interNET CONNECTION Note Internet addresses that you find useful in the space below for quick reference.

PROJECT

Mammalian Evolution

Interpersonal Groups of students can prepare a written report, oral report, or poster project about the geographic and reproductive isolation effect of plate tectonics on a mammalian family. Some families to research are: Bradypodidae, Myrmecophagidae, Camelidae, Mustelidae, Felidae, and Ursidae. Projects should contain details about the mammals, such as their structure and behavior, a brief summary of their fossil record, and explanations for how they evolved. L2 ELL COOP LEARN

Quick Demo

Use hypothetical examples to illustrate the concepts of geographic and reproductive isolation using the chalkboard or overhead projector. Show a population of organisms in an environment. Then split the population as a result of an event such as the formation of a volcano or a canyon that results in two new environments for the populations. Students in small groups can brainstorm three changes they predict will occur in each subpopulation over time.

Reinforcement

Reinforce the concept of geographic and reproductive isolation by providing students with examples of the reproductive behavior of closely related organisms. For example, wood frogs, *Rana sylvatica*, and leopard frogs, *Rana pipiens*, are species that evolved because of reproductive isolation. Wood frogs usually breed in late March or early April, and leopard frogs usually breed in mid-April.

Resource Manager

Reteaching Skills Transparency 24 and Master L1 ELL

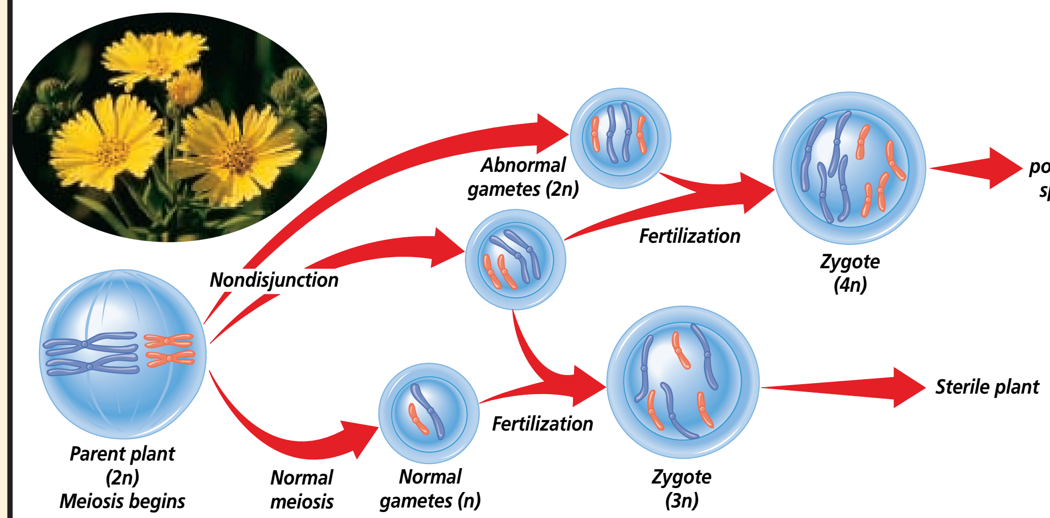


Figure 15.17
Many flowering plants, such as this California tarweed, are polyploids—individuals that result from mistakes made during meiosis.

Word Origin

polyploidy
From the Greek word *polys*, meaning "many." Polyploid plants contain multiple sets of chromosomes.

of tree frogs would evolve in the different forest patches or the populations might become extinct.

Reproductive isolation can result in speciation

As populations become increasingly distinct, reproductive isolation can arise. **Reproductive isolation** occurs when formerly interbreeding organisms can no longer mate and produce fertile offspring.

There are different types of reproductive isolation. One type occurs when the genetic material of the populations becomes so different that fertilization cannot occur. Some geographically separated populations of salamanders in California have this type of reproductive isolation. Another type of reproductive isolation is behavioral. For example, if one population of tree frogs mates in the fall, and another mates in the summer, these two populations will not mate with each other and are reproductively isolated.

A change in chromosome numbers and speciation

Chromosomes can also play a role in speciation. Many new species of plants and some species of animals have evolved in the same geographic area as a result of polyploidy (PAHL ih ployd ee), which is illustrated in *Figure 15.17*. Any species with a multiple of the normal set of chromosomes is known as a **polyploid.**

Mistakes during mitosis or meiosis can result in polyploid individuals. For example, if chromosomes do not separate properly during the first meiotic division, diploid (2*n*) gametes can be produced instead of the normal haploid (*n*) gametes. Polyploidy results in immediate reproductive isolation. When a polyploid mates with an individual of the normal species, the resulting zygotes may not develop normally because of the difference in chromosome numbers. In other cases, the zygotes develop into adults that probably cannot reproduce. However, polyploids within a population may interbreed and form a separate species.

Polyploids can arise from within a species or from hybridization between species. Many flowering plant species, as well as many important crop plants, such as wheat, cotton, apples, and bananas, originated by polyploidy.

Speciation can occur quickly or slowly

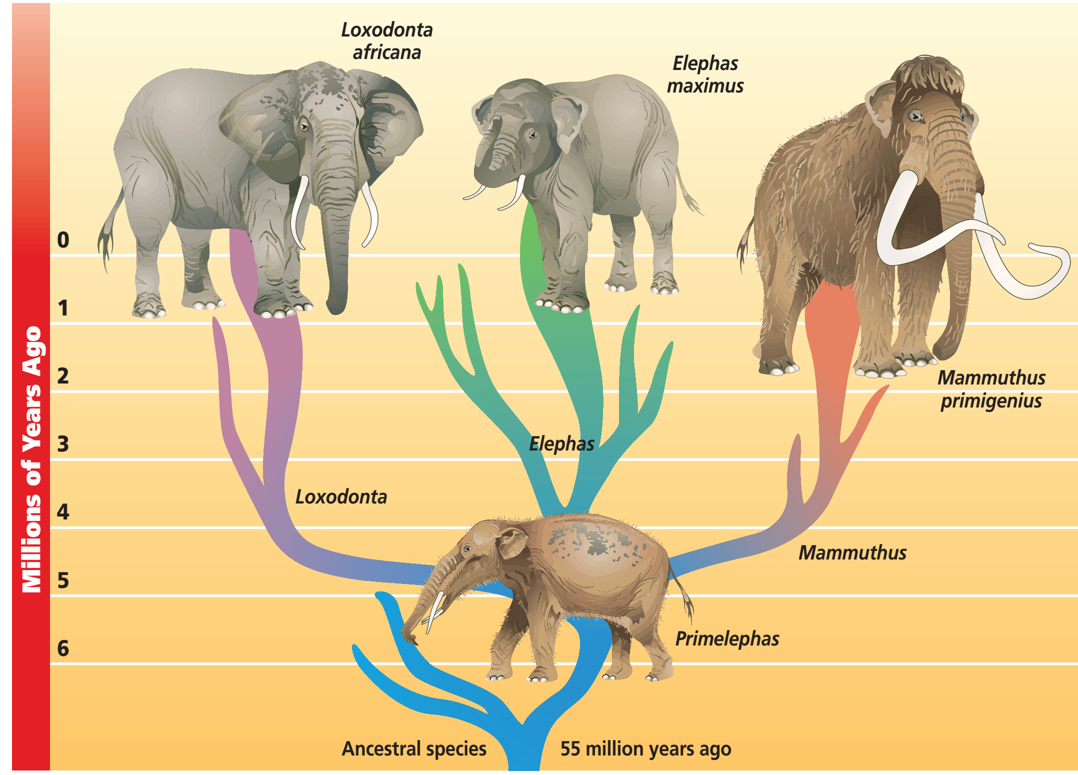
Although polyploid speciation takes only one generation, most other mechanisms of speciation do not occur as quickly. What is the usual rate of speciation?

Scientists once argued that evolution occurs at a slow, steady rate, with small, adaptive changes gradually accumulating over time in populations. **Gradualism** is the idea that species originate through a gradual change of adaptations. Some evidence from the fossil record supports gradualism. For example, fossil evidence shows that camels evolved slowly and steadily over time.

In 1971, Stephen J. Gould and Niles Eldridge proposed another hypothesis known as **punctuated equilibrium.** This hypothesis argues that speciation occurs relatively quickly, in rapid bursts, with long periods of genetic equilibrium in between. According to this hypothesis, environmental changes, such as higher temperatures or the introduction of a competitive species, lead to rapid changes in a population's gene pool. Speciation happens quickly—in about 10 000 years or less. Like gradualism, punctuated equilibrium is supported by fossil evidence as shown in *Figure 15.18.*

Biologists generally agree that both gradualism and punctuated equilibrium can result in speciation, depending on the circumstances. It shouldn't surprise you to see scientists offer alternative hypotheses to explain observations. The nature of science is such that new evidence or new ideas can modify theories.

Figure 15.18
The fossil record of elephant evolution supports the view of punctuated equilibrium. Three elephant species may have evolved from an ancestral population in a short time.



Concept Development

Darwin believed that species evolve slowly over long periods of time. For example, fossils show that today's horseshoe crabs, genus *Limulus*, are nearly identical to ancestors that lived hundreds of millions of years ago. If possible, show a modern specimen of the horseshoe crab and a fossil counterpart to demonstrate their similarities. Remind students that scientists have found limited support for the idea of gradualism in the fossil record. However, point out some examples that do support it.

Assessment

Portfolio Discuss the Abert and Kaibab squirrels of the Grand Canyon area. Have students prepare short summaries of the discussion to put in their portfolios. Summaries should describe the environment that each squirrel lives in, the characteristics of each species, and possible hypotheses for how the differences evolved. L2

GLENCOE TECHNOLOGY

VIDEODISC
The Secret of Life
Punctuated Equilibrium

Cultural Diversity

The Neutral Theory of Evolution

Explain to students the neutral theory of evolution developed by Japanese biologist Mootoo Kimura. This theory holds that most sequence changes that occur in DNA and proteins do not affect how the proteins do their job. In other words, most mutations have a neutral affect on organisms.

The neutral theory was heavily debated upon its presentation in 1968, but today it is viewed as an improvement of Darwinian theory because it provides testable predictions about molecular evolution. The strongest advocate of the neutral theory is Japanese geneticist Tomoko Ohta, head of Japan's National Institute of Genetics.

Meeting Individual Needs

Gifted

Linguistic Have the students research speciation rate. Students should first read Gould and Eldredge's 1972 article concerning punctuated equilibrium entitled "Punctuated Equilibria: An alternative to phyletic gradualism," found in *Models in Paleobiology*, T. J. M. Schopf (ed.), Freeman, Cooper, and Co. Have students compare the evidence for both punctuated equilibrium and gradualism. Their report should draw a conclusion about which hypothesis best supports the available evidence. L3

Reinforcement

Linguistic Reinforce the concept of the niche by asking students to write brief autobiographies in which they describe where they live and something about their school lives, activities, and hobbies. L1

Concept Development

Use the student autobiographies to develop the niche concept. Discuss some autobiographies and point out that, just as no two autobiographies are alike, no two niches on Earth are alike. Tie the concepts of niche and struggle for existence to adaptive radiation.

Display

Display examples of convergent structures in organisms, such as models or actual specimens of bird, bat, and insect wings.

GLENCOE TECHNOLOGY

VIDEODISC
Biology: The Dynamics of Life
Adapted for Survival (Ch. 5)
Disc 1, Side 2, 33 sec.

3 Assess

Check for Understanding

Develop five questions about types of natural selection and patterns of evolution. Have students work in groups to answer the questions. L1 COOP LEARN

Patterns of Evolution

Biologists have observed different patterns of evolution that occur throughout the world in different natural environments. These patterns support the idea that natural selection is an important agent for evolution.

Diversity in new environments

An extraordinary diversity of unique plants and animals live or have lived on the Hawaiian Islands, among them a group of birds called Hawaiian honeycreepers. This group of birds is interesting because, although similar in body size and shape, they differ sharply in color and beak shape. Different species of honeycreepers evolved to occupy their own niches.

Despite their differences, scientists hypothesize that honeycreepers, as shown in *Figure 15.19*, evolved from a single ancestral species that lived on the Hawaiian Islands long ago. When an ancestral species evolves into an array of species to fit a number of diverse habitats, the result is called **adaptive radiation.**

Adaptive radiation in both plants and animals has occurred and continues to occur throughout the world and is common on islands. For example, the many species of finches that Darwin observed on the Galapagos Islands are a typical example of adaptive radiation.

Adaptive radiation is a type of **divergent evolution,** the pattern of evolution in which species that once were similar to an ancestral species diverge, or become increasingly distinct. Divergent evolution occurs when populations adapting to different environmental conditions change, becoming less alike as they adapt, eventually resulting in new species.

Figure 15.19
Evolutionary biologists have suggested that the ancestors of all Hawaiian Island honeycreepers migrated from North America about 5 million years ago. As this ancestral bird population settled in the diverse Hawaiian niches, adaptive radiation occurred.

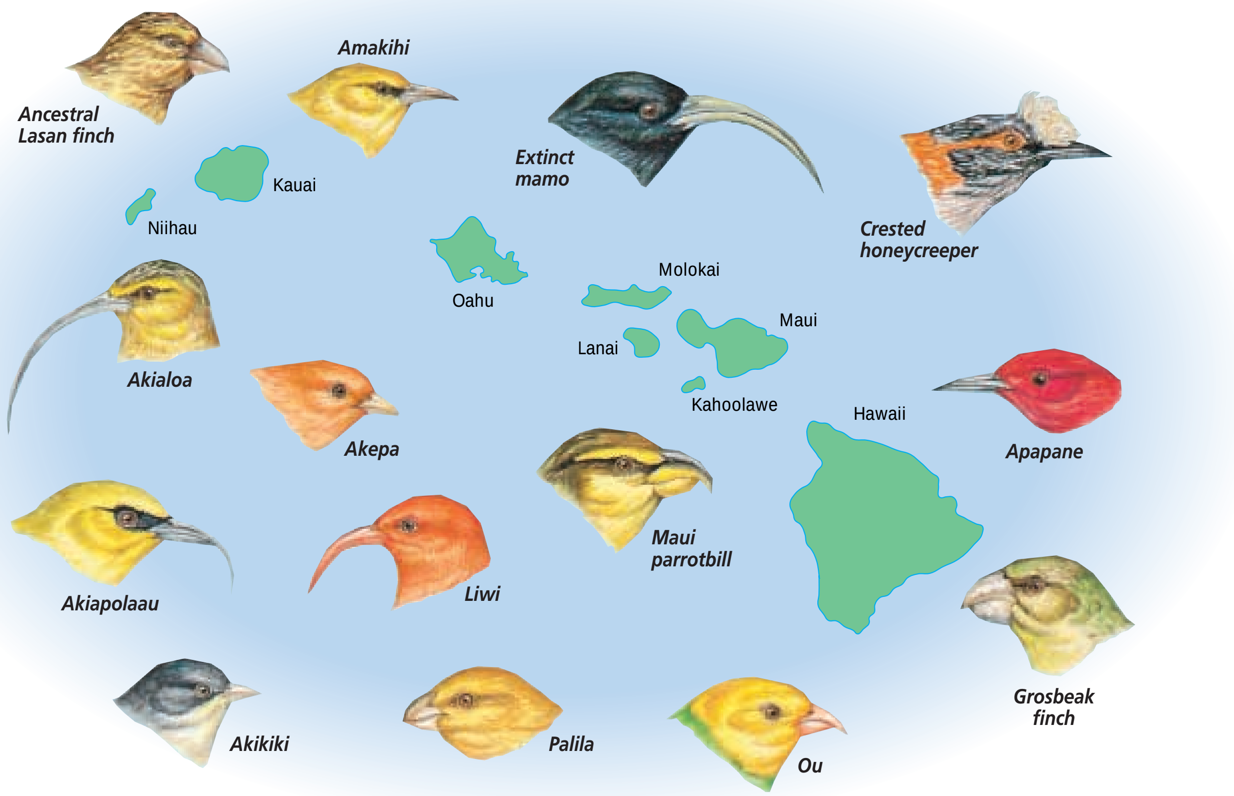
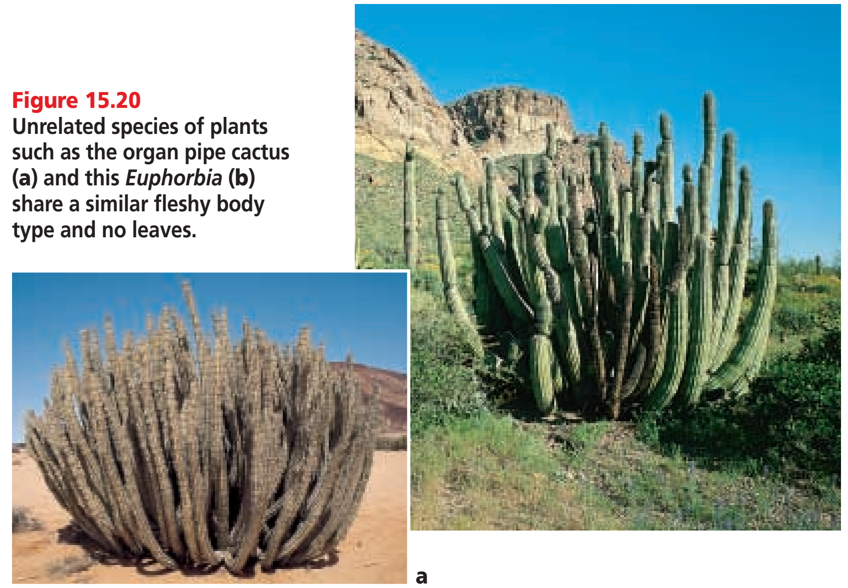


Figure 15.20
Unrelated species of plants such as the organ pipe cactus (a) and this *Euphorbia* (b) share a similar fleshy body type and no leaves.



Different species can look alike

A pattern of evolution in which distantly related organisms evolve similar traits is called **convergent evolution.** Convergent evolution occurs when unrelated species occupy similar environments in different parts of the world. Because they share similar environmental pressures, they share similar pressures of natural selection.

For example, in *Figure 15.20,* you see a cactus of the family Cactaceae, an organ pipe cactus, that grows in the deserts of North and South America and a plant of the family Euphorbiaceae that looks like the cactus and lives in African deserts. Although these plants are unrelated species, their environments are similar. You can see that they both have fleshy bodies and no leaves. That convergent evolution has apparently occurred in unrelated species, is further evidence for natural selection.

Section Assessment

Understanding Main Ideas

1. Explain why the evolution of resistance to antibiotics in bacteria is an example of directional selection.
2. How can geographic isolation change a population's gene pool?
3. Why is rapid evolutionary change more likely to occur in small populations?
4. How do gradualism and punctuated equilibrium differ? How are they similar?

Thinking Critically

5. Hummingbird moths are night-flying insects whose behavior and appearance are similar to those of hummingbirds. Explain how these two organisms demonstrate the concept of convergent evolution.

SKILL REVIEW

6. **Designing an Experiment** Biologists have discovered two species of squirrels living on opposite sides of the Grand Canyon. They hypothesize that they both evolved from a recent, common ancestor that lived in the area before the Grand Canyon formed. What observations or experiments could provide evidence for this hypothesis? For more help, refer to *Practicing Scientific Methods* in the **Skill Handbook.**

Reteach

Visual-Spatial Have students make a concept map to demonstrate how natural selection acts on the variation of a trait. L1 ELL

Extension

Linguistic Have the students write a summary about how Darwin's finches illustrate adaptive radiation. L2

Assessment

Skill Have students analyze the following data on rabbit population allele frequencies.

1st generation: $A = 0.5$, $a = 0.5$
2nd generation: $A = 0.6$, $a = 0.4$
3rd generation: $A = 0.7$, $a = 0.3$
4th generation: $A = 0.8$, $a = 0.2$
5th generation: $A = 0.9$, $a = 0.1$

Have students describe what is happening in the population if A represents an allele for white fur, and a represents an allele for brown fur. L2

4 Close

Discussion

Discuss some of the human cultural adaptations that "shield" us from the effects of natural selection, such as clothing, medicine, automobiles, etc.

Resource Manager

Reinforcement and Study Guide, pp. 68-69 L2
Content Mastery, pp. 73, 75-76 L1

Portfolio

Adaptive Radiation

Linguistic Have students write answers to the following for their portfolios.

- Describe some adaptive changes that might occur in a population of gray squirrels over time if the population became deposited suddenly on an island that contained a swamp, a desert, a tropical rain forest, and a snow-covered mountain.
- How do examples of adaptive radiation support the concept of evolution by natural selection? L2 P

Section Assessment

1. Only bacteria that are totally resistant to antibiotics survive.
2. It may result in different local environments for a separated population. Different adaptations are useful in different environments, and the gene pool will in time reflect the differences.
3. It occurs because of genetic drift and the limited number of mates.
4. Gradualism takes a much longer time than punctuated equilibrium, but they both result in evolution.
5. Although not closely related, they share similar environments and have evolved similar behaviors and appearances.
6. Analyze the DNA, structure, and behavior of each. Examine fossils.

INTERNET BioLab

Time Allotment
One class period

Process Skills
make and use tables, observe and infer, make and use graphs

PREPARATION

Alternative Materials

- Beads or other small objects may be substituted for beans.

Resource Manager

BioLab and MiniLab Worksheets, pp. 73-74 L2

INTERNET BioLab

Natural Selection and Allelic Frequency

Evolution can be described as the change in allelic frequencies of a gene pool over time. Natural selection can place pressure on specific phenotypes and cause a change in the frequency of the alleles that produce the phenotypes. In this activity, you will simulate the effects of eagle predation on a population of rabbits, where GG *represents the homozygous condition for gray fur,* Gg *is the heterozygous condition for gray fur, and* gg *represents the homozygous condition for white fur.*

PREPARATION

Problem

How does natural selection affect allelic frequency?

Objectives

In this BioLab, you will:

- **Simulate** natural selection by using beans of two different colors.
- **Calculate** allelic frequencies over five generations.
- **Demonstrate** how natural selection can affect allelic frequencies over time.
- **Use the Internet** to collect and compare data from other students.

Materials

colored pencils (2)
paper bag
graph paper
pinto beans
white navy beans

Skill Handbook

Use the **Skill Handbook** if you need additional help with this lab.

PROCEDURE

1. Copy the data table shown on the next page.
2. Place 50 pinto beans and 50 white navy beans into the paper bag.
3. Shake the bag. Remove two beans. These represent one rabbit's genotype. Set the pair aside, and continue to remove 49 more pairs.
4. Arrange the beans on a flat surface in two columns representing the two possible rabbit phenotypes, gray (genotypes *GG* or *Gg*) and white (genotype *gg*).
5. Examine your columns. Remove 25 percent of the gray rabbits and 100 percent of the white rabbits. These numbers represent a random selection pressure on your rabbit population. If the number you calculate is a fraction, remove a whole rabbit to make whole numbers.
6. Count the number of pinto and navy beans remaining. Record this number in your data table.
7. Calculate the allelic frequencies by dividing the number of beans of one type by 100. Record these numbers in your data table.
8. Begin the next generation by placing 100 beans into the bag. The proportions of pinto and navy beans should be the same as the percentages you calculated in step 7.
9. Repeat steps 3 through 8, collecting data for five generations.
10. Go to the Glencoe Science Web Site at the address shown below to **post your data.**
11. Graph the frequencies of each allele over five generations. Plot the frequency of the allele on the vertical axis and the number of the generation on the horizontal axis. Use a different colored pencil for each allele.

Data Table

	Allele *G*			Allele *g*		
Generation	**Number**	**Percentage**	**Frequency**	**Number**	**Percentage**	**Frequency**
Start	50	50	0.50	50	50	0.50
1						
2						
3						
4						
5						

ANALYZE AND CONCLUDE

1. **Analyzing Data** Did either allele disappear? Why or why not?
2. **Thinking Critically** What does your graph show about allelic frequencies and natural selection?
3. **Making Inferences** What would happen to the allelic frequencies if the number of eagles declined?
4. **Using the Internet** Explain any differences in allelic frequencies you observed between your data and the data from the Internet. What advantage is there to having a large amount of data? What problems might there be in using data from the internet?

Sharing Your Data

interNET CONNECTION Find this *BioLab* on the Glencoe Science Web Site at **www.glencoe.com/sec/science.** Post your data in the data table provided for this BioLab. Use the additional data from other students on the Internet, and graph and analyze the combined data.

INTERNET BioLab

ANALYZE AND CONCLUDE

1. Neither allele disappeared from the population because the *g* allele is also in the heterozygous *(Gg)* rabbits.
2. The graph shows an increase in the frequency of the *G* allele and a decrease in the frequency of the *g* allele due to natural selection against white rabbits.
3. There would be less selective pressure on white rabbits and, therefore, less decline in the frequency of the *g* allele.
4. Students should notice little difference in the allelic frequencies posted on the Internet and the frequencies they calculated. By combining data students may get more accurate results.

Sharing Your Data

interNET CONNECTION To navigate to the Internet BioLabs choose the *Biology: The Dynamics of Life* icon at Glencoe's web site. Click on the student site icon, then the BioLabs icon. The data from many trials supports a student's data and the conclusions the student may draw from the data.

PROCEDURE

Teaching Strategies

- Tell students that they will simulate natural selection on a population to see how allelic frequency changes.
- You may wish to circulate during this activity to ensure that students are following the procedure correctly.
- Have students wash their hands after handling the beans.

Data and Observations

Make sure students are correctly calculating allelic frequency after each "generation" and recording these data in their data tables. Students should observe changes in the allelic frequencies of the rabbit population. Student graphs should show an increase in the frequency of the *G* allele and a decrease in the *g* allele.

Assessment

Knowledge Ask students whether allele frequencies would change as fast if only 60% of the white rabbits were removed from the population each generation. Why or why not? *No, because the gene pool would contain more g alleles that could produce more white rabbits.* Use the Performance Task Assessment List for Analyzing the Data in **PASC,** p. 27. L2

Math Connection

Purpose

Students will examine the Hardy-Weinberg principle and learn about its implications.

Teaching Strategies

- Students should read this feature after learning the concept of genetic equilibrium.
- Illustrate to students how this principle is used in practice. Stress that population geneticists use it to study the evolution in populations.

Connection to Biology

No. The United States is not in genetic equilibrium because new genes enter the population, mating is probably not random, and natural selection affects the trait of human height.

Tying to Previous Knowledge

Review mutations and their effects. Emphasize that mutations affect genetic equilibrium by producing new alleles for a trait and also change the frequency of alleles already in the population. For example, the mutation that causes the sickle-cell trait occurs spontaneously in about five out of 100 million people.

Math Connection

Mathematics and Evolution

In the early 1900s, G. H. Hardy, a British mathematician, and W. Weinberg, a German doctor, independently discovered how the frequency of a trait's alleles in a population could be described mathematically.

Suppose that in a population of pea plants, 36 plants are homozygous dominant for the tall trait (*TT*), 48 plants are heterozygous tall (*Tt*), and 16 plants are short plants (*tt*). In the homozygous tall plants, there are (36) (2), or 72, *T* alleles and in the heterozygous plants there are 48 *T* alleles, for a total of 120 *T* alleles in the population. There are 48 *t* alleles in the heterozygous plants plus (16) (2), or 32, *t* alleles in the short plants, for a total of 80 *t* alleles in the population. The number of *T* and *t* alleles in the population is 200. The frequency of *T* alleles is 120/200 or 0.6, and the frequency of *t* alleles in 80/200, or 0.4.

The Hardy-Weinberg principle The Hardy-Weinberg principle states that the frequency of the alleles for a trait in a stable population will not vary. This statement is expressed as the equation $p + q = 1$, where p is the frequency of one allele for the trait and q is the frequency of the other allele. The sum of the frequencies of the alleles always includes 100 percent of the alleles, and is therefore stated as 1.

Squaring both sides of the equation produces the equation $p^2 + 2pq + q^2 = 1$. You can use this equation to determine the frequency of genotypes in a population: homozygous dominant individuals (p^2), heterozygous individuals ($2pq$), and recessive individuals (q^2). For example, in the pea plant population described above, the frequency of the genotypes would be

$$(0.6)(0.6) + 2(0.6)(0.4) + (0.4)(0.4) = 1$$

The frequency of the homozygous tall genotype is 0.36, the heterozygous genotype is 0.48, and the short genotype is 0.16.

In any sexually reproducing, large population, genotype frequencies will remain constant if no mutations occur, random mating occurs, no natural selection occurs, and no genes enter or leave the population.

Implications of the principle The Hardy-Weinberg principle is useful for several reasons. First, it explains that the genotypes in populations tend to remain the same. Second, because a recessive allele may be masked by its dominant allele, the equation is useful for determining the recessive allele's frequency in the population. Finally, the Hardy-Weinberg principle is useful in studying natural populations to determine how much natural selection may be occurring in the population.

Connection to Biology

The general population of the United States is getting taller. Assuming that height is a genetic trait, does this observation violate the Hardy-Weinberg principle? Explain your answer.

interNET CONNECTION To find out more about the Hardy-Weinberg principle, visit the Glencoe Science Web Site. **www.glencoe.com/sec/science**

A population of penguins

Meeting Individual Needs

Gifted

Logical-Mathematical Have students calculate allelic frequency by having them work with a "population" of differently shaped objects, such as pennies, popcorn, beads, or beans. Tell students which object represents each particular genotype, and have them calculate allelic frequency by counting the numbers of each genotype. Change how many individuals are in the population, as well as the numbers of each genotype in a population to produce new practice problems. L3

Chapter 15 Assessment

Summary

Section 15.1 Natural Selection and the Evidence for Evolution

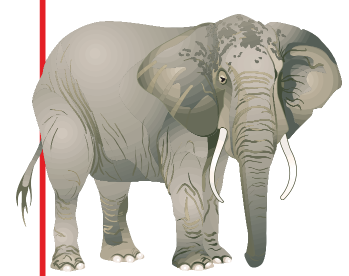
Main Ideas

- After many years of experimentation and observation, Charles Darwin proposed the idea that species originated through the process of natural selection.
- Natural selection is a mechanism of change in populations. In a specific environment, individuals with certain variations are likely to survive, reproduce, and pass these variations to future generations.
- Evolution has been observed in the lab and field, but much of the evidence for evolution has come from studies of fossils, anatomy, and biochemistry.

Vocabulary

analogous structure (p. 409)
artificial selection (p. 403)
camouflage (p. 406)
embryo (p. 410)
homologous structure (p. 408)
mimicry (p. 405)
natural selection (p. 403)
vestigial structure (p. 410)

Section 15.2 Mechanisms of Evolution



Main Ideas

- Evolution can occur only when a population's genetic equilibrium changes. Mutation, genetic drift, and gene flow can change a population's genetic equilibrium, especially in a small, isolated population. Natural selection is usually a factor that causes change in established gene pools—both large and small.
- The separation of populations by physical barriers can lead to speciation.
- There are many patterns of evolution in nature. These patterns support the idea that natural selection is an important mechanism of evolution.

Vocabulary

adaptive radiation (p. 420)
allelic frequency (p. 413)
convergent evolution (p. 421)
directional selection (p. 416)
disruptive selection (p. 416)
divergent evolution (p. 420)
gene pool (p. 413)
genetic drift (p. 414)
genetic equilibrium (p. 413)
geographic isolation (p. 417)
gradualism (p. 419)
polyploid (p. 418)
punctuated equilibrium (p. 419)
reproductive isolation (p. 418)
speciation (p. 417)
stabilizing selection (p. 416)

Understanding Main Ideas

1. Two closely related species of squirrels live on opposite sides of the Grand Canyon. The ancestral species probably evolved into two species because of ________.
   a. structural isolation
   b. punctuated isolation
   c. behavioral isolation
   d. geographic isolation
2. What type of evolutionary evidence do fossils provide?
   a. structural
   b. functional
   c. physiological
   d. critical
3. Which of the following is an example of direct evidence for evolution?
   a. fossils
   b. embryology
   c. vestigial structures
   d. bacterial resistance to penicillin

Main Ideas

Summary statements can be used by students to review the major concepts of the chapter.

Using the Vocabulary

To reinforce chapter vocabulary, use the Content Mastery Booklet and the activities in the Interactive Tutor for Biology: The Dynamics of Life or the Glencoe Science Web Site: **www.glencoe.com/sec/science**

THE PRINCETON REVIEW ***All Chapter Assessment questions and answers have been validated for accuracy and suitability by The Princeton Review.***

Understanding Main Ideas

1. d
2. a
3. d

GLENCOE TECHNOLOGY

VIDEOTAPE
MindJogger Videoquizzes
Chapter 15: *The Theory of Evolution*
Have students work in groups as they play the videoquiz game to review key chapter concepts.

Resource Manager

Chapter Assessment, pp. 85-90
MindJogger Videoquizzes
Computer Test Bank
BDOL Interactive CD-ROM, Chapter 15 quiz

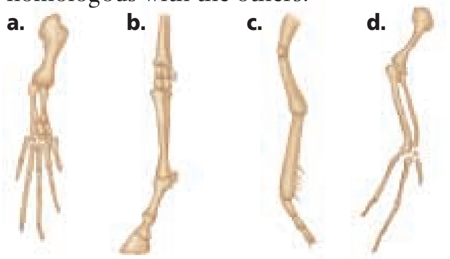
4. c
5. c
6. d
7. b
8. d
9. c
10. b
11. punctuated equilibrium
12. geographical isolation
13. gene pool
14. natural selection
15. variations
16. Mimicry
17. artificial
18. camouflage
19. homologous
20. adaptive radiation

Applying Main Ideas

21. Marine biomes are very stable and slow to change such environmental factors as salinity, temperature, light penetration, etc. In stable environments, natural selection pressures tend to remain stable as well. Shark populations may be close to genetic equilibrium. They have stable relationships with both the environment and other organisms in the environment.
22. Many adaptations are related to escaping from predators. Poisons are a natural defense. If a predator eats a brightly colored insect and becomes ill, it will avoid such an organism the next time. Bright colors indicate that the organism may be poisonous and deter predators.

Chapter 15 Assessment

4. Which of the structures shown below is not homologous with the others?



5. Which type of natural selection favors the average individuals in a population?
   a. directional
   b. disruptive
   c. stabilizing
   d. divergent
6. Which of the following pairs of terms is not related?
   a. analogous structures—butterfly wings
   b. evolution—natural selection
   c. vestigial structure—appendix
   d. adaptive radiation—convergent evolution
7. Unlike any other birds, hummingbirds have wings that allow them to hover and to fly backwards. This is an example of a _______ adaptation.
   a. physiological
   b. structural
   c. reproductive
   d. embryological
8. Which of the following is a true statement about evolution?
   a. Individuals evolve more slowly than populations.
   b. Individuals evolve; populations don't.
   c. Individuals evolve by changing the gene pool.
   d. Populations evolve; individuals don't.

The Princeton Review — Test-Taking Tip

Wear a Watch
If you are taking a timed test, you should make sure that you pace yourself and do not spend too much time on any one question, but don't spend time staring at the clock. When the test begins, place your watch on the desk and check it after each section of the test.

9. An example of a vestigial human structure is the _______.
   a. eye
   b. big toe
   c. appendix
   d. ribs
10. The fish and whale shown here are not closely related. Their structural similarities appear to be the result of _______.

   a. adaptive radiation
   b. convergent evolution
   c. divergent evolution
   d. punctuated equilibrium
11. The scientific hypothesis that explains how an ancestral population of elephants speciated quite rapidly after a long period of stability is _______.
12. Speciation due to physical barriers occurs as a result of _______.
13. An understanding of population genetics depends on an understanding of the _______, which is a collection of all the alleles in a population.
14. The mechanism Darwin proposed to explain how species adapt to their environment over many generations is _______.
15. The differences in the size of the peanuts in a bag are called _______.
16. _______ is the structural adaptation of an organism that enables it to resemble another harmful or distasteful species.
17. The existence of desirable characteristics in both crops and domestic animals results from the process called_______ selection.
18. A subtle adaptation that allows an organism to blend in with its surroundings is known as _______.
19. The wings of bats and the forelimbs of crocodiles are examples of _______ structures.
20. A species may find its way to an island and then evolve into many species in a process called _______.

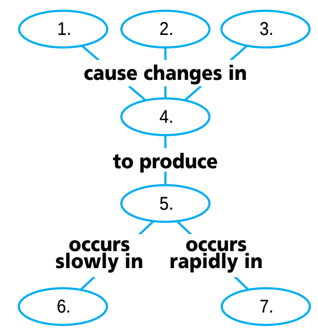
Chapter 15 Assessment

Applying Main Ideas

21. The structural characteristics of many species, such as sharks, have changed little over time. What evolutionary factors might be affecting their stability?
22. How might the bright colors of poisonous species aid in their survival?
23. Why is DNA a useful tool for determining possible relationships among the species of organisms?

Thinking Critically

24. **Observing and Inferring** Describe adaptive radiation as a form of divergent evolution.
25. **Interpreting Data** In a population of clams, let two alleles, *T* and *t*, represent shell color. The population consists of ten *TT* clams and ten *tt* clams. What are the allelic frequencies of the *T* and *t* in the population?
26. **Concept Mapping** Complete the concept map by using the following vocabulary terms: allelic frequency, geographic isolation, gradualism, natural selection, punctuated equilibrium, reproductive isolation, speciation.

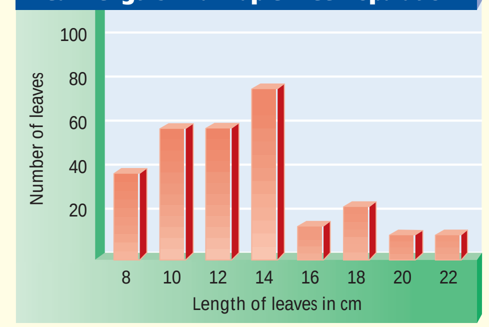


CD-ROM
For additional review, use the assessment options for this chapter found on the ***Biology: The Dynamics of Life Interactive CD-ROM*** and on the Glencoe Science Web Site.
www.glencoe.com/sec/science

Assessing Knowledge & Skills

The following graph shows leaf length in a population of maple trees.

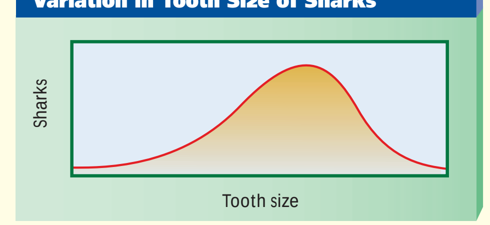
Leaf Lengths in a Maple Tree Population



Interpreting Data Study the graph and answer the following questions.

1. What was the range of leaf lengths?
   a. 14 cm
   b. 8-22 cm
   c. 20-100 cm
   d. 10-14 cm
2. What was the average leaf length?
   a. 8 cm
   b. 12 cm
   c. 14 cm
   d. 6 cm
3. What type of evolutionary pattern does the graph most closely match?
   a. artificial selection
   b. stabilizing selection
   c. disruptive evolution
   d. directional evolution
4. **Interpreting Data** Use the graph below to explain what might be occurring in this shark population.

Variation in Tooth Size of Sharks



23. It is easier to quantify differences in DNA than differences in behavior or morphology.

Thinking Critically

24. In adaptive radiation, a generalized ancestor encounters an area of many available niches and eventually diverges into many species. This is an example of divergent evolution, in which species similar to ancestral species adapt to different environmental conditions.
25. *T* = 0.5; *t* = 0.5
26. 1. Natural selection; 2. Reproductive isolation; 3. Geographic isolation; 4. Allelic frequency; 5. Speciation; 6. Gradualism; 7. Punctuated equilibrium

Assessing Knowledge & Skills

1. b
2. b
3. d
4. Directional selection is occurring in favor of larger teeth in sharks.