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

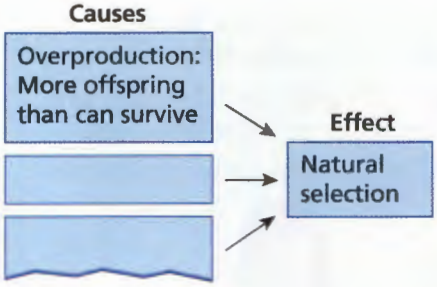
- What important observations did Darwin make on his voyage?
- What hypothesis did Darwin make to explain the differences between similar species?
- How does natural selection lead to evolution?

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.

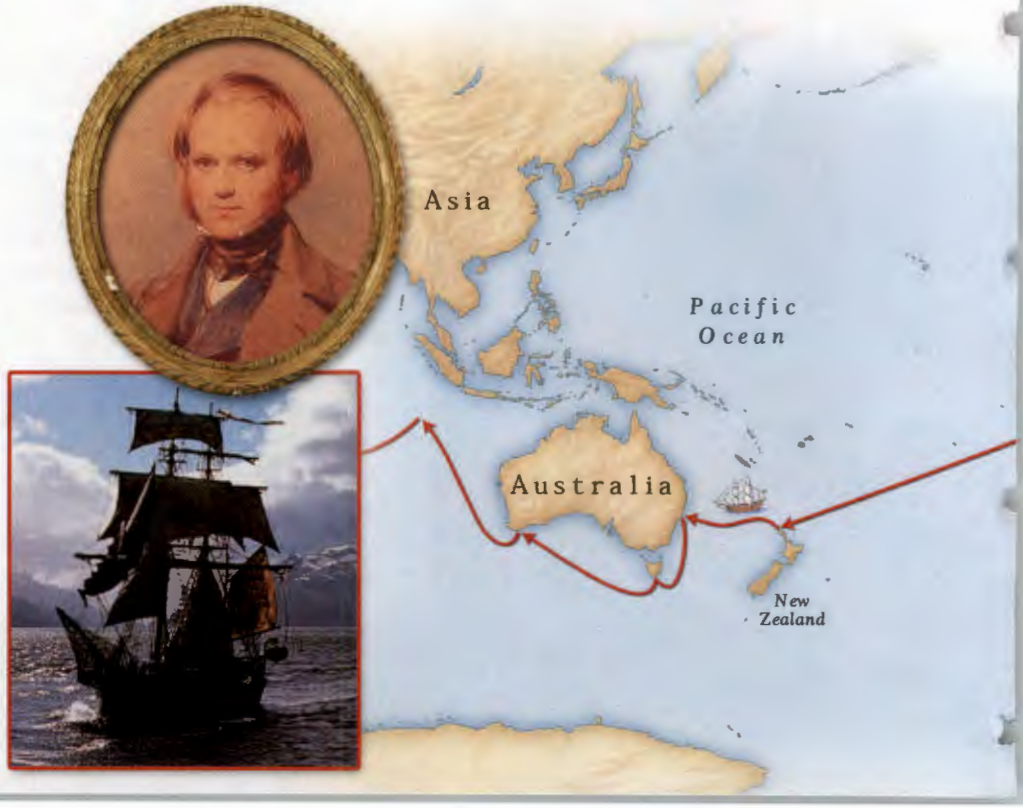


FIGURE 1
The Voyage of the *Beagle*
Charles Darwin sailed on the *Beagle* to the Galápagos Islands. He saw many unusual organisms on the islands, such as giant tortoises and the blue-footed booby.
Interpreting Maps *After leaving South America, where did the* Beagle *go?*

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.

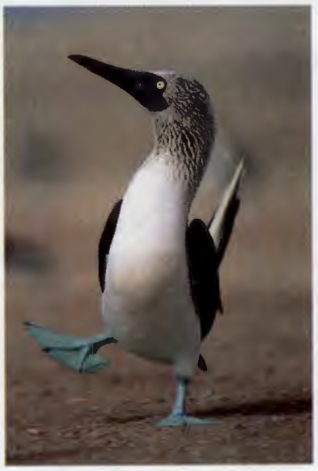
Reading Checkpoint What is a fossil?

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?*

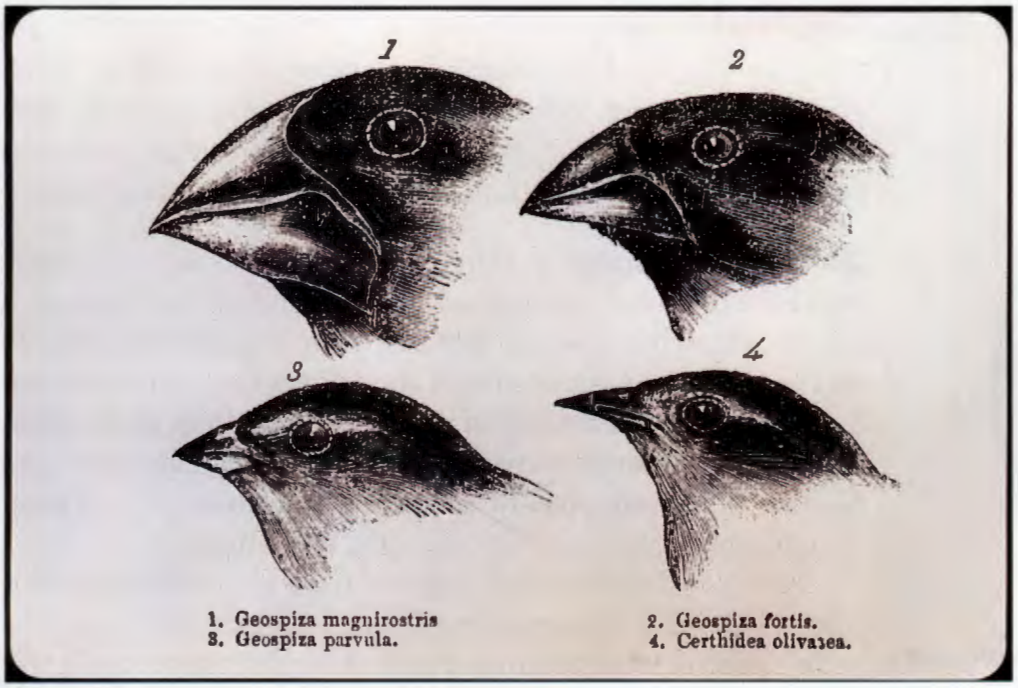


FIGURE 3
Galápagos Finches Darwin made these drawings of four species of Galápagos finches. The structure of each bird's beak is an adaptation related to the type of food the bird eats. **Comparing and Contrasting** *Identify some specific differences in these finches' beaks.*

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.

▲ Seattle Slew, great-grandfather of Funny Cide

Distorted Humor, father of Funny Cide ▲

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.**

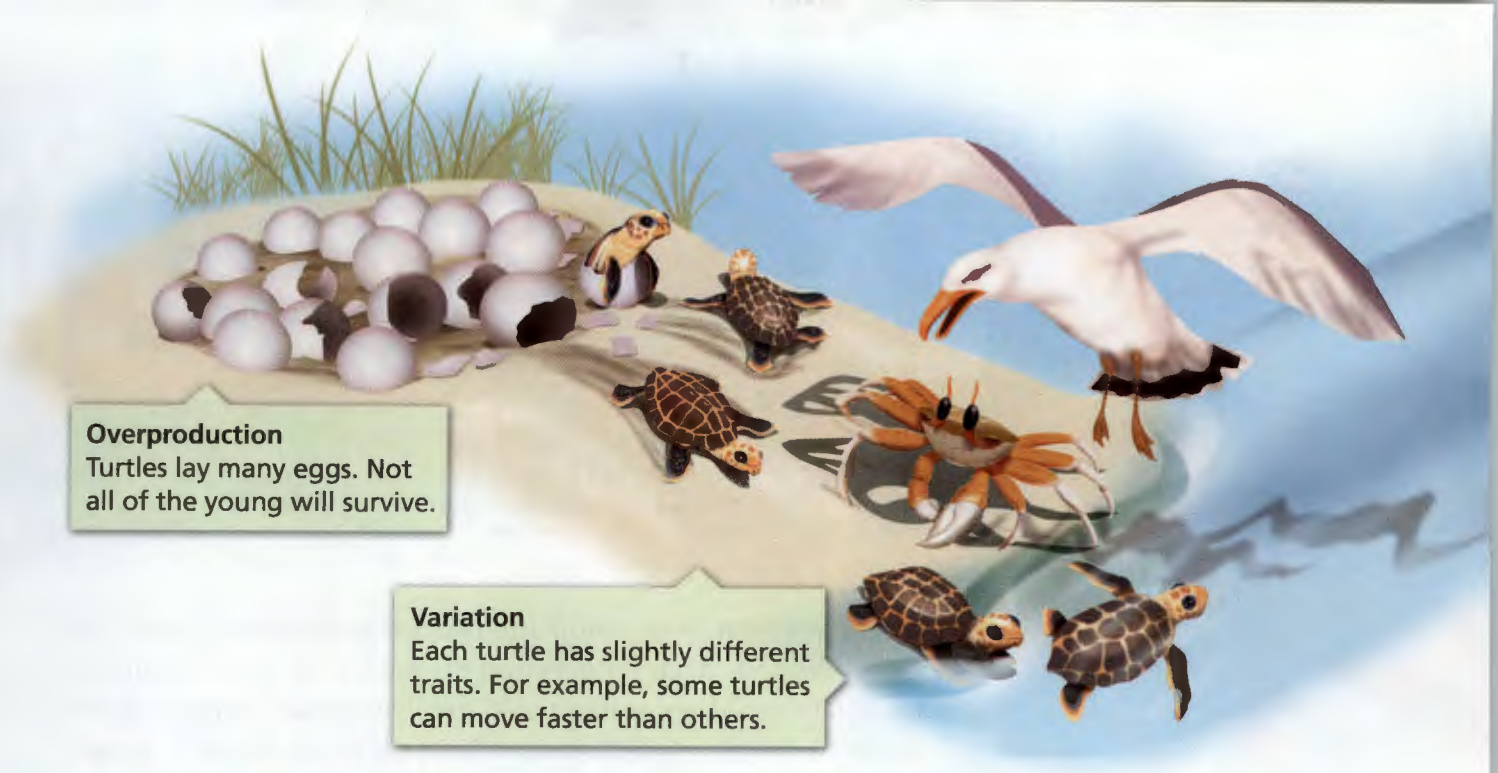
Darwin's ideas are often referred to as the theory of evolution. A **scientific theory** is a well-tested concept that explains a wide range of observations. From the evidence he collected, Darwin concluded that organisms on the Galápagos Islands had changed over time. However, Darwin did not know how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

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.



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?

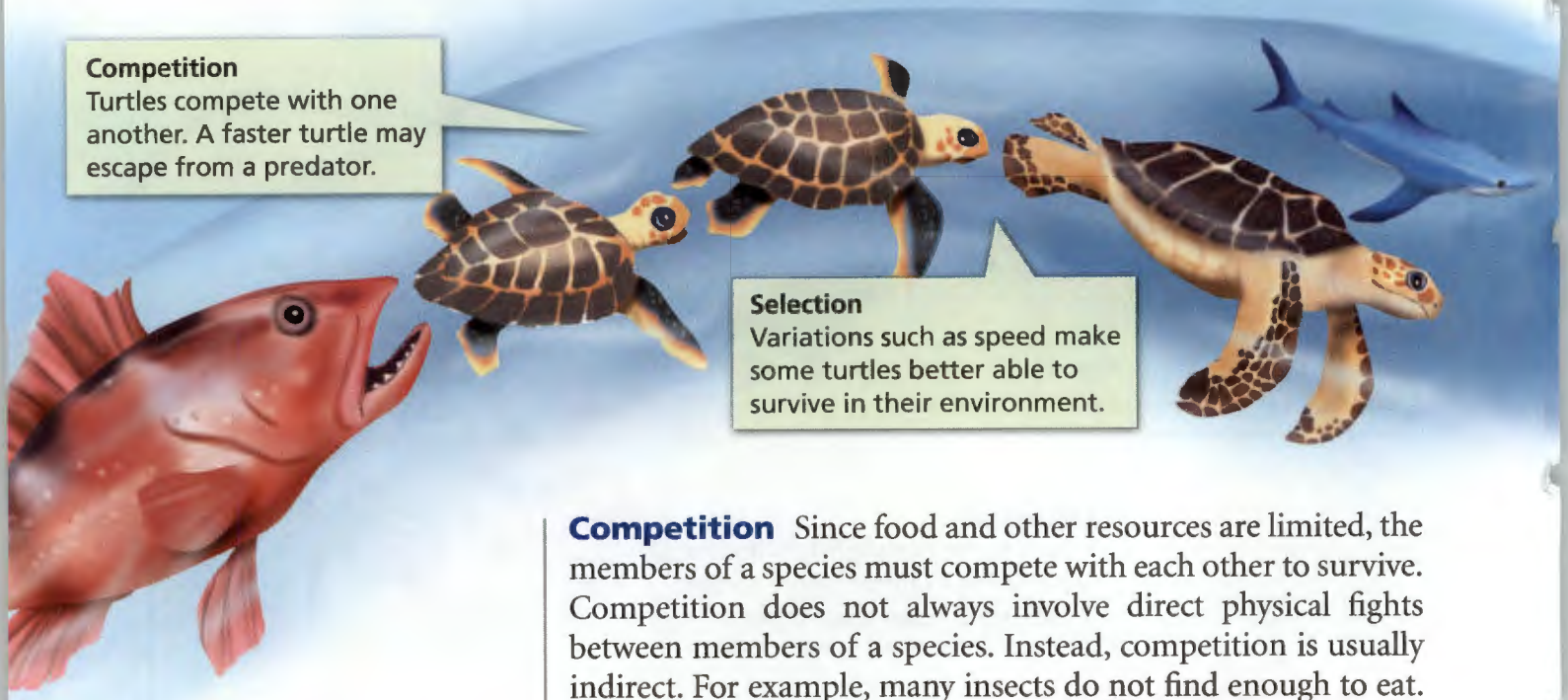


FIGURE 6
Competition and Selection
Variations among turtles make some of them better able to survive. Turtles that survive to become adults will be able to reproduce.
Applying Concepts *What are some variations that sea turtles might exhibit?*

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.

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 questions you would ask him. Then write answers that 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

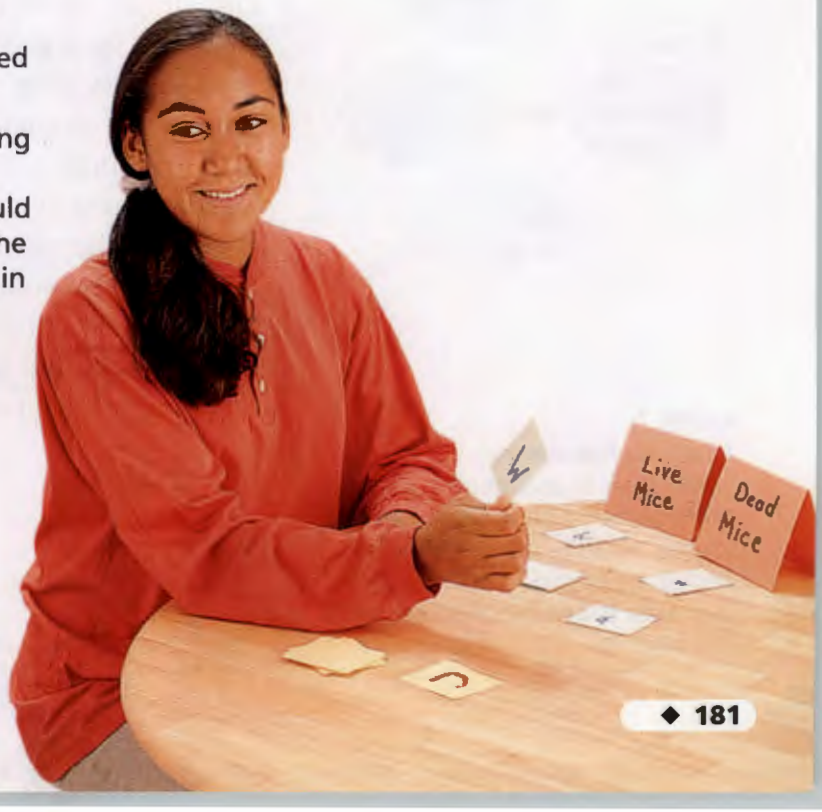
Table 2: Event Cards		
Number	**Label**	**Meaning**
5	S	Mouse survives.
1	D	Disease kills mouse.
1	P	Predator kills mice of all colors.
18	C	Predator kills mice that contrast with the environment.

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

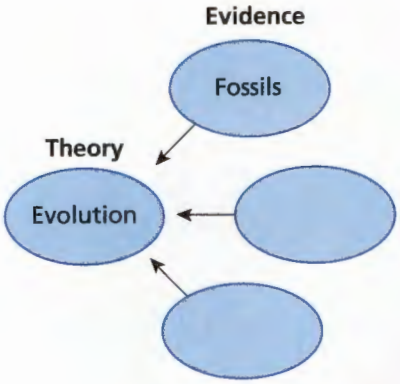
- What evidence supports the theory of evolution?
- How do scientists infer evolutionary relationships among organisms?
- How do new species form?

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.

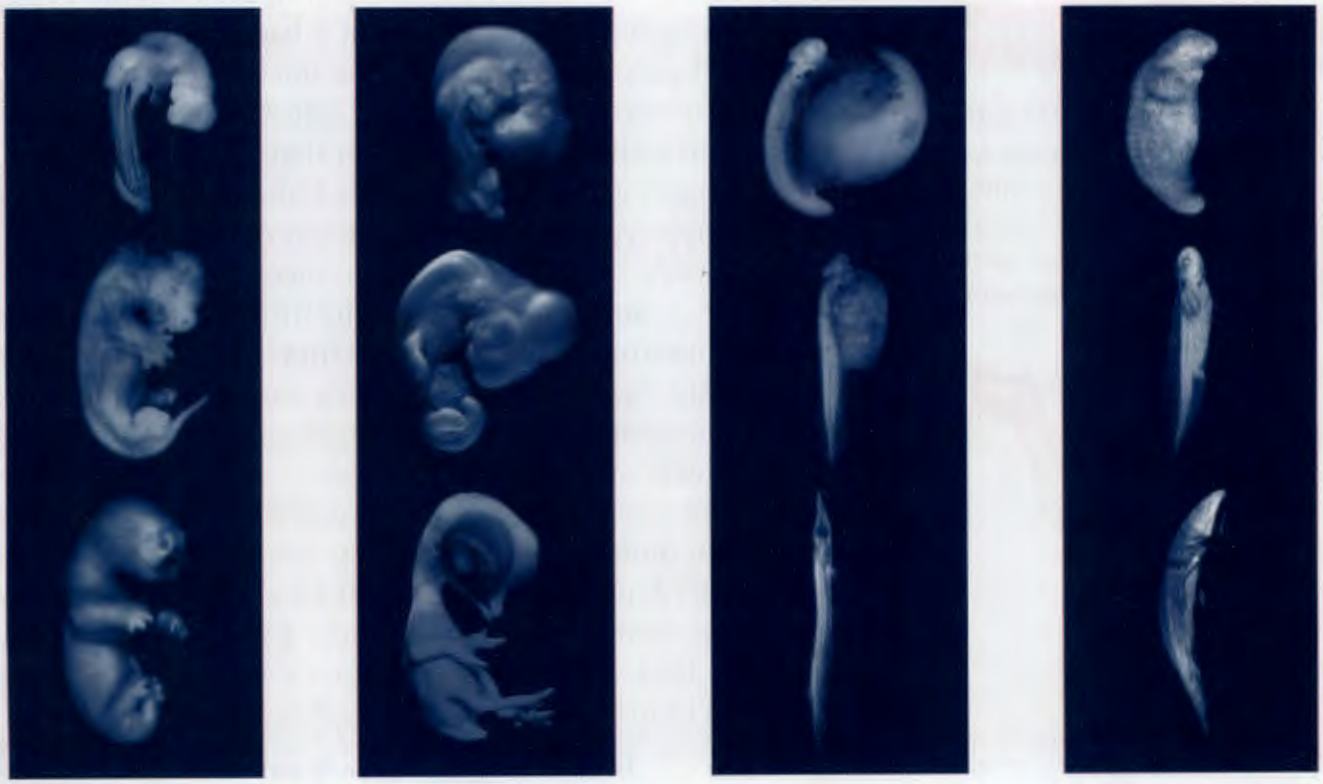
Interpreting the Evidence

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?*



Opossum Chicken Fish Salamander

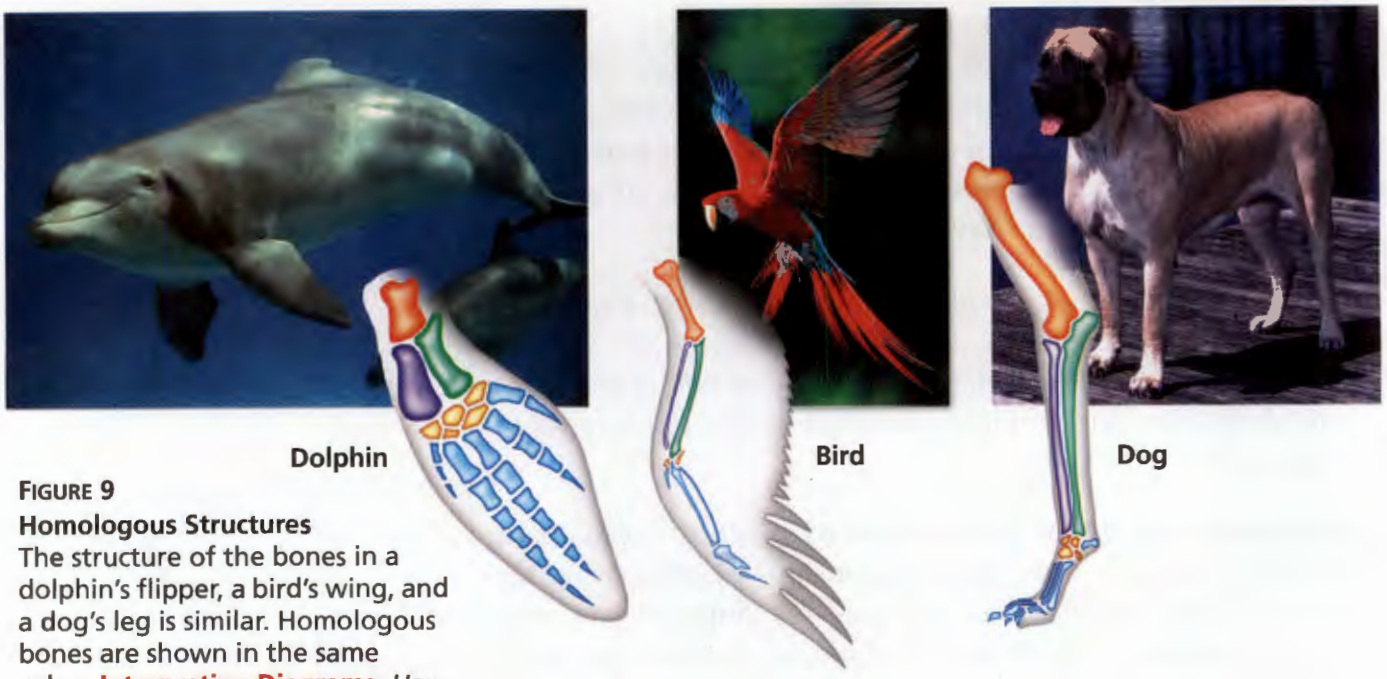


FIGURE 9
Homologous Structures
The structure of the bones in a dolphin's flipper, a bird's wing, and a dog's leg is similar. Homologous bones are shown in the same color. **Interpreting Diagrams** *How are all three orange bones similar?*

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).

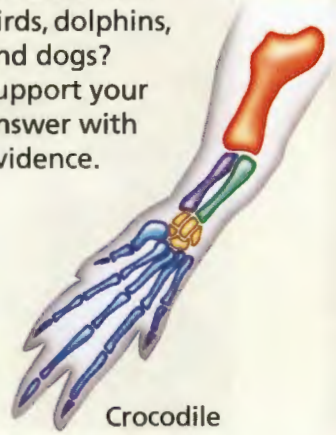
Sometimes scientists find fossils that support the evidence provided by homologous structures. For example, scientists have recently found fossils of ancient whalelike creatures. The fossils show that the ancestors of today's whales had legs and walked on land. This evidence supports other evidence that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

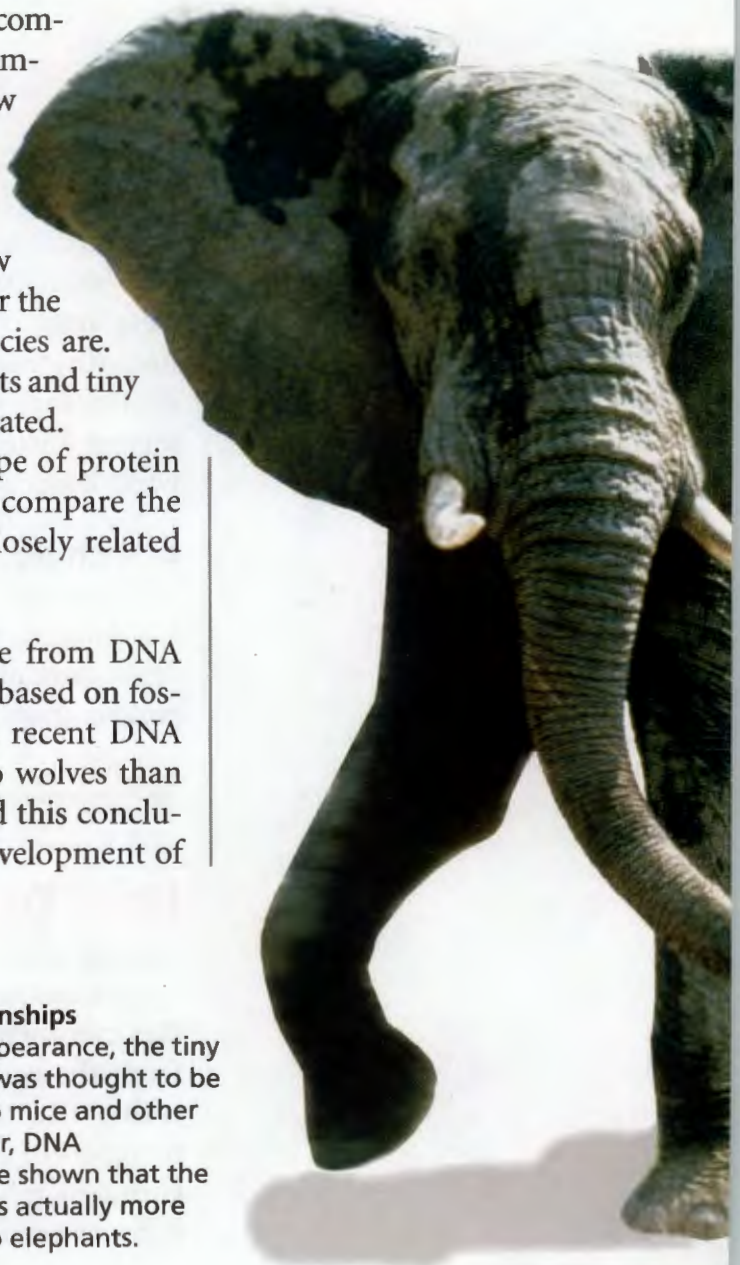


FIGURE 10
DNA and Relationships
Because of its appearance, the tiny elephant shrew was thought to be closely related to mice and other rodents. However, DNA comparisons have shown that the elephant shrew is actually more closely related to elephants.

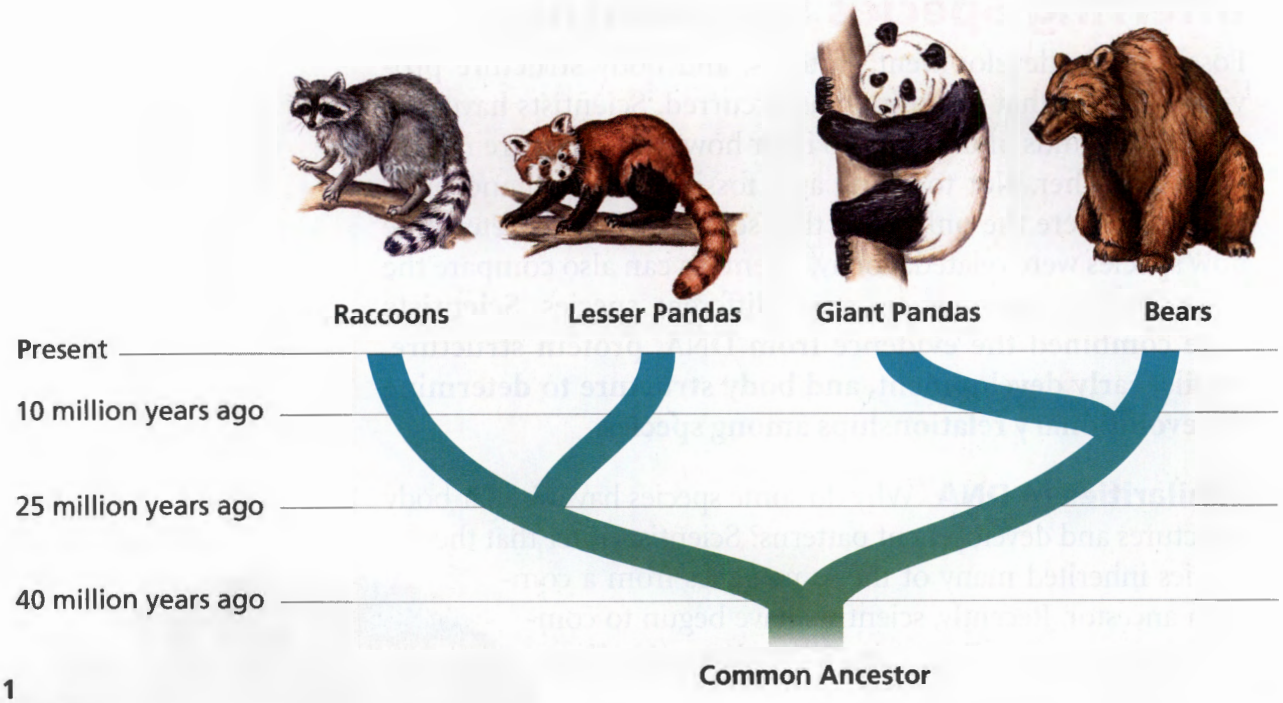


FIGURE 11
A Branching Tree
This branching tree shows how scientists now think that raccoons, lesser pandas, giant pandas, and bears are related.
Interpreting Diagrams *Are giant pandas more closely related to lesser pandas or to bears?*

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

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.

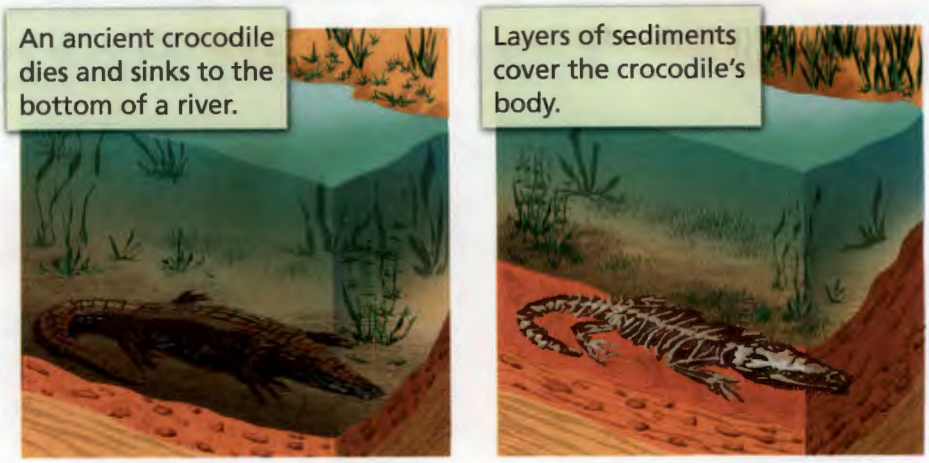


FIGURE 14
Fossil Formation
Most fossils, such as the fossil crocodile shown here, form in sedimentary rock. **Relating Cause and Effect** *In the process of fossil formation, what materials replace the crocodile's remains?*

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.

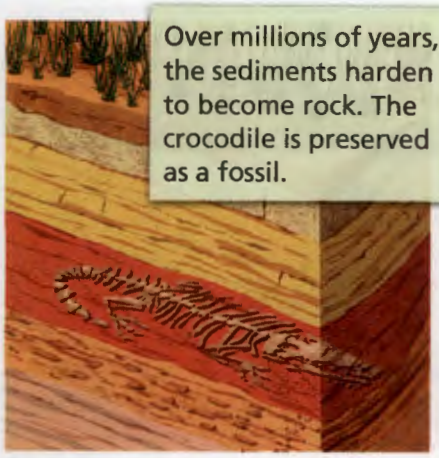
Reading Checkpoint **What is the difference between a mold and a cast?**

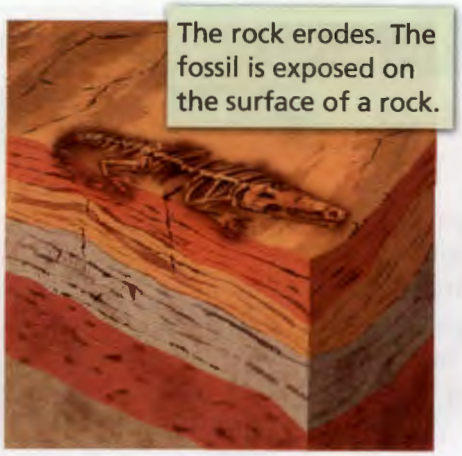
Lab zone Try This Activity

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.





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active art

For: Fossil Formation activity
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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.

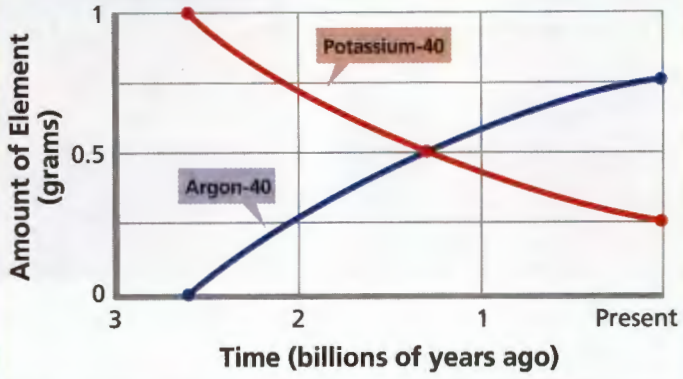
Relative dating can only be used when the rock layers have been preserved in their original sequence. Relative dating can help scientists determine whether one fossil is older than another. However, relative dating does not tell scientists the fossil's actual age.

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.

Decay of Potassium-40 Into Argon-40



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?**

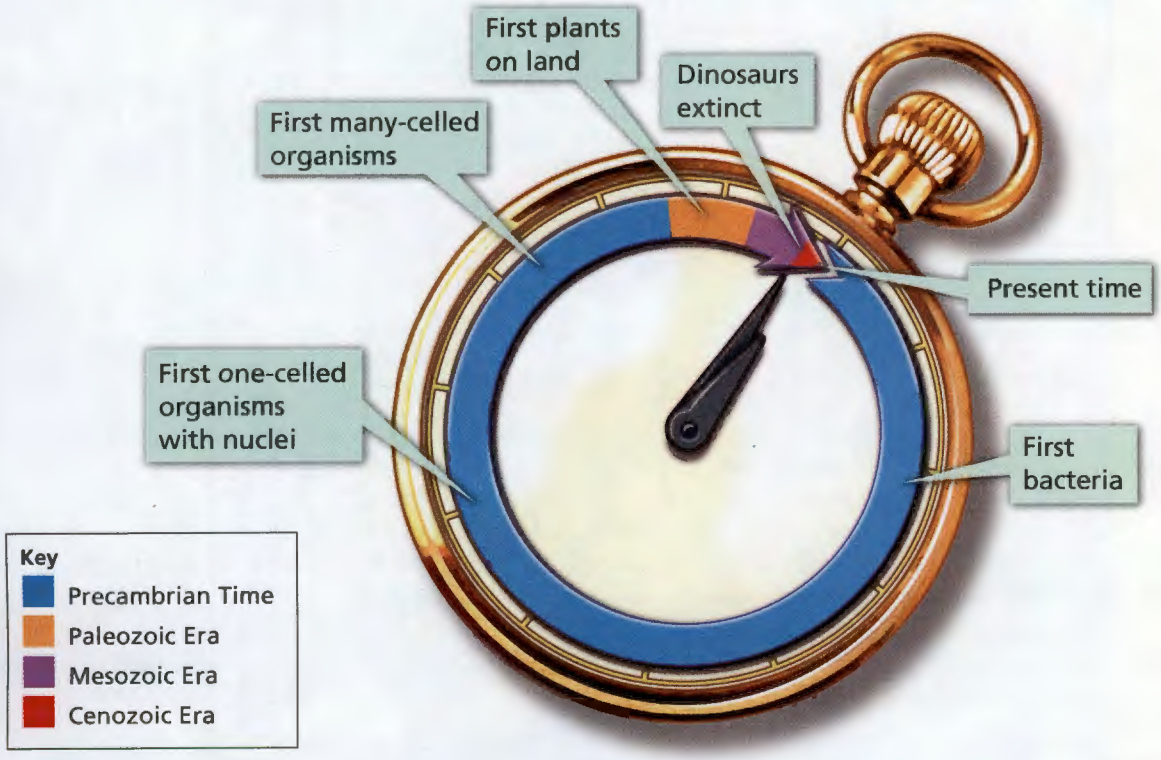


FIGURE 15
Earth's History as a Clock
Fossils found in rock layers tell the history of life on Earth. The history of life can be compared to 12 hours on a clock.
Interpreting Diagrams *At what time on a 12-hour time scale did plants appear on land?*

FIGURE 16

The Geologic Time Scale

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

Precambrian Time

4.6 billion–544 million years ago

Precambrian Time begins with the formation of Earth. The first living things — bacteria — appeared in seas 3.5 billion years ago. Algae and fungi evolved 1 billion years ago. Animals first appeared 600 million years ago.

Paleozoic Era

544–245 million years ago

Cambrian

544–505 million years ago

Invertebrate sea animals such as sponges, snails, clams, and worms evolve.

Ordovician

505–438 million years ago

The earliest fishes evolve. Although many new species of animals arise, many become extinct by the end of the period.

Silurian

438–408 million years ago

Land plants and animals evolve. The plants are similar to present-day mosses.

Devonian

408–360 million years ago

Many types of fishes live in the seas. Early amphibians evolve. They are fishlike animals that have legs and can breathe air. Ferns and cone-bearing plants appear on land.

Carboniferous

360–286 million years ago

Tropical forests become widespread. Many different insects and amphibians evolve. The earliest reptiles appear.

Mesozoic Era
245–66 million years ago

Cenozoic Era
66 million years ago to the present

Permian
286–245 million years ago

Conifer

Dimetrodon

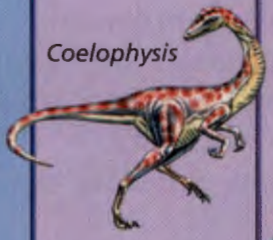
Dicynodon

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



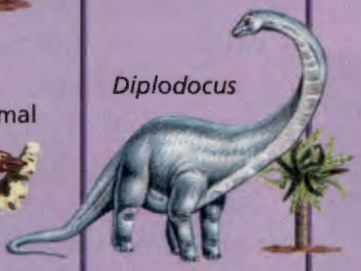
Coelophysis

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?*

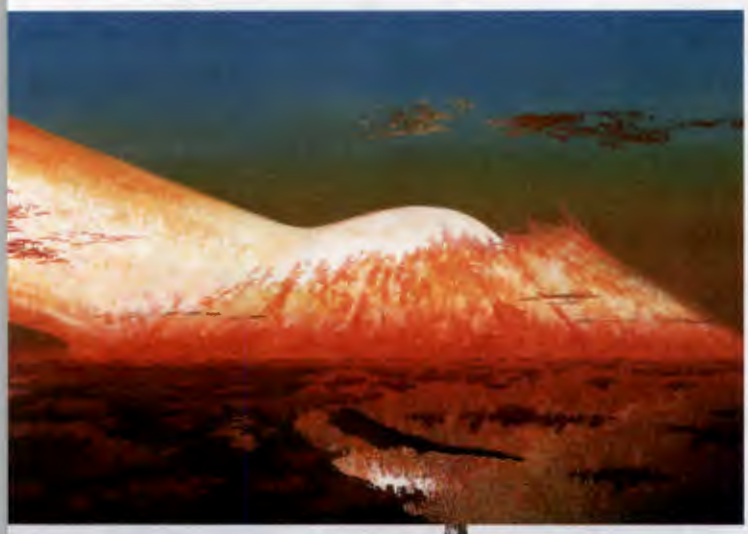
▲ An asteroid zooms toward Earth.

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.**

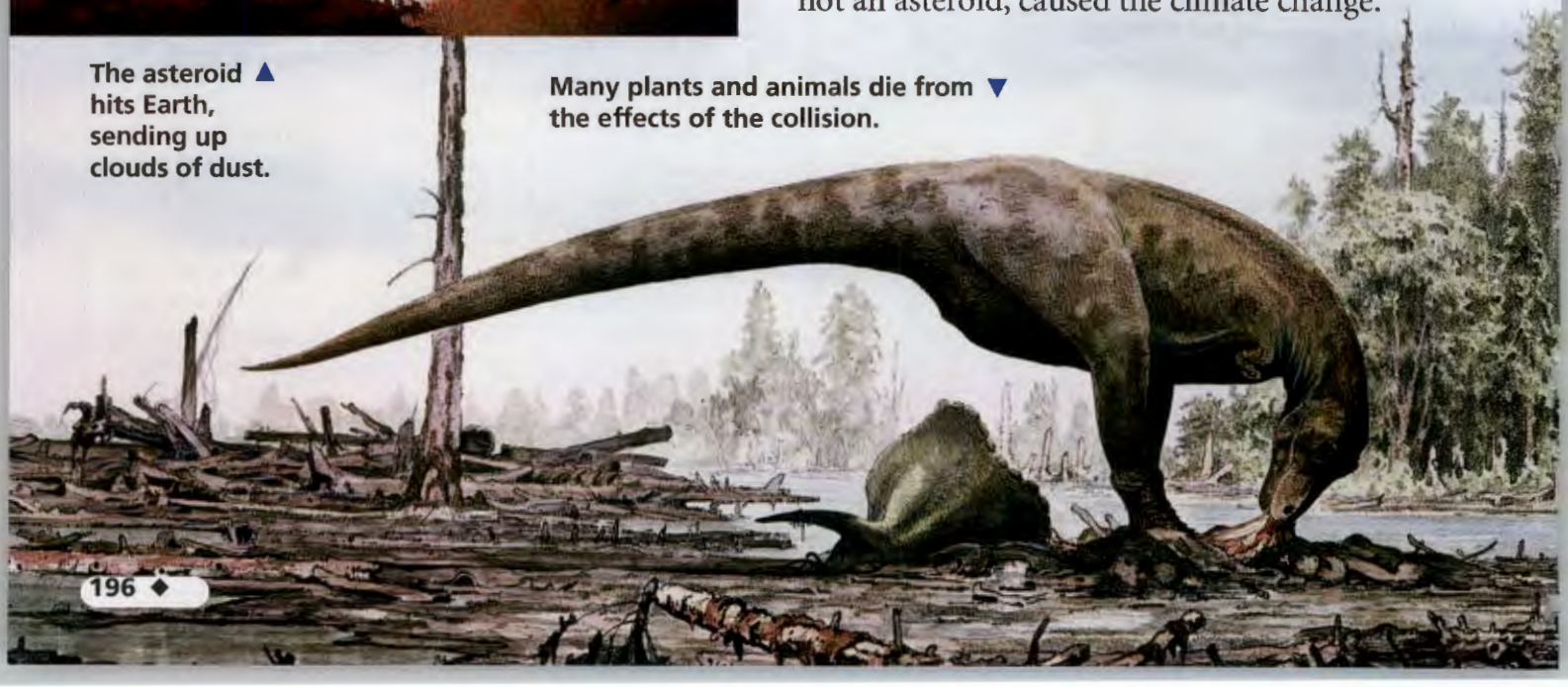
Mass Extinctions When many types of organisms become extinct at the same time, a mass extinction has occurred. Several mass extinctions have taken place during the history of life. One mass extinction, for example, occurred at the end of the Cretaceous Period, about 65 million years ago. During the Cretaceous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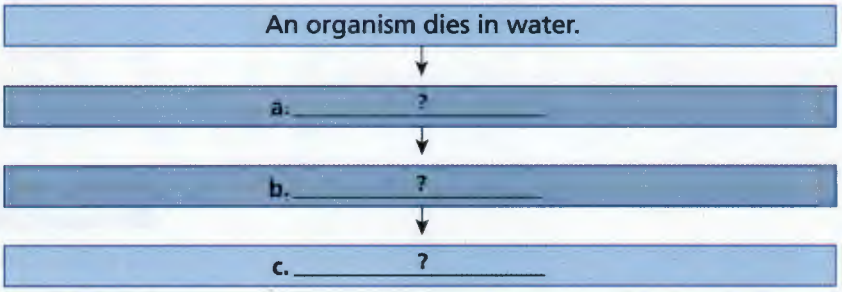
Organizing Information

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

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.

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.

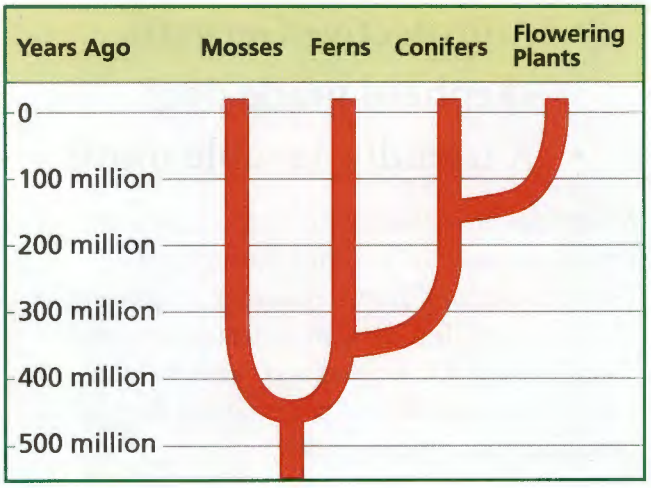
Choose the letter of the best answer.

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.

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

Dogs—Loyal Companions

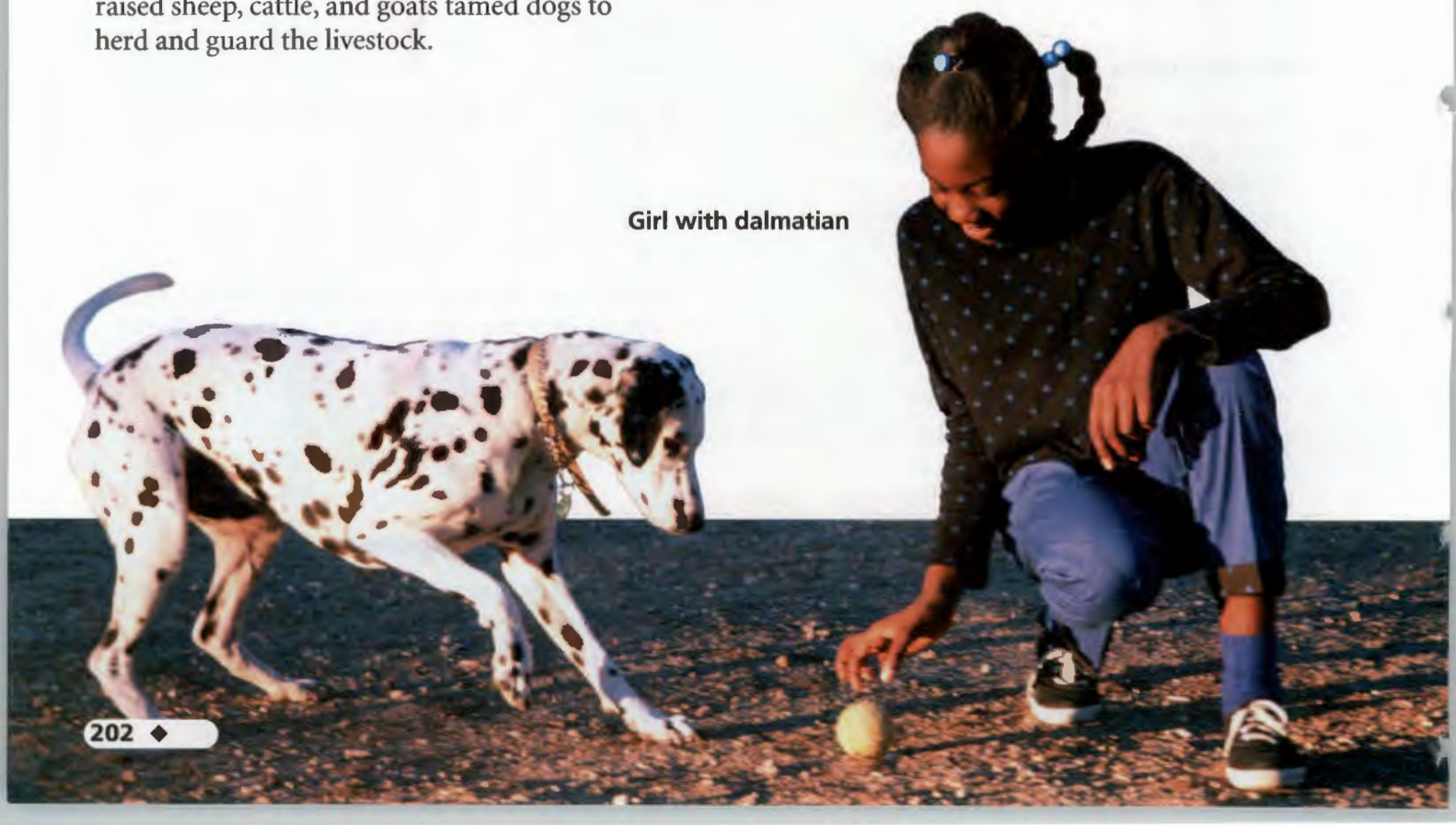
What's your image of a dog?

- 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



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.

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.

Russia

EUROPE

AFRICA

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.

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.

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

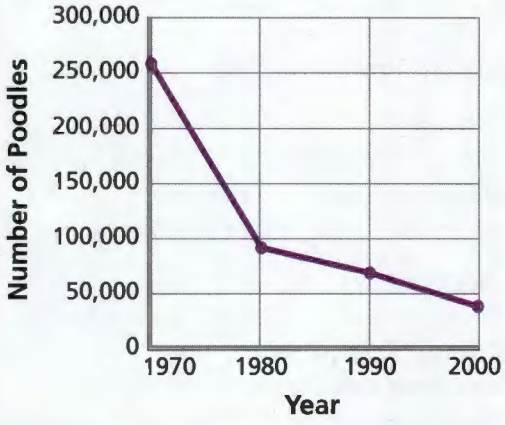
Use the table below to create your own line graph for Labrador retrievers and cocker spaniels. Which breed was more popular in 1980, Labrador retrievers or cocker spaniels?

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.