Chapter 6

Changes Over Time

The BIG Idea

Diversity and Adaptations

What process leads to the evolution and diversity of organisms?

Chapter Preview

Darwin observed Sally light-foot crabs and iguanas on the Galápagos Islands.

Discovery CHANNEL SCHOOL

Changes Over Time

- ▶ Video Preview
- Video Field Trip
- Video Assessment

Lab zone™

Chapter Project

Life's Long Calendar

Earth's history goes back billions of years. This chapter project will help you understand this huge time span. In this project, you'll find a way to convert enormous time periods into a more familiar scale.

Your Goal To use a familiar measurement scale to create two timelines for Earth's history

To complete the project you must

- represent Earth's history using a familiar scale, such as months on a calendar or yards on a football field
- use your chosen scale twice, once to plot out 5 billion years of history, and once to focus on the past 600 million years
- include markers on both scales to show important events in the history of life

Plan It! Preview Figure 16 in this chapter to see what events occurred during the two time periods. In a small group, discuss some familiar scales you might use for your timelines. You could select a time interval such as a year or a day. Alternatively, you could choose a distance interval such as the length of your schoolyard or the walls in your classroom. Decide on the kind of timelines you will make. Then plan and construct your timelines.

Section 1

Darwin's Theory

Reading Preview

Key Concepts

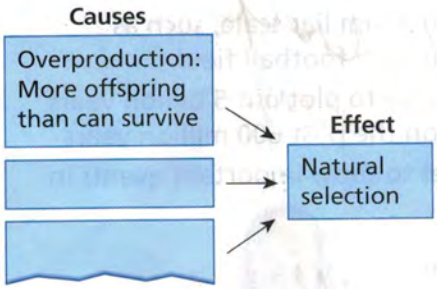
- What important observations did Darwin make on his voyage?
- What hypothesis did Darwin make to explain the differences between similar species?
- How does natural selection lead to evolution?

Key Terms

- species • fossil • adaptation
- evolution • scientific theory
- natural selection • variation

Target Reading Skill

Relating Cause and Effect In a graphic organizer, identify factors that cause natural selection.



Lab zone Discover Activity

How Do Living Things Vary?

1. Use a ruler to measure the length and width of 10 sunflower seeds. Record each measurement.
2. Now use a hand lens to carefully examine each seed. Record each seed's shape, color, and number of stripes.

Think It Over

Classifying In what ways are the seeds in your sample different from one another? In what ways are they similar? How could you group the seeds based on their similarities and differences?

In December 1831, the British ship HMS *Beagle* set sail from England on a five-year trip around the world. On board was a 22-year-old named Charles Darwin. Darwin eventually became the ship's naturalist—a person who studies the natural world. His job was to learn as much as he could about the living things he saw on the voyage. Darwin observed plants and animals he had never seen before. He wondered why they were so different from those in England. Darwin's observations led him to develop one of the most important scientific theories of all time: the theory of evolution by natural selection.

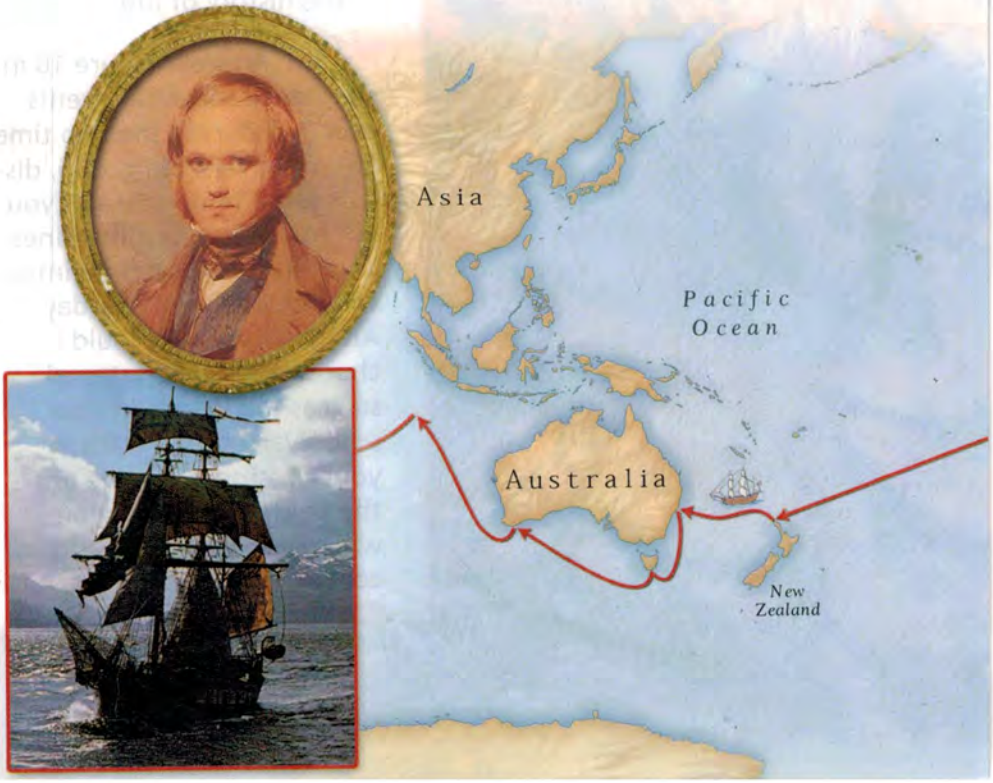


FIGURE 1
The Voyage of the *Beagle*
Charles Darwin sailed on the *Beagle* to the Galápagos Islands. He saw many unusual organisms on the islands, such as giant tortoises and the blue-footed booby.
Interpreting Maps *After leaving South America, where did the* Beagle *go?*

Replica of the *Beagle* ▶

Darwin's Observations

As you can see in Figure 1, the *Beagle* made many stops along the coast of South America. From there, the ship traveled to the Galápagos Islands. Darwin observed living things as he traveled. He thought about relationships among those organisms. **Darwin's important observations included the diversity of living things, the remains of ancient organisms, and the characteristics of organisms on the Galápagos Islands.**

Diversity Darwin was amazed by the tremendous diversity of living things that he saw. In Brazil, he saw insects that looked like flowers and ants that marched across the forest floor like huge armies. In Argentina, he saw sloths, animals that moved very slowly and spent much of their time hanging in trees.

Today scientists know that organisms are even more diverse than Darwin could ever have imagined. Scientists have identified more than 1.7 million species of organisms on Earth. A **species** is a group of similar organisms that can mate with each other and produce fertile offspring.

Fossils Darwin saw the fossil bones of animals that had died long ago. A **fossil** is the preserved remains or traces of an organism that lived in the past. Darwin was puzzled by some of the fossils he observed. For example, he saw fossil bones that resembled the bones of living sloths. The fossil bones were much larger than those of the sloths that were alive in Darwin's time. He wondered what had happened to the giant creatures from the past.

Reading Checkpoint What is a fossil?

Discovery CHANNEL SCHOOL

Changes Over Time

Video Preview
▶ Video Field Trip
Video Assessment

▲ Giant tortoise

▲ Blue-footed booby

Galápagos Organisms

In 1835, the *Beagle* reached the Galápagos Islands. Darwin observed many unusual life forms on these small islands, such as giant tortoises, or land turtles. Some of these tortoises could look him in the eye! After returning to England, Darwin thought about the organisms he had seen. He compared Galápagos organisms to organisms that lived elsewhere. He also compared organisms on different islands in the Galápagos group. He was surprised by some of the similarities and differences he saw.

Comparisons to South American Organisms Darwin found many similarities between Galápagos organisms and those in South America. Many of the birds on the islands, including hawks, mockingbirds, and finches, resembled those on the mainland. Many of the plants were similar to plants Darwin had collected on the mainland.

However, there were important differences between the organisms on the islands and those on the mainland. The iguanas on the Galápagos Islands had large claws that allowed them to grip slippery rocks, where they fed on seaweed. The iguanas on the mainland had smaller claws. Smaller claws allowed the mainland iguanas to climb trees, where they ate leaves. You can see these differences in Figure 2.

From his observations, Darwin hypothesized that a small number of different plant and animal species had come to the Galápagos Islands from the mainland. They might have been blown out to sea during a storm or set adrift on a fallen log. Once the plants and animals reached the islands, they reproduced. Eventually, their offspring became different from their mainland relatives.

FIGURE 2
Comparing Iguanas
Iguanas on mainland South America (above) have smaller claws than iguanas on the Galápagos Islands. **Comparing and Contrasting** *In what other ways are the iguanas different?*

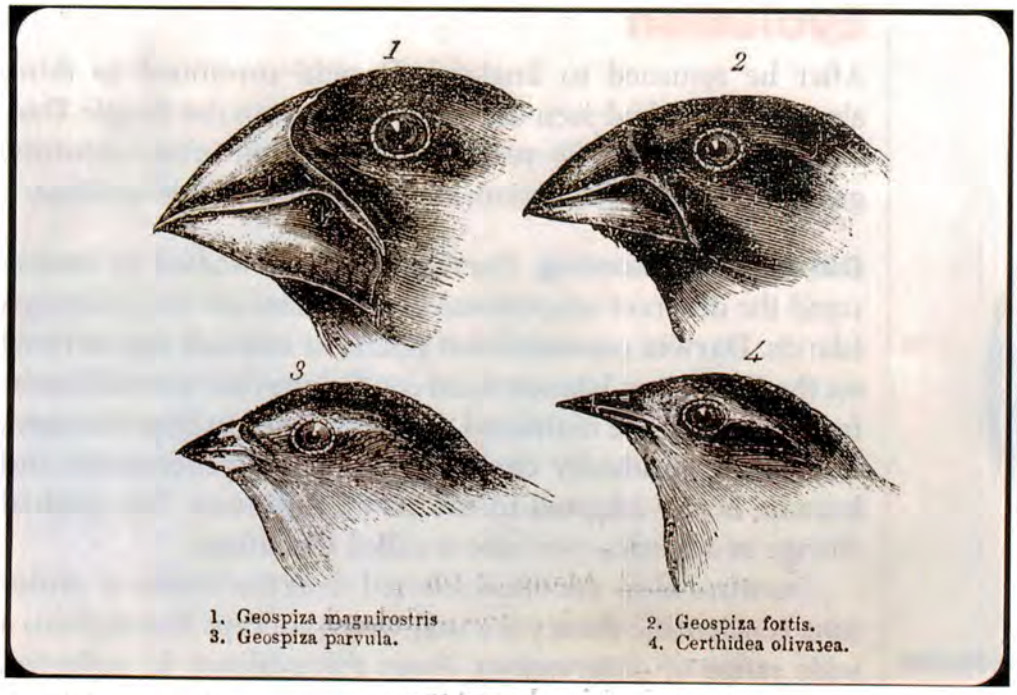


FIGURE 3
Galápagos Finches Darwin made these drawings of four species of Galápagos finches. The structure of each bird's beak is an adaptation related to the type of food the bird eats. **Comparing and Contrasting** *Identify some specific differences in these finches' beaks.*

Comparisons Among the Islands As he traveled from one Galápagos island to the next, Darwin also noticed many differences among organisms. For example, the tortoises on one island had dome-shaped shells. Those on another island had saddle-shaped shells. A government official in the islands told Darwin that he could tell which island a tortoise came from just by looking at its shell.

Adaptations Like the tortoises, the finches on the Galápagos were noticeably different from one island to the next. The most obvious differences were the varied sizes and shapes of the birds' beaks, as shown in Figure 3. An examination of the different finches showed that each species was well suited to the life it led. Finches that ate insects had narrow, needle-like beaks. Finches that ate seeds had strong, wide beaks.

Beak shape is an example of an **adaptation,** a trait that helps an organism survive and reproduce. The finches' beak structures help in obtaining food. Other adaptations help organisms avoid being eaten. For example, some plants, such as milkweed, are poisonous or have a bad taste. A variety of adaptations aid in reproduction. The bright colors of some flowers attract insects. When an insect lands on a flower, the insect may pick up pollen grains, which produce sperm. The insect then may carry the pollen grains to another flower, enabling fertilization to take place.

Reading Checkpoint **How did the beaks of Galápagos finches differ from one island to another?**

Lab zone Try This Activity

Bird Beak Adaptations

Use this activity to explore adaptations in birds.

1. Scatter a small amount of bird seed on a paper plate. Scatter 20 raisins on the plate to represent insects.
2. Obtain a variety of objects such as tweezers, hair clips, and clothespins. Pick one object to use as a "beak."
3. See how many seeds you can pick up and drop into a cup in 10 seconds.
4. Now see how many "insects" you can pick up and drop into a cup in 10 seconds.
5. Use a different "beak" and repeat Steps 3 and 4.

Inferring What type of beak worked well for seeds? For insects? How are different-shaped beaks useful for eating different foods?

Evolution

After he returned to England, Darwin continued to think about what he had seen during his voyage on the *Beagle*. Darwin spent the next 20 years consulting with other scientists, gathering more information, and thinking through his ideas.

Darwin's Reasoning Darwin especially wanted to understand the different adaptations of organisms on the Galápagos Islands. **Darwin reasoned that plants or animals that arrived on the Galápagos Islands faced conditions that were different from those on the mainland. Perhaps, Darwin hypothesized, the species gradually changed over many generations and became better adapted to the new conditions.** The gradual change in a species over time is called **evolution.**

Darwin's ideas are often referred to as the theory of evolution. A **scientific theory** is a well-tested concept that explains a wide range of observations. From the evidence he collected, Darwin concluded that organisms on the Galápagos Islands had changed over time. However, Darwin did not know how the changes had happened.

Selective Breeding Darwin studied other examples of changes in living things to help him understand how evolution might occur. One example that Darwin studied was the offspring of animals produced by selective breeding. English farmers in Darwin's time used selective breeding to produce sheep with fine wool. Darwin himself had bred pigeons with large, fan-shaped tails. By repeatedly allowing only those pigeons with many tail feathers to mate, breeders had produced pigeons with two or three times the usual number of tail feathers. Darwin thought that a process similar to selective breeding might happen in nature. But he wondered what process selected certain traits.

Reading Checkpoint What is a scientific theory?

▲ Seattle Slew, great-grandfather of Funny Cide

Distorted Humor, father of Funny Cide ▲

Funny Cide ▶

FIGURE 4
Selective Breeding
Race horses are selectively bred to obtain the trait of speed. Funny Cide's father, Distorted Humor, and great-grandfather, Seattle Slew, were known for their speed.

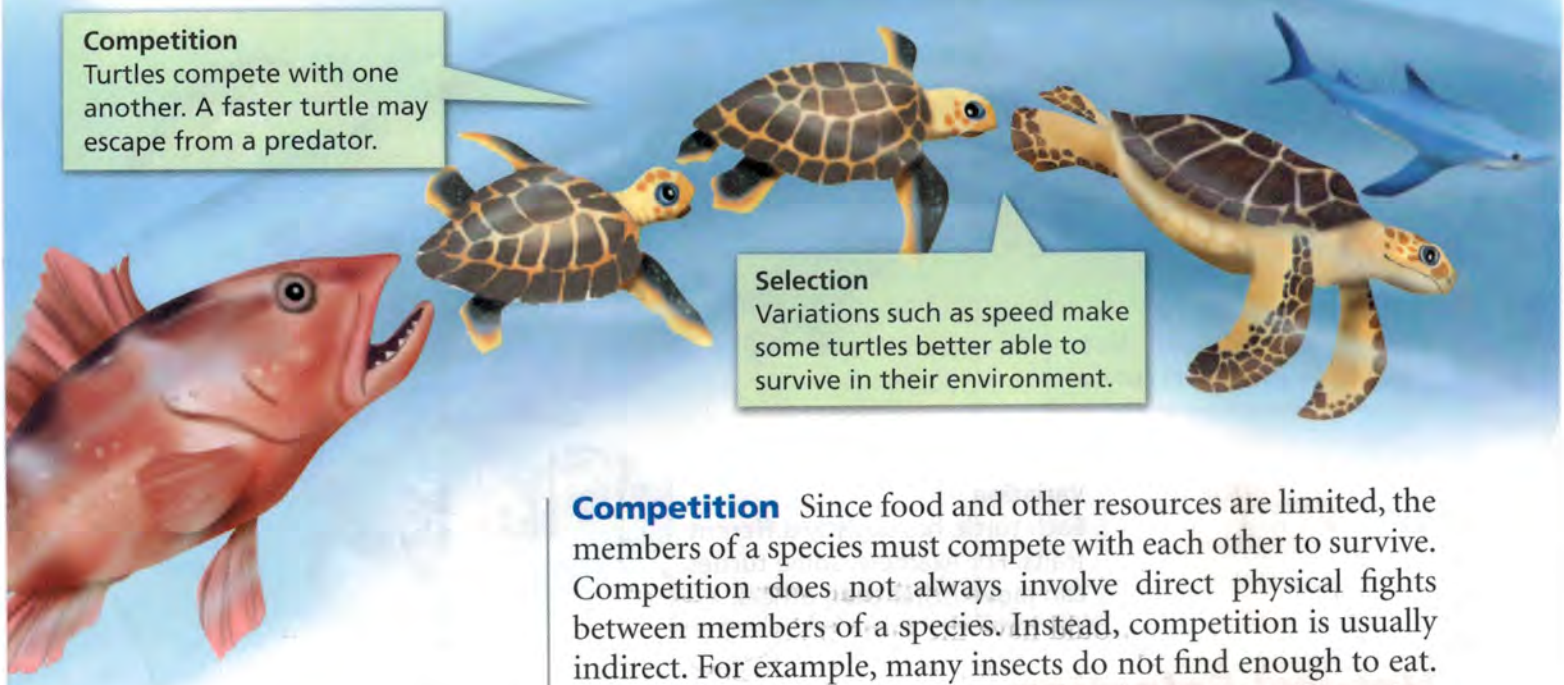


FIGURE 6
Competition and Selection
Variations among turtles make some of them better able to survive. Turtles that survive to become adults will be able to reproduce.
Applying Concepts *What are some variations that sea turtles might exhibit?*

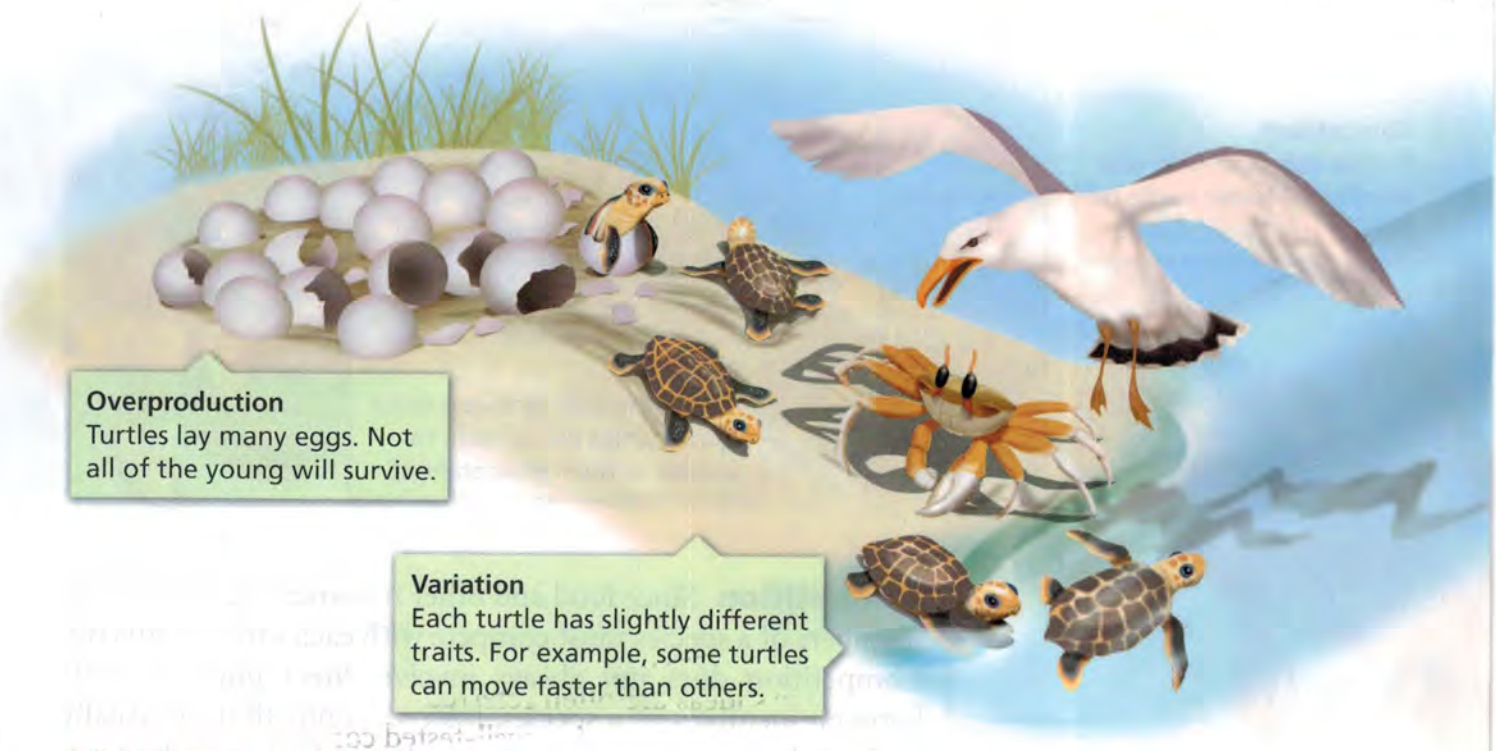
Competition Since food and other resources are limited, the members of a species must compete with each other to survive. Competition does not always involve direct physical fights between members of a species. Instead, competition is usually indirect. For example, many insects do not find enough to eat. Others are caught by predators. Only a few insects will survive.

Selection Darwin observed that some variations make individuals better adapted to their environment. Those individuals are more likely to survive and reproduce. Their offspring may inherit the helpful characteristic. The offspring, in turn, will be more likely to survive and reproduce, and thus pass on the characteristic to their offspring. After many generations, more members of the species will have the helpful characteristic.

In effect, the environment has "selected" organisms with helpful traits to become parents of the next generation. **Darwin proposed that, over a long time, natural selection can lead to change. Helpful variations may gradually accumulate in a species, while unfavorable ones may disappear.**

Environmental Change A change in the environment can affect an organism's ability to survive. The environmental change can therefore lead to selection. For example, monkey flowers are a type of plant. Most monkey flowers cannot grow in soil that has a high concentration of copper. However, because of genetic variation, some varieties of monkey flower now grow near copper mines, in spite of the copper in the soil.

Here is how natural selection might have resulted in monkey flowers that can grow in copper-contaminated soil. When the soil around a mine first became contaminated, a small number of monkey-flower plants may have been able to survive in the high level of copper. These plants grew and reproduced. After many generations, most of the seeds that sprouted in the soil produced monkey flowers that could withstand the copper.



Natural Selection

In 1858, Darwin and another British biologist, Alfred Russel Wallace, each proposed an explanation for how evolution could occur in nature. The next year, Darwin described this mechanism in a book entitled *The Origin of Species.* In his book, Darwin proposed that evolution occurs by means of natural selection. **Natural selection** is the process by which individuals that are better adapted to their environment are more likely to survive and reproduce than other members of the same species. Darwin identified factors that affect the process of natural selection: overproduction, competition, and variations. Figure 5 and Figure 6 show how natural selection might happen in a group of turtles.

Overproduction Darwin knew that most species produce far more offspring than can possibly survive. In many species, so many offspring are produced that there are not enough resources—food, water, and living space—for all of them. Many female insects, for example, lay thousands of eggs. If all newly hatched insects survived, they would soon crowd out all other plants and animals. Darwin knew that this doesn't happen. Why not?

Variations As you learned in your study of genetics, members of a species differ from one another in many of their traits. Any difference between individuals of the same species is called a **variation.** For example, certain insects may be able to eat foods that other insects of their species avoid. The color of a few insects may be different from that of most other insects in their species.

FIGURE 5
Overproduction and Variation
Like actual sea turtles, the turtles in this illustration produce many more offspring than will survive. Some turtles are better adapted than others to survive in their environment.
Relating Cause and Effect *What adaptations might help young sea turtles survive?*

Lab zone Skills Activity

Making Models

Scatter 15 black buttons and 15 white buttons on a sheet of white paper. Have a partner time you to see how many buttons you can pick up in 10 seconds. Pick up the buttons one at a time. Did you collect more buttons of one color than the other? Why? How can a variation such as color affect the process of natural selection?

Survival and Reproduction Only a few turtles survive long enough to reproduce. The offspring may inherit the favorable traits of the parents.

Genes and Natural Selection Without variations, all the members of a species would have the same traits. Natural selection would not occur because all individuals would have an equal chance of surviving and reproducing. But where do variations come from? How are they passed on from parents to offspring?

Darwin could not explain what caused variations or how they were passed on. As scientists later learned, variations can result from mutation and the shuffling of alleles during meiosis. Genes are passed from parents to their offspring. Because of this, only traits that are inherited, or controlled by genes, can be acted upon by natural selection.

Section 1 Assessment

Target Reading Skill

Relating Cause and Effect Work with a partner to check the information in your graphic organizer.

Reviewing Key Concepts

1. a. **Listing** List three general kinds of observations that Darwin made during the voyage of the *Beagle*.
   b. **Comparing and Contrasting** Contrast Galápagos iguanas to South American iguanas.
   c. **Applying Concepts** What is an adaptation? Explain how the claws of the Galápagos and South American iguanas are adaptations.
2. a. **Reviewing** How did Darwin explain why Galápagos species had different adaptations than similar South American species?
   b. **Developing Hypotheses** How does selective breeding support Darwin's hypothesis?
3. a. **Defining** What is variation? What is natural selection?
   b. **Relating Cause and Effect** How do variation and natural selection work together to help cause evolution?
   c. **Applying Concepts** Suppose the climate in an area becomes much drier than it was before. What kinds of variations in the area's plants might be acted on by natural selection?

Writing in Science

Interview You are a nineteenth-century reporter interviewing Charles Darwin about his theory of evolution. Write three questi you would ask him. Then write answers t Darwin might have given.

Lab zone Skills Lab

Nature at Work

Problem

How do species change over time?

Skills Focus

predicting, making models

Materials

- scissors
- marking pen
- construction paper, 2 colors

Procedure

1. Work on this lab with two other students. One student should choose construction paper of one color and make the team's 50 "mouse" cards, as described in Table 1. The second student should choose a different color construction paper and make the team's 25 "event" cards, as described in Table 2. The third student should copy the data table and record all the data.

PART 1 A White Sand Environment

2. Mix up the mouse cards.
3. Begin by using the cards to model what might happen to a group of mice in an environment of white sand dunes. Choose two mouse cards. Allele pairs *WW* and *Ww* produce a white mouse. Allele pair *ww* produces a brown mouse. Record the color of the mouse with a tally mark in the data table.
4. Choose an event card. An "S" card means the mouse survives. A "D" or a "P" card means the mouse dies. A "C" card means the mouse dies if its color contrasts with the white sand dunes. (Only brown mice will die when a "C" card is drawn.) Record each death with a tally mark in the data table.
5. If the mouse lives, put the two mouse cards in a "live mice" pile. If the mouse dies, put the cards in a "dead mice" pile. Put the event card at the bottom of its pack.
6. Repeat Steps 3 through 5 with the remaining mouse cards to study the first generation of mice. Record your results.
7. Leave the dead mice cards untouched. Mix up the cards from the live mice pile. Mix up the events cards.
8. Repeat Steps 3 through 7 for the second generation. Then repeat Steps 3 through 6 for the third generation.

PART 2 A Forest Floor Environment

9. How would the data differ if the mice in this model lived on a dark brown forest floor? Record your prediction in your notebook.
10. Make a new copy of the data table. Then use the cards to test your prediction. Remember that a "C" card now means that any mouse with white fur will die.

Data Table

Type of Environment:

Generation	Population		Deaths	
	White Mice	Brown Mice	White Mice	Brown Mice
1				
2				
3				

Table 1: Mouse Cards		
Number	**Label**	**Meaning**
25	*W*	Dominant allele for white fur
25	*w*	Recessive allele for brown fur

Table 2: Event Cards		
Number	**Label**	**Meaning**
5	S	Mouse survives.
1	D	Disease kills mouse.
1	P	Predator kills mice of all colors.
18	C	Predator kills mice that contrast with the environment.

Analyze and Conclude

1. **Calculating** In Part 1, how many white mice were there in each generation? How many brown mice? In each generation, which color mouse had the higher death rate? (*Hint:* To calculate the death rate for white mice, divide the number of white mice that died by the total number of white mice, then multiply by 100%.)
2. **Predicting** If the events in Part 1 occurred in nature, how would the group of mice change over time?
3. **Observing** How did the results in Part 2 differ from those in Part 1?
4. **Making Models** How would it affect your model if you increased the number of "C" cards? What would happen if you decreased the number of "C" cards?
5. **Communicating** Imagine that you are trying to explain the point of this lab to Charles Darwin. Write an explanation that you could give to him. To prepare to write, answer the following questions: What are some ways in which this investigation models natural selection? What are some ways in which natural selection differs from this model?

Design an Experiment

Choose a different species with a trait that interests you. Make a set of cards similar to these cards to investigate how natural selection might bring about the evolution of that species. *Obtain your teacher's permission before carrying out your investigation.*

Section 2

Evidence of Evolution

Reading Preview

Key Concepts

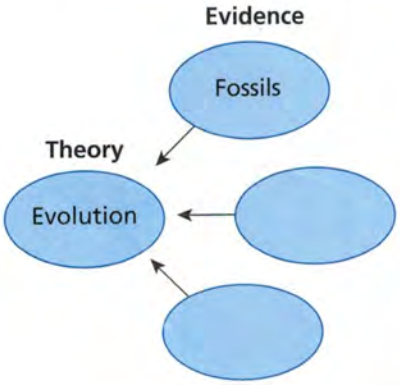
- What evidence supports the theory of evolution?
- How do scientists infer evolutionary relationships among organisms?
- How do new species form?

Key Terms

- homologous structures
- branching tree

Target Reading Skill

Identifying Supporting Evidence Evidence consists of facts that can be confirmed by testing or observation. As you read, identify the evidence that supports the theory of evolution. Write the evidence in a graphic organizer like the one below.



Lab zone Discover Activity

How Can You Classify Species?

1. Collect six to eight different pens. Each pen will represent a different species of similar organisms.
2. Choose a trait that varies among your pen species, such as size or ink color. Using this trait, try to divide the pen species into two groups.
3. Now choose another trait. Divide each group into two smaller groups.

Think It Over

Classifying Which of the pen species share the most characteristics? What might the similarities suggest about how the pen species evolved?

Does natural selection occur today? Evidence indicates that the answer is yes. Consider, for example, what happens when chemicals called pesticides are used to kill harmful insects such as the cockroaches below. When a pesticide is first used in a building, it kills almost all the insects. But a few insects have traits that protect them from the pesticide. These insects survive.

The surviving insects reproduce. Some of their offspring inherit the pesticide protection. The surviving offspring, in turn, reproduce. Every time the pesticide is used, the only insects that survive are those that are resistant to the harmful effects of the pesticide. After many years, most of the cockroaches in the building are resistant to the pesticide. Therefore, the pesticide is no longer effective in controlling the insects. The development of pesticide resistance is one type of evidence that supports Darwin's theory of evolution.

FIGURE 7
Pesticide Resistance
Many insects, including cockroaches such as these, are no longer killed by some pesticides. Increased pesticide resistance is evidence that natural selection is happening.

Interpreting the Evidence

Since Darwin's time, scientists have found a great deal of evidence that supports the theory of evolution. **Fossils, patterns of early development, and similar body structures all provide evidence that organisms have changed over time.**

Fossils By examining fossils, scientists can infer the structures of ancient organisms. Fossils show that, in many cases, organisms that lived in the past were very different than organisms alive today. You will learn more about the importance of fossils in the next section.

Similarities in Early Development Scientists also make inferences about evolutionary relationships by comparing the early development of different organisms. Suppose you were asked to compare an adult fish, salamander, chicken, and opossum. You would probably say they look quite different from each other. However, during early development, these four organisms are similar, as you can see in Figure 8. For example, during the early stages of development all four organisms have a tail and a row of tiny slits along their throats. These similarities suggest that these vertebrate species are related and share a common ancestor.

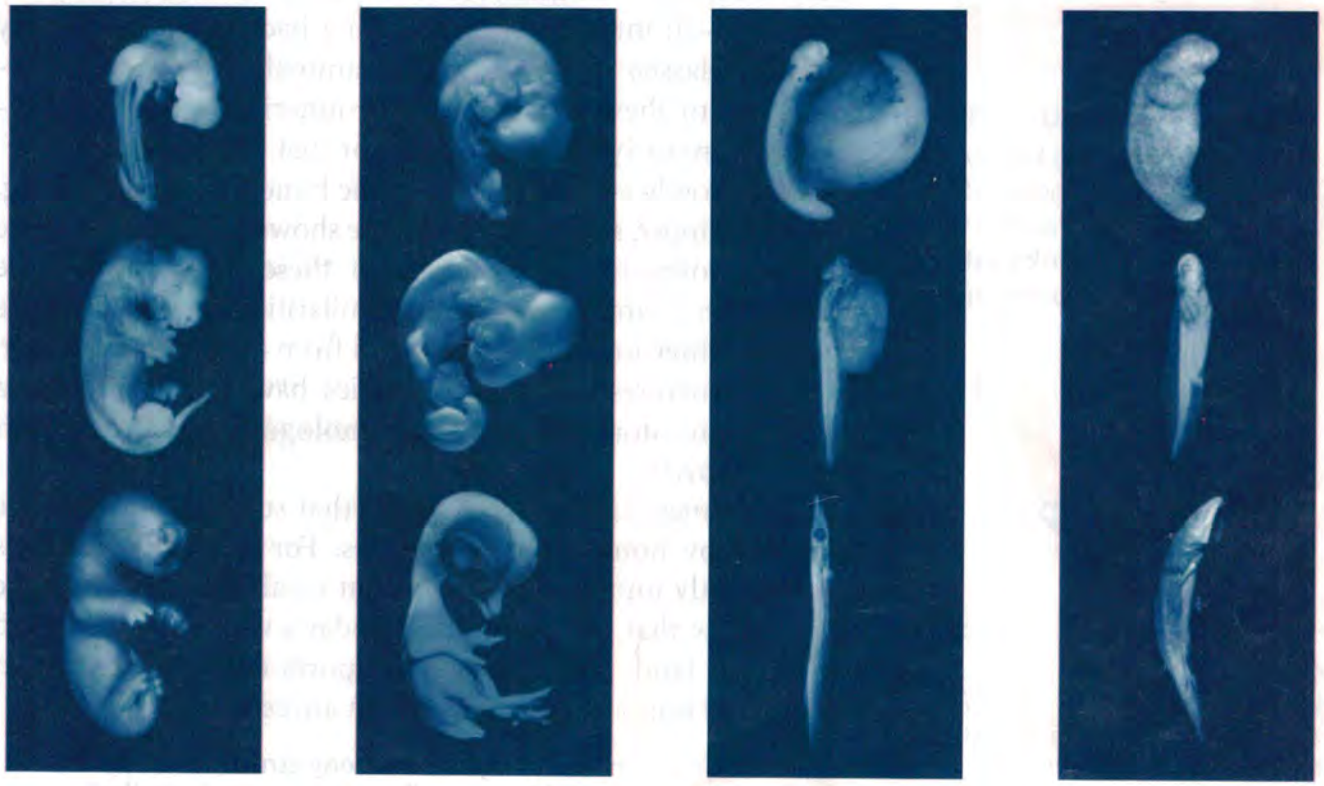


FIGURE 8
Similarities in Development
These animals look similar during their early development.
Comparing and Contrasting *What are some similarities you observe? What are some differences?*

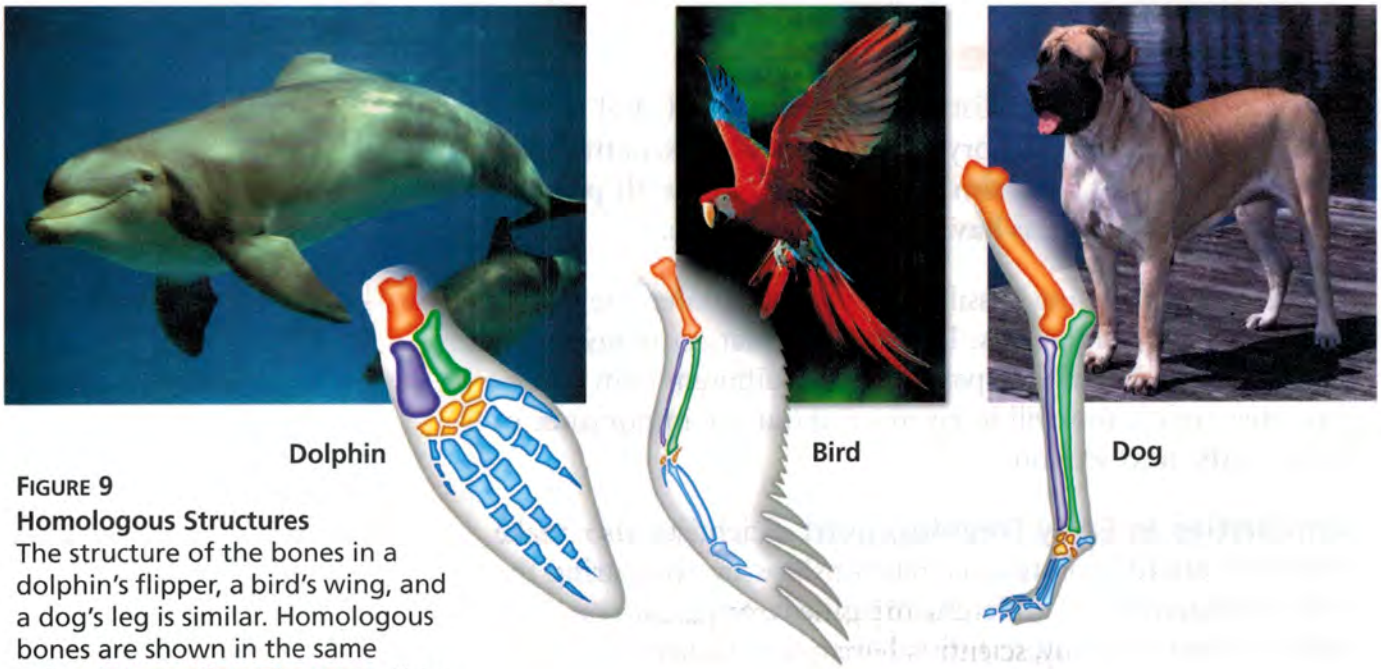


FIGURE 9
Homologous Structures
The structure of the bones in a dolphin's flipper, a bird's wing, and a dog's leg is similar. Homologous bones are shown in the same color. **Interpreting Diagrams** *How are all three orange bones similar?*

Similarities in Body Structure

Long ago, scientists began to compare the body structures of living species to look for clues about evolution. In fact, this is how Darwin came to understand that evolution had occurred on the Galápagos Islands. An organism's body structure is its basic body plan, such as how its bones are arranged. Fishes, amphibians, reptiles, birds, and mammals, for example, all have a similar body structure—an internal skeleton with a backbone. This is why scientists classify all five groups of animals together as vertebrates. All of these groups probably inherited a similar structure from an early vertebrate ancestor that they shared.

Look closely at the structure of the bones in the bird's wing, dolphin's flipper, and dog's leg that are shown in Figure 9. Notice that the bones in the forelimbs of these three animals are arranged in a similar way. These similarities provide evidence that these three organisms all evolved from a common ancestor. Similar structures that related species have inherited from a common ancestor are known as **homologous structures** (hoh MAHL uh gus).

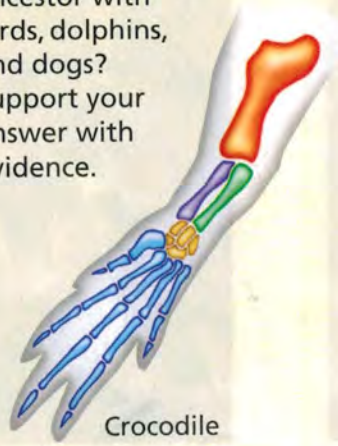
Sometimes scientists find fossils that support the evidence provided by homologous structures. For example, scientists have recently found fossils of ancient whalelike creatures. The fossils show that the ancestors of today's whales had legs and walked on land. This evidence supports other evidence that whales and humans share a common ancestor.

Reading Checkpoint **In what way are the body structures of fishes, amphibians, reptiles, and mammals similar?**

Lab zone Skills Activity

Drawing Conclusions

Look at the drawing below of the bones in a crocodile's leg. Compare this drawing to Figure 9. Do you think that crocodiles share a common ancestor with birds, dolphins, and dogs? Support your answer with evidence.



Crocodile

Inferring Species Relationships

Fossils, early development patterns, and body structure provide evidence that evolution has occurred. Scientists have also used these kinds of evidence to infer how organisms are related to one another. Not too long ago, fossils, embryos, and body structures were the only tools that scientists had to determine how species were related. Today, scientists can also compare the DNA and protein sequences of different species. **Scientists have combined the evidence from DNA, protein structure, fossils, early development, and body structure to determine the evolutionary relationships among species.**

Similarities in DNA Why do some species have similar body structures and development patterns? Scientists infer that the species inherited many of the same genes from a common ancestor. Recently, scientists have begun to compare the genes of different species to determine how closely related the species are.

Recall that genes are made of DNA. By comparing the sequence of nitrogen bases in the DNA of different species, scientists can infer how closely related the two species are. The more similar the DNA sequences, the more closely related the species are. For example, DNA analysis has shown that elephants and tiny elephant shrews, shown in Figure 10, are closely related.

The DNA bases along a gene specify what type of protein will be produced. Therefore, scientists can also compare the order of amino acids in a protein to see how closely related two species are.

Combining Evidence In most cases, evidence from DNA and protein structure has confirmed conclusions based on fossils, embryos, and body structure. For example, recent DNA comparisons show that dogs are more similar to wolves than they are to coyotes. Scientists had already reached this conclusion based on similarities in the structure and development of these three species.

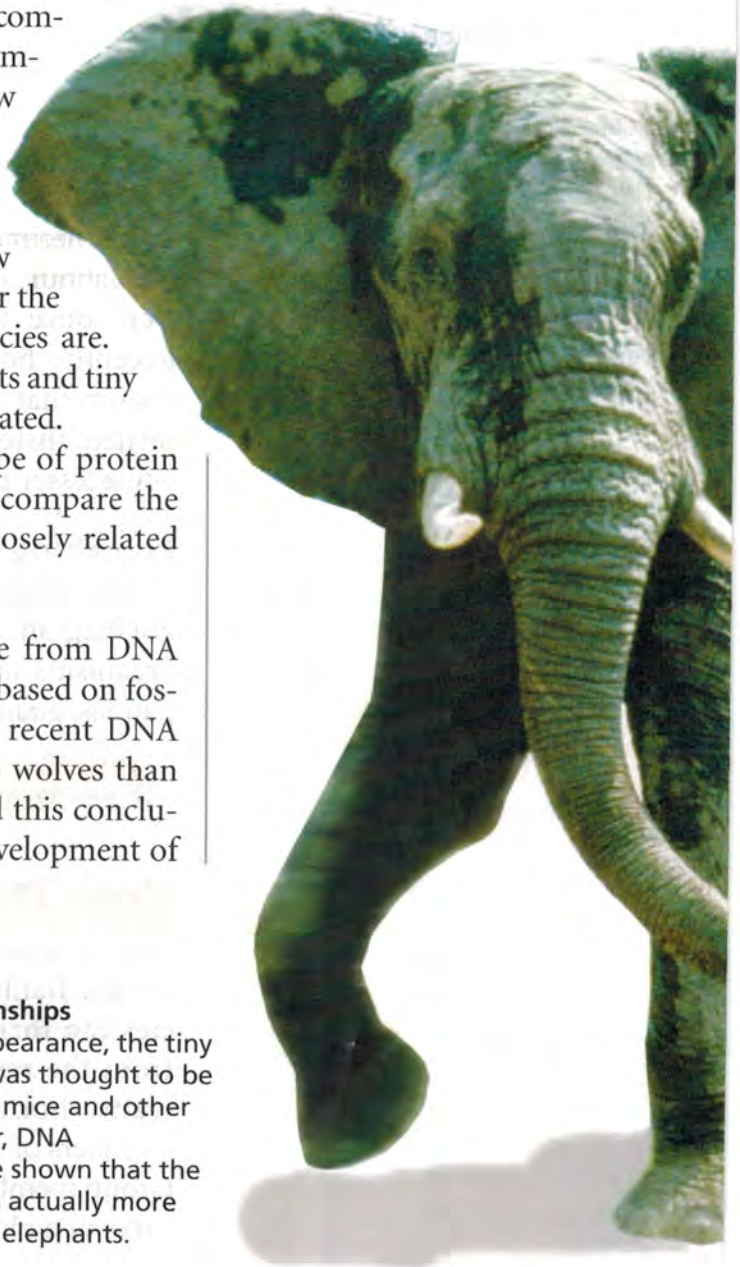


FIGURE 10
DNA and Relationships
Because of its appearance, the tiny elephant shrew was thought to be closely related to mice and other rodents. However, DNA comparisons have shown that the elephant shrew is actually more closely related to elephants.

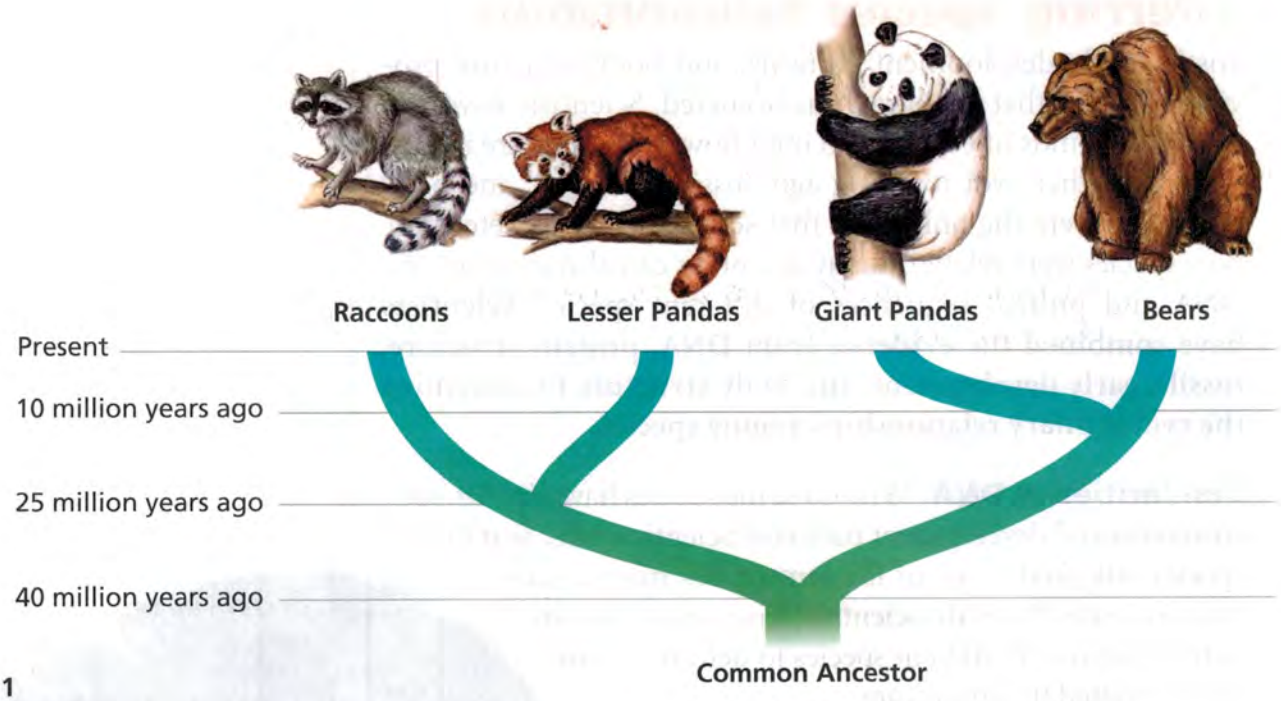


FIGURE 11
A Branching Tree
This branching tree shows how scientists now think that raccoons, lesser pandas, giant pandas, and bears are related.
Interpreting Diagrams *Are giant pandas more closely related to lesser pandas or to bears?*

Sometimes, however, scientists have changed their hypotheses about species relationships. For example, lesser pandas were once thought to be closely related to giant pandas. Recently, however, DNA analysis and other methods have shown that giant pandas and lesser pandas are not closely related. Instead, giant pandas are more closely related to bears, while lesser pandas are more closely related to raccoons.

Branching Trees Scientists use the combined evidence of species relationships to draw branching trees. A **branching tree** is a diagram that shows how scientists think different groups of organisms are related. Figure 11 shows how raccoons, lesser pandas, giant pandas, and bears may be related.

Reading Checkpoint **What is a branching tree?**

How Do New Species Form?

Natural selection explains how variations can lead to changes in a species. But how could an entirely new species form? **A new species can form when a group of individuals remains isolated from the rest of its species long enough to evolve different traits.** Isolation, or complete separation, occurs when some members of a species become cut off from the rest of the species. Group members may be separated by such things as a river, a volcano, or a mountain range.

Abert's squirrel and the Kaibab squirrel both live in forests in the Southwest. As you can see in Figure 12, the populations of the two kinds of squirrel are separated by the Grand Canyon. The Kaibab and Abert's squirrels belong to the same species, but they have slightly different characteristics. For example, the Kaibab squirrel has a black belly, while Abert's squirrel has a white belly. It is possible that one day Abert's squirrel and the Kaibab squirrel will become so different from each other that they will be separate species.

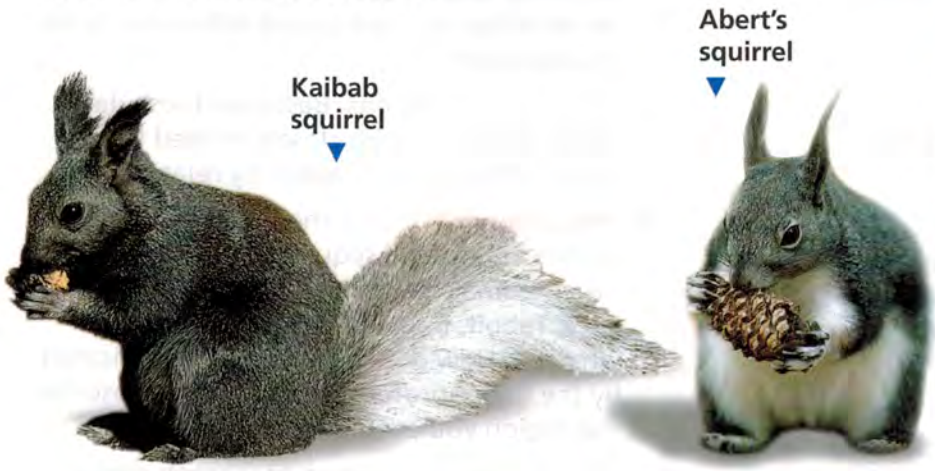


FIGURE 12
Kaibab and Abert's Squirrels These two kinds of squirrels have been isolated from one another for a long time. Eventually, this isolation may result in two different species.

Section 2 Assessment

Target Reading Skill

Identifying Supporting Evidence Refer to your graphic organizer about the theory of evolution as you answer Question 1 below.

Reviewing Key Concepts

1. a. **Listing** List three kinds of evidence that support the theory of evolution.
   b. **Comparing and Contrasting** What major difference have scientists discovered between today's whales and the fossils of whales' ancient ancestors?
   c. **Drawing Conclusions** How does this difference show that whales and animals with four legs are probably descended from a common ancestor?
2. a. **Identifying** When scientists try to determine how closely related species are, what evidence do they examine?
   b. **Inferring** Of the kinds of evidence you listed above, which are probably the most reliable? Explain your answer.
   c. **Applying Concepts** Insects and birds both have wings. What kinds of evidence might show whether or not insects and birds are closely related? Explain your answer.
3. a. **Reviewing** How can isolation lead to the formation of new species?
   b. **Predicting** A species of snake lives in a forest. A new road separates one group of the snakes from another. Is it likely that these two groups of snakes will become separate species? Why or why not?

Writing in Science

Explaining a Branching Tree Suppose the branching tree in Figure 11 is part of a museum exhibit. Write an explanation of the branching tree for museum visitors. Describe the relationships shown on the tree and identify evidence supporting the relationships.

Lab zone **Skills Lab**

Telltale Molecules

Problem

What information can protein structure reveal about evolutionary relationships among organisms?

Skills Focus

interpreting data, drawing conclusions

Procedure

1. Examine the table below. It shows the sequence of amino acids in one region of a protein, cytochrome c, for six different animals.
2. Predict which of the five other animals is most closely related to the horse. Which animal do you think is most distantly related?
3. Compare the amino acid sequence of the horse to that of the donkey. How many amino acids differ between the two species? Record that number in your notebook.
4. Compare the amino acid sequences of each of the other animals to that of the horse. Record the number of differences in your notebook.

Analyze and Conclude

1. **Interpreting Data** Which animal's amino acid sequence was most similar to that of the horse? What similarities and difference(s) did you observe?
2. **Drawing Conclusions** Based on these data, which species is most closely related to the horse? Which is most distantly related?
3. **Interpreting Data** For the entire protein, the horse's amino acid sequence differs from the other animals' as follows: donkey, 1 difference; rabbit, 6; snake, 22; turtle, 11; and whale, 5. How do the relationships indicated by the entire protein compare with those for the region you examined?
4. **Communicating** Write a paragraph explaining why data about amino acid sequences can provide information about evolutionary relationships among organisms.

More to Explore

Use the amino acid data to construct a branching tree that includes horses, donkeys, and snakes. The tree should show one way that the three species could have evolved from a common ancestor.

Section of Cytochrome c Protein in Animals

Animal	Amino Acid Position														
	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Horse	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Donkey	A	B	C	D	E	F	G	H	Z	J	K	L	M	N	O
Rabbit	A	B	C	D	E	Y	G	H	Z	J	K	L	M	N	O
Snake	A	B	C	D	E	Y	G	H	Z	J	K	W	M	N	O
Turtle	A	B	C	D	E	V	G	H	Z	J	K	U	M	N	O
Whale	A	B	C	D	E	Y	G	H	Z	J	K	L	M	N	O

Section 3

Integrating Earth Science

The Fossil Record

Reading Preview

Key Concepts

- How do most fossils form?
- How can scientists determine a fossil's age?
- What is the Geologic Time Scale?
- What are some unanswered questions about evolution?

Key Terms

- petrified fossil
- mold
- cast
- relative dating
- radioactive dating
- radioactive element
- half-life
- fossil record
- extinct
- gradualism
- punctuated equilibria

Target Reading Skill

Building Vocabulary After you read the section, write a definition of each Key Term in your own words.

Lab zone **Discover Activity**

What Can You Learn From Fossils?

1. Look at the fossil in the photograph. Describe the fossil's characteristics in as much detail as you can.
2. From your description in Step 1, try to figure out how the organism lived. How did it move? Where did it live?

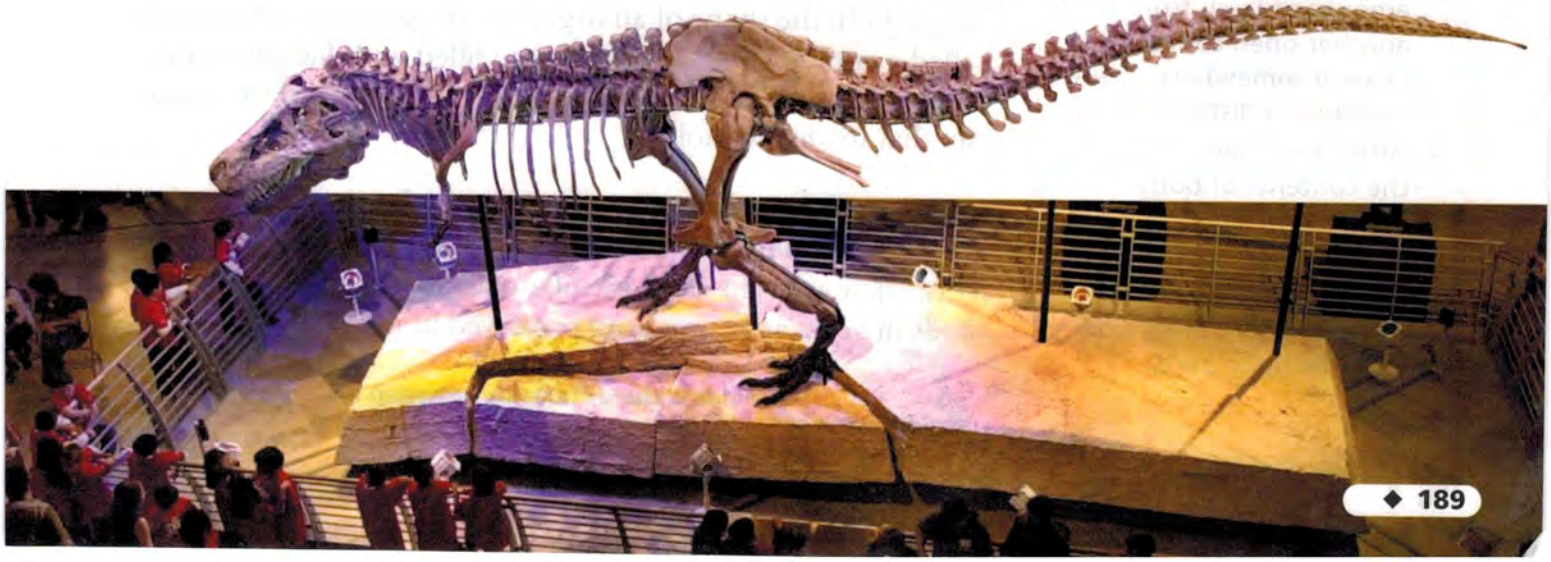
Think It Over

Inferring What type of present-day organism do you think is related to the fossil? Why?

The fossil dinosaur below has been nicknamed "Sue." If fossils could talk, Sue might say something like this: "I don't mind that museum visitors call me 'Sue,' but I do get annoyed when they refer to me as 'that old fossil.' I'm a 67-million-year old *Tyrannosaurus rex*, and I should get some respect. I was fearsome. My skull is one and a half meters long, and my longest tooth is more than 30 centimeters. Ah, the stories I could tell! But I'll have to let my bones speak for themselves. Scientists can learn a lot from studying fossils like me."

Of course, fossils can't really talk or think. But fossils such as Sue reveal life's history.

FIGURE 13 Dinosaur Fossil
The dinosaur nicknamed "Sue" was discovered in 1990 in South Dakota. Sue is now in the Field Museum in Chicago.



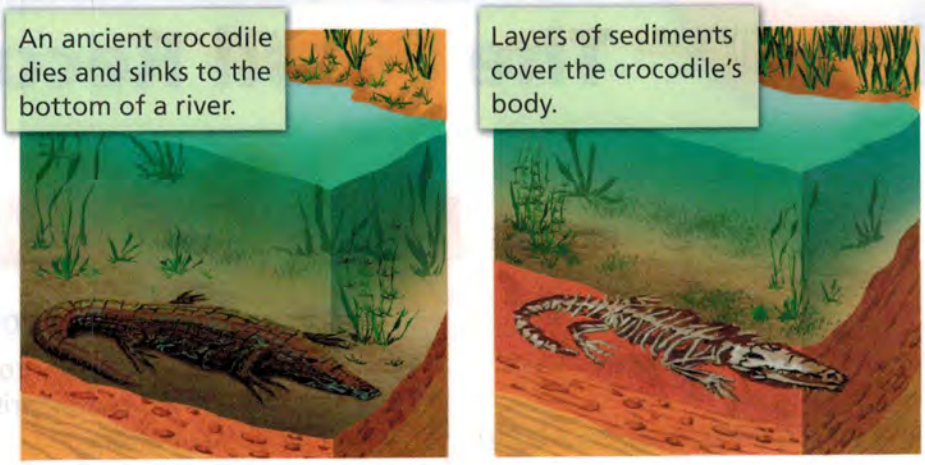


FIGURE 14
Fossil Formation
Most fossils, such as the fossil crocodile shown here, form in sedimentary rock. **Relating Cause and Effect** *In the process of fossil formation, what materials replace the crocodile's remains?*

How Do Fossils Form?

The formation of any fossil is a rare event. Usually only the hard parts of the organism, such as the bones or shells of animals, form fossils. **Most fossils form when organisms that die become buried in sediments.** Sediments are particles of soil and rock. When a river flows into a lake or ocean, the sediments that the river carries settle to the bottom. Layers of sediments may cover the dead organisms. Over millions of years, the layers may harden to become sedimentary rock. Figure 14 shows how a fossil can form.

Petrified Fossils Some remains that become buried in sediments are actually changed to rock. Minerals dissolved in the water soak into the buried remains. Gradually, the minerals replace the remains, changing them into rock. Fossils that form in this way are called **petrified fossils.**

Molds and Casts Sometimes shells or other hard parts buried by sediments gradually dissolve. An empty space remains in the place that the hard part once occupied. A hollow space in sediment in the shape of an organism or part of an organism is called a **mold.** A mold may become filled with hardened minerals, forming a cast. A **cast** is a copy of the shape of the organism that made the mold.

Preserved Remains Organisms can also be preserved in substances other than sediments. For example, entire organisms, such as huge elephant-like mammoths that lived thousands of years ago, have been preserved in ice.

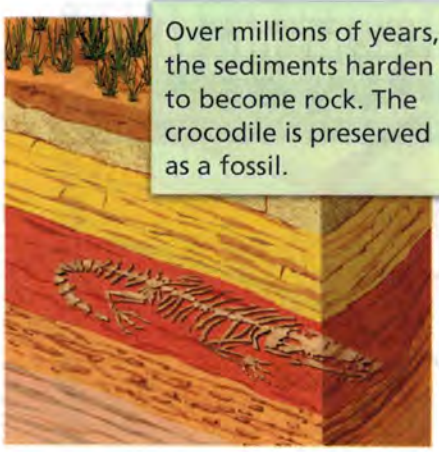
Reading Checkpoint **What is the difference between a mold and a cast?**

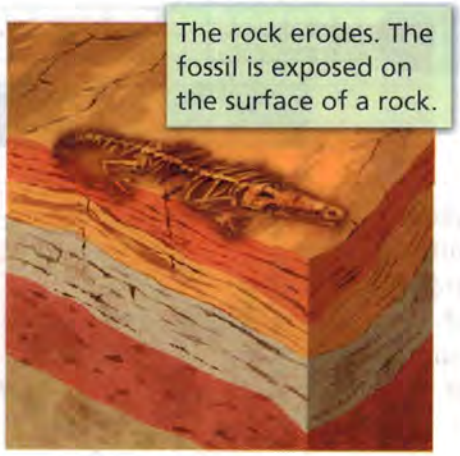
Lab zone **Try This Activity**

Preservation in Ice

1. Place fresh fruit, such as apple slices, strawberries, and blueberries, in an open plastic container.
2. Completely cover the fruit with water. Put the container in a freezer.
3. Place the same type and amount of fresh fruit in another open container. Leave it somewhere where no one will disturb it.
4. After three days, observe the contents of both containers.

Inferring Use your observations to explain why fossils preserved in ice can include soft, fleshy body parts.





Go Online
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Determining a Fossil's Age

To understand how living things have changed through time, scientists need to be able to determine the ages of fossils. They can then determine the order in which past events occurred. This information can be used to reconstruct the history of life on Earth.

For example, suppose a scientist is studying two fossils of ancient snails, Snail A and Snail B. The fossils are similar, but they are different enough that they are not the same species. Perhaps, the scientist hypothesizes, Snail A's species changed over time and eventually gave rise to Snail B's species. To help determine whether this hypothesis could be valid, the scientist must first learn which fossil—A or B—is older. **Scientists can determine a fossil's age in two ways: relative dating and radioactive dating.**

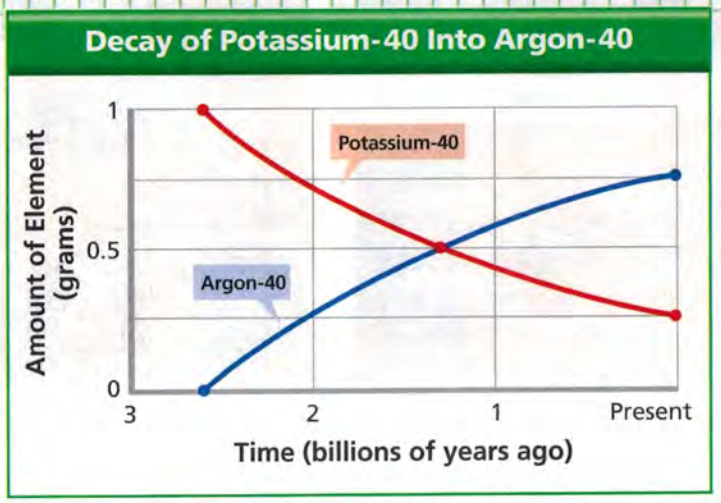
Relative Dating Scientists use **relative dating** to determine which of two fossils is older. To understand how relative dating works, imagine that a river has cut down through layers of sedimentary rock to form a canyon. If you look at the canyon walls, you can see the layers of sedimentary rock piled up one on top of another. The layers near the top of the canyon were formed most recently. These layers are the youngest rock layers. The lower down the canyon wall you go, the older the layers are. Therefore, fossils found in layers near the top of the canyon are younger than fossils found near the bottom of the canyon.

Relative dating can only be used when the rock layers have been preserved in their original sequence. Relative dating can help scientists determine whether one fossil is older than another. However, relative dating does not tell scientists the fossil's actual age.

Math Analyzing Data

Radioactive Decay

The half-life of potassium-40, a radioactive element, is 1.3 billion years. This means that half of the potassium-40 in a sample will break down into argon-40 every 1.3 billion years. The graph shows the breakdown of a 1-gram sample of potassium-40 into argon-40 over billions of years.



1. **Reading Graphs** What does the red line represent? What does the blue line represent?
2. **Reading Graphs** At 2.6 billion years ago, how much of the sample consisted of potassium 40? How much of the sample consisted of argon-40?
3. **Reading Graphs** At what point in time do the two graph lines cross?
4. **Interpreting Data** At the point where the graph lines cross, how much of the sample consisted of potassium-40? How much consisted of argon-40? Explain why this is the case.

Radioactive Dating A technique called **radioactive dating** allows scientists to determine the actual age of fossils. The rocks that fossils are found near contain **radioactive elements,** which are unstable elements that decay, or break down, into different elements. The **half-life** of a radioactive element is the time it takes for half of the atoms in a sample to decay. The graph in Analyzing Data shows how a sample of potassium-40, a radioactive element, breaks down into argon-40 over time.

Scientists can compare the amount of a radioactive element in a sample to the amount of the element into which it breaks down. This information can be used to calculate the age of the rock, and thus the age of the fossil.

Reading Checkpoint **What is a half-life?**

What Do Fossils Reveal?

Like pieces in a jigsaw puzzle, fossils can help scientists piece together information about Earth's past. From the fossil record, scientists have learned information about the history of life on Earth. The millions of fossils that scientists have collected are called the **fossil record.**

Extinct Organisms Almost all of the species preserved as fossils are now extinct. A species is **extinct** if no members of that species are still alive. Most of what scientists know about extinct species is based on the fossil record.

The Geologic Time Scale The fossil record provides clues about how and when new groups of organisms evolved. Using radioactive dating, scientists have calculated the ages of many different fossils and rocks. From this information, scientists have created a "calendar" of Earth's history that spans more than 4.6 billion years. Scientists have divided this large time span into smaller units called eras and periods. **This calendar of Earth's history is sometimes called the Geologic Time Scale.**

The largest span of time in the Geologic Time Scale is Precambrian Time, also called the Precambrian (pree KAM bree un). It covers the first 4 billion years of Earth's history. Scientists know very little about the Precambrian because there are few fossils from these ancient times. After the Precambrian, the Geologic Time Scale is divided into three major blocks of time, or eras. Each era is further divided into shorter periods. In Figure 16 on the next two pages, you can see the events that occurred during each time period.

Reading Checkpoint **What is the largest span in the Geologic Time Scale?**

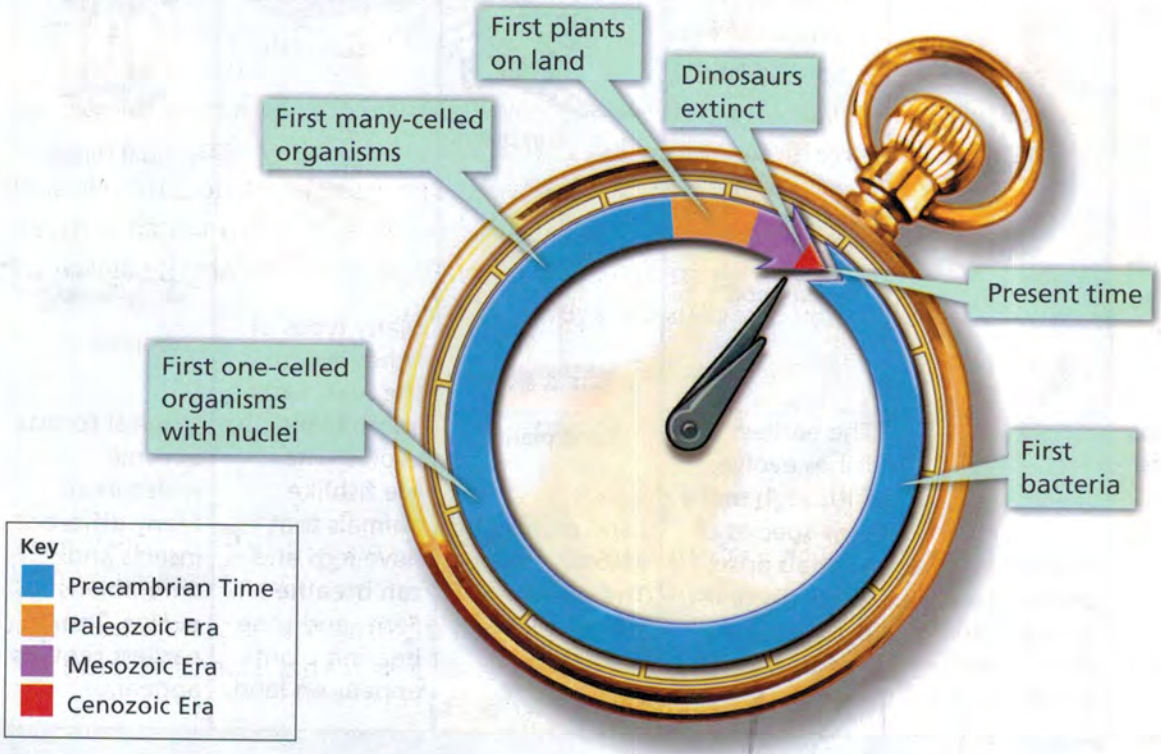
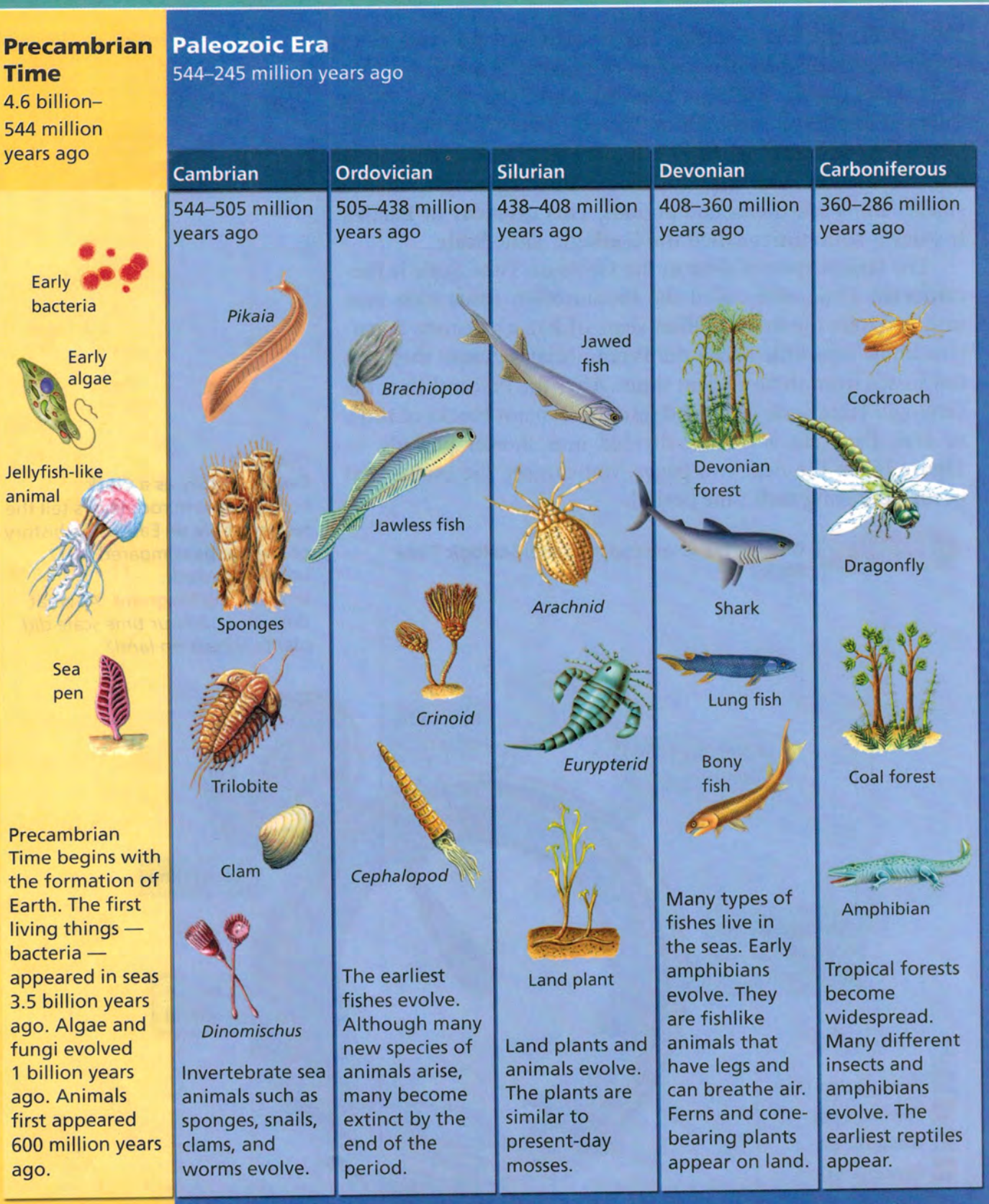


FIGURE 15
Earth's History as a Clock
Fossils found in rock layers tell the history of life on Earth. The history of life can be compared to 12 hours on a clock.
Interpreting Diagrams *At what time on a 12-hour time scale did plants appear on land?*

FIGURE 16

The Geologic Time Scale

Sequencing *Which organisms appeared first—amphibians or fishes?*



Mesozoic Era
245–66 million years ago

Cenozoic Era
66 million years ago to the present

Permian
286–245 million years ago

Conifer

Dimetrodon

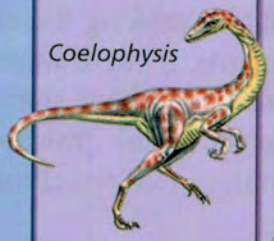
Dicynodon

Seed plants, insects, and reptiles become common. Reptile-like mammals appear. At the end of the period, most sea animals and amphibians become extinct.

Triassic
245–208 million years ago

Cycad

Early mammal



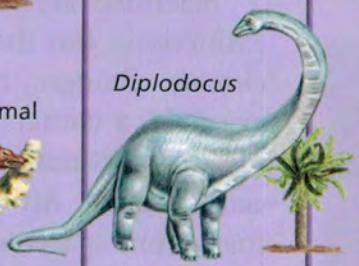
Coelophysis

The first dinosaurs evolve. First turtles and crocodiles appear. Mammals first appear. Cone-bearing trees and palmlike trees dominate forests.

Jurassic
208–144 million years ago

Morganucodon

Diplodocus



Archaeopteryx

Large dinosaurs roam the world. The first birds appear. Mammals become more common and varied.

Cretaceous
144–66 million years ago

Triceratops

Magnolia

Tyrannosaurus rex

Creodont

The first flowering plants appear. At the end of the period, a mass extinction causes the disappearance of many organisms, including the dinosaurs.

Tertiary
66–1.8 million years ago

Uintatherium

Plesiadapis

Hyracotherium

New groups of animals, including the first monkeys and apes, appear. Flowering plants become the most common kinds of plants. First grasses appear.

Quaternary
1.8 million years ago to the present

Saber-toothed cat

Megatherium

Homo sapiens

Mammals, flowering plants, and insects dominate land. Humans appear. Later in the period, many large mammals, including mammoths, become extinct.

FIGURE 17

Mass Extinctions

An asteroid may have caused the mass extinction that occurred about 65 million years ago.

Relating Cause and Effect *How could an asteroid have caused climate change?*

▲ An asteroid zooms toward Earth.

Unanswered Questions

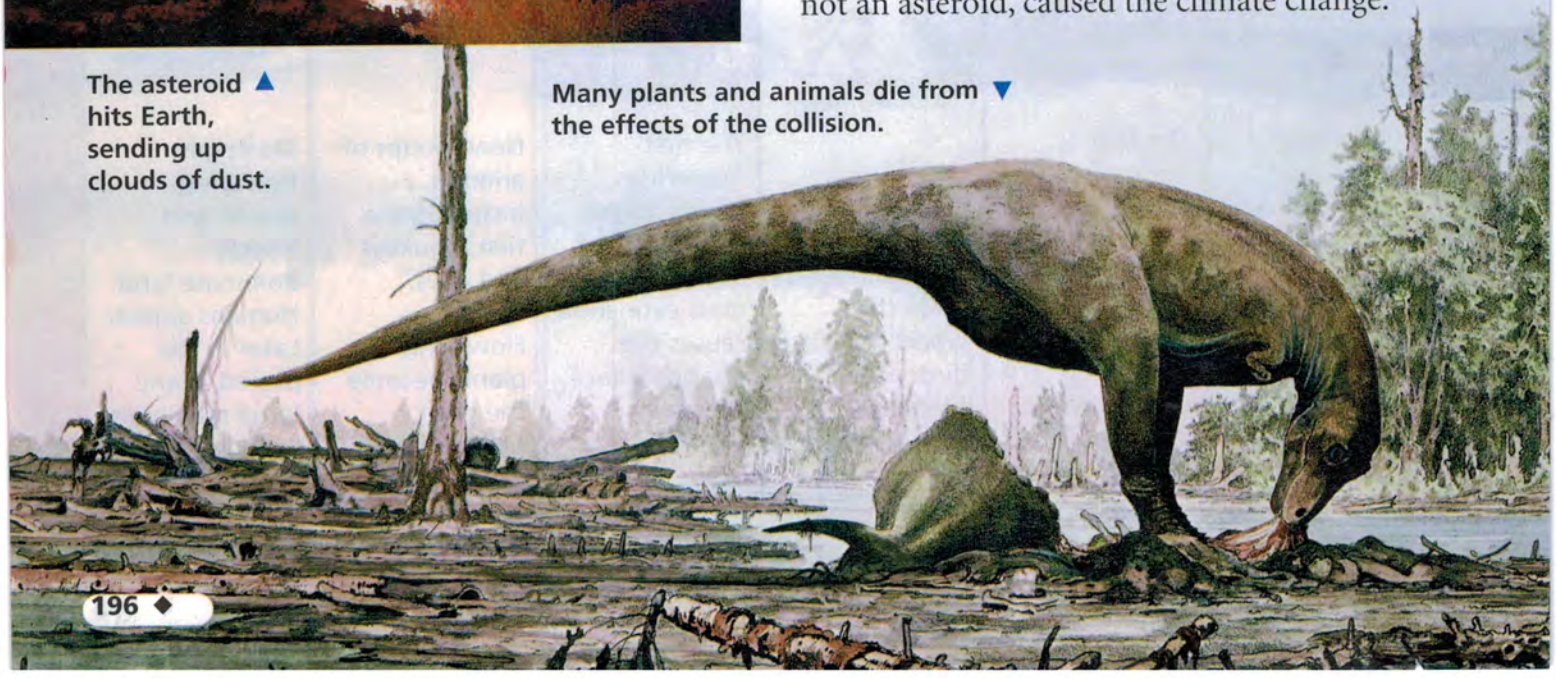
The fossil record has provided scientists with a lot of important information about past life on Earth. The fossil record, however, is incomplete, because most organisms died without leaving fossils behind. These gaps in the fossil record leave many questions unanswered. **Two unanswered questions about evolution involve the causes of mass extinctions and the rate at which evolution occurs.**

Mass Extinctions When many types of organisms become extinct at the same time, a mass extinction has occurred. Several mass extinctions have taken place during the history of life. One mass extinction, for example, occurred at the end of the Cretaceous Period, about 65 million years ago. During the Cretaceous mass extinction, many kinds of plants and animals, including the dinosaurs, disappeared forever.

Scientists are not sure what causes mass extinctions, but they hypothesize that major climate changes may be responsible. For example, a climate change may have caused the mass extinction at the end of the Cretaceous Period. An asteroid, which is a rocky mass from space, may have hit Earth, throwing huge clouds of dust and other materials into the air. The dust clouds would have blocked sunlight, making the climate cooler, and killing plants. If there were fewer plants, many animals would have starved. Some scientists, however, think volcanic eruptions, not an asteroid, caused the climate change.

The asteroid ▲ hits Earth, sending up clouds of dust.

Many plants and animals die from ▼ the effects of the collision.



Gradualism Scientists also are not sure how rapidly species change. One theory, called **gradualism,** proposes that evolution occurs slowly but steadily. According to this theory, tiny changes in a species gradually add up to major changes over very long periods of time. This is how Darwin thought evolution occurred.

If the theory of gradualism is correct, the fossil record should include intermediate forms between a fossil organism and its descendants. However, there are often long periods of time in which fossils show little or no change. Then, quite suddenly, fossils appear that are distinctly different. One possible explanation for the lack of intermediate forms is that the fossil record is incomplete. Scientists may eventually find more fossils to fill the gaps.

Punctuated Equilibria A theory that accounts for the gaps in the fossil record is called **punctuated equilibria.** According to this theory, species evolve quickly during relatively short periods. These periods of rapid change are separated by long periods of little or no change. Today most scientists think that evolution can occur gradually at some times and more rapidly at others.

Reading Checkpoint **What theory proposes that evolution occurs slowly but steadily?**

FIGURE 18
Trilobite
Trilobites were once common in Earth's oceans, but they were destroyed in a mass extinction.

Section 3 Assessment

Target Reading Skill **Building Vocabulary** Use your definitions to help you answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What are sediments? How are they involved in the formation of fossils?
   b. **Classifying** Identify the types of fossils.
   c. **Comparing and Contrasting** Which of the major types of fossils do not form in sediments? Describe how this type can form.
2. a. **Identifying** What are the two methods of determining a fossil's age?
   b. **Describing** Describe each method.
   c. **Applying Concepts** Some fossil organisms are frozen rather than preserved in sediment. Which method of dating would you use with frozen fossils? Why?
3. a. **Defining** What is the Geologic Time Scale? Into what smaller units is it divided?
   b. **Interpreting Diagrams** Look at Figure 16. Did the organisms during Precambrian Time have hard body parts?
   c. **Relating Cause and Effect** Give one reason why there are few Precambrian fossils.
4. a. **Reviewing** What are two unanswered questions about evolution?
   b. **Comparing and Contrasting** How are the theories of gradualism and punctuated equilibria different? How are they similar?

Lab zone **At-Home Activity**

Modeling Fossil Formation With an adult family member, spread some mud in a shallow pan. Use your fingertips to make "footprints" across the mud. Let the mud dry and harden. Explain how this is similar to fossil formation.

Chapter 6

Study Guide

The BIG Idea **Diversity and Adaptations** The process of natural selection—in which better adapted organisms are more likely to survive and reproduce—has resulted in the evolution and diversity of organisms.

1 Darwin's Theory

Key Concepts

- Darwin's important observations included the diversity of living things, the remains of ancient organisms, and the characteristics of organisms on the Galápagos Islands.
- Darwin reasoned that plants or animals that arrived on the Galápagos Islands faced conditions that were different from those on the mainland. Perhaps, Darwin hypothesized, the species gradually changed over many generations and became better adapted to the new conditions.
- Darwin proposed that, over a long period of time, natural selection can lead to change. Helpful variations may gradually accumulate in a species, while unfavorable ones may disappear.

Key Terms

• species • fossil • adaptation • evolution
• scientific theory • natural selection
• variation

2 Evidence of Evolution

Key Concepts

- Fossils, patterns of early development, and similar body structures all provide evidence that organisms have changed over time.
- Scientists have combined the evidence from DNA, protein structure, fossils, early development, and body structure to determine the evolutionary relationships among species.
- A new species can form when a group of individuals remains separated from the rest of its species long enough to evolve different traits.

Key Terms

homologous structures
branching tree

3 The Fossil Record

Key Concepts

- Most fossils form when organisms that die become buried in sediments.
- Scientists can determine a fossil's age in two ways: relative dating and radioactive dating.
- The calendar of Earth's history is sometimes called the Geologic Time Scale.
- Two unanswered questions about evolution involve mass extinctions and the rate at which evolution occurs.

Key Terms

petrified fossil
mold
cast
relative dating
radioactive dating
radioactive element
half-life
fossil record
extinct
gradualism
punctuated equilibria

Review and Assessment

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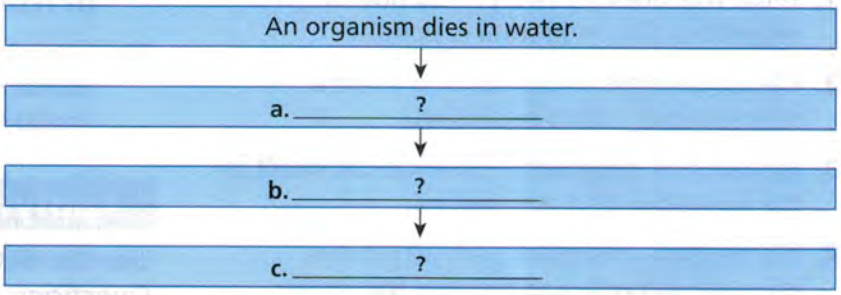
Organizing Information

Sequencing Copy the flowchart about fossil formation onto a separate sheet of paper. Complete the flowchart by writing a sentence describing each stage in the process of fossil formation. Then add a title. (For more on Sequencing, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. Changes in a species over long periods of time are called
   a. half-life.
   b. evolution.
   c. homologous structures.
   d. developmental stages.
2. A trait that helps an organism survive and reproduce is called a(n)
   a. variation.
   b. adaptation.
   c. species.
   d. selection.
3. Similar structures that related species have inherited from a common ancestor are called
   a. adaptations.
   b. punctuated equilibria.
   c. ancestral structures.
   d. homologous structures.
4. Fossils formed when an organism dissolves and leaves an empty space in a rock are called
   a. casts.
   b. molds.
   c. preserved remains.
   d. petrified fossils.
5. The rate of decay of a radioactive element is measured by its
   a. year.
   b. era.
   c. period.
   d. half-life.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Darwin's idea about how evolution occurs is called natural selection.
7. Most members of a species show differences, or variations.
8. A diagram that shows how organisms might be related is called gradualism.
9. The technique of relative dating can be used to determine the actual age of a fossil.
10. According to the theory of punctuated equilibria, evolution occurs slowly but steadily.

Writing in Science

Notebook Entry Imagine that you are a biologist exploring the Galápagos Islands. Write a notebook entry on one of the unusual species you have found on the islands. Include a description of how it is adapted to its environment.

Discovery CHANNEL SCHOOL

Changes Over Time
Video Preview
Video Field Trip
▶ Video Assessment

Popular Breeds

The popularity of different breeds of dogs changes over time. For example, the line graph shows how the number of poodles registered with the American Kennel Club changed between 1970 and 2000.

Standard poodle and puppy ▶

Math Activity

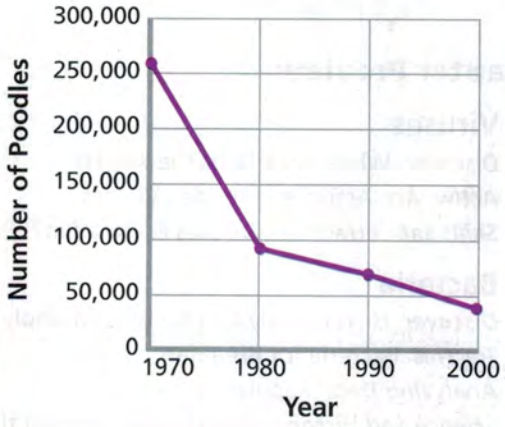
Use the table below to create your own line graph for Labrador retrievers and cocker spaniels. Which breed was more popular in 1980, Labrador retrievers or cocker spaniels?

How has the number of Labrador retrievers changed from 1970 to 2000? How has the number of cocker spaniels changed over the same time?

Dog Populations

Breed	1970	1980	1990	2000
Poodle	265,879	92,250	71,757	45,868
Labrador Retriever	25,667	52,398	95,768	172,841
Cocker Spaniel	21,811	76,113	105,642	29,393

Poodles in the U.S., 1970–2000



Tie It Together

Best-of-Breed Show

In many places, proud dog owners of all ages bring their animals to compete in dog shows.

Organize your own dog show.

With a partner, choose one specific breed of dog. Pick a breed shown on the map on the previous page, or use library resources to research another breed.

- Find out what the breed looks like, the time and place where it originated, and what traits it was first bred for.
- List your breed's characteristics, height, weight, and coloring.
- Research the breed's personality and behavior.
- Find out your breed's strengths. Learn what weaknesses may develop as a result of inbreeding.
- Make a poster for your breed. Include a drawing or photo and the information that you researched.
- With your class, organize the dog displays into categories of breeds, such as hunting dogs, herding dogs, and toy dogs.

Chapter 7

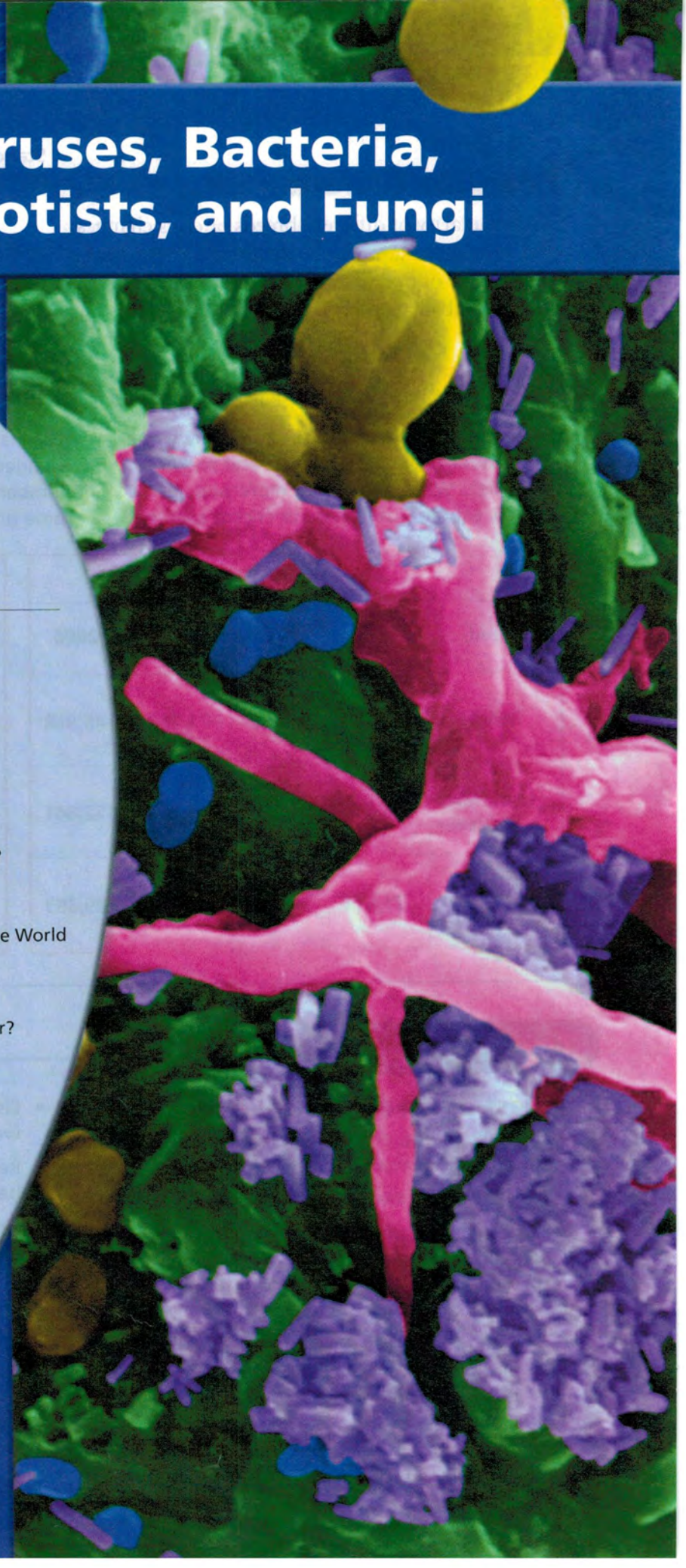
Viruses, Bacteria, Protists, and Fungi

The BIG Idea

Diversity and Adaptations

What are some key characteristics of viruses, bacteria, protists, and fungi?

Chapter Preview



Bacteria (blue and purple rods) and other microorganisms lurk in a kitchen sponge.

Lab zone™ Chapter **Project**

A Mushroom Farm

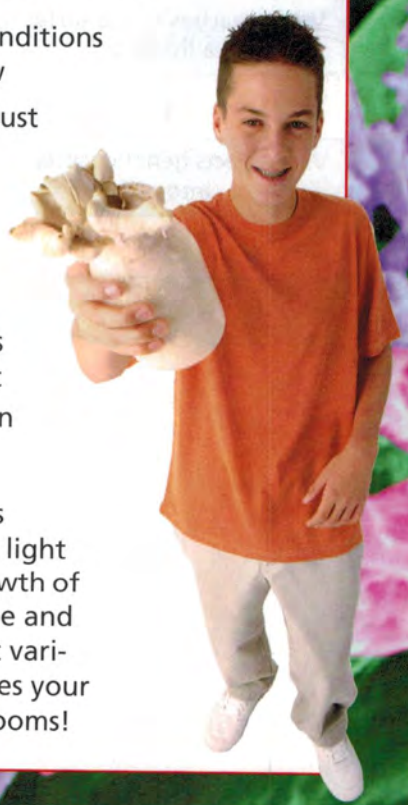
The fungi you're most familiar with are probably mushrooms. In some ways, mushrooms resemble plants, often growing near plants or even on them like small umbrellas. But mushrooms are very different from plants in some important ways. In this chapter project, you'll learn about these differences.

Your Goal To determine the conditions needed for mushrooms to grow

To complete this project, you must

- choose one variable and design a way to test how it affects mushroom growth
- make daily observations and record them in a data table
- prepare a poster that describes the results of your experiment
- follow the safety guidelines in Appendix A

Plan It! List possible hypotheses about the way variables such as light or moisture could affect the growth of mushrooms. Choose one variable and write out a plan for testing that variable. After your teacher approves your plan, start growing your mushrooms!



Review and Assessment

Checking Concepts

11. What role does the overproduction of organisms play in natural selection?
12. Use an example to explain how natural selection can lead to evolution.
13. Explain how geographic isolation can result in the formation of a new species.
14. On the basis of similar body structures, scientists hypothesize that two species are closely related. What other evidence would the scientists look for to support their hypothesis?
15. Explain why similarities in the early development of different species suggest that the species are related.
16. What is meant by *extinct?* How do scientists obtain information about extinct species?
17. What are mass extinctions? What may cause mass extinction?

Thinking Critically

18. **Relating Cause and Effect** Why did Darwin's visit to the Galápagos Islands have such an important influence on his development of the theory of evolution?
19. **Applying Concepts** Some insects look just like sticks. How could this be an advantage to the insects? How could this trait have evolved through natural selection?
20. **Predicting** Which of the organisms shown below is least likely to become a fossil? Explain your answer.

Snail Dandelion Squirrel

21. **Making Judgments** What type of evidence is the best indicator of how closely two species are related? Explain your answer.
22. **Comparing and Contrasting** How are selective breeding and natural selection similar? How are they different?

Applying Skills

Use the data in the table below to answer Questions 23–25.

Radioactive carbon-14 decays to nitrogen with a half-life of 5,730 years. The table contains information about the amounts of carbon-14 and nitrogen in three fossils. The table also gives information about the position of each fossil in rock layers.

Fossil	Amount of Carbon-14 in Fossil	Amount of Nitrogen in Fossil	Position of Fossil in Rock Layers
A	1 gram	7 grams	Bottom layer
B	4 grams	4 grams	Top layer
C	2 grams	6 grams	Middle layer

23. **Inferring** Use the positions of the fossils in the rock layers to put the fossils in their probable order from the youngest to the oldest.
24. **Calculating** Calculate the age of each fossil using the data about carbon-14 and nitrogen.
25. **Drawing Conclusions** Do your answers to Questions 23 and 24 agree or disagree with each other? Explain.

Lab zone Chapter Project

Performance Assessment Complete both your timelines. Display your completed timelines for the class. Be prepared to explain why you chose the scale that you did. Also, describe how your timelines are related to each other.

Viruses

Reading Preview

Key Concepts

- How are viruses like organisms?
- What is the structure of a virus?
- How do viruses multiply?
- How can you treat a viral disease?

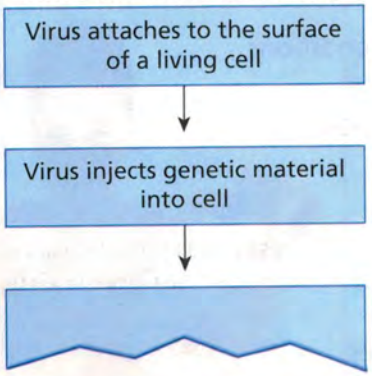
Key Terms

- virus • host • parasite
- bacteriophage • vaccine

Target Reading Skill

Sequencing As you read, make two flowcharts that show how active and hidden viruses multiply.

How Active Viruses Multiply



Lab zone Discover Activity

Which Lock Does the Key Fit?

1. Your teacher will give you a key.
2. Study the key closely. Think about what shape the keyhole on its lock must have. On a piece of paper, draw the shape of the keyhole.
3. The lock for your key is contained in the group of locks your teacher will provide. Try to match your key to its lock without inserting the key into the keyhole.

Think It Over

Inferring How might a unique "lock" on its surface help a cell protect itself from invading organisms?

It is a dark and quiet night. An enemy spy slips silently across the border. Invisible to the guards, the spy creeps cautiously along the edge of the road, heading toward the command center. Undetected, the spy sneaks by the center's security system and reaches the door. Breaking into the control room, the spy takes command of the central computer. The enemy is in control.

What Is a Virus?

Although this spy story may read like a movie script, it describes events similar to those that can occur in your body. The spy acts very much like a virus invading an organism.

Characteristics of Viruses A **virus** is a tiny, nonliving particle that invades and then multiplies inside a living cell. Viruses are not cells. They do not have the characteristics of organisms. **The only way in which viruses are like organisms is that they can multiply.** Although viruses can multiply, they multiply differently than organisms. Viruses can only multiply when they are inside a living cell.

No organisms are safe from viruses. The organism that a virus multiplies inside is called a host. A **host** is a living thing that provides a source of energy for a virus or an organism. Viruses act like **parasites** (PA ruh syts), organisms that live on or in a host and cause it harm. Almost all viruses destroy their host cells.

Standardized Test Prep

Test-Taking Tip

Anticipating the Answer

You can sometimes figure out an answer before you look at the answer choices. After you think of your own answer, compare it with the answer choices. Select the answer that most closely matches your own answer. This strategy can be especially useful for questions that test vocabulary. Try to answer the question below before you look at the answer choices.

Sample Question

A well-tested concept that explains a wide range of observations is known as a(n)

- **A** hypothesis.
- **B** controlled experiment.
- **C** scientific theory.
- **D** inference.

Answer

Choice **C** is correct, because the definition of *scientific theory* is "a well-tested concept that explains a wide range of observations." Even though the other answer choices are all scientific processes, none is the correct answer.

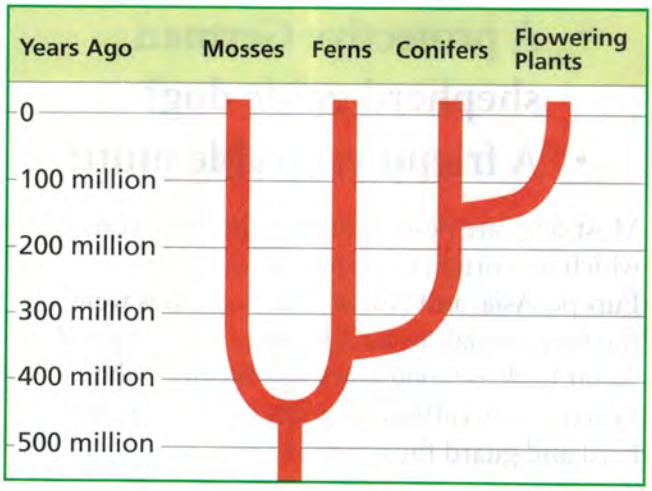
Choose the letter of the best answer.

1. The process by which individuals that are better adapted to their environment are more likely to survive and reproduce than other members of the same species is called
   - **A** natural selection.
   - **B** evolution.
   - **C** competition.
   - **D** overproduction.

2. Which of the following is the best example of an adaptation that helps an organism survive in its environment?
   - **F** green coloring in a lizard living on gray rocks
   - **G** a thick coat of fur on an animal that lives in the desert
   - **H** extensive root system in a desert plant
   - **J** thin, delicate leaves on a plant in a cold climate

3. Which of the following is the weakest evidence supporting a close evolutionary relationship between two animals?
   - **A** The bones of a bird's wings are similar to the bones of a dog's legs.
   - **B** Human embryos look like turtle embryos in their early development.
   - **C** Lesser pandas look like bears.
   - **D** The amino acid sequence in mouse hemoglobin is similar to the amino acid sequence in chimpanzee hemoglobin.

Use the diagram below and your knowledge of science to answer Questions 4–5.



4. About how long ago did mosses first appear?
   - **F** 100 million years ago
   - **G** 150 million years ago
   - **H** 350 million years ago
   - **J** 450 million years ago

5. Which group of plants would have DNA that is most similar to the DNA of flowering plants?
   - **A** mosses
   - **B** ferns
   - **C** conifers
   - **D** They would all be equally alike.

Constructed Response

6. Relative dating and radioactive dating are two methods for determining the age of a fossil. Compare and contrast these two methods.

The Structure of Viruses Viruses are smaller than cells and vary in size and shape. Some viruses are round. Others are shaped like rods, bricks, threads, or bullets. There are even viruses that have complex, robot-like shapes, such as the bacteriophage in Figure 1. A **bacteriophage** (bak TEER ee oh fayj) is a virus that infects bacteria. In fact, its name means "bacteria eater."

Although viruses may look different from one another, they all have a similar structure. **All viruses have two basic parts: a protein coat that protects the virus and an inner core made of genetic material.** A virus's genetic material contains the instructions for making new viruses. Some viruses are also surrounded by an additional outer membrane, or envelope.

The proteins on the surface of a virus play an important role during the invasion of a host cell. Each virus contains unique surface proteins. The shape of the surface proteins allows the virus to attach to certain cells in the host. Like keys, a virus's proteins fit only into certain "locks," or proteins, on the surface of a host's cells. Figure 2 shows how the lock-and-key action works.

Because the lock-and-key action of a virus is specific, a certain virus can attach only to one or a few types of cells. For example, most cold viruses infect cells only in the nose and throat of humans. These cells are the ones with proteins on their surface that complement or "fit" those on the virus.

Reading Checkpoint **What information does a virus's genetic material contain?**

FIGURE 1
Bacteriophage
This robot-like virus infects bacteria.

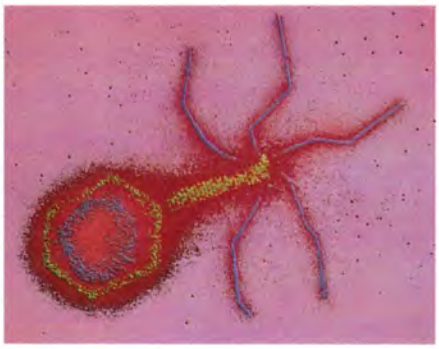
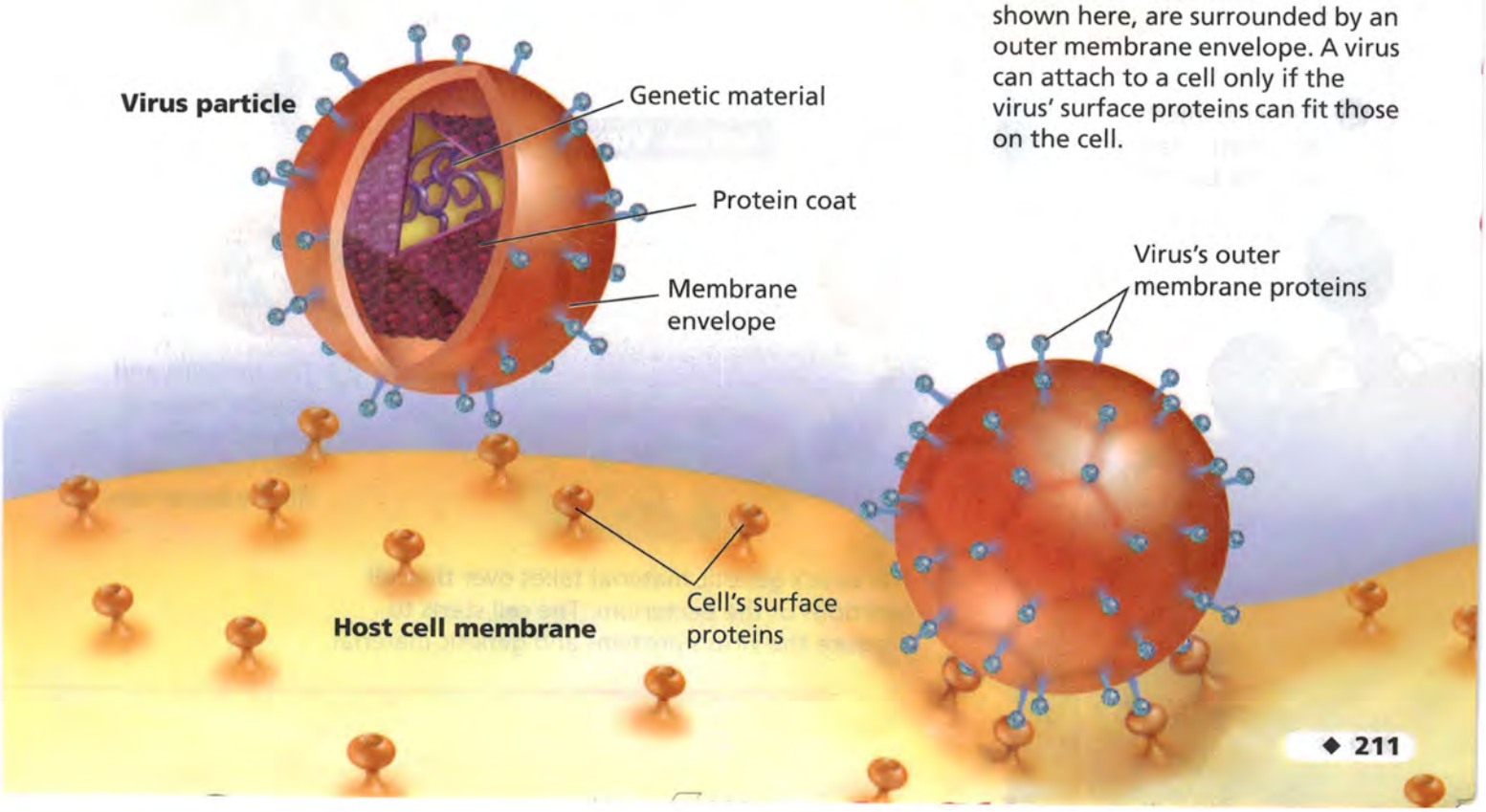


FIGURE 2
Virus Structure and Infection
All viruses consist of genetic material surrounded by a protein coat. Some viruses, like the ones shown here, are surrounded by an outer membrane envelope. A virus can attach to a cell only if the virus' surface proteins can fit those on the cell.



Interdisciplinary
Exploration

Egyptian Art
More than 3,000 years ago, an artist drew three dogs chasing a hyena.

Dogs—Loyal Companions

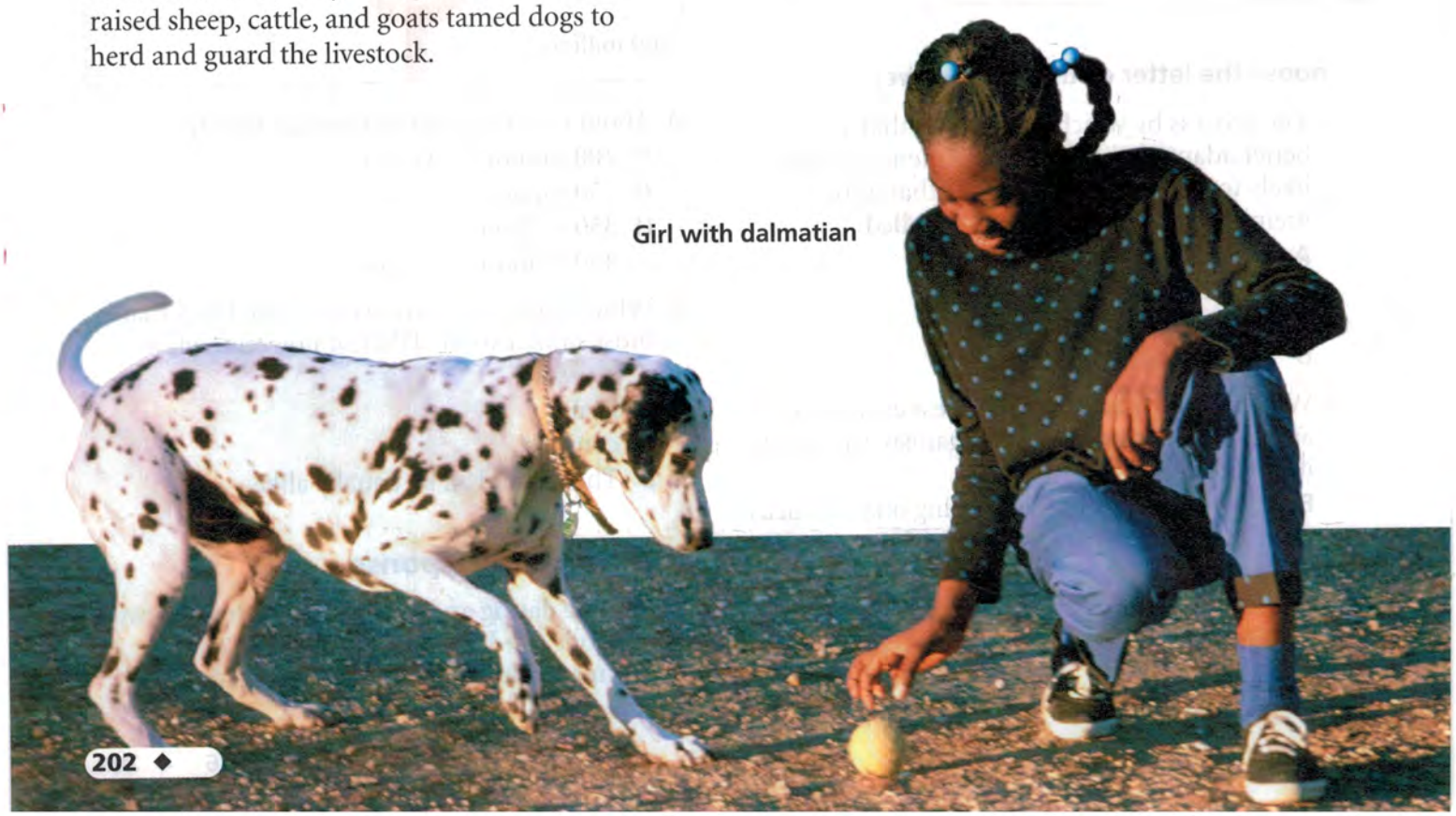
What's your image of a dog?

- **A powerful Great Dane?**
- **A tiny, lively Chihuahua?**
- **A protective German shepherd guide dog?**
- **A friendly, lovable mutt?**

Most dogs are descendants of the gray wolf, which was originally found throughout Europe, Asia, and North America. Dogs were the first animals to be domesticated, or tamed. As far back as 9,000 years ago, farmers who raised sheep, cattle, and goats tamed dogs to herd and guard the livestock.

After taming dogs, people began to breed them for traits that people valued. Early herding dogs helped shepherds. Speedy hunting dogs learned to chase deer and other game. Strong, sturdy working dogs pulled sleds and even rescued people. Small, quick terriers hunted animals, such as rats. "Toy" dogs were companions to people of wealth and leisure. More recently, sporting dogs were trained to flush out and retrieve birds. Still others were bred to be guard dogs. But perhaps the real reasons people bred dogs were for loyalty and companionship.

Girl with dalmatian



How Viruses Multiply

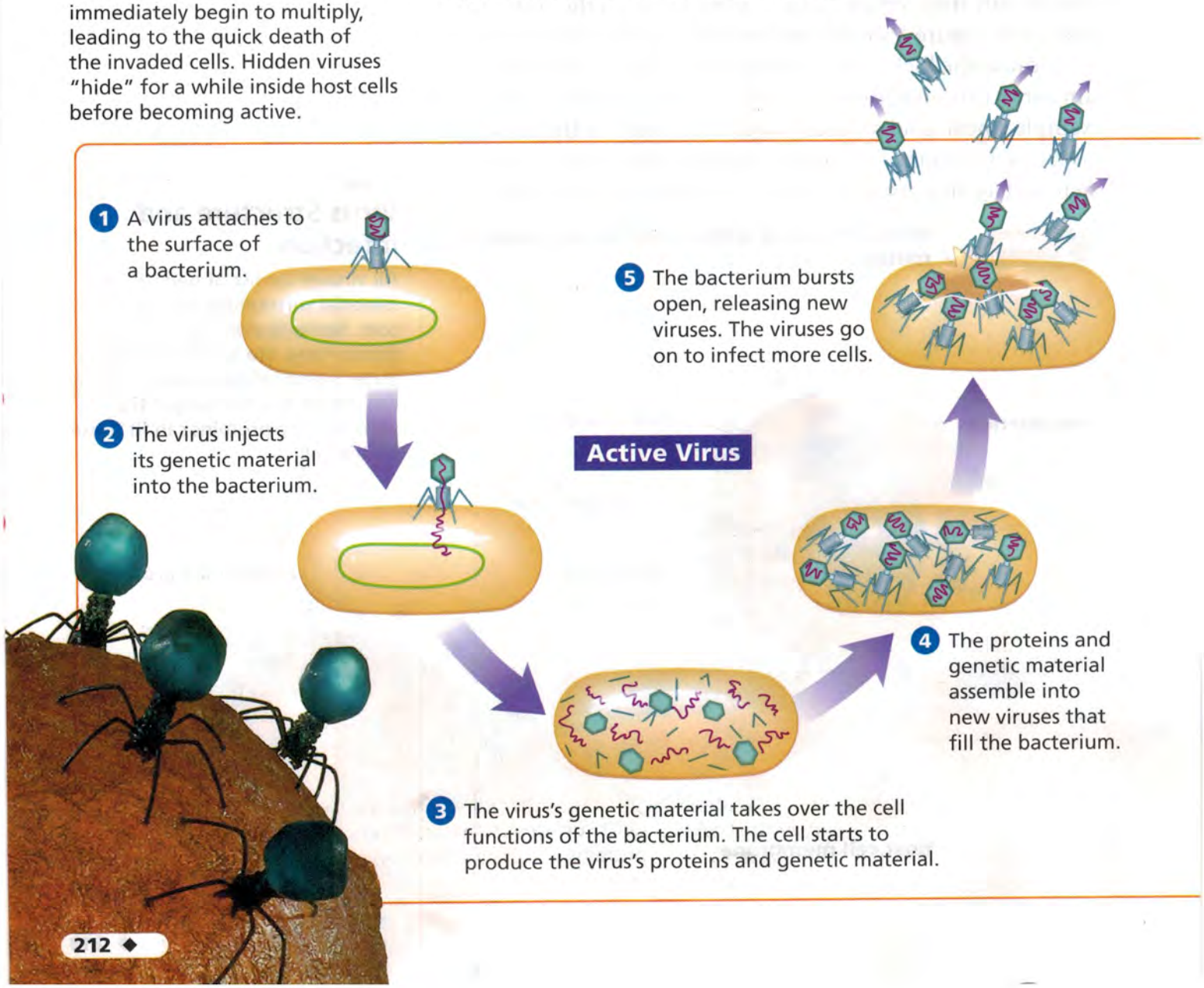
After a virus attaches to a host cell, it enters the cell. **Once inside a cell, a virus's genetic material takes over many of the cell's functions. It instructs the cell to produce the virus's proteins and genetic material. These proteins and genetic material then assemble into new viruses.** Some viruses take over cell functions immediately. Other viruses wait for a while.

Active Viruses After entering a cell, an active virus immediately goes into action. The virus's genetic material takes over cell functions, and the cell quickly begins to produce the virus's proteins and genetic material. Then these parts assemble into new viruses. Like a photocopy machine left in the "on" position, the invaded cell makes copy after copy of new viruses. When it is full of new viruses, the host cell bursts open, releasing hundreds of new viruses as it dies.

FIGURE 3

Active and Hidden Viruses

Active viruses enter cells and immediately begin to multiply, leading to the quick death of the invaded cells. Hidden viruses "hide" for a while inside host cells before becoming active.



From Wolf to Purebred

About 10,000 years ago, some wolves may have been attracted to human settlements. They may have found it easier to feed on food scraps than to hunt for themselves. Gradually the wolves came to depend on people for food. The wolves, in turn, kept the campsites clean and safe. They ate the garbage and barked to warn of approaching strangers. These wolves were the ancestors of the dogs you know today.

Over time, dogs became more and more a part of human society. People began to breed dogs for the traits needed for tasks such as herding sheep and hunting. Large, aggressive dogs, for example, were bred to be herding dogs, while fast dogs with a keen sense of smell were bred to be hunting dogs. Today, there are hundreds of breeds. They range from the tiny Chihuahua to the massive Saint Bernard, one of which can weigh as much as 50 Chihuahuas.

Today, people breed dogs mostly for their appearance and personality. Physical features such as long ears or a narrow snout are valued in particular breeds of dogs. To create "pure" breeds of dogs, breeders use a method known as inbreeding. Inbreeding involves mating dogs that are genetically very similar. Inbreeding is the surest way to produce dogs with a uniform physical appearance.

One undesirable result of inbreeding is an increase in genetic disorders. Experts estimate that 25 percent of all purebred dogs have a genetic disorder. Dalmatians, for example, often inherit deafness. German shepherds may develop severe hip problems. Mixed-breed dogs, in contrast, are less likely to inherit genetic disorders.

Fur Color in Retrievers
In Labrador retrievers, the allele for dark-colored fur is dominant over the allele for yellow fur.

Science Activity

Most traits that dogs are bred for are controlled by more than one gene. A few traits, however, show simpler inheritance patterns. For example, in Labrador retrievers, a single gene with one dominant and one recessive allele determines whether the dog's fur will be dark or yellow. The allele for dark fur (D) is dominant over the allele for yellow fur (d).

- Construct a Punnett square for a cross between two Labrador retrievers that are both heterozygous for dark fur (Dd).
- Suppose there were eight puppies in the litter. Predict how many would have dark fur and how many would have yellow fur.
- Construct a second Punnett square for a cross between a Labrador retriever with yellow fur (dd) and one with dark fur (Dd). In a litter with six puppies, predict how many would have dark fur and how many would have yellow fur.

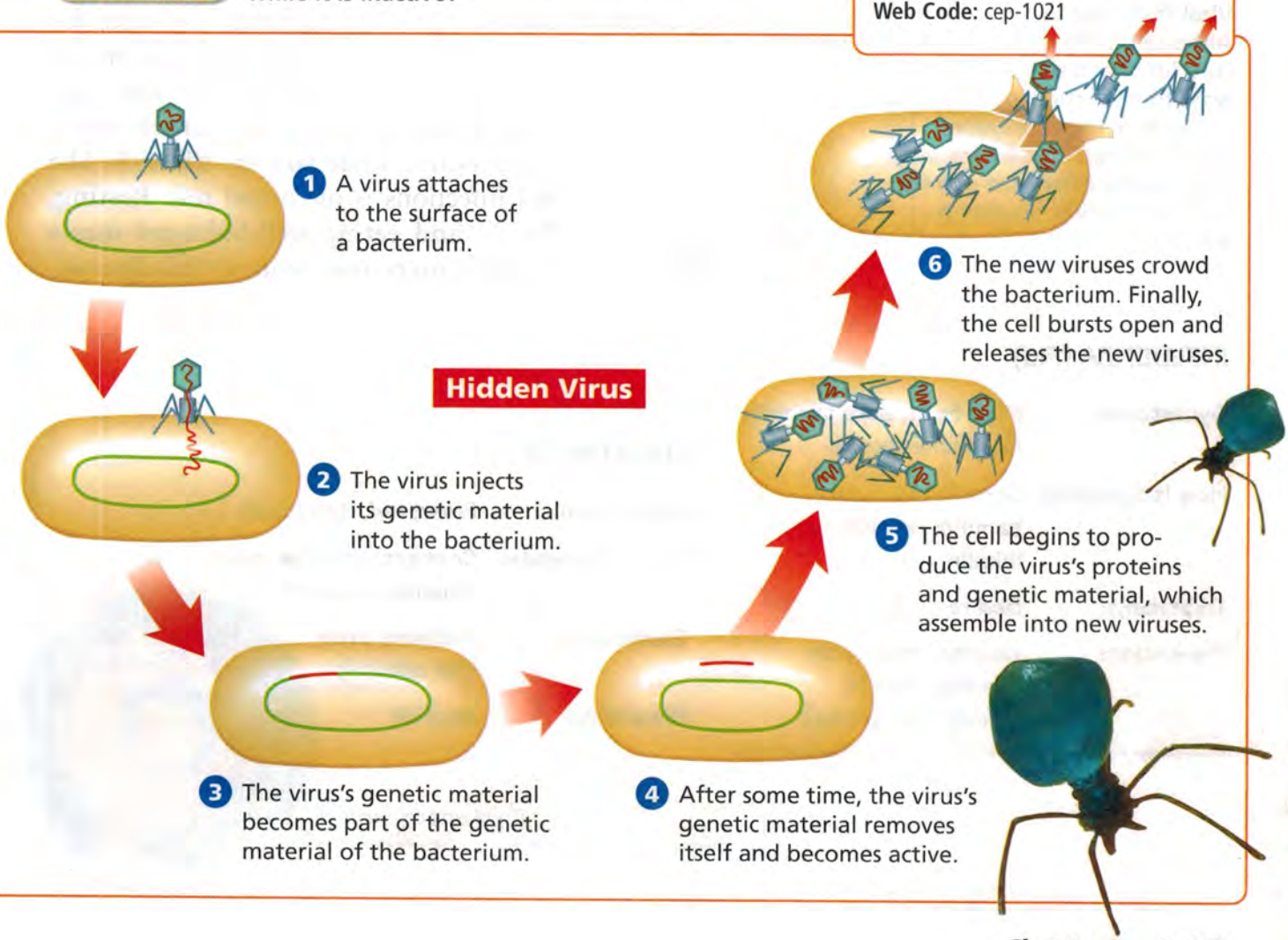
Hidden Viruses Other viruses do not immediately become active. Instead, they "hide" for a while. After a hidden virus enters a host cell, its genetic material becomes part of the cell's genetic material. The virus does not appear to affect the cell's functions and may stay in this inactive state for years. Each time the host cell divides, the virus's genetic material is copied along with the host's genetic material. Then, under certain conditions, the virus's genetic material suddenly becomes active. It takes over the cell's functions in much the same way that active viruses do. Soon, the cell is full of new viruses and bursts open.

The virus that causes cold sores is an example of a hidden virus. It can remain inactive for months or years inside nerve cells in the face. While hidden, the virus causes no symptoms. When it becomes active, the virus causes a swollen, painful sore to form near the mouth. Strong sunlight and stress are two factors that scientists believe may activate a cold sore virus. After an active period, the virus once again "hides" in the nerve cells until it becomes active again.

Reading Checkpoint **Where in a host cell does a hidden virus "hide" while it is inactive?**

Go Online active art

For: Active and Hidden Viruses activity
Visit: PHSchool.com
Web Code: cep-1021



Dogs and People

Over thousands of years, people have developed many different breeds of dogs. Each of the dogs shown on the map was bred for a purpose—hunting, herding, guarding, pulling sleds—as well as companionship. Every breed has its own story.

Border Collie
Great Britain, after A.D. 1100
This breed was developed in the counties near the border between England and Scotland for herding sheep. The border collie's ancestors were crossbreeds of local sheepdogs and dogs brought to Scotland by the Vikings.

Golden Retriever
Great Britain, A.D. 1870s
Lord Tweedmouth developed this breed to help hunters retrieve waterfowl and other small animals.

Dachshund
Germany, A.D. 1600s
These dogs were bred to catch badgers or rats. Their short legs and long body can fit into a badger's burrow. In fact, in German the word *Dachshund* means "badger dog."

Basset Hound
France, A.D. 1500s
Second only to the bloodhound at following a scent, the basset hound has short legs and a compact body that help it run through underbrush.

Greyhound
Egypt, 3000 B.C.
These speedy, slender hounds were bred for chasing prey. Today, greyhounds are famous as racers.

Viruses and Disease

If you've ever had a cold sore or been sick with the flu, you know that viruses can cause disease. Some diseases, such as colds, are mild—people are sick for a short time but soon recover. Other diseases, such as acquired immunodeficiency syndrome, or AIDS, have much more serious consequences on the body.

Viruses also cause diseases in organisms other than humans. For example, apple trees infected by the apple mosaic virus may produce less fruit. House pets, such as dogs and cats, can get deadly viral diseases, such as rabies and distemper.

The Spread of Viral Diseases Viral diseases can be spread in various ways. For example, some viral diseases can be spread through contact with a contaminated object, while others are spread through the bite of an infected animal. Some viruses, such as cold and flu viruses, can travel in tiny drops of moisture that an infected person sneezes or coughs into the air. Other viruses can spread only through contact with body fluids, such as blood.

Treating Viral Diseases There are currently no cures for viral diseases. However, many over-the-counter medications can help relieve symptoms of a viral infection. While they can make you feel better, these medications can also delay your recovery if you resume your normal routine while you are still sick. The best treatment for viral infections is often bed rest. **Resting, drinking plenty of fluids, and eating well-balanced meals may be all you can do while you recover from a viral disease.**

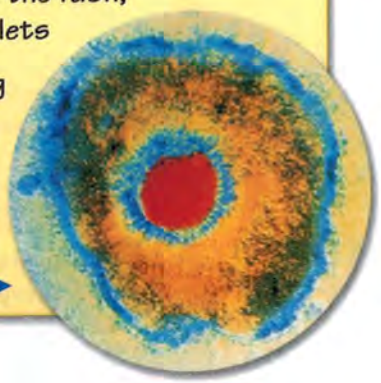
FIGURE 4
Viral Diseases
Although there is currently no cure for viral diseases, there are ways to treat the symptoms and prevent their transmission.
Relating Cause and Effect *Why does the flu often pass quickly from one family member to another?*

INFLUENZA (Flu)

Symptoms:	High fever; sore throat; headache; cough
How It Spreads:	Contact with contaminated objects; inhaling droplets
Treatment:	Bed rest; fluids
Prevention:	Vaccine (mainly for the high-risk ill, elderly, and young)

CHICKENPOX

Symptoms:	Fever; red, itchy rash
How It Spreads:	Contact with the rash; inhaling droplets
Treatment:	Antiviral drug (for adults)
Prevention:	Vaccine



Chickenpox virus ▶

Siberian Husky
Siberia, 1000 B.C.
The Chukchi people of northeastern Siberia used these strong working dogs to pull sleds long distances across the snow.

Pekingese
China, A.D. 700s
These lapdogs were bred as pets in ancient China. One Chinese name for a Pekingese means "lion dog," which refers to the dog's long, golden mane.

Chow Chow
China, 150 B.C.
Chow chows, the working dogs of ancient China, worked as hunters, herders, and guard dogs.

Akita
Japan, A.D. 1600s
This breed was developed in the cold mountains of northern Japan as a guard dog and hunting dog. The Akita is able to hunt in deep snow and is also a powerful swimmer.

China

Japan

Lhasa Apso
Tibet, A.D. 1100
This breed has a long, thick coat that protects it from the cold air of the high Tibetan plateau. In spite of its small size, the Lhasa apso guarded homes and temples.

Social Studies Activity

Draw a timeline that shows the approximate date of origin of different breeds of domestic dogs from 3000 B.C. to the present. Use the information on the map to fill out your timeline. Include information about where each breed was developed.

Lab zone **Skills Lab**

How Many Viruses Fit on a Pin?

Problem

How can a model help you understand how small viruses are?

Skills Focus

calculating, making models

Materials

- straight pin
- long strips of paper
- pencil
- meter stick
- scissors
- tape
- calculator (optional)

Procedure

1. Examine the head of a straight pin. Write a prediction about the number of viruses that could fit on the pinhead. **CAUTION:** *Avoid pushing the pin against anyone's skin.*
2. Assume that the pinhead has a diameter of about 1 mm. If the pinhead were enlarged 10,000 times, then its diameter would measure 10 m. Create a model of the pinhead by cutting and taping together narrow strips of paper to make a strip that is 10 m long. The strip of paper represents the diameter of the enlarged pinhead.
3. Lay the 10-m strip of paper on the floor of your classroom or in the hall. Imagine creating a large circle that had the strip as its diameter. The circle would be the pinhead at the enlarged size. Calculate the area of the enlarged pinhead using this formula:

   $$\text{Area} = \pi \times \text{Radius}^2$$

   Remember that you can find the radius by dividing the diameter by 2.
4. A virus particle may measure 200 nm on each side (1 nm equals a billionth of a meter). If the virus were enlarged 10,000 times, each side would measure 0.002 m. Cut out a square 0.002 m by 0.002 m to serve as a model for a virus. (*Hint*: 0.002 m = 2 mm.)
5. Next, find the area in meters of one virus particle at the enlarged size. Remember that the area of a square equals side × side.
6. Now divide the area of the pinhead that you calculated in Step 3 by the area of one virus particle to find out how many viruses could fit on the pinhead.
7. Exchange your work with a partner, and check each other's calculations.

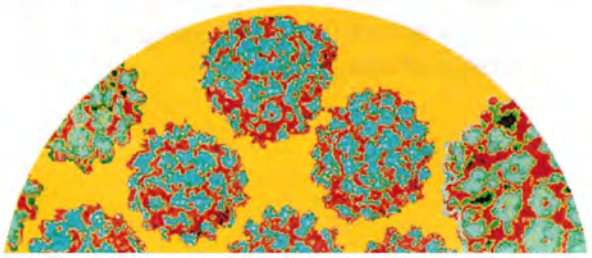
Analyze and Conclude

1. **Calculating** Approximately how many viruses can fit on the head of a pin?
2. **Predicting** How does your calculation compare with the prediction you made? If the two numbers are very different, explain why your prediction may have been inaccurate.
3. **Making Models** What did you learn about the size of viruses by magnifying both the viruses and pinhead to 10,000 times their actual size?
4. **Communicating** In a paragraph, explain why scientists sometimes make and use enlarged models of very small things such as viruses.

More to Explore

Think of another everyday object that you could use to model some other facts about viruses, such as their shapes or how they infect cells. Describe your model and explain why the object would be a good choice.

These papilloma viruses, which cause warts, are about 50 nm in diameter. ▼



Preventing Viral Diseases Of course, you'd probably rather not get sick in the first place. An important tool that helps prevent the spread of many viral diseases is vaccines. A **vaccine** is a substance introduced into the body to stimulate the production of chemicals that destroy specific disease-causing viruses and organisms. A viral vaccine may be made from weakened or altered viruses. Because they have been weakened or altered, the viruses in the vaccine do not cause disease. Instead, they trigger the body's natural defenses. In effect, the vaccine puts the body "on alert." If that disease-causing virus ever invades the body, it is destroyed before it can cause disease. You may have been vaccinated against diseases such as polio, measles, and chickenpox.

Another important way to protect against viral diseases is to keep your body healthy. You need to eat nutritious food, as well as get enough sleep, fluids, and exercise. You can also protect yourself by washing your hands often and by not sharing eating or drinking utensils.

Unfortunately, despite your best efforts, you'll probably get viral infections, such as colds, from time to time. When you do get ill, get plenty of rest, and follow your doctor's recommendations. Also, it's very important to try not to infect others.

Reading Checkpoint **Why don't vaccines cause disease themselves?**

FIGURE 5
Vaccines
Veterinarians can give pets vaccine injections that protect the animals against many viral diseases.

Section 1 Assessment

Target Reading Skill **Sequencing** Refer to your flowcharts about how viruses multiply as you answer Question 3.

Reviewing Key Concepts

1. a. **Defining** What is a virus?
   b. **Comparing and Contrasting** How are viruses similar to organisms?
   c. **Inferring** Scientists hypothesize that viruses could not have existed on Earth before organisms appeared. Use what you know about viruses to support this hypothesis.
2. a. **Identifying** What basic structure do all viruses share?
   b. **Relating Cause and Effect** What role do the proteins in a virus's outer coat play in the invasion of a host cell?
3. a. **Reviewing** How does an active virus multiply?
   b. **Sequencing** List the additional steps that occur when a hidden virus multiplies.
   c. **Classifying** Do you think that the cold virus is an active virus or a hidden virus? Explain.
4. a. **Reviewing** What is often the best treatment for viral diseases?
   b. **Explaining** How are vaccines important in preventing viral diseases?

Writing in Science

Public Service Announcement Write a public service announcement for a radio show that teaches young children how to stay healthy during cold and flu season.

Picking a Puppy

People look for different traits in the dogs they choose. Here is how one expert selected his dog based on good breeding and personality.

James Herriot, a country veterinarian in Yorkshire, England, had owned several dogs during his lifetime. But he had always wanted a Border terrier. These small, sturdy dogs are descendants of working terrier breeds that lived on the border of England and Scotland. For centuries they were used to hunt foxes, rats, and other small animals. In this story, Herriot and his wife, Helen, follow up on an advertisement for Border terrier puppies.

James Herriot
In several popular books published in the 1970s and 1980s, James Herriot wrote warm, humorous stories about the animals he cared for.

◀ **Border terriers**

She [Helen, his wife] turned to me and spoke agitatedly, "I've got Mrs. Mason on the line now. There's only one pup left out of the litter and there are people coming from as far as eighty miles away to see it. We'll have to hurry. What a long time you've been out there!"

We bolted our lunch and Helen, Rosie, granddaughter Emma and I drove out to Bedale. Mrs. Mason led us into the kitchen and pointed to a tiny brindle creature twisting and writhing under the table.

"That's him," she said.

I reached down and lifted the puppy as he curled his little body round, apparently trying to touch his tail with his nose. But that tail wagged furiously and the pink tongue was busy at my hand. I knew he was ours before my quick examination for hernia and overshot jaw.

The deal was quickly struck and we went outside to inspect the puppy's relations. His mother and grandmother were out there. They lived in little barrels which served as kennels and both of them darted out and stood up at our legs, tails lashing, mouths panting in delight. I felt vastly reassured. With happy, healthy ancestors like those I knew we had every chance of a first rate dog.

As we drove home with the puppy in Emma's arms, the warm thought came to me. The wheel had indeed turned. After nearly fifty years I had my Border terrier.

Language Arts Activity

James Herriot describes this scene using dialog and first-person narrative. The narrative describes Herriot's feelings about a memorable event—finally finding the dog he had wanted for so long. Write a first-person narrative describing a memorable event in your life. You might choose a childhood memory or a personal achievement at school. What emotions did you feel? How did you make your decision? If possible, use dialog in your writing.

Section 2

Bacteria

Reading Preview

Key Concepts

- How do the cells of bacteria differ from those of eukaryotes?
- What do bacteria need to survive?
- Under what conditions do bacteria thrive and reproduce?
- What positive roles do bacteria play in people's lives?

Key Terms

- bacteria • flagellum
- binary fission
- asexual reproduction
- sexual reproduction
- conjugation • endospore
- pasteurization • decomposer

Target Reading Skill

Building Vocabulary After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone **Discover Activity**

How Quickly Can Bacteria Multiply?

1. Your teacher will give you some beans and paper cups. Number the cups 1 through 8. Each bean will represent a bacterial cell.
2. Put one bean into cup 1 to represent the first generation of bacteria. Approximately every 20 minutes, a bacterial cell reproduces by dividing into two cells. Put two beans into cup 2 to represent the second generation of bacteria.
3. Calculate how many bacterial cells there would be in the third generation if each cell in cup 2 divided into two cells. Place the correct number of beans in cup 3.
4. Repeat Step 3 five more times. All the cups should now contain beans. How many cells are in the eighth generation? How much time has elapsed since the first generation?

Think It Over

Inferring Based on this activity, explain why the number of bacteria can increase rapidly in a short period of time.

They thrive in your container of yogurt. They lurk in your kitchen sponge. They coat your skin and swarm inside your nose. You cannot escape them because they live almost everywhere—under rocks, in the ocean, and all over your body. In fact, there are more of these organisms in your mouth than there are people on Earth! You don't notice them because they are very small. These organisms are bacteria.

The Bacterial Cell

Although there are billions of bacteria on Earth, they were not discovered until the late 1600s. A Dutch merchant named Anton van Leeuwenhoek (LAY vun hook) found them by accident. Leeuwenhoek made microscopes as a hobby. One day, while using one of his microscopes to look at scrapings from his teeth, he saw some tiny, wormlike organisms in the sample. However, Leeuwenhoek's microscopes were not powerful enough to see any details inside these organisms.

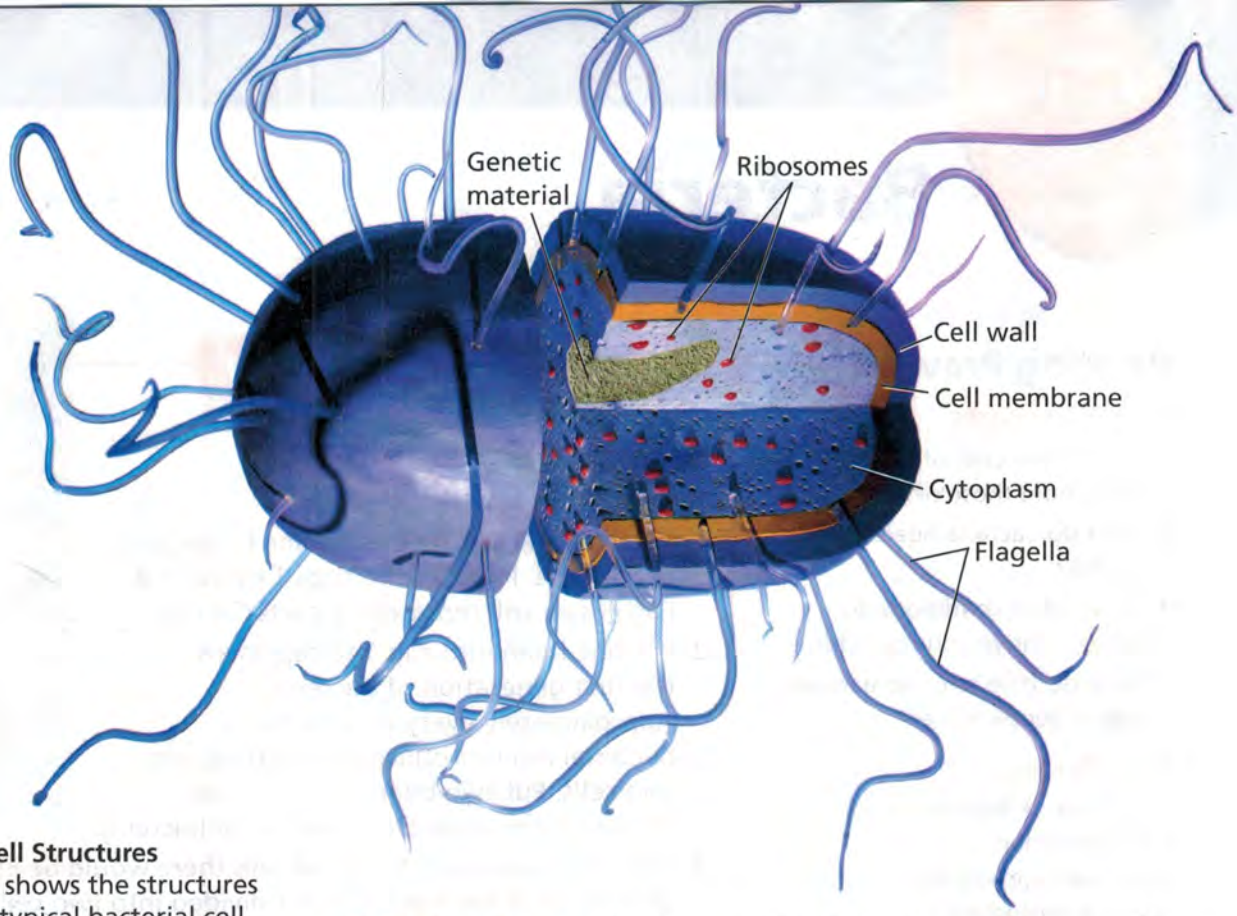
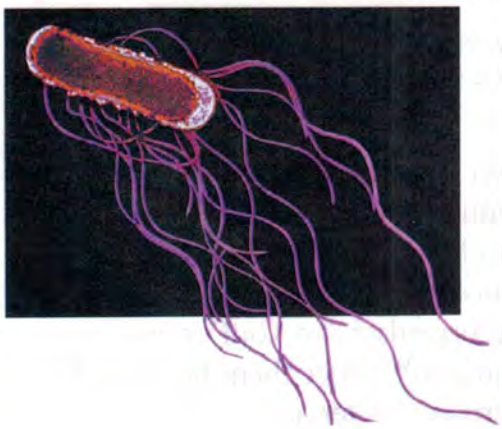


FIGURE 6
Bacterial Cell Structures
This model shows the structures found in a typical bacterial cell.
Relating Diagrams and Photos
What structures does the Salmonella *bacterium in the photograph use to move?*



Cell Structures If Leeuwenhoek had owned a modern microscope, he would have seen the single-celled organisms known as **bacteria** (singular *bacterium*) in detail. **Bacteria are prokaryotes. The genetic material in their cells is not contained in a nucleus.** A bacterial cell lacks a nucleus and also lacks many other structures, such as mitochondria and Golgi bodies, that are found in the cells of eukaryotes.

Most bacterial cells, like plant cells, are surrounded by a rigid cell wall. Just inside the cell wall is the cell membrane. The region inside the cell membrane is called the cytoplasm. Located in the cytoplasm are ribosomes and the genetic material, which looks like a tangled string. If you could untangle the genetic material, you would see that it forms a circular shape.

A bacterial cell may also have a **flagellum** (fluh JEL um) (plural *flagella*), a long, whiplike structure that helps a cell to move. A flagellum moves the cell by spinning in place like a propeller. A bacterial cell can have many flagella, one, or none. Most bacteria that do not have flagella cannot move on their own. Instead, they are carried from place to place by the air, water currents, objects, or other methods.

Cell Sizes Bacteria vary greatly in size. The largest known bacterium is about as big as the period at the end of this sentence. An average bacterium, however, is much smaller. For example, strep throat bacteria are about 0.5 to 1 micrometer in diameter. A micrometer is one millionth of a meter.

Cell Shapes If you observed bacteria under a microscope, you would notice that most bacterial cells have one of three basic shapes: spherical, rodlike, or spiral. The chemical makeup of the cell wall determines the shape of a bacterial cell. The shape of the cell helps scientists identify the type of bacteria. For example, bacteria that cause strep throat are spherical.

Obtaining Food and Energy

From the bacteria that live in soil to those that live in the pores of your skin, all bacteria need certain things to survive. **Bacteria must have a source of food and a way of breaking down the food to release its energy.**

Obtaining Food Some bacteria are autotrophs and make their own food. Autotrophic bacteria make food in one of two ways. Some capture and use the sun's energy as plants do. Others, such as bacteria that live deep in mud, do not use the sun's energy. Instead, these bacteria use the energy from chemical substances in their environment to make their food.

Some bacteria are heterotrophs and cannot make their own food. Instead, these bacteria consume other organisms or the food that other organisms make. Heterotrophic bacteria consume a variety of foods—from milk and meat, which you might also eat, to the decaying leaves on a forest floor.

Respiration Like all organisms, bacteria need a constant supply of energy. This energy comes from breaking down food in the process of respiration. Like many other organisms, most bacteria need oxygen to break down their food. But a few kinds of bacteria do not need oxygen for respiration. In fact, those bacteria die if oxygen is present in their surroundings.

Reading Checkpoint **Where does the energy that bacteria need come from?**

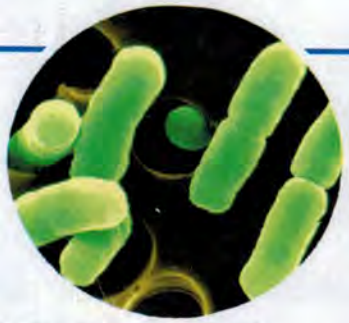
Lab zone Try This Activity

Bacteria for Breakfast

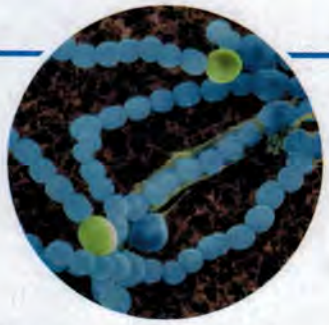
1. Put on your apron. Add water to plain yogurt to make a thin mixture.
2. With a plastic dropper, place a drop of the mixture on a glass slide.
3. Use another plastic dropper to add one drop of methylene blue dye to the slide. **CAUTION:** *This dye can stain your skin.*
4. Put a coverslip on the slide. Observe the slide under both the low- and high-power lenses of a microscope.

Observing Draw what you see under high power.

FIGURE 7
Obtaining Food
Bacteria obtain food in several ways.



▲ These heterotrophic bacteria, found in yogurt, break down the sugars in milk for food.



▲ The autotrophic bacteria that cause the green, cloudy scum in some ponds use the sun's energy to make food.

▲ These autotrophic bacteria, found in hot springs, use chemical energy from their environment to make food.

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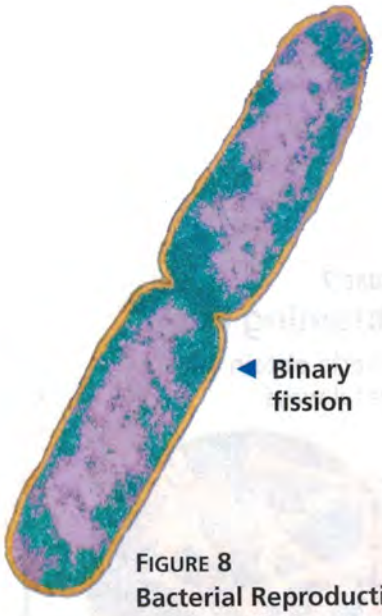
Reproduction

When bacteria have plenty of food, the right temperature, and other suitable conditions, they thrive and reproduce frequently. Under these ideal conditions, some bacteria can reproduce as often as once every 20 minutes. So it's a good thing that growing conditions for bacteria are rarely ideal!

Asexual Reproduction Bacteria reproduce by a process called **binary fission,** in which one cell divides to form two identical cells. Binary fission is a form of asexual reproduction. **Asexual reproduction** is a reproductive process that involves only one parent and produces offspring that are identical to the parent. During binary fission, a cell first duplicates its genetic material and then divides into two separate cells. Each new cell gets its own complete copy of the parent cell's genetic material as well as some of the parent's ribosomes and cytoplasm.

Sexual Reproduction Some bacteria may at times undergo a form of sexual reproduction. In **sexual reproduction,** two parents combine their genetic material to produce a new organism, which differs from both parents. During a process called **conjugation** (kahn juh GAY shun), one bacterium transfers some genetic material to another bacterium through a threadlike bridge. After the transfer, the cells separate.

Conjugation results in bacteria with new combinations of genetic material. Then, when these bacteria divide by binary fission, the new combinations of genetic material pass to the offspring. Conjugation does not increase the number of bacteria. However, it does result in bacteria that are genetically different.



◀ Binary fission

Conjugation ▶

FIGURE 8
Bacterial Reproduction
In binary fission, one cell divides to form two identical cells. During conjugation, one bacterium transfers genetic material to another bacterium.

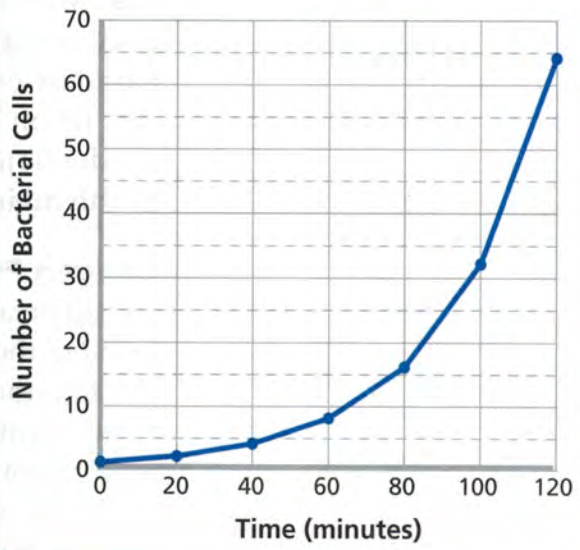
Math Analyzing Data

Population Explosion

Suppose a bacterium reproduces by binary fission every 20 minutes. The new cells survive and reproduce at the same rate. This graph shows how the bacterial population would grow from a single bacterium.

1. **Reading Graphs** What variable is being plotted on the horizontal axis? What is being plotted on the vertical axis?
2. **Interpreting Data** According to the graph, how many cells are there after 20 minutes? After 1 hour? After 2 hours?
3. **Drawing Conclusions** Describe the pattern you see in the way the bacterial population increases over 2 hours.

Bacterial Reproduction by Binary Fission



Endospore Formation Sometimes, conditions in the environment become unfavorable for the growth of bacteria. For example, food sources can disappear, water can dry up, or the temperature can fall or rise dramatically. Some bacteria can survive harsh conditions by forming endospores like those in Figure 9. An **endospore** is a small, rounded, thick-walled, resting cell that forms inside a bacterial cell. It contains the cell's genetic material and some of its cytoplasm.

Because endospores can resist freezing, heating, and drying, they can survive for many years. For example, the bacteria that cause botulism, *Clostridium botulinum*, produce heat-resistant endospores that can survive in improperly canned foods. Endospores are also light—a breeze can lift and carry them to new places. If an endospore lands in a place where conditions are suitable, it opens up. Then the bacterium can begin to grow and multiply.

Reading Checkpoint **Under what conditions do endospores form?**

FIGURE 9
Endospores
The red circles within these bacteria are endospores that can survive for years. When conditions in the environment become favorable, the bacteria can begin to grow and multiply.

The Role of Bacteria in Nature

When you hear the word *bacteria*, you may think about getting sick. After all, strep throat, many ear infections, and other diseases are caused by bacteria. However, most bacteria are either harmless or helpful to people. In fact, in many ways, people depend on bacteria. **Bacteria are involved in oxygen and food production, environmental recycling and cleanup, and in health maintenance and medicine production.**

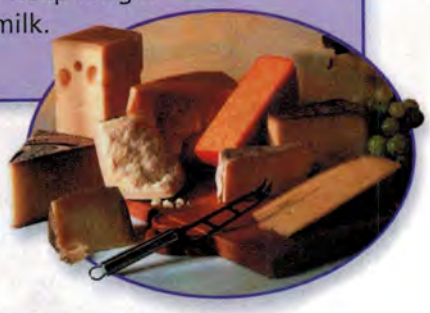
Oxygen Production Would it surprise you to learn that the air you breathe depends in part on bacteria? As autotrophic bacteria use the sun's energy to produce food, they also release oxygen into the air. Billions of years ago, there was little oxygen in Earth's atmosphere. Scientists think that autotrophic bacteria were responsible for first adding oxygen to Earth's atmosphere. Today, the distant offspring of those bacteria help keep oxygen levels in the air stable.

Science and **History**

Bacteria and Foods of the World

Ancient cultures lacked refrigeration and other modern methods of preventing food spoilage. People in these cultures developed ways of using bacteria to preserve foods. You may enjoy some of these foods today.

2300 B.C. Cheese
Ancient Egyptians made cheese from milk. Cheese-making begins when bacteria feed on the sugars in milk. The milk separates into solid curds and liquid whey. The curds are processed into cheeses, which keep longer than milk.



1000 B.C. Pickled Vegetables
The Chinese salted vegetables and packed them in containers. Naturally occurring bacteria fed on the vegetables and produced a sour taste. The salt pulled water out of the vegetables and left them crisp. These vegetables were part of the food rations given to workers who built the Great Wall of China.

500 B.C. Dried Meat
People who lived in the regions around the Mediterranean Sea chopped meat, seasoned it with salt and spices, rolled it, and hung it to dry. Bacteria in the drying meat gave unique flavors to the food. The rolled meat would keep for weeks in cool places.

2500 B.C. | 1500 B.C. | 500 B.C.

Food Production Do you like cheese, sauerkraut, or pickles? The activities of helpful bacteria produce all of these foods and more. For example, bacteria that grow in apple cider change the cider to vinegar. Bacteria that grow in milk produce dairy products such as buttermilk, yogurt, sour cream, and cheeses.

However, some bacteria cause food to spoil when they break down the food's chemicals. Spoiled food usually smells or tastes foul and can make you very sick. Refrigerating and heating foods are two ways to slow down food spoilage. Another method, called pasteurization, is most often used to treat beverages such as milk and juice. During **pasteurization,** the food is heated to a temperature that is high enough to kill most harmful bacteria without changing the taste of the food. As you might have guessed, this process was named after Louis Pasteur, its inventor.

Writing in Science

Research and Write Find out more about one of these ancient food-production methods and the culture that developed it. Write a report about the importance of the food to the culture.

A.D. 500
Soy Sauce

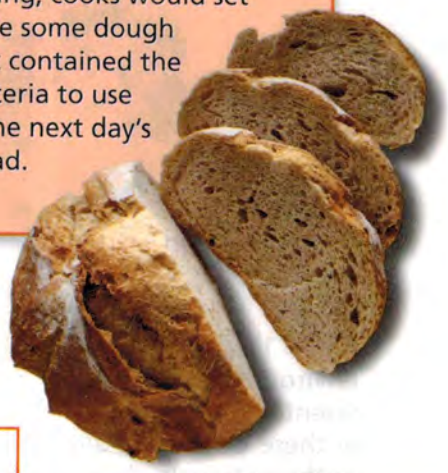
People in China crushed soybeans into mixtures of wheat, salt, bacteria, and other microorganisms. The microorganisms fed on the proteins in the wheat and soybeans. The salt pulled water out of the mixture. The protein-rich soy paste that remained was used to flavor foods. The soy sauce you may use today is made in a similar manner.

A.D. 1500
Chocolate Beverage

People in the West Indies mixed beans from the cocoa plant with bacteria and other microorganisms and then dried and roasted them. The roasted beans were then brewed to produce a beverage with a chocolate flavor. The drink was served cold with honey, spices, and vanilla.

A.D. 1850
Sourdough Bread

Gold prospectors in California ate sourdough bread. The *Lactobacillus sanfrancisco* bacteria gave the bread its sour taste. Each day before baking, cooks would set aside some dough that contained the bacteria to use in the next day's bread.



A.D. 500 A.D. 1500 A.D. 2500

FIGURE 10
Environmental Recycling
Decomposing bacteria are at work recycling the chemicals in these leaves. **Predicting** *What might a forest be like if there were no decomposing bacteria in the soil?*

Environmental Recycling If you recycle glass or plastic, then you have something in common with some heterotrophic bacteria. These bacteria, which live in the soil, are **decomposers**—organisms that break down large chemicals in dead organisms into small chemicals.

Decomposers are "nature's recyclers." They return basic chemicals to the environment for other living things to reuse. For example, the leaves of many trees die in autumn and drop to the ground. Decomposing bacteria spend the next months breaking down the chemicals in the dead leaves. The broken-down chemicals mix with the soil and can then be absorbed by the roots of nearby plants.

Another type of recycling bacteria, called nitrogen-fixing bacteria, help plants survive. Nitrogen-fixing bacteria live in the soil and in swellings on the roots of certain plants, such as peanut, pea, and soybean. These helpful bacteria convert nitrogen gas from the air into nitrogen products that plants need to grow. On their own, plants cannot use nitrogen present in the air. Therefore, nitrogen-fixing bacteria are vital to the plants' survival.

Environmental Cleanup Some bacteria help to clean up Earth's land and water. Can you imagine having a bowl of oil for dinner instead of soup? Well, some bacteria prefer the oil. They convert the poisonous chemicals in oil into harmless substances. Scientists have put these bacteria to work cleaning up oil spills in oceans and gasoline leaks in the soil under gas stations.

Reading Checkpoint **What role do bacterial decomposers play in the environment?**

FIGURE 11
Environmental Cleanup
Scientists use bacteria such as these *Ochrobactrum anthropi* to help clean up oil spills.

Health and Medicine Did you know that many of the bacteria living in your body actually keep you healthy? In your digestive system, for example, your intestines teem with bacteria. Some help you digest your food. Some make vitamins that your body needs. Others compete for space with disease-causing organisms, preventing the harmful bacteria from attaching to your intestines and making you sick.

Scientists have put some bacteria to work making medicines and other substances. The first medicine-producing bacteria were made in the 1970s. By manipulating the bacteria's genetic material, scientists engineered bacteria to produce human insulin. Although healthy people can make their own insulin, those with some types of diabetes cannot. Many people with diabetes need to take insulin daily. Thanks to bacteria's fast rate of reproduction, large numbers of insulin-making bacteria can be grown in huge vats. The human insulin they produce is then purified and made into medicine.

FIGURE 12
Bacteria and Digestion
Bacteria living naturally in your intestines help you digest food.

Section 2 Assessment

Target Reading Skill **Building Vocabulary**
Use your definitions to help answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** Where is the genetic material located in a bacterial cell?
   b. **Describing** What is the role of flagella in a bacterial cell?
2. a. **Listing** What are the three ways in which bacteria obtain food?
   b. **Describing** How do bacteria obtain energy to carry out their functions?
   c. **Inferring** You have just discovered a new bacterium that lives inside sealed cans of food. How do you think these bacteria obtain food and energy?
3. a. **Defining** What is binary fission?
   b. **Explaining** Under what conditions do bacteria thrive and reproduce frequently by binary fission?
   c. **Inferring** Why might bacteria that undergo conjugation be better able to survive when conditions become less than ideal?
4. a. **Listing** A friend states that all bacteria are harmful to people. List three reasons why this statement is inaccurate.
   b. **Applying Concepts** In what ways might bacteria contribute to the success of a garden in which pea plants are growing?

Lab zone At-Home Activity

Edible Bacteria With a family member, look around your kitchen for foods that are made using bacteria. Read the food labels to see if bacteria are used in the food's production. Discuss with your family member the helpful roles that bacteria play in people's lives.

Section 3

Protists

Reading Preview

Key Concept

- What are the characteristics of animal-like, plantlike, and funguslike protists?

Key Terms

- protist • protozoan
- pseudopod
- contractile vacuole • cilia
- symbiosis • mutualism
- algae • spore

Target Reading Skill

Outlining As you read, make an outline about protists that you can use for review. Use the red section headings for the main topics and the blue headings for the subtopics.

Protists
I. What is a protist?
II. Animal-like protists
A. Protozoans with pseudopods
B.
C.

Lab zone **Discover Activity**

What Lives in a Drop of Pond Water?

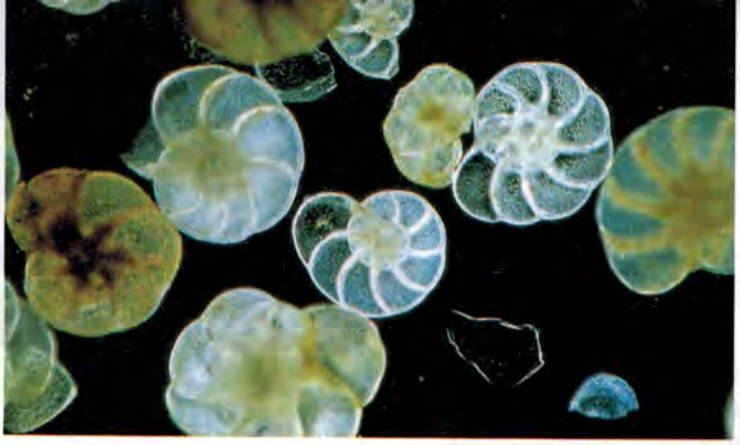
1. Use a plastic dropper to place a drop of pond water on a microscope slide.
2. Put the slide under your microscope's low-power lens. Focus on the objects you see.
3. Find at least three different objects that you think might be organisms. Observe them for a few minutes.
4. Draw the three organisms in your notebook. Below each sketch, describe the movements or behaviors of the organism. Wash your hands thoroughly when you have finished.

Think It Over

Observing What characteristics did you observe that made you think that each organism was alive?

Look at the objects in Figure 13. What do they look like to you? Jewels? Beads? Stained glass ornaments? You might be surprised to learn that these beautiful, delicate structures are the walls of unicellular organisms called diatoms. Diatoms live in both fresh water and salt water and are an important food source for many marine organisms. They have been called the "jewels of the sea."

FIGURE 13
Diatoms
These glasslike organisms are classified as protists.



▲ These shells are the remains of unicellular, animal-like protists called foraminifera.

FIGURE 14 Protists

Protists include animal-like, plantlike, and funguslike organisms.

Comparing and Contrasting *In what ways do protists differ from one another?*

▲ This red alga is a multicellular, plantlike protist found on ocean floors.

▲ The yellow slime mold oozing off the leaf is a funguslike protist.

What Is a Protist?

Diatoms are only one of the vast varieties of protists. **Protists** are eukaryotes that cannot be classified as animals, plants, or fungi. Because protists are so different from one another, you can think of them as the "odds and ends" kingdom. However, protists do share some characteristics. In addition to being eukaryotes, all protists live in moist surroundings.

The word that best describes protists is *diversity*. For example, most protists are unicellular, but some are multicellular. Some are heterotrophs, some are autotrophs, and others are both. Some protists cannot move, while others zoom around their moist surroundings.

Because of the great variety of protists, scientists have proposed several ways of grouping these organisms. One useful way of grouping protists is to divide them into three categories, based on characteristics they share with organisms in other kingdoms: animal-like protists, plantlike protists, and funguslike protists.

Reading Checkpoint **In what kind of environment do all protists live?**

Animal-Like Protists

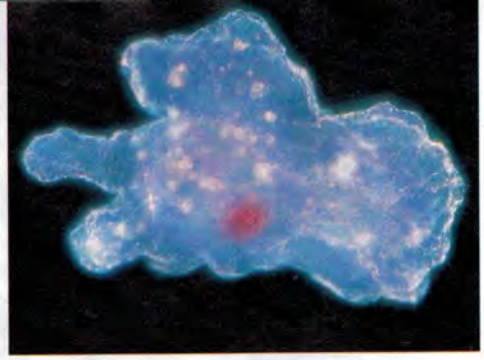
What image pops into your head when you think of an animal? A tiger chasing its prey? A snake slithering onto a rock? Most people immediately associate animals with movement. In fact, movement is often involved with an important characteristic of animals—obtaining food. All animals are heterotrophs that must obtain food by eating other organisms.

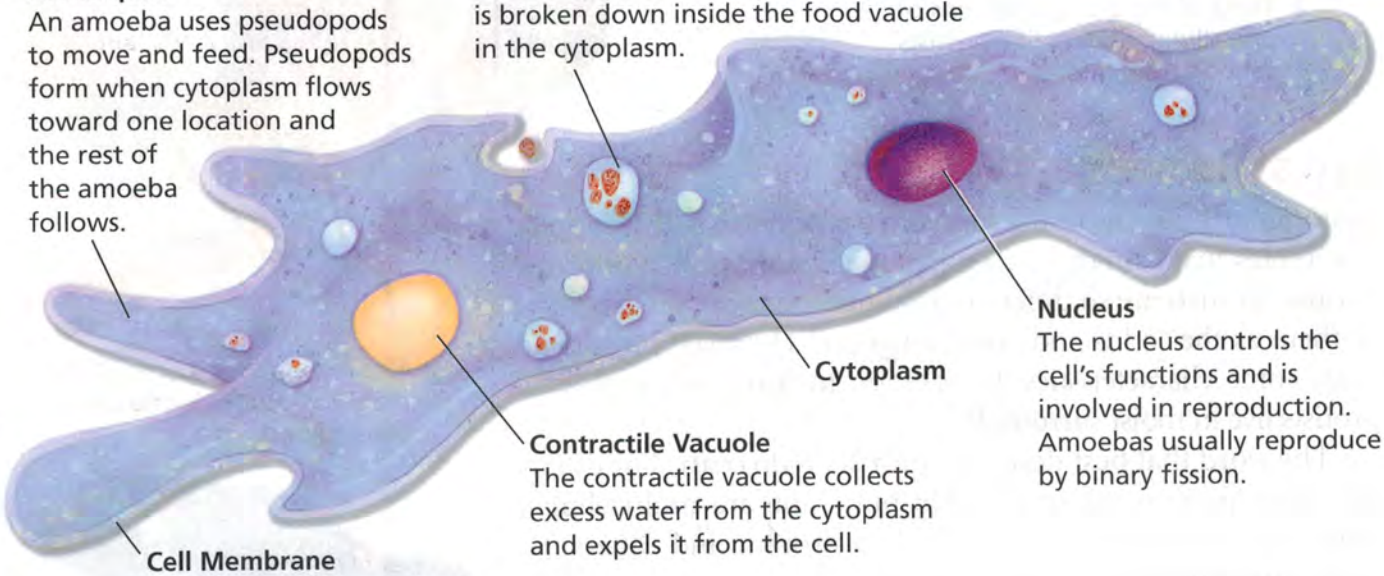
Like animals, animal-like protists are heterotrophs, and most are able to move from place to place to obtain food. But unlike animals, animal-like protists, or **protozoans** (proh tuh ZOH unz), are unicellular. Protozoans can be classified into four groups, based on the way they move and live.

FIGURE 15

Amoeba

Amoebas are sarcodines that live in either water or soil. They feed on bacteria and smaller protists.





Food Vacuole
When the ends of two pseudopods fuse, they form a food vacuole. Food is broken down inside the food vacuole in the cytoplasm.

Pseudopod
An amoeba uses pseudopods to move and feed. Pseudopods form when cytoplasm flows toward one location and the rest of the amoeba follows.

Nucleus
The nucleus controls the cell's functions and is involved in reproduction. Amoebas usually reproduce by binary fission.

Cytoplasm

Contractile Vacuole
The contractile vacuole collects excess water from the cytoplasm and expels it from the cell.

Cell Membrane
Because the cell membrane is very thin and flexible, an amoeba's shape changes constantly.

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Protozoans With Pseudopods The amoeba in Figure 15 belongs to the group of protozoans called sarcodines. Sarcodines move and feed by forming **pseudopods** (SOO duh pahdz)—temporary bulges of the cell. The word *pseudopod* means "false foot." Pseudopods form when cytoplasm flows toward one location and the rest of the organism follows. Pseudopods enable sarcodines to move. For example, amoebas use pseudopods to move away from bright light. Sarcodines also use pseudopods to trap food. The organism extends a pseudopod on each side of the food particle. The two pseudopods then join together, trapping the particle inside.

Protozoans that live in fresh water, such as amoebas, have a problem. Small particles, like those of water, pass easily through the cell membrane into the cytoplasm. If excess water were to build up inside the cell, the amoeba would burst. Fortunately, amoebas have a **contractile vacuole** (kun TRAK til VAK yoo ohl), a structure that collects the extra water and then expels it from the cell.

FIGURE 16
Paramecium
Paramecia are ciliates that live mostly in fresh water. Like amoebas, paramecia feed on bacteria and smaller protists.

Pellicle
A stiff but flexible covering, called the pellicle, surrounds a paramecium and gives it shape.

Contractile Vacuoles
Two contractile vacuoles collect excess water from the cytoplasm and expel it from the cell.

Large Nucleus

Small Nucleus

Anal Pore
Wastes leave through the anal pore.

Cytoplasm

Oral Groove
The oral groove is a funnel-like indentation lined with cilia. The cilia move water containing food into the vacuole that forms at the end of the oral groove.

Cilia
Thousands of cilia project through the pellicle. The beating cilia enable a paramecium to move smoothly in one direction.

Food Vacuole
A food vacuole forms and pinches off from the oral groove. It moves into the cytoplasm. Inside the vacuole, the food is broken down and then distributed.

Protozoans With Cilia The second group of animal-like protists are the ciliates. Ciliates have structures called **cilia** (SIL ee uh), which are hairlike projections from cells that move with a wavelike motion. Ciliates use their cilia to move and obtain food. Cilia act something like tiny oars to move a ciliate. Their movement sweeps food into the organism.

The cells of ciliates, like the paramecium in Figure 16, are complex. Notice that the paramecium has two contractile vacuoles that expel water from the cell. It also has more than one nucleus. The large nucleus controls the everyday tasks of the cell. The small nucleus functions in reproduction.

Paramecia usually reproduce asexually by binary fission. Sometimes, however, paramecia reproduce by conjugation. This occurs when two paramecia join together and exchange some of their genetic material.

Reading Checkpoint What are cilia?

FIGURE 17
Giardia
When people drink from freshwater streams and lakes, they can get hiker's disease. *Giardia intestinalis* (inset) is the protozoan responsible for this disease.
Inferring *Why is it important for hikers to filter stream water?*

Protozoans With Flagella The third group of protozoans are flagellates (FLAJ uh lits), protists that use long, whiplike flagella to move. A flagellate may have one or more flagella.

Some of these protozoans live inside the bodies of other organisms. For example, one type of flagellate lives in the intestines of termites. There, they digest the wood that the termites eat, producing sugars for themselves and for the termites. In turn, the termites protect the protozoans. The interaction between these two species is an example of **symbiosis** (sim bee OH sis)—a close relationship in which at least one of the species benefits. When both partners benefit from living together, the relationship is a type of symbiosis called **mutualism.**

Sometimes, however, a protozoan harms its host. For example, *Giardia* is a parasite in humans. Wild animals, such as beavers, deposit *Giardia* in freshwater streams, rivers, and lakes. When a person drinks water containing *Giardia*, these protozoans attach to the person's intestine, where they feed and reproduce. The person develops a serious intestinal condition commonly called hiker's disease.

Protozoans That Are Parasites The fourth type of protozoans are characterized more by the way they live than by the way they move. They are all parasites that feed on the cells and body fluids of their hosts. These protozoans move in a variety of ways. Some have flagella, and some depend on hosts for transport. One even produces a layer of slime that allows it to slide from place to place!

Many of these parasites have more than one host. For example, *Plasmodium* is a protozoan that causes malaria, a disease of the blood. Two hosts are involved in *Plasmodium's* life cycle—humans and a species of mosquitoes found in tropical areas. The disease spreads when a healthy mosquito bites a person with malaria, becomes infected, and then bites a healthy person. Symptoms of malaria include high fevers that alternate with severe chills. These symptoms can last for weeks, then disappear, only to reappear a few months later.

Reading Checkpoint **What is symbiosis?**

FIGURE 18
Malaria Mosquito
Anopheles mosquitoes can carry the parasitic protozoan *Plasmodium*, which causes malaria in people.

Plantlike Protists

Plantlike protists, which are commonly called **algae** (AL jee), are extremely diverse. **Like plants, algae are autotrophs.** Most are able to use the sun's energy to make their own food.

Algae play a significant role in many environments. For example, algae that live near the surface of ponds, lakes, and oceans are an important food source for other organisms in the water. In addition, much of the oxygen in Earth's atmosphere is made by these algae.

Algae vary greatly in size. Some algae are unicellular, while others are multicellular. Still others are groups of unicellular organisms that live together in colonies. Colonies can contain from a few cells up to thousands of cells. In a colony, most cells carry out all functions. But, some cells may become specialized to perform certain functions, such as reproduction.

Algae exist in a wide variety of colors because they contain many types of pigments. You may recall that pigments are chemicals that produce color. Depending on their pigments, algae can be green, yellow, red, brown, orange, or even black.

Diatoms Diatoms are unicellular protists with beautiful glasslike cell walls. Some float near the surface of lakes or oceans. Others attach to objects such as rocks in shallow water. Diatoms are a food source for heterotrophs in the water. Many diatoms can move by oozing chemicals out of slits in their cell walls. They then glide in the slime.

When diatoms die, their cell walls collect on the bottoms of oceans and lakes. Over time, they form layers of a coarse substance called diatomaceous (dy uh tuh MAY shus) earth. Diatomaceous earth makes a good polishing agent and is used in household scouring products. It is even used as an insecticide—the diatoms' sharp cell walls puncture the bodies of insects.

Dinoflagellates Dinoflagellates (dy noh FLAJ uh lits) are unicellular algae surrounded by stiff plates that look like a suit of armor. Because they have different amounts of green, orange, and other pigments, dinoflagellates exist in a variety of colors.

All dinoflagellates have two flagella held in grooves between their plates. When the flagella beat, the dinoflagellates twirl like toy tops as they move through the water. Many glow in the dark. They light up the ocean's surface when disturbed by a passing boat or swimmer.

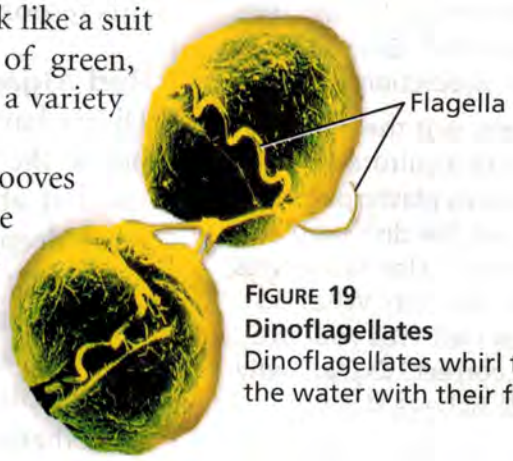


FIGURE 19
Dinoflagellates
Dinoflagellates whirl through the water with their flagella.

Lab zone **Try This Activity**

Watching Protists

In this activity you will watch the interaction between paramecium, an animal-like protist, and *Chlorella*, a plantlike protist.

1. Use a plastic dropper to place 1 drop of paramecium culture on a microscope slide. Add some cotton fibers to slow down the paramecia.
2. Use the microscope's low-power objective to find some paramecia.
3. Add 1 drop of *Chlorella* to the paramecium culture on your slide.
4. Switch to high power and locate a paramecium. Observe what happens. Then wash your hands.

Inferring What evidence do you have that paramecia are heterotrophs? That *Chlorella* are autotrophs?

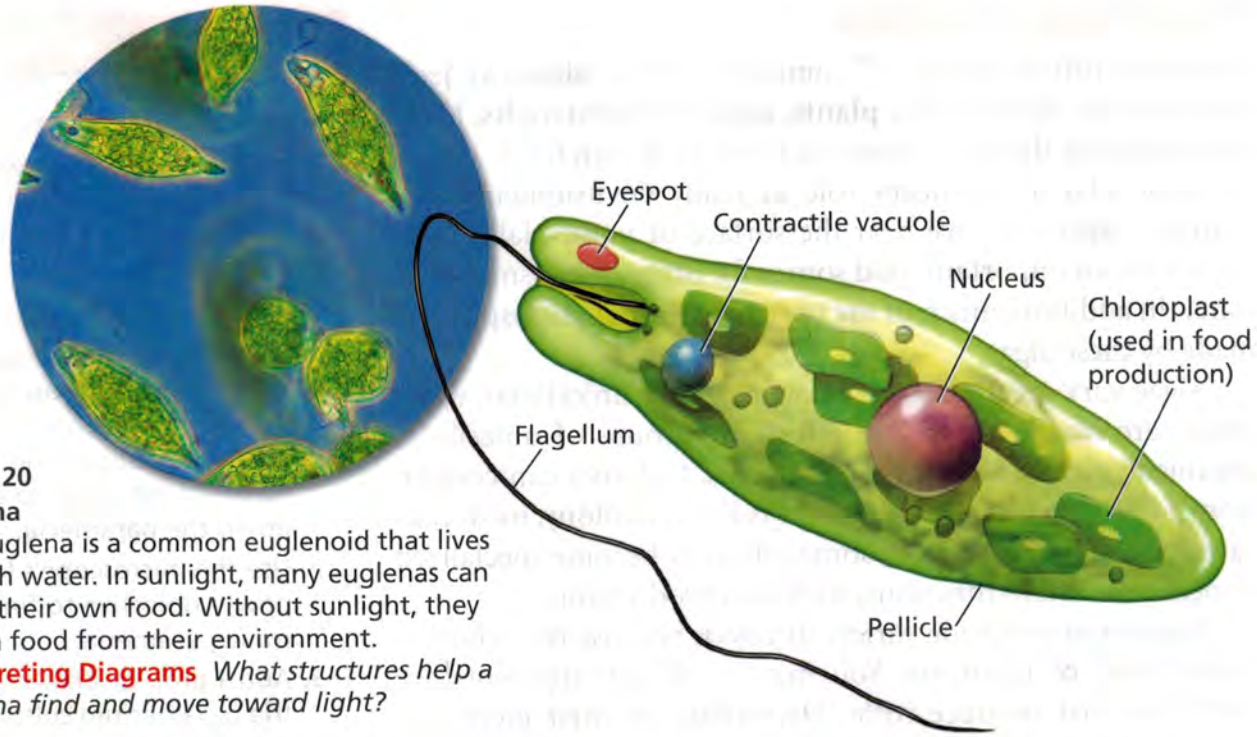


FIGURE 20
Euglena
The euglena is a common euglenoid that lives in fresh water. In sunlight, many euglenas can make their own food. Without sunlight, they obtain food from their environment.
Interpreting Diagrams *What structures help a euglena find and move toward light?*

Euglenoids Euglenoids (yoo GLEE noydz) are green, unicellular algae that are found mostly in fresh water. Unlike other algae, euglenoids have one animal-like characteristic—they can be heterotrophs under certain conditions. When sunlight is available, most euglenoids are autotrophs that produce their own food. However, when sunlight is not available, euglenoids will act like heterotrophs by obtaining food from their environment. Some euglenoids live entirely as heterotrophs.

In Figure 20, you see a euglena, which is a common euglenoid. Notice the long, whiplike flagellum that helps the organism move. Locate the eyespot near the flagellum. Although the eyespot is not really an eye, it contains pigments. These pigments are sensitive to light and help the euglena recognize the direction of a light source. You can imagine how important this response is to an organism that needs light to make food.

Red Algae Almost all red algae are multicellular seaweeds. Divers have found red algae growing more than 260 meters below the ocean's surface. Their red pigments are especially good at absorbing the small amount of light that is able to reach deep ocean waters.

People use red algae in a variety of ways. Carrageenan (ka ruh JEE nun) and agar, substances extracted from red algae, are used in products such as ice cream and hair conditioner. For people in many Asian cultures, red algae is a nutrient-rich food that is eaten fresh, dried, or toasted.

Lab zone Skills Activity

Predicting

Predict what will happen when you pour a culture of euglena into a petri dish, and then cover half the dish with aluminum foil. Give a reason for your prediction.

Then carry out the experiment with a culture of euglena in a plastic petri dish. Cover half the dish with aluminum foil. After 10 minutes, uncover the dish. What do you observe? Was your prediction correct? Explain why euglena behave this way.

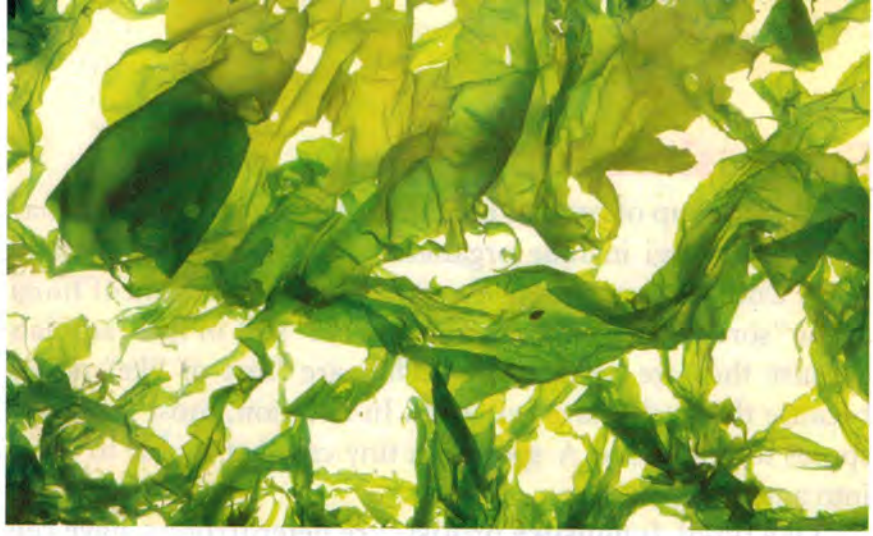


FIGURE 21
Green Algae
Green algae range in size from unicellular organisms to multicellular seaweeds. This multicellular sea lettuce, *Ulva*, lives in oceans.

Green Algae Green algae, which contain green pigments, are quite diverse. Most green algae are unicellular. Some, however, form colonies, and a few are multicellular. Most green algae live in either fresh water or salt water. The few that live on land are found on rocks, in the crevices of tree bark, or in moist soils.

Green algae are actually very closely related to plants that live on land. Green algae and plants contain the same type of chlorophyll and share other important similarities. In fact, some scientists think that green algae belong in the plant kingdom.

Brown Algae Many of the organisms that are commonly called seaweeds are brown algae. In addition to their brown pigment, brown algae also contain green, yellow, and orange pigments. As you can see in Figure 22, a typical brown alga has many plantlike structures. Holdfasts anchor the alga to rocks. Stalks support the blades, which are the leaflike structures of the alga. Many brown algae also have gas-filled sacs called bladders that allow the algae to float upright in the water.

Brown algae flourish in cool, rocky waters. Brown algae called rockweed live along the Atlantic coast of North America. Giant kelps, which can grow as long as 100 meters, live in some Pacific coastal waters. The giant kelps form large underwater "forests" where many organisms, including sea otters and abalone, live.

Some people eat brown algae. In addition, substances called algins are extracted from brown algae and used as thickeners in puddings and other foods.

Reading Checkpoint **What color pigments can brown algae contain?**

FIGURE 22 Brown Algae
Giant kelps are brown algae that have many plantlike structures.
Interpreting Diagrams *What plant structures do the kelp's holdfasts and blades resemble?*

Funguslike Protists

The third group of protists are the funguslike protists. You may recall that fungi include organisms such as mushrooms and yeast. Until you learn more about fungi, you can think of fungi as the "sort of like" organisms. Fungi are "sort of like" animals because they are heterotrophs. They are "sort of like" plants because their cells have cell walls. In addition, most fungi use spores to reproduce. A **spore** is a tiny cell that is able to grow into a new organism.

Like fungi, funguslike protists are heterotrophs, have cell walls, and use spores to reproduce. All funguslike protists are able to move at some point in their lives. The three types of funguslike protists are slime molds, water molds, and downy mildews.

Slime Molds Slime molds are often brilliantly colored. They live on forest floors and other moist, shady places. They ooze along the surfaces of decaying materials, feeding on bacteria and other microorganisms. Some slime molds are so small that you need a microscope to see them. Others may cover an area of several meters!

Slime molds begin their life cycle as tiny, individual amoeba-like cells. The cells use pseudopods to feed and creep around. Later, the cells grow bigger or join together to form a giant, jellylike mass. In some species, the giant mass is multicellular and forms when food is scarce. In others, the giant mass is actually a giant cell with many nuclei.

The mass oozes along as a single unit. When environmental conditions become harsh, spore-producing structures grow out of the mass and release spores. Eventually the spores develop into a new generation of slime molds.

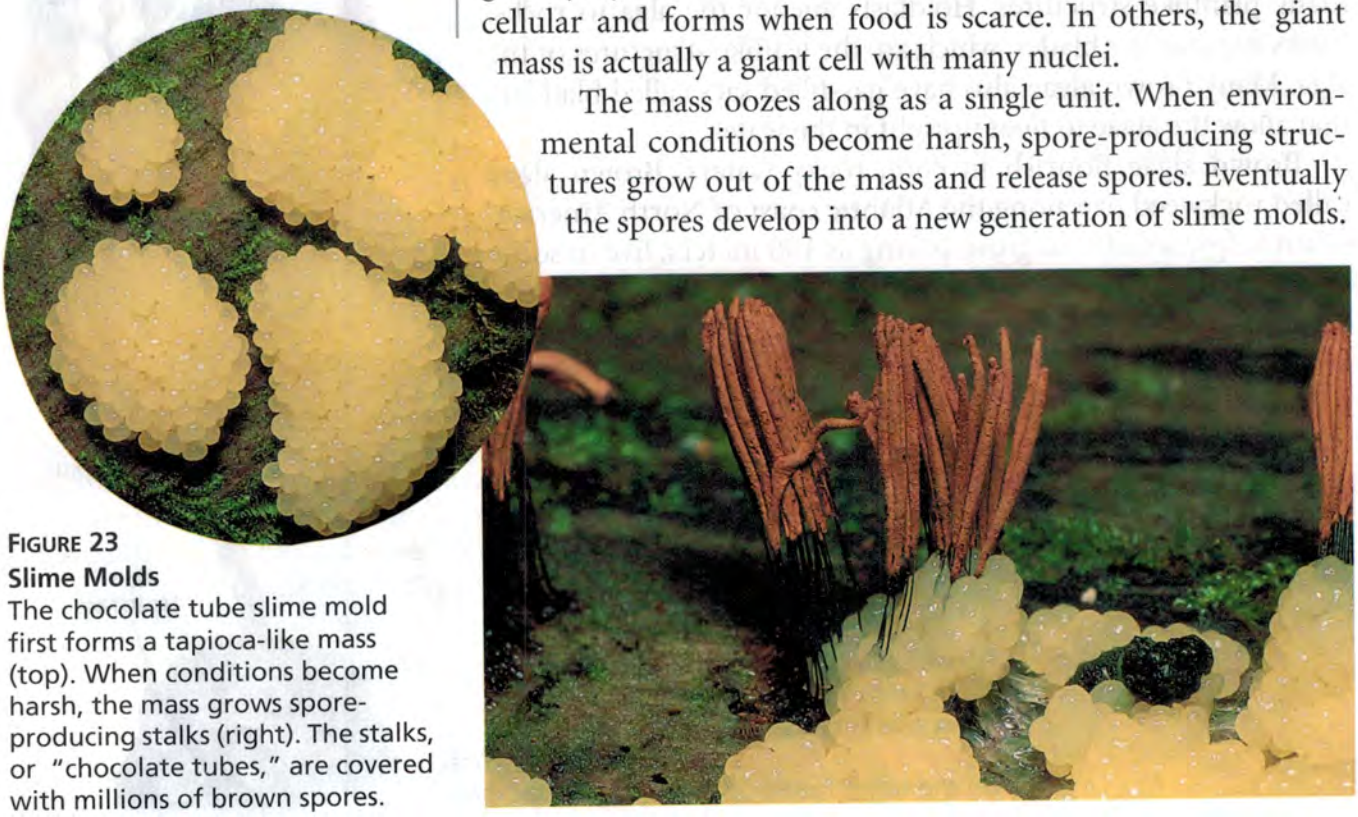


FIGURE 23
Slime Molds
The chocolate tube slime mold first forms a tapioca-like mass (top). When conditions become harsh, the mass grows spore-producing stalks (right). The stalks, or "chocolate tubes," are covered with millions of brown spores.

Water Molds and Downy Mildews Most water molds and downy mildews live in water or moist places. These organisms often grow as tiny threads that look like fuzz. Figure 24 shows a fish attacked by a water mold and a leaf covered by downy mildew.

Water molds and downy mildews attack many food crops, such as potatoes, corn, and grapes. A water mold impacted history when it destroyed the Irish potato crops in 1845 and 1846. The loss of these crops led to a famine. More than one million people in Ireland died, and many others moved to the United States and other countries.

▲ Water mold on fish

▼ Downy mildew on grape leaf

Reading Checkpoint **In what environments are water molds found?**

FIGURE 24
Water Molds and Downy Mildews
Many water molds are decomposers of dead aquatic organisms. Others are parasites of fish and other animals. Downy mildews are parasites of many food crops.

Section 3 Assessment

Target Reading Skill **Outlining** Use your outline about protists to help you answer the questions below.

Reviewing Key Concepts

1. a. **Listing** List the four types of animal-like protists. How does each type move or live?
   b. **Comparing and Contrasting** How are these four types of protists similar to animals? How are they different?
   c. **Classifying** You observe an animal-like protist under the microscope. It has no hairlike or whiplike structures. It moves by forming temporary bulges of cytoplasm. How would you classify this protist?
2. a. **Reviewing** In what way are diatoms, dinoflagellates, and other plantlike protists similar to plants?
   b. **Making Generalizations** Why is sunlight important to plantlike protists?
   c. **Making Judgments** Would you classify euglena as an animal-like protist or as a plantlike protist? Explain.
3. a. **Listing** What are the three types of funguslike protists?
   b. **Describing** In what ways are funguslike protists similar to fungi?

Lab zone At-Home Activity

Algae Scavenger Hunt Look around your house with a family member to find products that contain substances made from algae. Look at both food and nonfood items. Before you begin, tell your family member that substances such as diatomaceous earth, algin, and carrageenan are products that come from algae. Make a list of the products and the algae-based ingredient they contain. Share your list with the class.

Section 4

Fungi

Reading Preview

Key Concepts

- What characteristics do fungi share?
- How do fungi reproduce?
- What roles do fungi play in nature?

Key Terms

- fungi • hyphae
- fruiting body • budding
- lichen

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, write answers to your questions.

Fungi

Question	Answer
What are fungi?	Fungi are . . .

Lab zone Discover Activity

Do All Molds Look Alike?

1. Your teacher will give you two sealed, clear plastic bags—one containing moldy bread and another containing moldy fruit. **CAUTION:** *Do not open the sealed bags at any time.*
2. In your notebook, describe what you see.
3. Next, use a hand lens to examine each mold. Sketch each mold in your notebook and list its characteristics.
4. Return the sealed bags to your teacher. Wash your hands.

Think It Over

Observing How are the molds similar? How are they different?

A speck of dust lands on a cricket's back. But this is no ordinary dust—it is alive! Tiny glistening threads emerge from the dust and begin to grow into the cricket's moist body. As they grow, the threads release chemicals that slowly dissolve the cricket's tissues. Soon, the cricket's body is little more than a hollow shell filled with a tangle of the threads. Then the threads begin to grow up and out of the dead cricket, producing long stalks with knobs at their tips. When a knob breaks open, it will release thousands of dustlike specks, which the wind can carry to new victims.

What Are Fungi?

The strange cricket-killing organism is a member of the fungi kingdom. Although you may not have heard of a cricket-killing fungus before, you are probably familiar with other kinds of fungi. For example, the molds that grow on stale bread and the mushrooms that sprout in yards are all fungi.

Most **fungi** share several important characteristics. **Fungi are eukaryotes that have cell walls, are heterotrophs that feed by absorbing their food, and use spores to reproduce.** In addition, fungi need moist, warm places in which to grow. They thrive on moist foods, damp tree barks, lawns coated with dew, and even wet bathroom tiles.

A killer fungus has attacked this bush cricket.

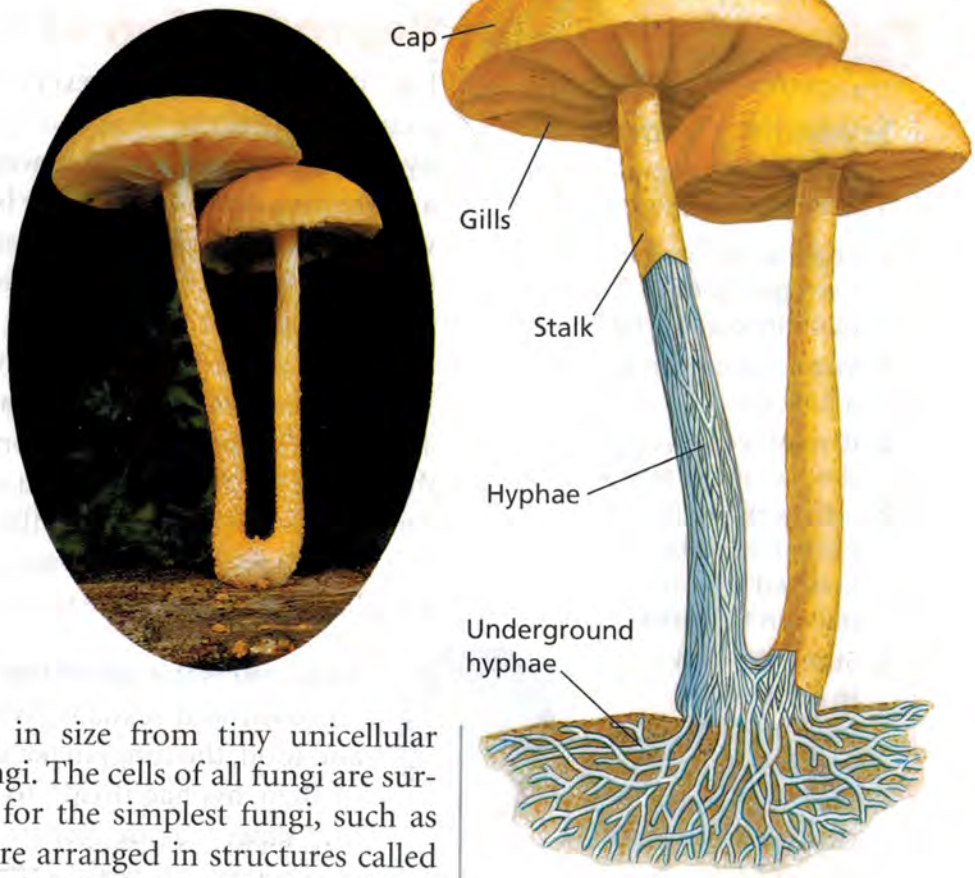


FIGURE 25
Structure of a Mushroom
The hyphae in the stalk and cap of a mushroom are packed tightly to form firm structures. Underground hyphae are arranged loosely.
Inferring *What function might underground hyphae perform?*

Cell Structure Fungi range in size from tiny unicellular yeasts to large multicellular fungi. The cells of all fungi are surrounded by cell walls. Except for the simplest fungi, such as yeast, the cells of most fungi are arranged in structures called hyphae. **Hyphae** (HY fee) (singular hypha) are the branching, threadlike tubes that make up the bodies of multicellular fungi. The hyphae of some fungi are continuous threads of cytoplasm that contain many nuclei. Substances move quickly and freely through the hyphae.

What a fungus looks like depends on how its hyphae are arranged. In some fungi, the threadlike hyphae are loosely tangled. Fuzzy-looking molds that grow on old foods have loosely tangled hyphae. Other fungi have tightly packed hyphae. The stalks and caps of mushrooms are made of hyphae packed so tightly that they appear solid. Underground, however, a mushroom's hyphae form a loose, threadlike maze in the soil.

Obtaining Food Fungi absorb food through hyphae that grow into a food source. First, the fungus grows hyphae into the food source. Then digestive chemicals ooze from the hyphae into the food. The chemicals break down the food into small substances that can be absorbed by the hyphae. As an analogy, imagine yourself sinking your fingers down into a chocolate cake and dripping digestive chemicals out of your fingertips. Then imagine your fingers absorbing the digested particles of the cake!

Reading Checkpoint **What do the bodies of multicellular fungi consist of?**

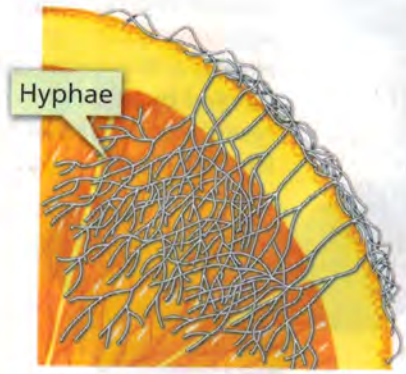


FIGURE 26
Mold Growing on Food Source
The mold *Penicillium* often grows on old fruits such as oranges. Some of its hyphae grow deep into the food source.

Lab zone Try This Activity

Spreading Spores

In this activity, you will make a model of a fruiting body.

1. Break a cotton ball into five equal pieces. Roll each piece into a tiny ball.
2. Insert the cotton balls into a balloon.
3. Repeat Steps 1 and 2 until the balloon is almost full.
4. Inflate the balloon. Tie a knot in its neck. Tape the knotted end of the balloon to a stick.
5. Stand the stick upright in a mound of modeling clay.
6. Pop the balloon with a pin. Observe what happens.

Making Models Draw a diagram of the model you made. Label the stalk, the spore case, and the spores. Use your model to explain why fungi are found just about everywhere.

Reproduction in Fungi

Like it or not, fungi are everywhere. The way they reproduce guarantees their survival and spread. **Fungi usually reproduce by making spores. The lightweight spores are surrounded by a protective covering and can be carried easily through air or water to new sites.** Fungi produce millions of spores, more than can ever survive. Only a few spores will fall where conditions are right for them to grow.

Fungi produce spores in reproductive structures called **fruiting bodies.** The appearances of fruiting bodies vary among different fungi. For some fungi, such as mushrooms, the part of the fungus that you see is the fruiting body. In other fungi, such as bread molds, the fruiting bodies are tiny, stalklike hyphae that grow upward from the rest of the hyphae. A knoblike spore case at the tip of each stalk contains the spores.

Asexual Reproduction Most fungi reproduce both asexually and sexually. When there is adequate moisture and food, the fungi make spores asexually. Cells at the tips of their hyphae divide to form spores. The spores grow into fungi that are genetically identical to the parent.

Unicellular yeast cells undergo a form of asexual reproduction called **budding.** In budding, no spores are produced. Instead, a small yeast cell grows from the body of a parent cell in a way somewhat similar to the way a bud forms on a tree branch. The new cell then breaks away and lives on its own.

Sexual Reproduction Most fungi can also reproduce sexually, especially when growing conditions become unfavorable. In sexual reproduction, the hyphae of two fungi grow together and genetic material is exchanged. Eventually, a new reproductive structure grows from the joined hyphae and produces spores. The spores develop into fungi that differ genetically from either parent.

Classification of Fungi Figure 28 shows three major groups of fungi. The groups are named for the appearance of their reproductive structures. Additional groups include water species that produce spores with flagella and those that form tight associations with plant roots.

Reading Checkpoint **What is budding?**

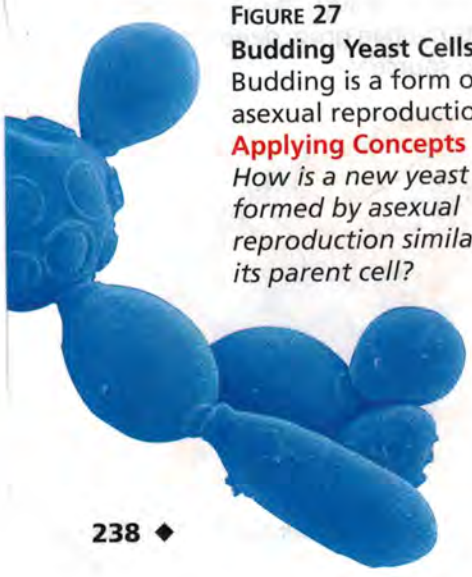


FIGURE 27
Budding Yeast Cells
Budding is a form of asexual reproduction.
Applying Concepts
How is a new yeast cell formed by asexual reproduction similar to its parent cell?

The Role of Fungi in Nature

Fungi affect humans and other organisms in many ways. **Many fungi provide foods for people. Fungi play important roles as decomposers and recyclers on Earth. Some fungi cause disease while others fight disease. Still other fungi live in symbiosis with other organisms.**

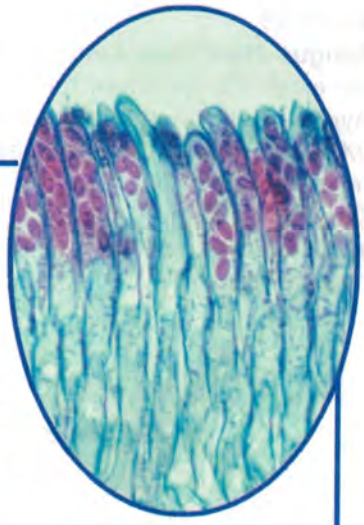
Food and Fungi Yeasts, molds, and mushrooms are important food sources. Bakers add yeast to bread dough to make it rise. Yeast cells use the sugar in the dough for food and produce carbon dioxide gas as they feed. The gas forms bubbles, which cause the dough to rise. You see these bubbles as holes in a slice of bread. Molds are used to make foods such as some cheeses. The blue streaks in blue cheese, for example, are actually growths of *Penicillium roqueforti*. People enjoy eating mushrooms in salads and on pizza. You should never pick or eat wild mushrooms, however, because some mushrooms are extremely poisonous.

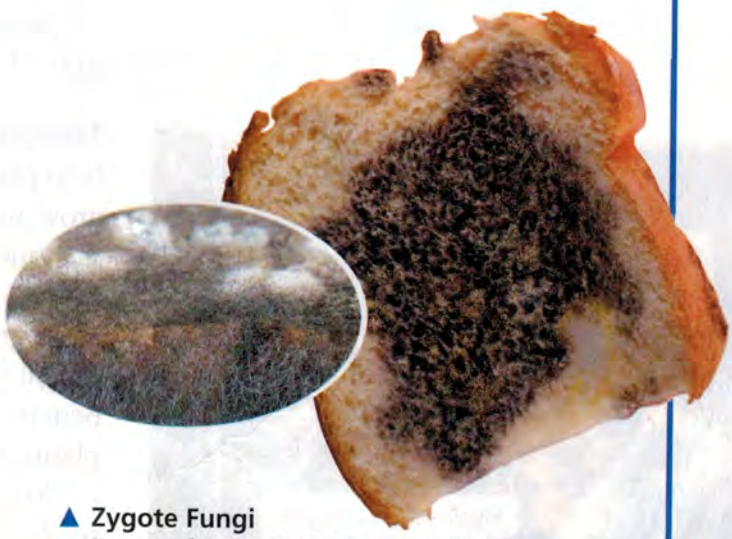
FIGURE 28
Classification of Fungi

Three major groups of fungi include sac fungi, club fungi, and zygote fungi.

▲ **Club Fungi**
Club fungi produce spores in tiny clublike structures. This group includes mushrooms, rusts, and puffballs, such as these.

Sac Fungi ▶
Sac fungi produce spores in structures that look like long sacs, such as these. The largest group of fungi, they include yeasts, morels, and truffles.





▲ **Zygote Fungi**
Zygote fungi produce very resistant spores. This group includes many common fruit and bread molds, like this *Rhizopus*.

Environmental Recycling Like bacteria, many fungi are decomposers. For example, many fungi live in the soil and break down the chemicals in dead plant matter. This process returns important nutrients to the soil. Without fungi and bacteria, Earth would be buried under dead plants and animals!

Disease-Fighting Fungi In 1928, a Scottish biologist named Alexander Fleming was examining petri dishes in which he was growing bacteria. To his surprise, Fleming noticed a spot of a bluish-green mold growing in one dish. Curiously, no bacteria were growing near the mold. Fleming hypothesized that the mold, a fungus named *Penicillium*, produced a substance that killed the bacteria near it.

Fleming's work contributed to the development of the first antibiotic, penicillin. Since the discovery of penicillin, many antibiotics have been isolated from both fungi and bacteria.

Disease-Causing Fungi Many fungi are parasites that cause serious diseases in plants. The sac fungus that causes Dutch elm disease is responsible for killing millions of elm trees in North America and Europe. Corn smut and wheat rust are two club fungi that cause diseases in important food crops. Fungal plant diseases also affect other crops, including rice, cotton, and soybeans, resulting in huge crop losses every year.

Some fungi cause diseases in humans. Athlete's foot fungus causes an itchy irritation in the damp places between toes. Ringworm, another fungal disease, causes an itchy, circular rash on the skin. Because the fungi that cause these diseases produce spores at the site of infection, the diseases can spread easily from person to person. Both diseases can be treated with antifungal medications.

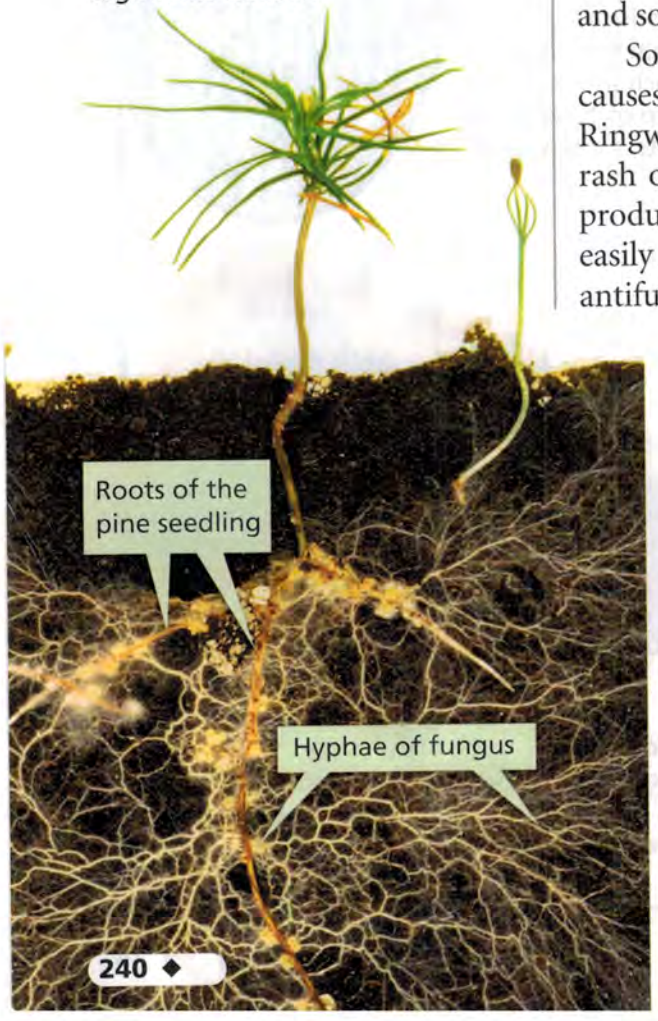


FIGURE 29
Fungus–Plant Root Associations
An extensive system of fungal hyphae has grown in association with the roots of the pine seedling in the middle.
Classifying *What type of symbiosis do these two organisms exhibit?*

Fungus-Plant Root Associations Some fungi help plants grow larger and healthier when their hyphae grow into, or on, the plant's roots. The hyphae spread out underground and absorb water and nutrients from the soil for the plant. With more water and nutrients, the plant grows larger than it would have grown without its fungal partner. The plant is not the only partner that benefits. The fungi get to feed on the extra food that the plant makes and stores.

Most plants have fungal partners. Many plants are so dependent on the fungi that they cannot survive without them. For example, orchid seeds cannot develop without their fungal partners.

FIGURE 30 Lichens
The British soldier lichen consists of a fungus and an alga. The inset shows how entwined the alga is among the fungus's hyphae.

Lichens A **lichen** (LY kun) consists of a fungus and either algae or autotrophic bacteria that live together in a mutualistic relationship. You have probably seen some familiar lichens—irregular, flat, crusty patches that grow on tree barks or rocks. The fungus benefits from the food produced by the algae or bacteria. The algae or bacteria, in turn, obtain shelter, water, and minerals from the fungus.

Lichens are often called "pioneer" organisms because they are the first organisms to appear on the bare rocks in an area after a volcanic eruption, fire, or rock slide has occurred. Over time, the lichens break down the rock into soil in which other organisms can grow. Lichens are also useful as indicators of air pollution. Many species of lichens are very sensitive to pollutants and die when pollution levels rise. By monitoring the growth of lichens, scientists can assess the air quality in an area.

Reading Checkpoint **What two organisms make up a lichen?**

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Section 4 Assessment

Target Reading Skill **Asking Questions** Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. **Listing** List three characteristics that a bread mold shares with a mushroom.
   b. **Comparing and Contrasting** How are the cells of a bread mold arranged? How are the cells of a mushroom arranged?
   c. **Summarizing** How does the cell structure of a fungus help it obtain food?
2. a. **Reviewing** What role do spores play in the reproduction of fungi?
   b. **Sequencing** Outline the steps by which fungi produce spores by sexual reproduction.
   c. **Inferring** Why is it advantageous to a fungus to produce millions of spores?
3. a. **Identifying** Name six roles that fungi play in nature.
   b. **Predicting** Suppose all the fungi in a forest disappeared. What do you think the forest would be like without fungi?

Writing in Science

Wanted Poster Design a "Wanted" poster for a mold that has been ruining food in your kitchen. Present the mold as a "criminal of the kitchen." Include detailed descriptions of the mold's physical characteristics, what it needs to grow, how it grows, and any other details that will help your family identify this mold. Propose ways to prevent new molds from growing in your kitchen.

Lab zone **Skills Lab**

What's for Lunch?

Problem

How does the presence of sugar or salt affect the activity of yeast?

Skills Focus

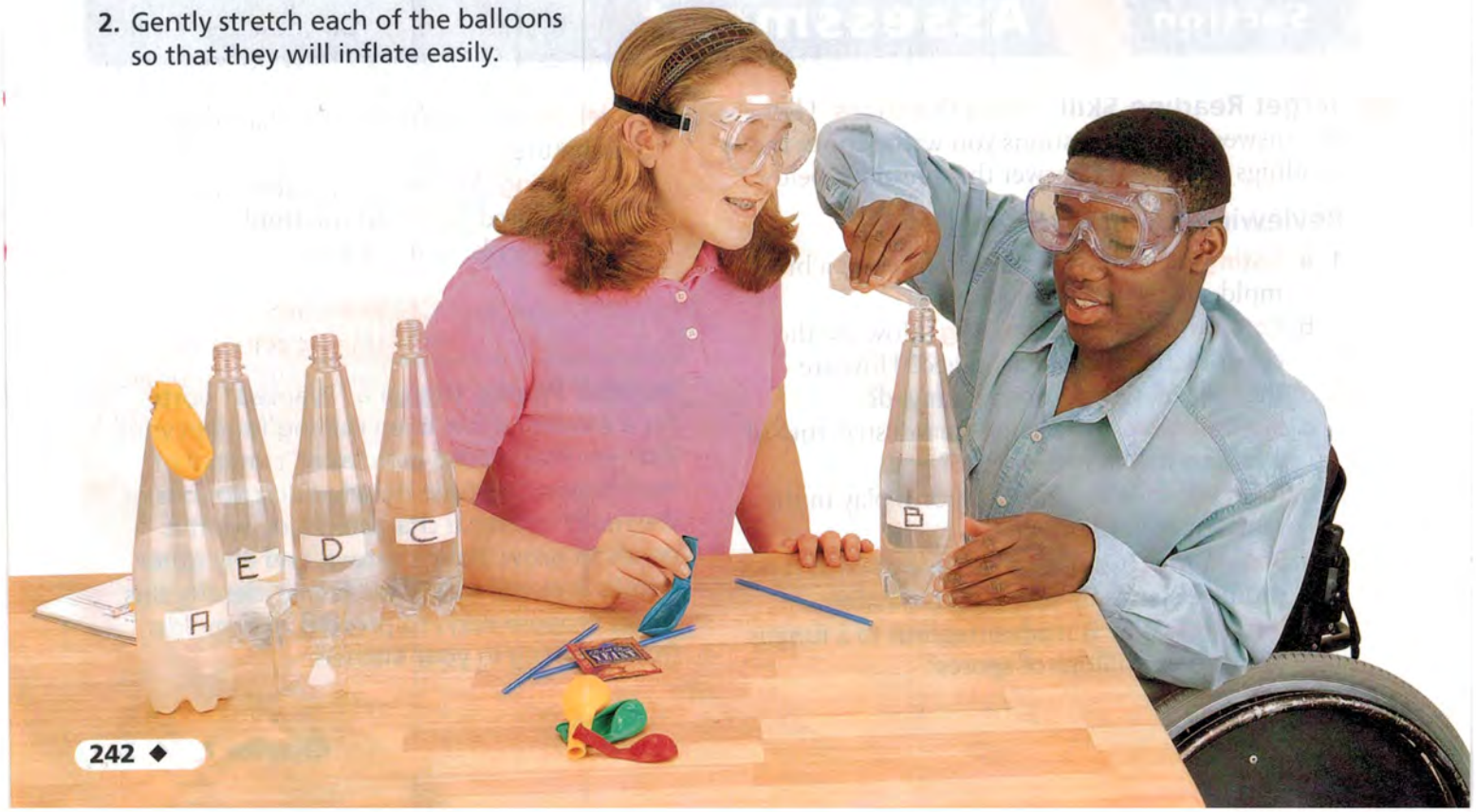
measuring, inferring, drawing conclusions

Materials

- 5 small plastic narrow-necked bottles
- 5 round balloons • 5 plastic straws
- dry powdered yeast • sugar • salt
- warm water (40°–45°C) • marking pen
- beaker • graduated cylinder • metric ruler
- string

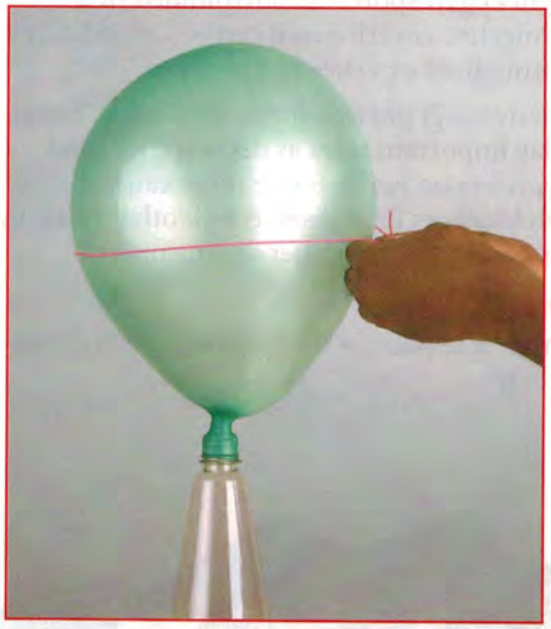
Procedure

1. Copy the data table into your notebook. Then read over the entire procedure to see how you will test the activity of the yeast cells in bottles A through E. Write a prediction about what will happen in each bottle.
2. Gently stretch each of the balloons so that they will inflate easily.
3. Using the marking pen, label the bottles *A, B, C, D,* and *E.*
4. Use a beaker to fill each bottle with the same amount of warm water. **CAUTION:** *Glass is fragile. Handle the beaker gently to avoid breakage. Do not touch broken glass.*
5. Put 25 mL of salt into bottle B.
6. Put 25 mL of sugar into bottles C and E.
7. Put 50 mL of sugar into bottle D.
8. Put 6 mL of powdered yeast into bottle A, and stir the mixture with a clean straw. Remove the straw and discard it.
9. Immediately place a balloon over the opening of bottle A. Make sure that the balloon opening fits very tightly around the neck of the bottle.
10. Repeat Steps 8 and 9 for bottle B, bottle C, and bottle D.



Data Table						
Bottle	Prediction	Observations	Circumference			
			10 min	20 min	30 min	40 min
A (Yeast alone)						
B (Yeast and 25 mL of salt)						
C (Yeast and 25 mL of sugar)						
D (Yeast and 50 mL of sugar)						
E (No yeast and 25 mL of sugar)						

11. Place a balloon over bottle E without adding yeast to the bottle.
12. Place the five bottles in a warm spot away from drafts. Every ten minutes for 40 minutes, measure the circumference of each balloon by placing a string around the balloon at its widest point. Include your measurements in the data table.



Analyze and Conclude

1. **Measuring** Which balloons changed in size during this lab? How did they change?
2. **Inferring** Explain why the balloon changed size in some bottles and not in others. What caused that change in size?
3. **Interpreting Data** What did the results from bottle C show, compared with the results from bottle D? Why was it important to include bottle E in this investigation?
4. **Drawing Conclusions** Do yeast use salt or sugar as a food source? How do you know?
5. **Communicating** In a paragraph, summarize what you learned about yeast from this investigation. Be sure to support each of your conclusions with the evidence you gathered.

Design an Experiment

Develop a hypothesis about whether temperature affects the activity of yeast cells. Then design an experiment to test your hypothesis. *Obtain your teacher's permission before carrying out your investigation.*

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Chapter 7

Study Guide

The BIG Idea **Diversity and Adaptations** Viruses are not living. Bacteria are unicellular prokaryotes. Protists are eukaryotes that cannot be classified as animals, plants, or fungi. Fungi are heterotrophic eukaryotes.

1 Viruses

Key Concepts

- The only way in which viruses are like organisms is that they can multiply.
- All viruses have two basic parts: an outer coat that protects the virus and an inner core made of genetic material.
- Once inside a cell, a virus's genetic material takes over many of the cell's functions. The genetic material instructs the cell to produce the virus's proteins and genetic material. These proteins and genetic material then assemble into new viruses.
- Resting, drinking plenty of fluids, and eating well-balanced meals may be all you can do while you recover from a viral disease.

Key Terms

• virus • host • parasite • bacteriophage
• vaccine

2 Bacteria

Key Concepts

- Bacteria are prokaryotes. The genetic material in their cells is not contained in a nucleus.
- Bacteria must have a source of food and a way of breaking down the food to release its energy.
- When bacteria have plenty of food, the right temperature, and other suitable conditions, they thrive and reproduce frequently.
- Bacteria are involved in oxygen and food production, environmental recycling and cleanup, and in health maintenance and medicine production.

Key Terms

• bacteria • flagellum • binary fission
• asexual reproduction • sexual reproduction
• conjugation • endospore • pasteurization
• decomposer

3 Protists

Key Concepts

- Like animals, animal-like protists are heterotrophs, and most are able to move from place to place to obtain food.
- Like plants, algae are autotrophs.
- Like fungi, funguslike protists are heterotrophs, have cell walls, and use spores to reproduce.

Key Terms

• protist • protozoan • pseudopod
• contractile vacuole • cilia • symbiosis
• mutualism • algae • spore

4 Fungi

Key Concepts

- Fungi are eukaryotes that have cell walls, are heterotrophs that feed by absorbing their food, and use spores to reproduce.
- Fungi usually reproduce by making spores. The lightweight spores are surrounded by a protective covering and can be carried easily through air or water to new sites.
- Many fungi provide foods for people. Fungi play important roles as decomposers and recyclers on Earth. Some fungi cause disease while others fight disease. Still other fungi live in symbiosis with other organisms.

Key Terms

• fungi • hyphae • fruiting body • budding
• lichen

Review and Assessment

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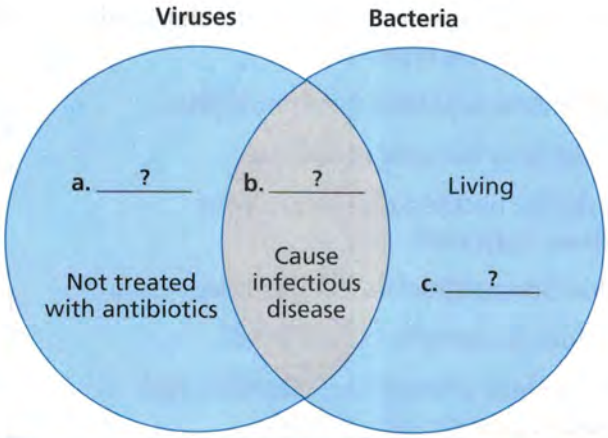
Organizing Information

Comparing and Contrasting Copy the Venn diagram comparing viruses and bacteria onto a separate sheet of paper. Then complete it and add a title. (For more information on Comparing and Contrasting, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. Bacteriophages are viruses that attack and destroy
   a. other viruses. **b.** bacteria.
   c. plants. **d.** humans.
2. Which part of a virus determines which host cells it can infect?
   a. nucleus
   b. ribosomes
   c. flagellum
   d. surface proteins
3. Most bacteria are surrounded by a rigid protective structure called the
   a. cell wall.
   b. cell membrane.
   c. protein coat.
   d. flagellum.
4. Which of the following characteristics describes all protists?
   a. They are unicellular.
   b. They can be seen with the unaided eye.
   c. Their cells have nuclei.
   d. They are unable to move on their own.
5. A lichen is a symbiotic association between
   a. fungi and plant roots.
   b. algae and fungi.
   c. algae and bacteria.
   d. protozoans and algae.

If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.

6. Active viruses enter a cell and immediately begin to multiply.
7. During conjugation, one bacterium transfers genetic material to another bacterial cell.
8. Plantlike protists are called protozoans.
9. Bacteria form endospores to survive unfavorable conditions in their surroundings.
10. Most fungi are made up of threadlike structures called spores.

Writing in Science

Informational Pamphlet Create a pamphlet to teach young children about fungi. Explain where fungi live, how they feed, and the roles they play. Include illustrations as well.

Discovery CHANNEL SCHOOL

Protists and Fungi
Video Preview
Video Field Trip
▶ Video Assessment

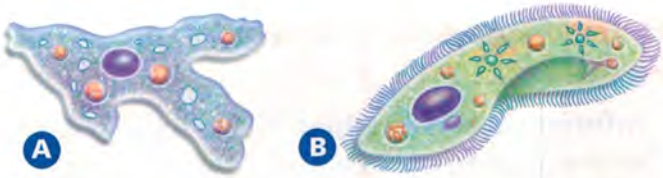
Review and Assessment

Checking Concepts

11. Explain why a certain virus will attach to only one type or a few types of cells.
12. Describe how a hidden virus multiplies.
13. Describe how bacteria reproduce.
14. How do the bacteria that live in your intestines help you?
15. Explain how antibiotics kill bacteria.
16. How does an amoeba obtain food?
17. Compare how animal-like, plantlike, and funguslike protists obtain food.
18. How does sexual reproduction occur in fungi?

Thinking Critically

19. **Comparing and Contrasting** Describe the similarities and differences between active and hidden viruses.
20. **Problem Solving** Bacteria will grow in the laboratory on a gelatin-like substance called agar. Viruses will not grow on agar. If you needed to grow viruses in the laboratory, what kind of substance would you have to use? Explain your reasoning.
21. **Comparing and Contrasting** Identify the organisms below. Describe the method by which each obtains food.



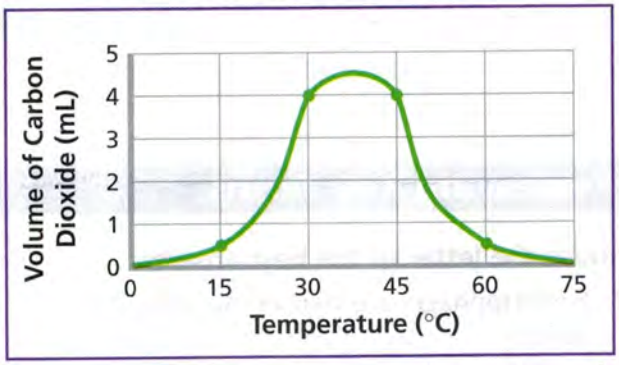
22. **Predicting** If all algae suddenly disappeared from Earth's waters, what would happen to living things on Earth? Explain your answer.
23. **Making Judgments** You see an advertisement for a new, powerful fungicide guaranteed to kill most fungi on contact. What should people take into consideration before choosing to buy this fungicide?

Applying Skills

Use the graph to answer Questions 24–27.

When yeast is added to bread dough, the yeast cells produce carbon dioxide, which causes the dough to rise. The graph below shows how temperature affects the amount of carbon dioxide that is produced.

Temperature and Carbon Dioxide Production



24. **Interpreting Data** Based on the graph, at what temperature does yeast produce the most carbon dioxide?
25. **Inferring** Use the graph to explain why yeast is dissolved in warm water, rather than in cold water, when it is used to make bread.
26. **Predicting** Based on the graph, would you expect bread dough to rise if it were placed in a refrigerator (which is kept at about 2° to 5°C)? Explain.
27. **Drawing Conclusions** Explain how temperature affects the amount of carbon dioxide that the yeast cells produce.

Lab zone Chapter Project

Performance Assessment Create a poster that summarizes your experiment for the class. In your poster, include your hypothesis and describe the conditions that produced the best mushroom growth. Use diagrams and graphs to display your results. Did the project raise any new questions about mushrooms for you? If so, how could you answer those questions?