chapter 6

Adaptations over Time

The BIG Idea

Life-forms have changed over time.

SECTION 1
Ideas About Evolution
Main Idea Charles Darwin and other scientists observed that species change over time by different methods.

SECTION 2
Clues About Evolution
Main Idea Scientists find clues about evolution by studying fossils, development of embryos, structures of organisms, and DNA.

SECTION 3
The Evolution of Primates
Main Idea Evidence indicates that the ancient ancestor of present-day humans appeared on Earth for 4–6 million years ago.

Adaptation? No problem.

Cockroaches have existed for millions of years, yet they are still adapted to their environment. Since they first appeared, many species have disappeared, and other well-adapted species have evolved.

Science Journal Pick a favorite plant or animal and list in your Science Journal all the ways it is well-suited to its environment.

Start-Up Activities

Launch LAB

Adaptation for a Hunter

The cheetah is nature's fastest hunter, but it can run swiftly for only short distances. Its fur blends in with tall grass, making it almost invisible as it hides and waits for prey. Then the cheetah pounces, capturing the prey before it can run away.

1. Spread a sheet of newspaper classified ads on the floor.
2. Using a hole puncher, make 100 circles from each of the following types of paper: white paper, black paper, and classified ads.
3. Scatter all the circles on the newspaper on the floor. For 10 s, pick up as many circles as possible, one at a time. Have a partner time you.
4. Count the number of each kind of paper circle that you picked up. Record your results in your Science Journal.
5. **Think Critically** Which paper circles were most difficult to find? What can you infer about a cheetah's coloring from this activity? Enter your responses to these questions in your Science Journal.

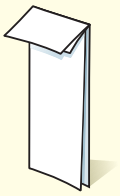
FOLDABLES™ Study Organizer

Principles of Natural Selection

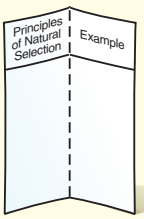
Make the following Foldable to help you understand the process of natural selection.

STEP 1 **Fold** a sheet of paper in half lengthwise.

STEP 2 **Fold** paper down 2.5 cm from the top. (Hint: From the tip of your index finger to your middle knuckle is about 2.5 cm.)



STEP 3 **Open and draw** lines along the 2.5-cm fold and the center fold. **Label** as shown.



Summarize in a Table As you read, list the five principles of natural selection in the left-hand column. In the right-hand column, briefly write an example for each principle.

ScienceOnline

Preview this chapter's content and activities at booka.msscience.com

Get Ready to Read

Questioning

1 Learn It! Asking questions helps you to understand what you read. As you read, think about the questions you'd like answered. Often you can find the answer in the next paragraph or lesson. Learn to ask good questions by asking who, what, when, where, why, and how.

2 Practice It! Read the following passage from Section 2.

> One way to find the approximate age of fossils within a rock layer is relative dating. Relative dating is based on the idea that, in undisturbed areas, younger rock layers are deposited on top of older rock layers, as shown in **Figure 10.** Relative dating provides only an estimate of a fossil's age. The estimate is made by comparing the ages of rock layers found above and below the fossil layer. For example, suppose a 50 million-year-old rock layer lies below a fossil, and a 35-million-year-old layer lies above it. According to relative dating, the fossil is probably between 35 million and 50 million years old.
>
> *—from page 167*

Here are some questions you might ask about this paragraph:

- How do the ages of rock layers help determine the age of a fossil?
- What must be true of the area where rock layers are used for relative dating?
- Does relative dating determine the actual fossil age or an estimate of a fossil's age?

3 Apply It! As you read the chapter, look for answers to questions that are part of the text.

Reading Tip

Test yourself. Create questions and then read to find answers to your own questions.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 **Before you read** the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 **After you read** the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D		Statement	After You Read A or D
	1	Darwin's observations in the Galápagos Islands helped him develop his theory of evolution by natural selection.	
	2	When some geographic barrier, such as mountains, separate members of a species, each group remains unchanged over time.	
	3	One principle of natural selection is that organisms best able to survive in an environment are more likely to reproduce and pass their traits to future generations.	
	4	Variation makes one member of a species different from other members of the same species.	
	5	Fossils can be the actual remains of an organism.	
	6	Evolution only happens slowly over time.	
	7	Present-day organisms can provide clues about evolution.	
	8	Plants were the first forms of life to evolve.	

Science Online

Print out a worksheet of this page at booka.msscience.com

section 1

Ideas About Evolution

as you read

What You'll Learn

- **Describe** Lamarck's hypothesis of acquired characteristics and Darwin's theory of natural selection.
- **Identify** why variations in organisms are important.
- **Compare and contrast** gradualism and punctuated equilibrium.

Why It's Important

The theory of evolution suggests why there are so many different living things.

Review Vocabulary

hypothesis: an explanation that can be tested

New Vocabulary

- species
- evolution
- natural selection
- variation
- adaptation
- gradualism
- punctuated equilibrium

Early Models of Evolution

Millions of species of plants, animals, and other organisms live on Earth today. Do you suppose they are exactly the same as they were when they first appeared—or have any of them changed? A **species** is a group of organisms that share similar characteristics and can reproduce among themselves to produce fertile offspring. Many characteristics of a species are inherited when they pass from parent to offspring. Change in these inherited characteristics over time is **evolution.** **Figure 1** shows how the characteristics of the camel have changed over time.

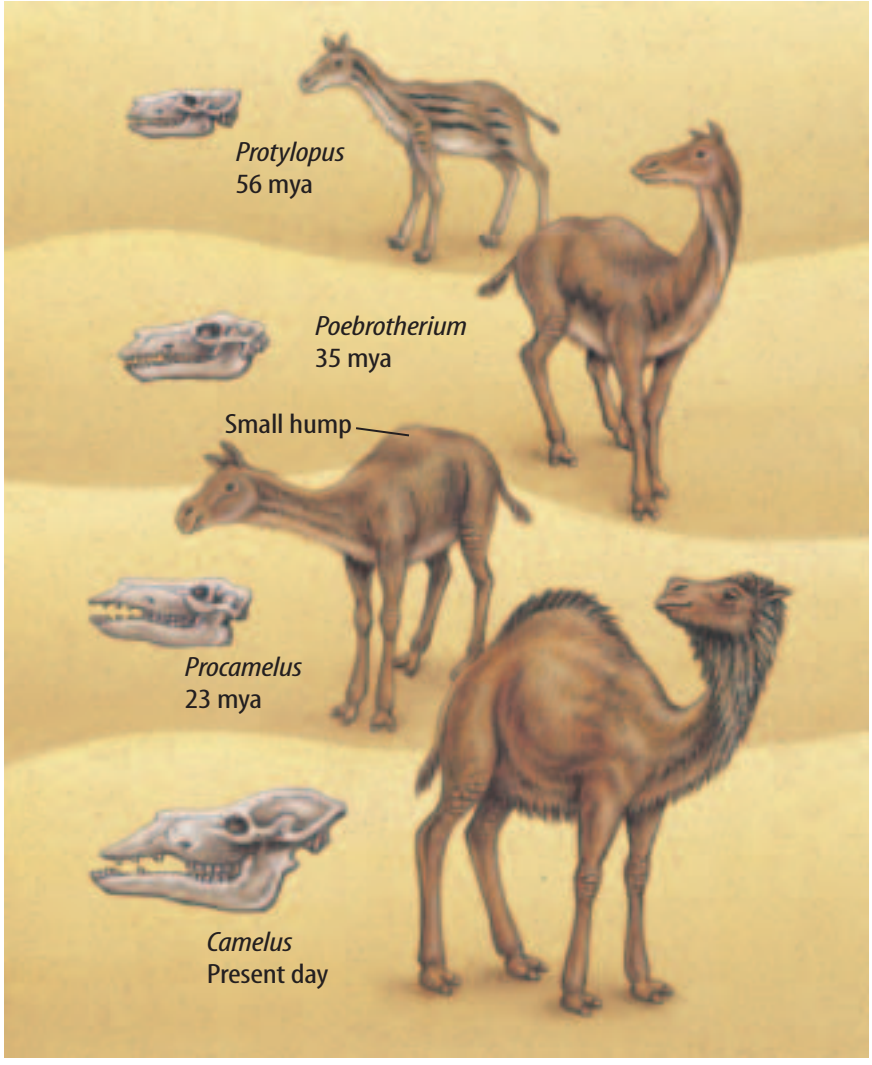


Figure 1 By studying fossils, scientists have traced the hypothesized evolution of the camel.
Discuss *the changes you observe in camels over time.*

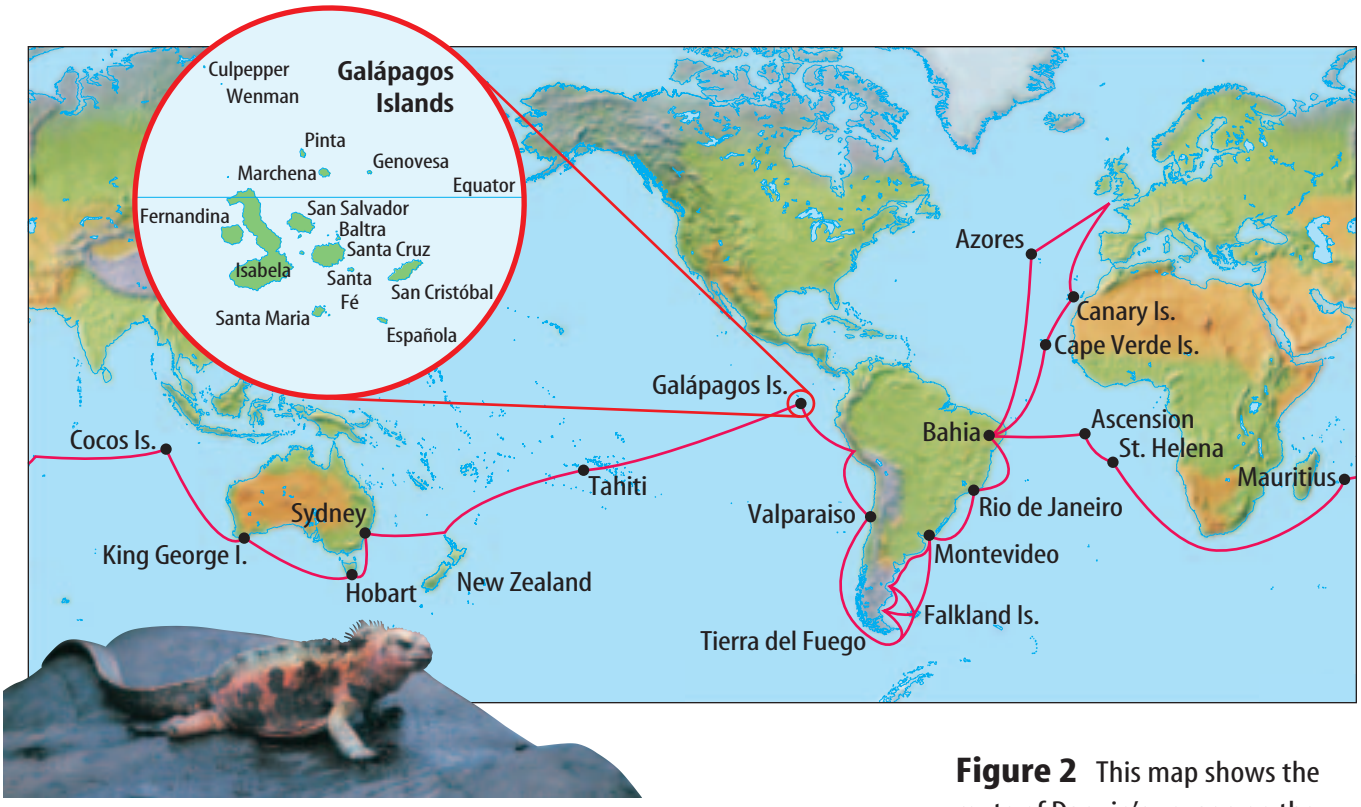


Figure 2 This map shows the route of Darwin's voyage on the HMS *Beagle*. Darwin noticed many species on the Galápagos Islands that he had not seen along the coast of South America, including the marine iguana. This species is the only lizard in the world known to enter the ocean and feed on seaweed.

Hypothesis of Acquired Characteristics In 1809, Jean Baptiste de Lamarck proposed a hypothesis to explain how species change over time. He suggested that characteristics, or traits, developed during a parent organism's lifetime are inherited by its offspring. His hypothesis is called the inheritance of acquired characteristics. Scientists collected data on traits that are passed from parents to offspring. The data showed that traits developed during a parent's lifetime, such as large muscles built by hard work or exercise, are not passed on to offspring. The evidence did not support Lamarck's hypothesis.

Reading Check ***What was Lamarck's explanation of evolution?***

Darwin's Model of Evolution

In December 1831, the HMS *Beagle* sailed from England on a journey to explore the South American coast. On board was a young naturalist named Charles Darwin. During the journey, Darwin recorded observations about the plants and animals he saw. He was amazed by the variety of life on the Galápagos Islands, which are about 1,000 km from the coast of Ecuador. Darwin hypothesized that the plants and animals on the Galápagos Islands originally came from Central and South America. But the islands were home to many species he had not seen in South America, including giant cactus trees, huge land tortoises, and the iguana shown in **Figure 2.**

Figure 3 Darwin observed that the beak shape of each species of Galápagos finch is related to its eating habits.

Finches that eat nuts and seeds have short, strong beaks for breaking hard shells.

Finches that feed on insects have long, slender beaks for probing beneath tree bark.

Finches with medium-sized beaks eat a variety of foods including seeds and insects.

Science Online

Topic: Darwin's Finches

Visit booka.msscience.com for Web links to information about the finches Darwin observed.

Activity In your Science Journal, describe the similarities and differences of any two species of Galápagos finches.

Darwin's Observations Darwin observed 13 species of finches on the Galápagos Islands. He noticed that all 13 species were similar, except for differences in body size, beak shape, and eating habits, as shown in **Figure 3.** He also noticed that all the Galápagos finch species were similar to one finch species he had seen on the South American coast.

Darwin reasoned that the Galápagos finches must have had to compete for food. Finches with beak shapes that allowed them to eat available food survived longer and produced more offspring than finches without those beak shapes. After many generations, these groups of finches became separate species.

Reading Check *How did Darwin explain the evolution of the different species of Galápagos finches?*

Natural Selection

After the voyage, Charles Darwin returned to England and continued to think about his observations. He collected more evidence on inherited traits by breeding racing pigeons. He also studied breeds of dogs and varieties of flowers. In the mid 1800s, Darwin developed a theory of evolution that is accepted by most scientists today. He described his ideas in a book called *On the Origin of Species,* which was published in 1859.

Darwin's Theory Darwin's observations led many other scientists to conduct experiments on inherited characteristics. After many years, Darwin's ideas became known as the theory of evolution by natural selection. **Natural selection** means that organisms with traits best suited to their environment are more likely to survive and reproduce. Their traits are passed to more offspring. All living organisms produce more offspring than survive. Galápagos finches lay several eggs every few months. Darwin realized that in just a few years, several pairs of finches could produce a large population. A population is all of the individuals of a species living in the same area. Members of a large population compete for living space, food, and other resources. Those that are best able to survive are more likely to reproduce and pass on their traits to the next generation.

The principles that describe how natural selection works are listed in **Table 1.** Over time, as new data was gathered and reported, changes were made to Darwin's original ideas about evolution by natural selection. His theory remains one of the most important ideas in the study of life science.

Table 1 The Principles of Natural Selection

1. Organisms produce more offspring than can survive.
2. Differences, or variations, occur among individuals of a species.
3. Some variations are passed to offspring.
4. Some variations are helpful. Individuals with helpful variations survive and reproduce better than those without these variations.
5. Over time, the offspring of individuals with helpful variations make up more of a population and eventually may become a separate species.

Applying Science

Does natural selection take place in a fish tank?

Alejandro raises tropical fish as a hobby. Could the observations that he makes over several weeks illustrate the principles of natural selection?

Identifying the Problem

Alejandro keeps a detailed journal of his observations, some of which are given in the table to the right.

Solving the Problem

Refer to **Table 1** and match each of Alejandro's journal entries with the principle(s) it demonstrates. Here's a hint: *Some entries may not match any of the principles of natural selection. Some entries may match more than one principle.*

Fish Tank Observations

Date	Observation
June 6	6 fish are placed in aquarium tank.
July 22	16 new young appear.
July 24	3 young have short or missing tail fins. 13 young have normal tail fins.
July 28	Young with short or missing tail fins die.
August 1	2 normal fish die—from overcrowding?
August 12	30 new young appear.
August 15	5 young have short or missing tail fins. 25 young have normal tail fins.
August 18	Young with short or missing tail fins die.
August 20	Tank is overcrowded. Fish are divided equally into two tanks.

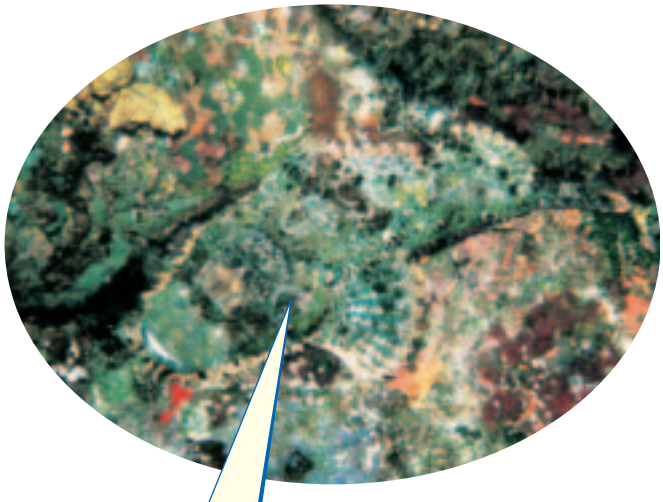
Evolution of English
If someone from Shakespeare's time were to speak to you today, you probably would not understand her. Languages, like species, change over time. In your Science Journal, discuss some words or phrases that you use that your parents or teachers do not use correctly.

Variation and Adaptation

Darwin's theory of evolution by natural selection emphasizes the differences among individuals of a species. These differences are called variations. A **variation** is an inherited trait that makes an individual different from other members of its species. Variations result from permanent changes, or mutations, in an organism's genes. Some gene changes produce small variations, such as differences in the shape of human hairlines. Other gene changes produce large variations, such as an albino squirrel in a population of gray squirrels or fruit without seeds. Over time, more and more individuals of the species might inherit these variations. If individuals with these variations continue to survive and reproduce over many generations, a new species can evolve. It might take hundreds, thousands, or millions of generations for a new species to evolve.

Some variations are more helpful than others. An **adaptation** is any variation that makes an organism better suited to its environment. The variations that result in an adaptation can involve an organism's color, shape, behavior, or chemical makeup. Camouflage (KA muh flahj) is an adaptation. A camouflaged organism, like the one shown in **Figure 4,** blends into its environment and is more likely to survive and reproduce.

Figure 4 Variations that provide an advantage tend to increase in a population over time. Variations that result in a disadvantage tend to decrease in a population over time.



Camouflage allows organisms to blend into their environments.
Infer *how its coloration gives this scorpion fish a survival advantage.*

Albinism can prevent an organism from blending into its environment.
Infer *what might happen to an albino lemur in its natural environment.*

A Virginia white-tailed deer can be 0.9 m to 1.1 m tall at the shoulder.

A Key deer can be 0.6 m to 0.7 m tall at the shoulder.

Infer *why Key deer are smaller than Virginia white-tailed deer.*

Figure 5 During the last ice age, Virginia white-tailed deer moved south ahead of an advancing ice sheet. When ice sheets melted worldwide about 4,000–10,000 years ago, ocean levels rose. Some deer were isolated on a chain of islands and evolved into a new subspecies, the Key deer. Key deer live only on approximately 30 islands in the subtropical lower keys of Florida.

Changes in the Sources of Genes Over time, the genetic makeup of a species might change its appearance. For example, as the genetic makeup of a species of seed-eating Galápagos finch changed, so did the size and shape of its beak. Many kinds of environmental factors help bring about changes. When individuals of the same species move into or out of an area, they might bring in or remove genes and variations. Suppose a family from another country moves to your neighborhood. They might bring different foods, customs, and ways of speaking with them. In a similar way, when new individuals enter an existing population, they can bring in different genes and variations.

Geographic Isolation Sometimes mountains, lakes, or other geologic features isolate a small number of individuals from the rest of a population. Over several generations, variations that do not exist in the larger population might begin to be more common in the isolated population. Also, gene mutations can occur that add variations to populations. Over time, the two populations can become so different that they no longer can breed with each other. Key deer, like the one shown in **Figure 5,** evolved because of geographic isolation about 4,000–6,000 years ago.

Mini LAB

Modeling Evolution

Procedure

1. On a piece of **paper,** print the word *train.*
2. Add, subtract, or change one letter to make a new word.
3. Repeat step 2 with the new word.
4. Repeat steps 2 and 3 two more times.
5. Make a "family tree" that shows how your first word changed over time.

Analysis

Compare your tree to those of other people. How is this process similar to evolution by natural selection?

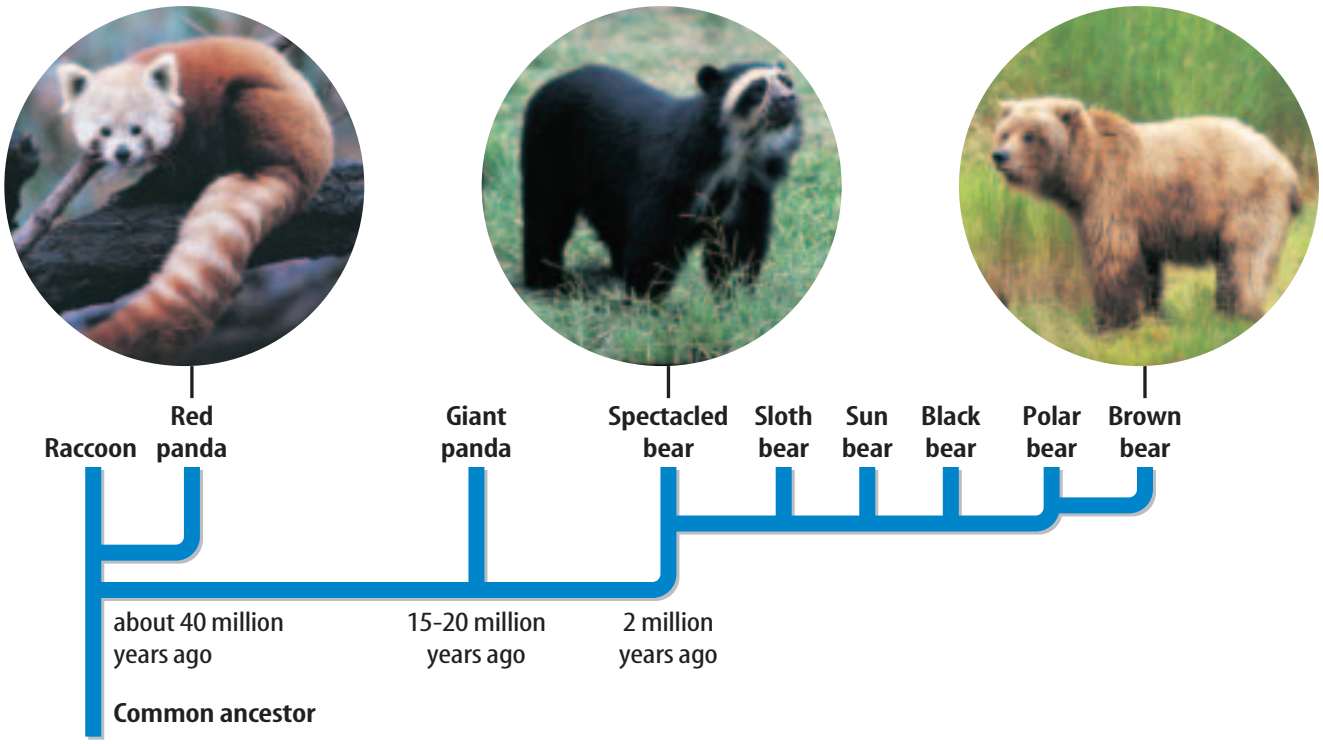


Figure 6 The hypothesized evolution of bears illustrates the punctuated equilibrium model of evolution.
Discuss *how the six species on the far right are explained better by punctuated equilibrium.*

The Speed of Evolution

Scientists do not agree on how quickly evolution occurs. Many scientists hypothesize that evolution occurs slowly, perhaps over tens or hundreds of millions of years. Other scientists hypothesize that evolution can occur quickly. Most scientists agree that evidence supports both of these models.

Gradualism Darwin hypothesized that evolution takes place slowly. The model that describes evolution as a slow, ongoing process by which one species changes to a new species is known as **gradualism.** According to the gradualism model, a continuing series of mutations and variations over time will result in a new species. Look back at **Figure 1,** which shows the evolution of the camel over tens of millions of years. Fossil evidence shows a series of intermediate forms that indicate a gradual change from the earliest camel species to today's species.

Punctuated Equilibrium Gradualism doesn't explain the evolution of all species. For some species, the fossil record shows few intermediate forms—one species suddenly changes to another. According to the **punctuated equilibrium** model, rapid evolution comes about when the mutation of a few genes results in the appearance of a new species over a relatively short period of time. The fossil record gives examples of this type of evolution, as you can see in **Figure 6.**

Punctuated Equilibrium Today Evolution by the punctuated equilibrium model can occur over a few thousand or million years, and sometimes even faster. For example, many bacteria have changed in a few decades. The antibiotic penicillin originally came from the fungus shown in **Figure 7.** But many bacteria species that were once easily killed by penicillin no longer are harmed by it. These bacteria have developed resistance to the drug. Penicillin has been in use since 1943. Just four years later, in 1947, a species of bacteria that causes pneumonia and other infections already had developed resistance to the drug. By the 1990s, several disease-producing bacteria had become resistant to penicillin and many other antibiotics.

How did penicillin-resistant bacteria evolve so quickly? As in any population, some organisms have variations that allow them to survive unfavorable living conditions when other organisms cannot. When penicillin was used to kill bacteria, those with the penicillin-resistant variation survived, reproduced, and passed this trait to their offspring. Over a period of time, this bacteria population became penicillin-resistant.

Figure 7 The fungus growing in this petri dish is *Penicillium,* the original source of penicillin. It produces an antibiotic substance that prevents the growth of certain bacteria.

section 1 review

Summary

Early Models of Evolution

- Evolution is change in the characteristics of a species over time.
- Lamarck proposed the hypothesis of inherited acquired characteristics.

Natural Selection

- Darwin proposed evolution by natural selection, a process by which organisms best suited to their environments are most likely to survive and reproduce.
- Organisms have more offspring than can survive, individuals of a species vary, and many of these variations are passed to offspring.

Variation and Adaptation

- Adaptations are variations that help an organism survive or reproduce in its environment.
- Mutations are the source of new variations.

The Speed of Evolution

- Evolution may be a slow or fast process depending on the species under study.

Self Check

1. **Compare** Lamarck's and Darwin's ideas about how evolution takes place.
2. **Explain** why variations are important to understanding change in a population over time.
3. **Discuss** how the gradualism model of evolution differs from the punctuated equilibrium model of evolution.
4. **Describe** how geographic isolation contributes to evolution.
5. **Think Critically** What adaptations would be helpful for an animal species that was moved to the Arctic?
6. **Concept Map** Use information given in **Figure 6** to make a map that shows how raccoons, red pandas, giant pandas, polar bears, and black bears are related to a common ancestor.

Applying Math

7. **Use Percentages** The evolution of the camel can be traced back at least 56 million years. Use **Figure 1** to estimate the percent of this time that the modern camel has existed.

LAB

Hidden Frogs

Through natural selection, animals become adapted for survival in their environment. Adaptations include shapes, colors, and even textures that help an animal blend into its surroundings. These adaptations are called camouflage. The red-eyed tree frog's mint green body blends in with tropical forest vegetation as shown in the photo on the right. Could you design camouflage for a desert frog? A temperate forest frog?

Real-World Question

What type of camouflage would best suit a frog living in a particular habitat?

Goals

- **Create** a frog model camouflaged to blend in with its surroundings.

Materials (for each group)

cardboard form of a frog
colored markers
crayons
colored pencils
glue
beads
sequins
modeling clay

Safety Precautions

Procedure

1. Choose one of the following habitats for your frog model: muddy shore of a pond, orchid flowers in a tropical rain forest, multicolored clay in a desert, or the leaves and branches of trees in a temperate forest.
2. **List** the features of your chosen habitat that will determine the camouflage your frog model will need.
3. **Brainstorm** with your group the body shape, coloring, and skin texture that would make the best camouflage for your model. Record your ideas in your Science Journal.
4. **Draw** in your Science Journal samples of colors, patterns, texture, and other features your frog model might have.
5. Show your design ideas to your teacher and ask for further input.
6. **Construct** your frog model.

Conclude and Apply

1. **Explain** how the characteristics of the habitat helped you decide on the specific frog features you chose.
2. **Infer** how the color patterns and other physical features of real frogs develop in nature.
3. **Explain** why it might be harmful to release a frog into a habitat for which it is not adapted.

Communicating Your Data

Create a poster or other visual display that represents the habitat you chose for this activity. Use your display to show classmates how your design helps camouflage your frog model. **For more help, refer to the Science Skill Handbook.**

Frans Lanting/Minden Pictures

section 2

Clues About Evolution

Clues from Fossils

Imagine going on a fossil hunt in Wyoming. Your companions are paleontologists—scientists who study the past by collecting and examining fossils. As you climb a low hill, you notice a curved piece of stone jutting out of the sandy soil. One of the paleontologists carefully brushes the soil away and congratulates you on your find. You've discovered part of the fossilized shell of a turtle like the one shown in **Figure 8.**

The Green River Formation covers parts of Wyoming, Utah, and Colorado. On your fossil hunt, you learn that about 50 million years ago, during the Eocene Epoch, this region was covered by lakes. The water was home to fish, crocodiles, lizards, and turtles. Palms, fig trees, willows, and cattails grew on the lakeshores. Insects and birds flew through the air. How do scientists know all this? After many of the plants and animals of that time died, they were covered with silt and mud. Over millions of years, they became the fossils that have made the Green River Formation one of the richest fossil deposits in the world.

as you read

What You'll Learn

- **Identify** the importance of fossils as evidence of evolution.
- **Explain** how relative and radiometric dating are used to estimate the age of fossils.
- **List** examples of five types of evidence for evolution.

Why It's Important

The scientific evidence for evolution helps you understand why this theory is so important to the study of biology.

Review Vocabulary

epoch: next-smaller division of geological time after a period; is characterized by differences in life-forms that may vary regionally

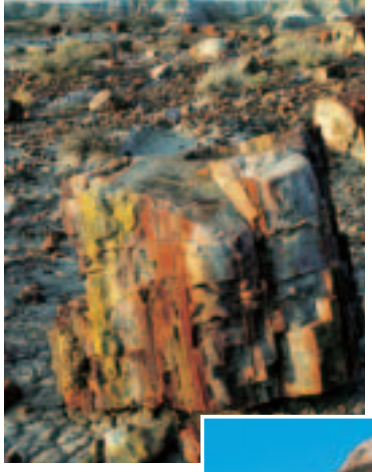
New Vocabulary

- sedimentary rock
- radioactive element
- embryology
- homologous
- vestigial structure

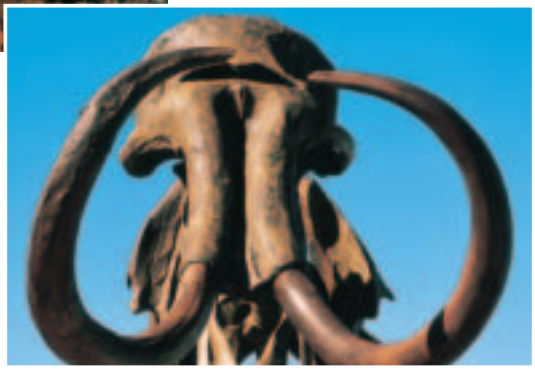
Figure 8 The desert of the Green River Formation is home to pronghorn antelope, elks, coyotes, and eagles. Fossil evidence shows that about 50 million years ago the environment was much warmer and wetter than it is today.

Figure 9 Examples of several different types of fossils are shown here.
Infer *which of these would most likely be found in a layer of sedimentary rock.*

Imprint fossils A leaf, feather, bones, or even the entire body of an organism can leave an imprint on sediment that later hardens to become rock.

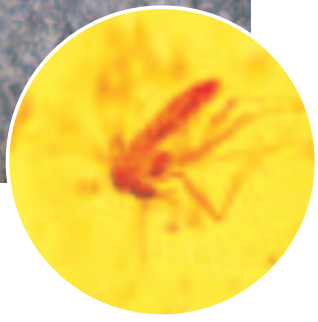


Mineralized fossils Minerals can replace wood or bone to create a piece of petrified wood as shown to the left or a mineralized bone fossil.



Frozen fossils The remains of organisms like this mammoth can be trapped in ice that remains frozen for thousands of years.

Cast fossils Minerals can fill in the hollows of animal tracks, as shown to the right, a mollusk shell, or other parts of an organism to create a cast.



Fossils in amber When the sticky resin of certain cone-bearing plants hardens over time, amber forms. It can contain the remains of trapped insects.

Types of Fossils

Most of the evidence for evolution comes from fossils. A fossil is the remains, an imprint, or a trace of a prehistoric organism. Several types of fossils are shown in **Figure 9.** Most fossils are found in sedimentary rock. **Sedimentary rock** is formed when layers of sand, silt, clay, or mud are compacted and cemented together, or when minerals are deposited from a solution. Limestone, sandstone, and shale are all examples of sedimentary rock. Fossils are found more often in limestone than in any other kind of sedimentary rock. The fossil record provides evidence that living things have evolved.

Determining a Fossil's Age

Paleontologists use detective skills to determine the age of dinosaur fossils or the remains of other ancient organisms. They can use clues provided by unique rock layers and the fossils they contain. The clues provide information about the geology, weather, and life-forms that must have been present during each geologic time period. Two basic methods—relative dating and radiometric dating—can be used, alone or together, to estimate the ages of rocks and fossils.

Relative Dating One way to find the approximate age of fossils found within a rock layer is relative dating. Relative dating is based on the idea that in undisturbed areas, younger rock layers are deposited on top of older rock layers, as shown in **Figure 10.** Relative dating provides only an estimate of a fossil's age. The estimate is made by comparing the ages of rock layers found above and below the fossil layer. For example, suppose a 50-million-year-old rock layer lies below a fossil, and a 35-million-year-old layer lies above it. According to relative dating, the fossil is between 35 million and 50 million years old.

Reading Check ***Why can relative dating be used only to estimate the age of a fossil?***

Radiometric Dating Scientists can obtain a more accurate estimate of the age of a rock layer by using radioactive elements. A **radioactive element** gives off a steady amount of radiation as it slowly changes to a nonradioactive element. Each radioactive element gives off radiation at a different rate. Scientists can estimate the age of the rock by comparing the amount of radioactive element with the amount of nonradioactive element in the rock. This method of dating does not always produce exact results, because the original amount of radioactive element in the rock can never be determined for certain.

Science Online

Topic: Fossil Finds

Visit booka.msscience.com for Web links to information about recent fossil discoveries.

Activity Prepare a newspaper article describing how one of these discoveries was made, what it reveals about past life on Earth, and how it has impacted our understanding of what the past environments of Earth were like.

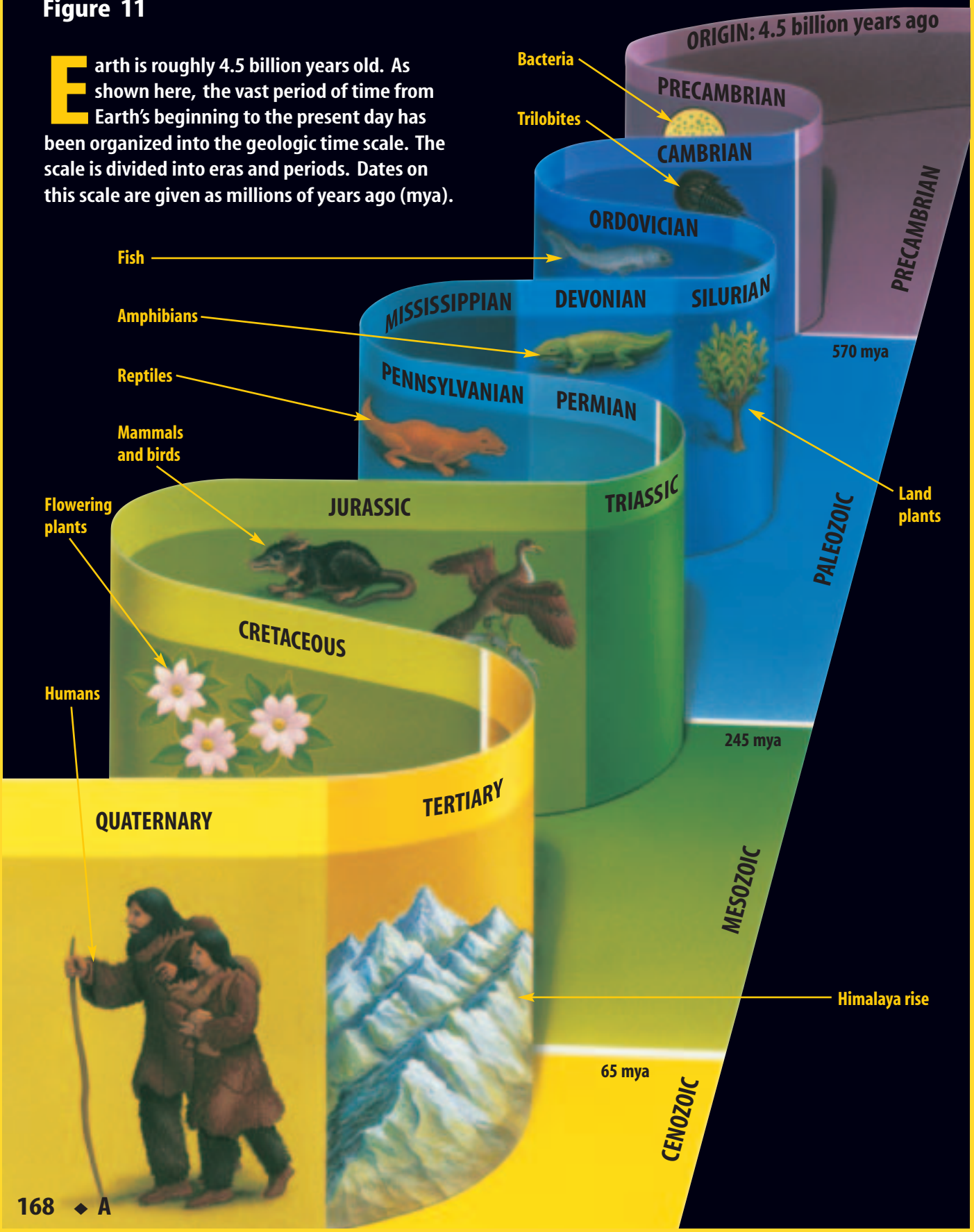
Figure 10 In Bryce Canyon, erosion by water and wind has cut through the sedimentary rock, exposing the layers.
Infer *the relative age of rocks in the lowest layers compared to the top layer.*

NATIONAL GEOGRAPHIC

VISUALIZING THE GEOLOGIC TIME SCALE

Figure 11

Earth is roughly 4.5 billion years old. As shown here, the vast period of time from Earth's beginning to the present day has been organized into the geologic time scale. The scale is divided into eras and periods. Dates on this scale are given as millions of years ago (mya).



Fossils and Evolution

Fossils provide a record of organisms that lived in the past. However, the fossil record is incomplete, or has gaps, much like a book with missing pages. The gaps exist because most organisms do not become fossils. By looking at fossils, scientists conclude that many simpler forms of life existed earlier in Earth's history, and more complex forms of life appeared later, as shown in **Figure 11.** Fossils provide indirect evidence that evolution has occurred on Earth.

Almost every week, fossil discoveries are made somewhere in the world. When fossils are found, they are used to help scientists understand the past. Scientists can use fossils to make models that show what the organisms might have looked like. From fossils, scientists can sometimes determine whether the organisms lived in family groups or alone, what types of food they ate, what kind of environment they lived in, and many other things about them. Most fossils represent extinct organisms. From a study of the fossil record, scientists have concluded that more than 99 percent of all organisms that have ever existed on Earth are now extinct.

Evolution in Fossils Many organisms have a history that has been preserved in sedimentary rock. Fossils show that the bones of animals such as horses and whales have become reduced in size or number over geologic time, as the species has evolved. In your Science Journal, explain what information can be gathered from changes in structures that occur over time.

More Clues About Evolution

Besides fossils, what other clues exist about evolution? Sometimes, evolution can be observed directly. Plant breeders observe evolution when they use cross-breeding to produce genetic changes in plants. The development of antibiotic resistance in bacteria is another direct observation of evolution. Entomologists have noted similar rapid evolution of pesticide-resistant insect species. These observations provide direct evidence that evolution occurs. Also, many examples of indirect evidence for evolution exist. They include similarities in embryo structures, the chemical makeup of organisms including DNA, and the way organisms develop into adults. Indirect evidence does not provide proof of evolution, but it does support the idea that evolution takes place over time.

Embryology The study of embryos and their development is called **embryology** (em bree AH luh jee). An embryo is the earliest growth stage of an organism. A tail and pharyngeal pouches are found at some point in the embryos of fish, reptiles, birds, and mammals, as **Figure 12** shows. Fish develop gills, but the other organisms develop other structures as their development continues. Fish, birds, and reptiles keep their tails, but many mammals lose theirs. These similarities suggest an evolutionary relationship among all vertebrate species.

Figure 12 Similarities in the embryos of fish, chickens, and rabbits show evidence of evolution. **Evaluate** *these embryos as evidence for evolution.*

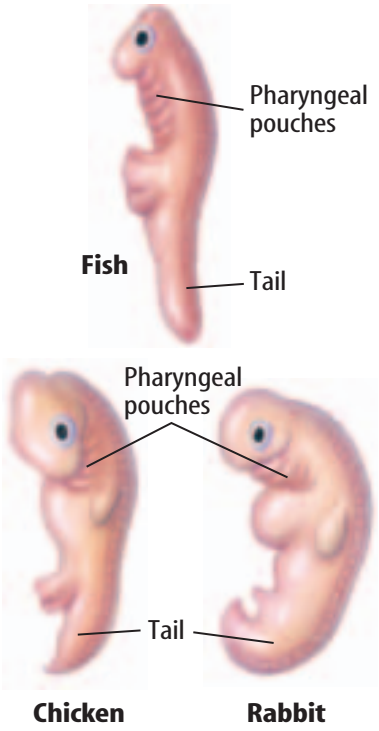


Figure 13 A porpoise flipper, frog forelimb, human arm, and bat wing are homologous. These structures show different arrangements and shapes of the bones of the forelimb. They have the same number of bones, muscles, and blood vessels, and they developed from similar tissues.

Homologous Structures

What do the structures shown in **Figure 13** have in common? Although they have different functions, each of these structures is made up of the same kind of bones. Body parts that are similar in origin and structure are called **homologous** (hoh MAH luh gus). Homologous structures also can be similar in function. They often indicate that two or more species share common ancestors.

Reading Check *What do homologous structures indicate?*

Vestigial Structures

The bodies of some organisms include **vestigial** (veh STIH jee ul) **structures**—structures that don't seem to have a function. Vestigial structures also provide evidence for evolution. For example, manatees, snakes, and whales no longer have back legs, but, like all animals with legs, they still have pelvic bones. The human appendix is a vestigial structure. The appendix appears to be a small version of the cecum, which is an important part of the digestive tract of many mammals. Scientists hypothesize that vestigial structures, like those shown in **Figure 14,** are body parts that once functioned in an ancestor.

Figure 14 Humans have three small muscles around each ear that are vestigial. In some mammals, such as horses, these muscles are large. They allow a horse to turn its ears toward the source of a sound. Humans cannot rotate their ears, but some people can wiggle their ears.

Figure 15 Gorillas have DNA and proteins that are similar to humans and other primates.

DNA If you enjoy science fiction, you have read books or seen movies in which scientists re-create dinosaurs and other extinct organisms from DNA taken from fossils. DNA is the molecule that controls heredity and directs the development of every organism. In a cell with a nucleus, DNA is found in genes that make up the chromosomes. Scientists compare DNA from living organisms to identify similarities among species. Examinations of ancient DNA often provide additional evidence of how some species evolved from their extinct ancestors. By looking at DNA, scientists also can determine how closely related organisms are. For example, DNA studies indicate that dogs are the closest relatives of bears.

Similar DNA also can suggest common ancestry. Apes such as the gorillas shown in **Figure 15,** chimpanzees, and orangutans have 24 pairs of chromosomes. Humans have 23 pairs. When two of an ape's chromosomes are laid end to end, a match for human chromosome number 2 is formed. Also, similar proteins such as hemoglobin—the oxygen-carrying protein in red blood cells—are found in many primates. This can be further evidence that primates have a common ancestor.

section 2 review

Summary

Clues from Fossils

- Scientists learn about past life by studying fossils.

Determining a Fossil's Age

- The relative date of a fossil can be estimated from the ages of rocks in nearby layers.
- Radiometric dating using radioactive elements gives more accurate dates for fossils.

Fossils and Evolution

- The fossil record has gaps which may yet be filled with later discoveries.

More Clues About Evolution

- Homologous structures, similar embryos, or vestigial structures can show evolutionary relationships.
- Evolutionary relationships among organisms can be inferred from DNA comparisons.

Self Check

1. **Compare and contrast** relative dating and radiometric dating.
2. **Discuss** the importance of fossils as evidence of evolution and describe five different kinds of fossils.
3. **Explain** how DNA can provide some evidence of evolution.
4. **List** three examples of direct evidence for evolution.
5. **Interpret Scientific Illustrations** According to data in **Figure 11,** what was the longest geologic era? What was the shortest era? In what period did mammals appear?
6. **Think Critically** Compare and contrast the five types of evidence that support the theory of evolution.

Applying Math

7. **Use Percentages** The Cenozoic Era represents about 65 million years. Approximately what percent of Earth's 4.5-billion-year history does this era represent?

Peter Veit/DRK Photo

section 3

The Evolution of Primates

as you read

What You'll Learn

- **Describe** the differences among living primates.
- **Identify** the adaptations of primates.
- **Discuss** the evolutionary history of modern primates.

Why It's Important

Studying primate evolution will help you appreciate the differences among primates.

Review Vocabulary

opposable: can be placed against another digit of a hand or foot

New Vocabulary

- primate
- hominid
- *Homo sapiens*

Primates

Humans, monkeys, and apes belong to the group of mammals known as the **primates.** All primates have opposable thumbs, binocular vision, and flexible shoulders that allow the arms to rotate. These shared characteristics indicate that all primates may have evolved from a common ancestor.

Having an opposable thumb allows you to cross your thumb over your palm and touch your fingers. This means that you can grasp and hold things with your hands. An opposable thumb allows tree-dwelling primates to hold on to branches.

Binocular vision permits you to judge depth or distance with your eyes. In a similar way, it allows tree-dwelling primates to judge the distances as they move between branches. Flexible shoulders and rotating forelimbs also help tree-dwelling primates move from branch to branch. They also allow humans to do the backstroke, as shown in **Figure 16.**

Primates are divided into two major groups. The first group, the strepsirhines (STREP suh rines), includes lemurs and tarsiers like those shown in **Figure 17.** The second group, haplorhines (HAP luh rines), includes monkeys, apes, and humans.

Figure 16 The ability to rotate the shoulder in a complete circle allows humans to swim through water and tree-dwelling primates to travel through treetops.

Tarsier

Lemur

Figure 17 Tarsiers and lemurs are active at night. Tarsiers are commonly found in the rain forests of Southeast Asia. Lemurs live on Madagascar and other nearby islands.
List *the traits that distinguish these animals as primates.*

Hominids

About 4 million to 6 million years ago, humanlike primates appeared that were different from the other primates. These ancestors, called **hominids,** ate both meat and plants and walked upright on two legs. Hominids shared some characteristics with gorillas, orangutans, and chimpanzees, but a larger brain separated them from the apes.

African Origins

In the early 1920s, a fossil skull was discovered in a quarry in South Africa. The skull had a small space for the brain, but it had a humanlike jaw and teeth. The fossil, named *Australopithecus,* was one of the oldest hominids discovered. An almost-complete skeleton of *Australopithecus* was found in northern Africa in 1974. This hominid fossil, shown in **Figure 18,** was called Lucy and had a small brain but is thought to have walked upright. This fossil indicates that modern hominids might have evolved from similar ancestors.

Figure 18 The fossil remains of Lucy are estimated to be 2.9 million to 3.4 million years old.

Mini LAB

Living Without Thumbs

Procedure

1. Using **tape,** fasten down each of your thumbs next to the palm of each hand.
2. Leave your thumbs taped down for at least 1 h. During this time, do the following activities: eat a meal, change clothes, and brush your teeth. Be careful not to try anything that could be dangerous.
3. Untape your thumbs, then write about your experiences in your **Science Journal.**

Analysis

1. Did not having use of your thumbs significantly affect the way you did anything? Explain.
2. Infer how having opposable thumbs could have influenced primate evolution.

Try at Home

Figure 19 Many of the oldest humanlike skeletons have been found in this area of east Africa.

Early Humans In the 1960s in the region of Africa shown in **Figure 19,** a hominid fossil, which was more like present-day humans than *Australopithecus,* was discovered. The hominid was named *Homo habilis,* meaning "handy man," because simple stone tools were found near him. *Homo habilis* is estimated to be 1.5 million to 2 million years old. Based upon many fossil comparisons, scientists have suggested that *Homo habilis* gave rise to another species, *Homo erectus,* about 1.6 million years ago. This hominid had a larger brain than *Homo habilis. Homo erectus* traveled from Africa to Southeast Asia, China, and possibly Europe. *Homo habilis* and *Homo erectus* are thought to be ancestors of humans because they had larger brains and more humanlike features than *Australopithecus.*

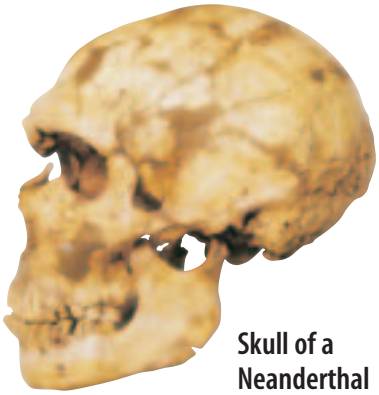
Reading Check ***Why was* Homo habilis *given that name?***

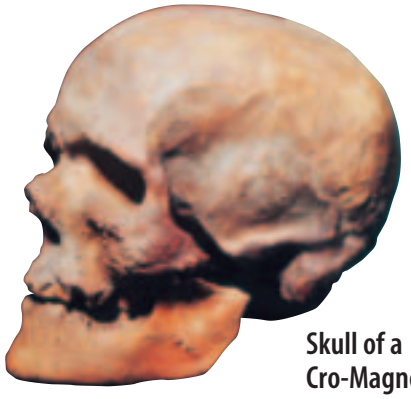
Humans

The fossil record indicates that ***Homo sapiens*** evolved about 400,000 years ago. By about 125,000 years ago, two early human groups, Neanderthals (nee AN dur tawlz) and Cro-Magnon humans, as shown in **Figure 20,** probably lived at the same time in parts of Africa and Europe.

Neanderthals Short, heavy bodies with thick bones, small chins, and heavy browridges were physical characteristics of Neanderthals. Family groups lived in caves and used well-made stone tools to hunt large animals. Neanderthals disappeared from the fossil record about 30,000 years ago. They probably are not direct ancestors of modern humans, but represent a side branch of human evolution.

Figure 20 Compare the skull of a Neanderthal with the skull of a Cro-Magnon. **Describe** *what differences you can see between these two skulls.*


Skull of a Neanderthal


Skull of a Cro-Magnon

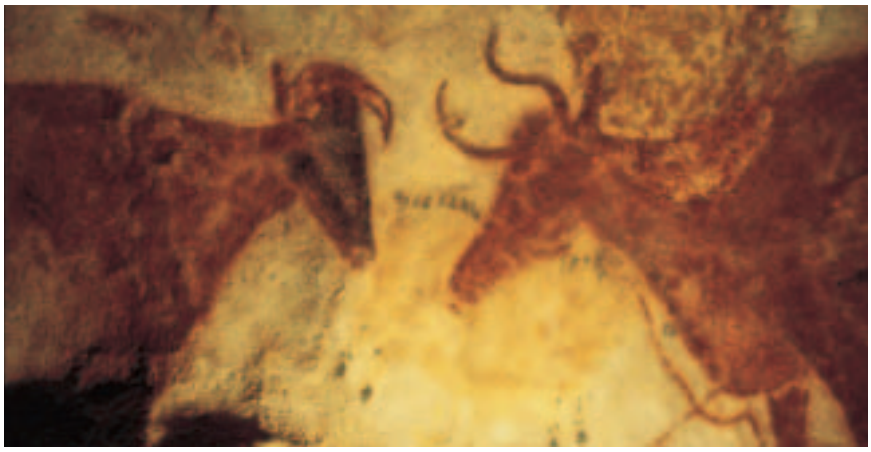


Figure 21 Paintings on cave walls have led scientists to hypothesize that Cro-Magnon humans had a well-developed culture.

Cro-Magnon Humans Cro-Magnon fossils have been found in Europe, Asia, and Australia and date from 10,000 to about 40,000 years in age. Standing about 1.6 m to 1.7 m tall, the physical appearance of Cro-Magnon people was almost the same as that of modern humans. They lived in caves, made stone carvings, and buried their dead. As shown in **Figure 21,** the oldest recorded art has been found on the walls of caves in France, where Cro-Magnon humans first painted bison, horses, and people carrying spears. Cro-Magnon humans are thought to be direct ancestors of early humans, *Homo sapiens,* which means "wise human." Evidence indicates that modern humans, *Homo sapiens sapiens,* evolved from *Homo sapiens.*

section 3 review

Summary

Primates

- Primates are an order of mammals characterized by opposable thumbs, binocular vision, and flexible shoulder joints.
- Primates are divided into strepsirrhines and haplorhines.
- Hominids are human ancestors that first appeared in Africa 4–6 million years ago.
- Hominids in the genus *Homo* first used tools and had larger brains than previous primates.

Humans

- *Homo sapiens* first appeared about 400,000 years ago.
- Cro-Magnon humans and Neanderthals coexisted in many places until Neanderthals disappeared about 30,000 years ago.
- *Homo sapiens* looked like modern humans and are believed to be our direct ancestors.

Self Check

1. **Describe** three kinds of evidence suggesting that all primates might have shared a common ancestor.
2. **Discuss** the importance of *Australopithecus.*
3. **Compare and contrast** Neanderthals, Cro-Magnon humans, and early humans.
4. **Identify** three groups most scientists consider to be direct ancestors of modern humans.
5. **Think Critically** Propose a hypothesis to explain why teeth are the most abundant fossil of hominids.

Applying Skills

6. **Concept Map** Make a concept map to show in what sequence hominids appeared. Use the following: *Homo sapiens sapiens,* Neanderthal, *Homo habilis, Australopithecus, Homo sapiens,* and Cro-Magnon human.
7. **Write** a story in your Science Journal about what life might have been like when both Neanderthals and Cro-Magnon humans were alive.

LAB

Design Your Own

Recognizing Variation in a Population

Goals

- **Design** an experiment that will allow you to collect data about variation in a population.
- **Observe, measure, and analyze** variations in a population.

Possible Materials

fruit and seeds from one plant species
metric ruler
magnifying lens
graph paper

Safety Precautions

WARNING: *Do not put any fruit or seeds in your mouth.*

Real-World Question

When you first observe a flock of pigeons, you might think all the birds look alike. However, if you look closer, you will notice minor differences, or variations, among the individuals. Different pigeons might have different color markings, or some might be smaller or larger than others. Individuals of the same species—whether they're birds, plants, or worms—might look alike at first, but some variations undoubtedly exist. According to the principles of natural selection, evolution could not occur without variations. What kinds of variations have you noticed among species of plants or animals? How can you measure variation in a plant or animal population?

Form a Hypothesis

Make a hypothesis about the amount of variation in the fruit and seeds of one species of plant.

Test Your Hypothesis

Make a Plan

1. As a group, agree upon and write out the prediction.
2. **List** the steps you need to take to test your prediction. Be specific. Describe exactly what you will do at each step. List your materials.
3. **Decide** what characteristic of fruit and seeds you will study. For example, you could measure the length of fruit and seeds or count the number of seeds per fruit.
4. **Design** a data table in your Science Journal to collect data about two variations. Use the table to record the data your group collects.
5. **Identify** any constants, variables, and controls of the experiment.
6. How many fruit and seeds will you examine? Will your data be more accurate if you examine larger numbers?
7. **Summarize** your data in a graph or chart.

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. Carry out the experiment as planned.
3. While the experiment is going on, write down any observations you make and complete the data table in your Science Journal.

Analyze Your Data

1. **Calculate** the mean and range of variation in your experiment. The range is the difference between the largest and the smallest measurements. The mean is the sum of all the data divided by the sample size.
2. **Graph** your group's results by making a line graph for the variations you measured. Place the range of variation on the *x*-axis and the number of organisms that had that measurement on the *y*-axis.

Conclude and Apply

1. **Explain** your results in terms of natural selection.
2. **Discuss** the factors you used to determine the amount of variation present.
3. **Infer** why one or more of the variations you observed in this activity might be helpful to the survival of the individual.

Communicating Your Data

Create a poster or other exhibit that illustrates the variations you and your classmates observed.

Aaron Haupt

TIME SCIENCE AND HISTORY

SCIENCE CAN CHANGE THE COURSE OF HISTORY!

Fighting HIV

The first cases of AIDS, or acquired immune deficiency syndrome, in humans were reported in the early 1980s. AIDS is caused by the human immunodeficiency virus, or HIV.

A major problem in AIDS research is the rapid evolution of HIV. When HIV multiplies inside a host cell, new versions of the virus are produced as well as identical copies of the virus that invaded the cell. New versions of the virus soon can outnumber the original version. A treatment that works against today's HIV might not work against tomorrow's version.

These rapid changes in HIV also mean that different strains of the virus exist in different places around the world. Treatments developed in the United States work only for people who contracted the virus in the United States. This leaves people in some parts of the world without effective treatments. So, researchers such as geneticist Flossie Wong-Staal at the University of California, San Diego, must look for new ways to fight the evolving virus.

Working Backwards

Flossie Wong-Staal is taking a new approach. First, her team identifies the parts of a human cell that HIV depends on and the parts of the human cell that HIV needs but the human cell doesn't need. Then the team looks for a way to remove—or inactivate—those unneeded parts. This technique limits the virus's ability to multiply.

Wong-Staal's research combines three important aspects of science—a deep understanding of how cells and genes operate, great skill in the techniques of genetics, and great ideas. Understanding, skill, and great ideas are the best weapons so far in the fight to conquer HIV.

Wong-Staal was on one of the two teams that first identified HIV as the virus that causes AIDS.

Research **Use the link to the right and other sources to determine which nations have the highest rates of HIV infection. Which nation has the highest rate? Where does the U.S. rank? Next, find data from ten years ago. Have the rankings changed?**

Science Online

For more information, visit booka.msscience.com/time

Reviewing Main Ideas

Section 1 Ideas About Evolution

1. Evolution is one of the central ideas of biology. It explains how living things have changed in the past and is a basis for predicting how they might change in the future.
2. Charles Darwin developed the theory of evolution by natural selection to explain how evolutionary changes account for the diversity of organisms on Earth.
3. Natural selection includes concepts of variation, overproduction, and competition.
4. According to natural selection, organisms with traits best suited to their environment are more likely to survive and reproduce.

Section 2 Clues About Evolution

1. Fossils provide evidence for evolution.
2. Relative dating and radiometric dating can be used to estimate the age of fossils.
3. The evolution of antibiotic-resistant bacteria, pesticide-resistant insects, and rapid genetic changes in plant species provides direct evidence that evolution occurs.
4. Homologous structures, vestigial structures, comparative embryology, and similarities in DNA provide indirect evidence of evolution.

Section 3 The Evolution of Primates

1. Primates include monkeys, apes, and humans. Hominids are humanlike primates.
2. The earliest known hominid fossil is *Australopithecus.*
3. *Homo sapiens* are thought to have evolved from Cro-Magnon humans about 400,000 years ago.

Visualizing Main Ideas

Copy and complete the following spider map on evolution.

chapter 6 Review

Using Vocabulary

adaptation p. 160
embryology p. 169
evolution p. 156
gradualism p. 162
hominid p. 173
Homo sapiens p. 174
homologous p. 170
natural selection p. 159
primate p. 172
punctuated equilibrium p. 162
radioactive element p. 167
sedimentary rock p. 166
species p. 156
variation p. 160
vestigial structure p. 170

Fill in the blanks with the correct vocabulary word or words.

1. _____ contains many different kinds of fossils.

2. The muscles that move the human ear appear to be _____.

3. Forelimbs of bats, humans, and seals are _____.

4. Opposable thumbs are a characteristic of _____.

5. The study of _____ can provide evidence of evolution.

6. The principles of _____ include variation and competition.

7. _____ likely evolved directly from Cro-Magnons.

Checking Concepts

Choose the word or phrase that best answers the question.

8. What is an example of adaptation?
A) a fossil
B) gradualism
C) camouflage
D) embryo

9. What method provides the most accurate estimate of a fossil's age?
A) natural selection
B) radiometric dating
C) relative dating
D) camouflage

10. What do homologous structures, vestigial structures, and fossils provide evidence of?
A) gradualism
B) food choice
C) populations
D) evolution

11. Which model of evolution shows change over a relatively short period of time?
A) embryology
B) adaptation
C) gradualism
D) punctuated equilibrium

12. What might a series of helpful variations in a species result in?
A) adaptation
B) fossils
C) embryology
D) climate change

Use the following chart to answer question 13.

Homo habilis
↓
Homo erectus
↓
?
↓
Homo sapiens

13. Which correctly fills the gap in the line of descent from *Homo habilis*?
A) Neanderthal
B) *Australopithecus*
C) Cro-Magnon human
D) chimpanzee

14. What is the study of an organism's early development called?
A) adaptation
B) relative dating
C) natural selection
D) embryology

Thinking Critically

15. Predict what type of bird the foot pictured at right would belong to. Explain your reasoning.

16. Discuss how Lamarck and Darwin would have explained the large eyes of an owl.

17. Explain, using an example, how a new species of organism could evolve.

18. Identify how the color-changing ability of chameleons is an adaptation.

19. Form a hypothesis as to why ponds are not overpopulated by frogs in summer. Use the concept of natural selection to help you.

20. Sequence Make an events-chain concept map of the events that led Charles Darwin to his theory of evolution by natural selection.

Use the table below to answer question 21.

Chemicals Present in Bacteria	
Species 1	A, G, T, C, L, E, S, H
Species 2	A, G, T, C, L, D, H
Species 3	A,G, T, C, L, D, P, U, S, R, I, V
Species 4	A, G, T, C, L, D, H

21. Interpret Data Each letter above represents a chemical found in a species of bacteria. Which species are most closely related?

22. Discuss the evidence you would use to determine whether the evolution of a group were best explained by gradualism. How would this differ from a group that followed a punctuated equilibrium model?

23. Describe the processes a scientist would use to figure out the age of a fossil.

24. Evaluate the possibility for each of the five types of fossils in **Figure 9** to yield a DNA sample. Remember that only biological tissue will contain DNA.

Performance Activities

25. Collection With permission, collect fossils from your area and identify them. Show your collection to your class.

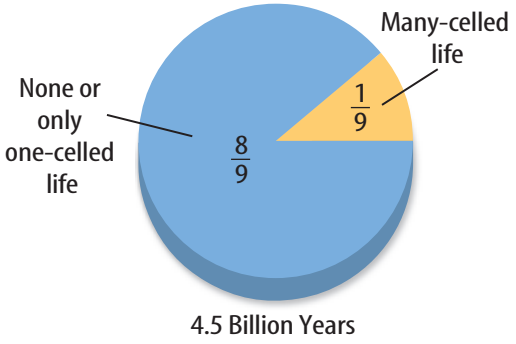
26. Brochure Assume that you are head of an advertising company. Develop a brochure to explain Darwin's theory of evolution by natural selection.

Applying Math

27. Relative Age The rate of radioactive decay is measured in half-lives—the amount of time it takes for one half of a radioactive element to decay. Determine the relative age of a fossil given the following information:

- Rock layers are undisturbed.
- The layer below the fossil has potassium-40 with a half-life of 1 million years and only one half of the original potassium is left.
- The layer above the fossil has carbon-14 with a half-life of 5,730 years and one-sixteenth of the carbon isotope remains.

Use the graph below to answer question 28.



28. First Appearances If Earth is 4.5 billion years old, how long ago did the first many-celled life-forms appear?

Part 1 Multiple Choice

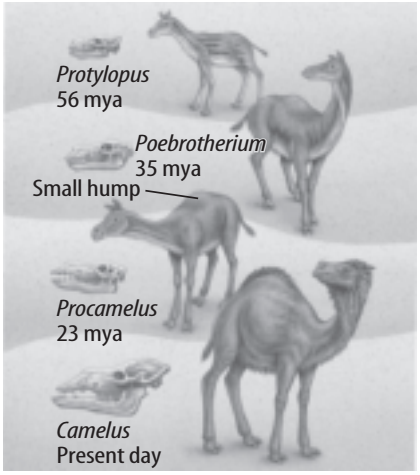
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. A species is a group of organisms
- **A.** that lives together with similar characteristics.
- **B.** that shares similar characteristics and can reproduce among themselves to produce fertile offspring.
- **C.** across a wide area that cannot reproduce.
- **D.** that chooses mates from among themselves.

2. Which of the following is considered an important factor in natural selection?
- **A.** limited reproduction
- **B.** competition for resources
- **C.** no variations within a population
- **D.** plentiful food and other resources

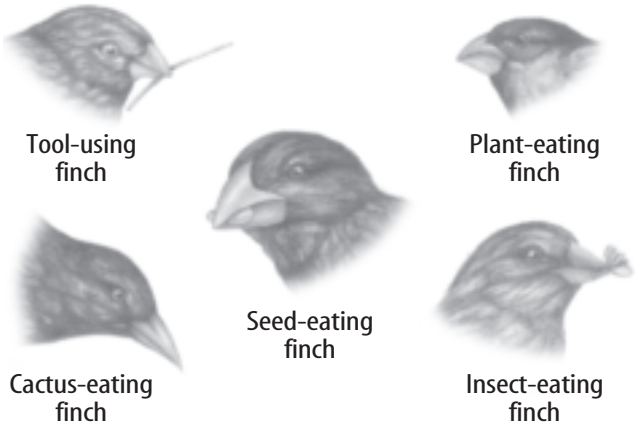
3. The marine iguana of the Galápagos Islands enters the ocean and feeds on seaweed. What is this an example of?
- **A.** adaptation
- **B.** gradualism
- **C.** survival of the fittest
- **D.** acquired characteristic

Use the illustration below to answer question 4.



4. According to Lamarck's hypothesis of acquired characteristics, which statement best explains the changes in the camel over time?
- **A.** All characteristics developed during an individual's lifetime are passed on to offspring.
- **B.** Characteristics that do not help the animal survive are passed to offspring.
- **C.** Variation of the species leads to adaptation.
- **D.** Individuals moving from one area to another carry with them new characteristics.

Use the illustrations below to answer question 5.



5. What, besides competition for food, contributed to the evolution of the species of Darwin's finches?
- **A.** predation
- **B.** natural disaster
- **C.** DNA
- **D.** variation in beak shapes

6. Some harmless species imitate or mimic a poisonous species as a means for increased survival. What is this an example of?
- **A.** acquired characteristics
- **B.** adaptation
- **C.** variation
- **D.** geographic isolation

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

7. How does camouflage benefit a species?

Use the photo below to answer question 8.

8. Describe an environment where the albino lemur would not be at a disadvantage.

9. Variation between members of a species plays an important role in Darwin's theory of evolution. What happens to variation in endangered species where the number of individuals is very low?

10. Describe what happens to an endangered species if a variation provides an advantage for the species. What would happen if the variation resulted in a disadvantage?

11. Using the theory of natural selection, hypothesize why the Cro-Magnon humans survived and the Neanderthals disappeared.

Test-Taking Tip

Never Leave Any Answer Blank Answer each question as best you can. You can receive partial credit for partially correct answers.

Question 16 If you cannot remember all primate characteristics, list as many as you can.

Part 3 Open Ended

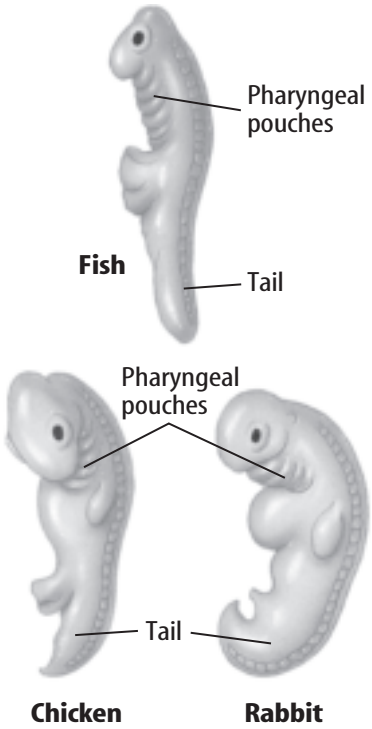
Record your answers on a sheet of paper.

12. What are the two groups of early humans that lived about 125,000 years ago in Africa and Europe? Describe their general appearance and characteristics. Compare these characteristics to modern humans.

13. Explain how bacterial resistance to antibiotics is an example of punctuated equilibrium.

14. Why are radioactive elements useful in dating fossils? Does this method improve accuracy over relative dating?

Use the illustrations below to answer question 15.



15. Why would scientists study embryos? What features of these three embryos support evolution?

16. How does DNA evidence provide support that primates have a common ancestor?