Chapter 7

Changes Over Time

CALIFORNIA Standards Preview

S 7.3 Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept:

- **a.** Students know both genetic variation and environmental factors are causes of evolution and diversity of organisms.
- **b.** Students know the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.
- **c.** Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.
- **d.** Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.
- **e.** Students know that extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.

S 7.4 Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

- **e.** Students know fossils provide evidence of how life and environmental conditions have changed.

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

Video Preview
Discovery Channel School
Changes Over Time

Focus on the
BIG Idea

S 7.3.a

What factors have caused the evolution and diversity of organisms?

Check What You Know

You plant a packet of zinnia seeds, and later, the zinnias begin to bloom. You notice that no two plants are exactly alike. For example, some flowers have different colors than others. What accounts for these differences? Write an explanation.

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Identify Multiple Meanings

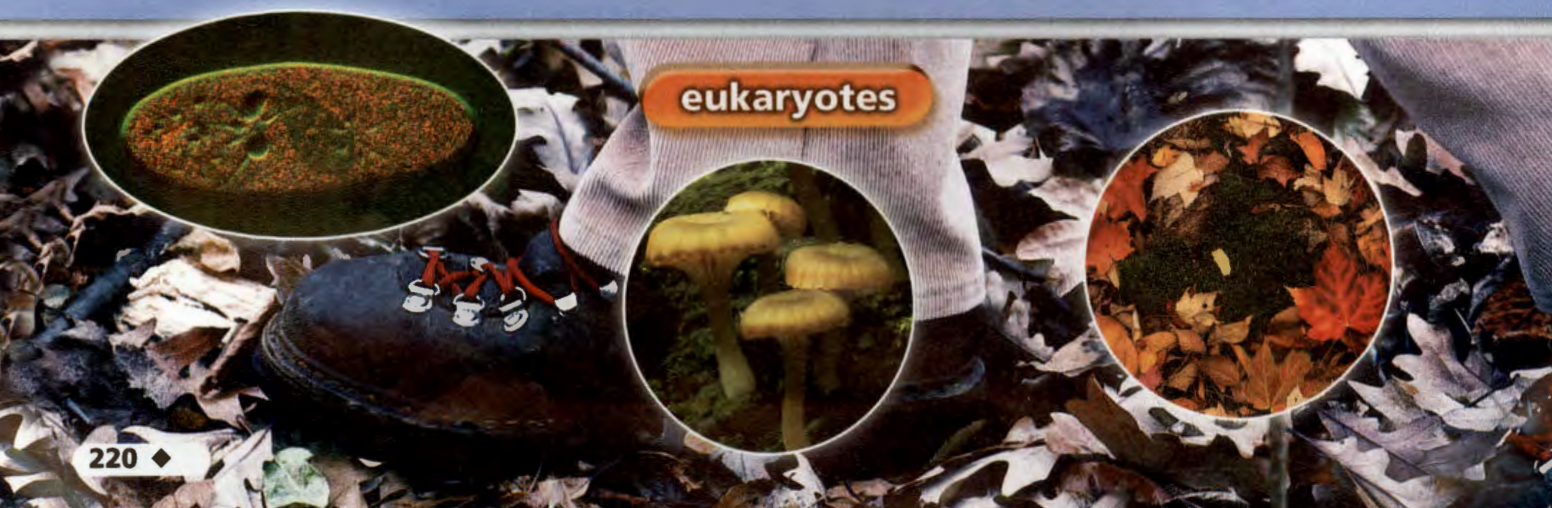
Some words, such as *theory* and *cast,* have different meanings in science and in everyday use. Look at the different meanings of *theory* and *cast* in the graphic below.

Word	Everyday Meaning	Scientific Meaning
theory	*n.* A guess; an idea of how or why something might happen **Example:** Emily has a theory that basketball is harder to play than baseball.	*n.* A well-tested concept that explains a wide range of observations **Example:** The cell theory says that all organisms are made of cells.
cast	*n.* A device that protects a broken bone by preventing it from moving **Example:** Tim's broken elbow has healed, so the cast can be removed.	*n.* A type of fossil that forms when a mold becomes filled with minerals **Example:** The cast of the foot print shows that the extinct animal had five toes.

Apply It!

In the sentences below, identify which meaning of the word *theory* was used—the everyday meaning or the scientific meaning.

1. The theory of evolution explains how organisms have changed over time.
2. Do you have a theory about why Sarah is a vegetarian?



Chapter 7 Vocabulary

Section 1 (page 224)
species
fossil
adaptation
evolution
scientific theory
natural selection
variation

Section 2 (page 234)
comparative anatomy
homologous structures
mold
cast
petrified fossil
trace fossil
paleontologist
gradualism
punctuated equilibria

Section 3 (page 241)
habitat
extinct

Section 4 (page 248)
classification
taxonomy
binomial nomenclature
genus
prokaryote
eukaryote

Section 5 (page 255)
branching tree diagram
shared derived characteristic

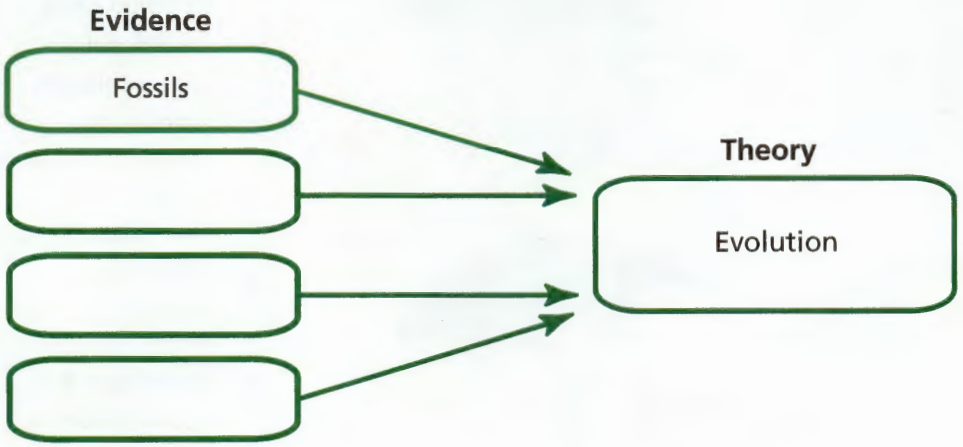
Interactive Textbook
Build Science Vocabulary Online
Visit: PHSchool.com
Web Code: cvj-2070

How to Read Science

Reading Skill

Identify Supporting Evidence

Scientific theories are always supported by a great deal of evidence. Evidence consists of facts that can be confirmed by testing or observation. A huge amount of evidence supports the theory of evolution. Section 2 of this chapter identifies and explains this evidence. Look at the incomplete graphic organizer below. Notice that fossils provide one kind of evidence.



Apply It!

Copy the incomplete graphic organizer into your notebook. As you read Section 2, fill in the missing spaces with other kinds of evidence that support the theory of evolution.

Lab zone

Standards Investigation

S 7.3.c

Extinction and Fossils

During the long history of life on Earth, many organisms have become extinct. Scientists have been able to learn a lot about many of these organisms because of the fossils they left behind. In this investigation, you will learn about an extinct organism whose fossils have been discovered in California.

Your Goal

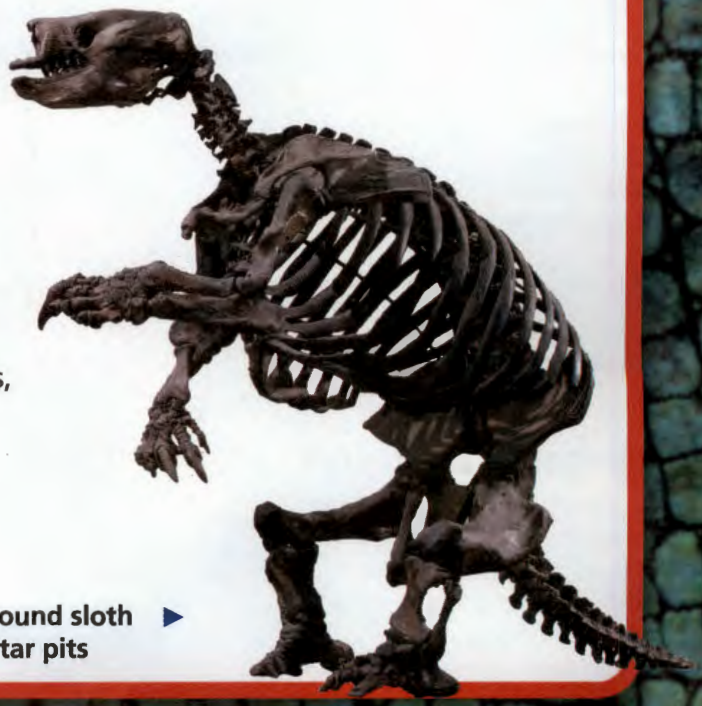
To choose an extinct organism whose fossils have been discovered in California, and to research and present information about that organism

To complete this project you must

- research an extinct organism whose fossils have been found in California
- identify the environment that the organism probably lived in
- describe what may have led to the organism's extinction
- create a way of displaying your findings to the class
- follow the safety guidelines in Appendix A

Plan It!

Begin by choosing an extinct organism whose fossils have been discovered in California. Then find the information you need about the organism. Natural history museums and the Internet are good sources for identifying fossils found in California and for finding answers to your questions. Finally, decide how you will present that information to your class. Some possibilities include posters, booklets, and three-dimensional displays.



Fossil of a grazing ground sloth found in the La Brea tar pits ▶

Section 1

Darwin's Theory

California Standards Focus

S 7.3.a Students know both genetic variation and environmental factors are causes of evolution and diversity of organisms.

S 7.3.b Students know the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.

- What important observations did Darwin make on his voyage?
- How did Darwin account for the diversity of species and the differences between similar species?
- How does natural selection lead to evolution?

Key Terms

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

Lab zone Standards Warm-Up

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 organisms, the remains of ancient organisms, and the characteristics of organisms on the Galápagos Islands.**

Video Field Trip
Discovery Channel School
Changes Over Time

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?

▲ 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?*

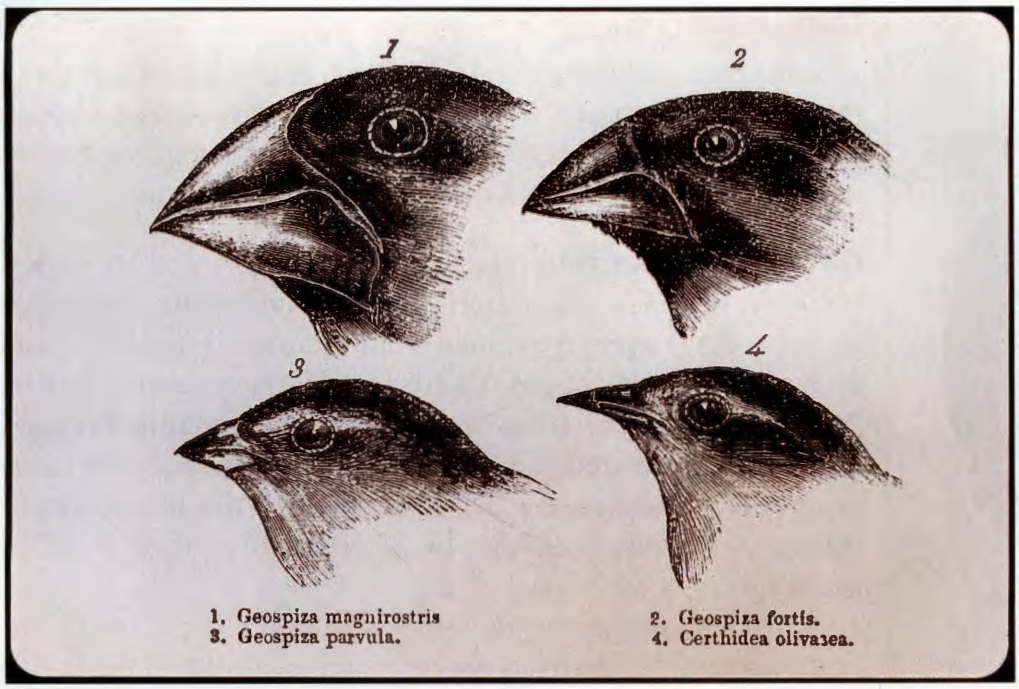


FIGURE 3
Galápagos Finches Darwin made these drawings of four species of Galápagos finches. The structure of each bird's beak is an adaptation related to the type of food the bird eats. **Comparing and Contrasting** *Identify some specific differences in these finches' beaks.*

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 in its environment. 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 the diversity of species he had seen during his voyage. Darwin spent the next 20 years consulting with other scientists, gathering more information, and thinking through his ideas.

Darwin's Reasoning Darwin especially wanted to understand the different adaptations of organisms on the Galápagos Islands. **Darwin reasoned that plants or animals that arrived on the Galápagos Islands faced environmental factors 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 environments.** 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. Pigeon breeders had produced pigeons with two or three times the usual number of tail feathers. The pigeon breeders did this by repeatedly allowing only those pigeons with many tail feathers to mate. Darwin thought that a process similar to selective breeding might happen in nature. But he wondered what process selected certain traits.

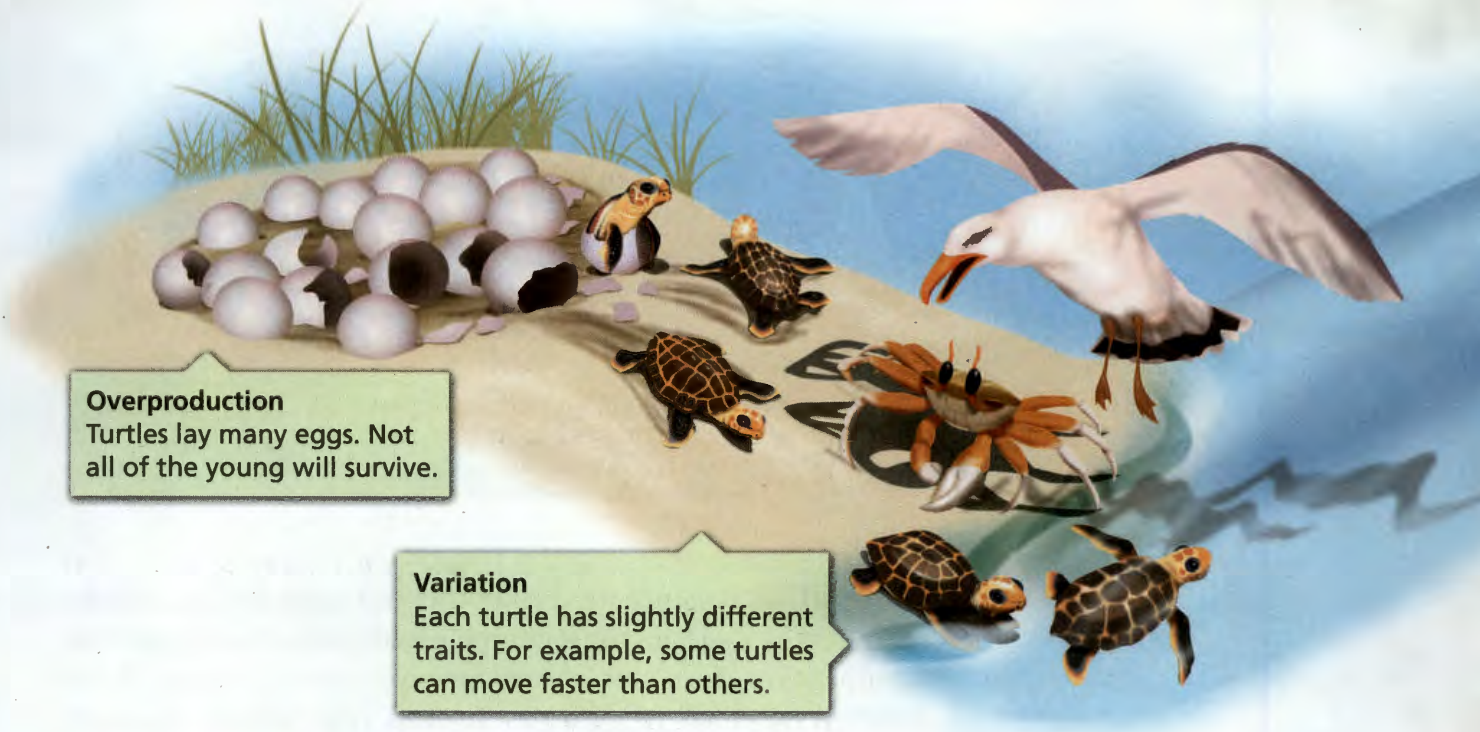
Seattle Slew, ▲ grandfather of Funny Cide

Distorted Humor, ▲ father of Funny Cide

Funny Cide ▶

Reading Checkpoint **What is a scientific theory?**

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 1859, Darwin published a book called *On the Origin of Species by Natural Selection.* In it, Darwin proposed that evolution occurs in nature through a mechanism he called natural selection. In **natural selection**, 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, variations, and competition. Figure 5 and Figure 6 show how natural selection might happen in a group of turtles.

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?*

Overproduction Darwin read *Essay on the Principle of Population* by an Englishman named Thomas Robert Malthus. Malthus argued that humans and other organisms tend to produce a lot of offspring. Malthus pointed out that sometimes the food supply is not large enough to feed all these offspring. Darwin knew that, in addition to food, living things needed other resources, such as water and living space. He also knew that overproduction occurs in many species. 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 genetics, members of a species differ from one another in many of their traits. A difference between individuals of the same species is called a genetic **variation**. For example, certain insects may be able to eat foods that other insects of their species avoid. This characteristic gives the insects an advantage over most insects in their species.

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?

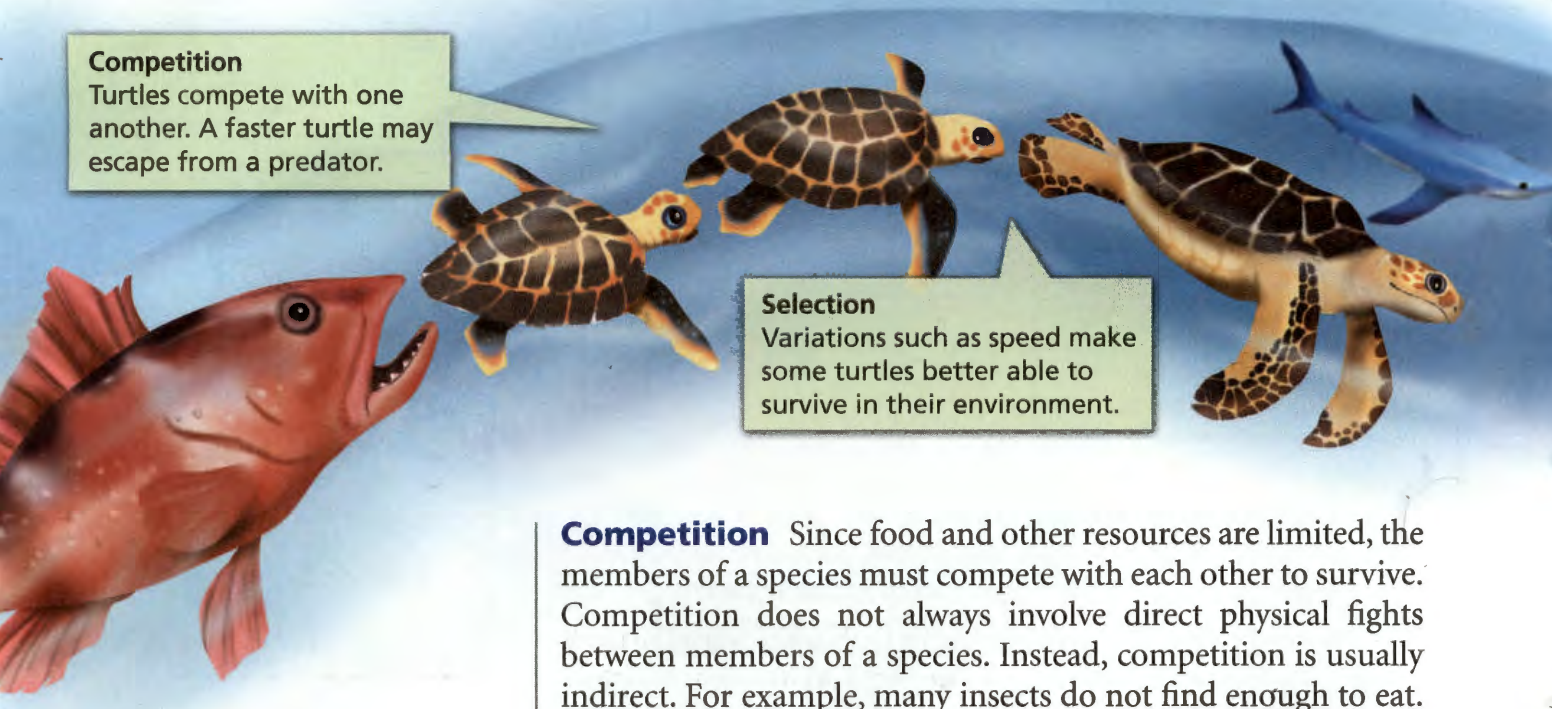


FIGURE 6
Competition and Selection
Variations among turtles make some of them better able to survive. Turtles that survive to become adults will be able to reproduce.
Applying Concepts *What are some variations that sea turtles might exhibit?*

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 Factors Factors in the environment can affect an organism's ability to survive. Environmental factors 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.

Go Online
NSTA SCILINKS
For: Links on Charles Darwin
Visit: www.SciLinks.org
Web Code: scn-0351

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 Like environmental factors, genetic variation contributes to evolution. Without variations, all 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.

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

S 7.3.a, 7.3.b, E-LA: Writing 7.2.1, Reading 7.1.0

Vocabulary Skill **Identify Multiple Meanings** What does *competition* mean to a scientist studying evolution? What is another meaning of *competition*?

Reviewing Key Concepts

1. a. **Listing** List three general kinds of observations that Darwin made during his voyage.
   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 genetic variation and environmental factors work together to cause natural selection?
   c. **Applying Concepts** How do monkey flowers near mines show that natural selection causes evolution?

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.

Nature at Work

S 7.3.a, 7.3.b, 7.7.c, 7.7.e

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

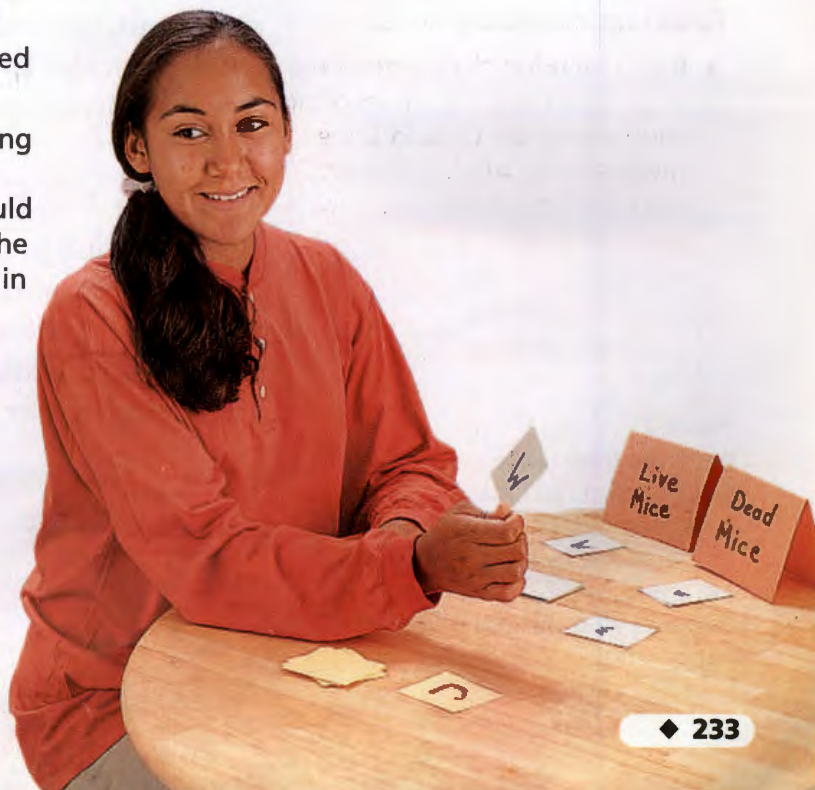
Table 2: Event Cards		
Number	**Label**	**Meaning**
5	S	Mouse survives.
1	D	Disease kills mouse.
1	P	Predator kills mice of all colors.
18	C	Predator kills mice that contrast with the environment.

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

CALIFORNIA Standards Focus

S 7.3.c Students know how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.

S 7.4.e Students know fossils provide evidence of how life and environmental conditions have changed.

- What evidence supports the theory of evolution?
- How do fossils form?
- What do scientists learn from fossils?

Key Terms

- comparative anatomy
- homologous structures
- mold
- cast
- petrified fossil
- trace fossil
- paleontologist
- gradualism
- punctuated equilibria

Lab zone Standards Warm-Up

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?

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 not harmed by the pesticide. After many years, most of the cockroaches in the building are resistant to the pesticide. The development of pesticide resistance is one type of evidence that supports the theory of evolution.

Forms of Evidence

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

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.

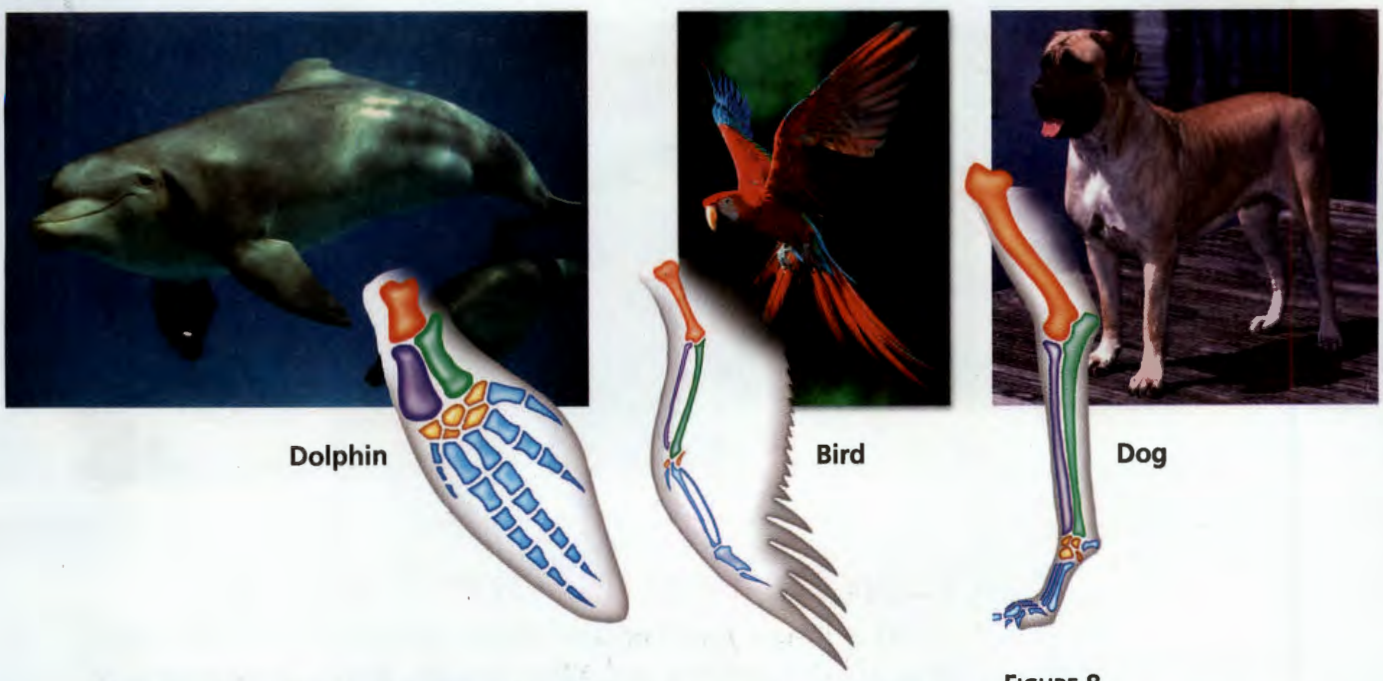


FIGURE 8
Homologous Structures
The structure of the bones in a dolphin's flipper, a bird's wing, and a dog's leg is similar. Homologous bones are shown in the same color. **Interpreting Diagrams** *How are all three orange bones similar?*

Similarities in Body Structure The comparison of the structures of different organisms is called **comparative anatomy**. An organism's anatomy is its body structure. Fishes, amphibians, reptiles, birds, and mammals all have a similar anatomy—an internal skeleton with a backbone. This is why scientists classify all five groups as vertebrates. All these groups probably inherited a similar structure from an early vertebrate ancestor that they shared.

Figure 8 shows that the bones of the front limbs of dolphins, birds, and dogs 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).

Similarities in Early Development Scientists make inferences about evolutionary relationships by comparing how different species develop before birth. During early development, all vertebrates have a tail and rows of tiny slits in their throats. These similarities suggest that vertebrate species share a common ancestor.

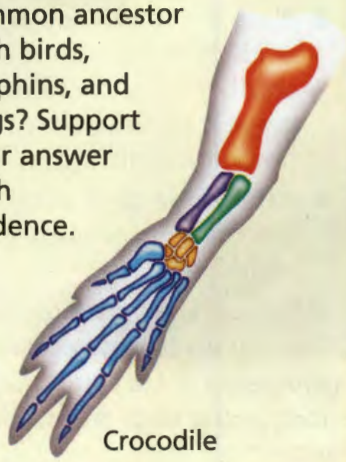
Similarities in DNA and Proteins The structure of organisms' DNA and protein molecules also provides evidence of evolution. If two species have similar DNA and proteins, they probably evolved from the same ancestor.

Reading Checkpoint **What are homologous structures?**

Lab zone Skills Activity

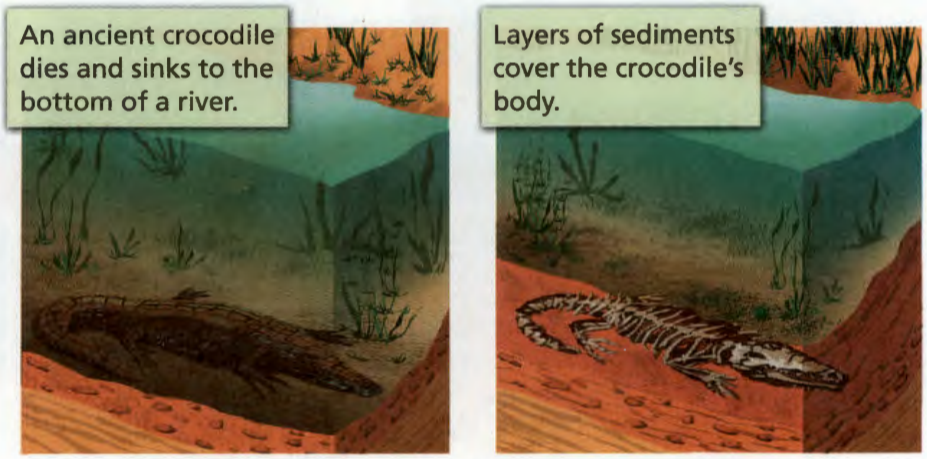
Drawing Conclusions

Look at the drawing below of the bones in a crocodile's leg. Compare this drawing to Figure 8. Do you think that crocodiles share a common ancestor with birds, dolphins, and dogs? Support your answer with evidence.



Crocodile

FIGURE 9
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?

Fossil evidence supports the theory of evolution. 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.

Molds and Casts The most common fossils are molds and casts. Both copy the shape of ancient organisms. A **mold** is a hollow area in sediment in the shape of an organism or part of an organism. A mold forms when the hard part of the organism, such as a shell, is buried in sediment.

Later, water carrying dissolved minerals and sediment may seep into the empty space of a mold. If the water deposits the minerals and sediments there, the result is a cast. A **cast** is a solid copy of the shape of an organism. A cast is the opposite of its mold. Both the mold and cast preserve details of the animal's structure.

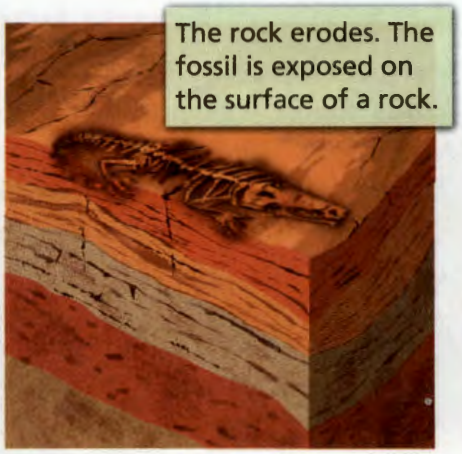
Petrified Fossils A fossil may form when the remains of an organism become petrified. **Petrified fossils** are fossils in which minerals replace all or part of an organism. Fossil tree trunks are an example of petrified wood. These fossils formed after sediment covered the wood. Then water rich in dissolved minerals soaked into spaces in the plant's cells. Over time, the minerals came out of solution and hardened. Some of the original wood remains in petrified wood, but minerals have hardened and preserved the wood.

Lab zone **Try This Activity**

Preservation in Ice

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

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



Go Online
active art

For: Fossil Formation activity
Visit: PHSchool.com
Web Code: cep-3053

Trace Fossils Most types of fossils preserve the shapes of ancient animals and plants. In contrast, **trace fossils** provide evidence of the activities of ancient organisms. A fossilized footprint is one example of a trace fossil. The mud or sand that the animal stepped in was buried by layers of sediment. Slowly the sediment became solid rock, preserving the footprint for millions of years.

From fossil footprints, scientists can find answers to questions about an animal's size and behavior. Did the animal walk on two or four legs? Did it live alone or as part of a group?

Other types of trace fossils also provide clues about ancient organisms. A trail or burrow can give clues about the size and shape of an organism, where it lived, and how it obtained food.

Preserved Remains Some processes preserve the remains of organisms with little or no change. For example, some remains are preserved when organisms become trapped in tar. Tar is sticky oil that seeps from Earth's surface. Many fossils preserved in tar have been found at the Rancho La Brea tar pits in Los Angeles, California. Thousands of years ago, animals came to drink the water that covered these pits. Somehow, they became stuck in the tar and then died. The tar soaked into their bones, preserving the bones from decay.

Ancient organisms also have been preserved in amber. Amber is the hardened resin, or sap, of evergreen trees. First, an insect is trapped on sticky resin. After the insect dies, more resin covers it, sealing it from air and protecting its body from decay.

Freezing can also preserve remains. The frozen remains of woolly mammoths, huge ancient relatives of elephants, have been found in very cold regions of Siberia and Alaska. Freezing *has* preserved even the mammoths' hair and skin.

Reading Checkpoint **What are three ways in which the remains of an organism can be preserved with little change?**

FIGURE 10

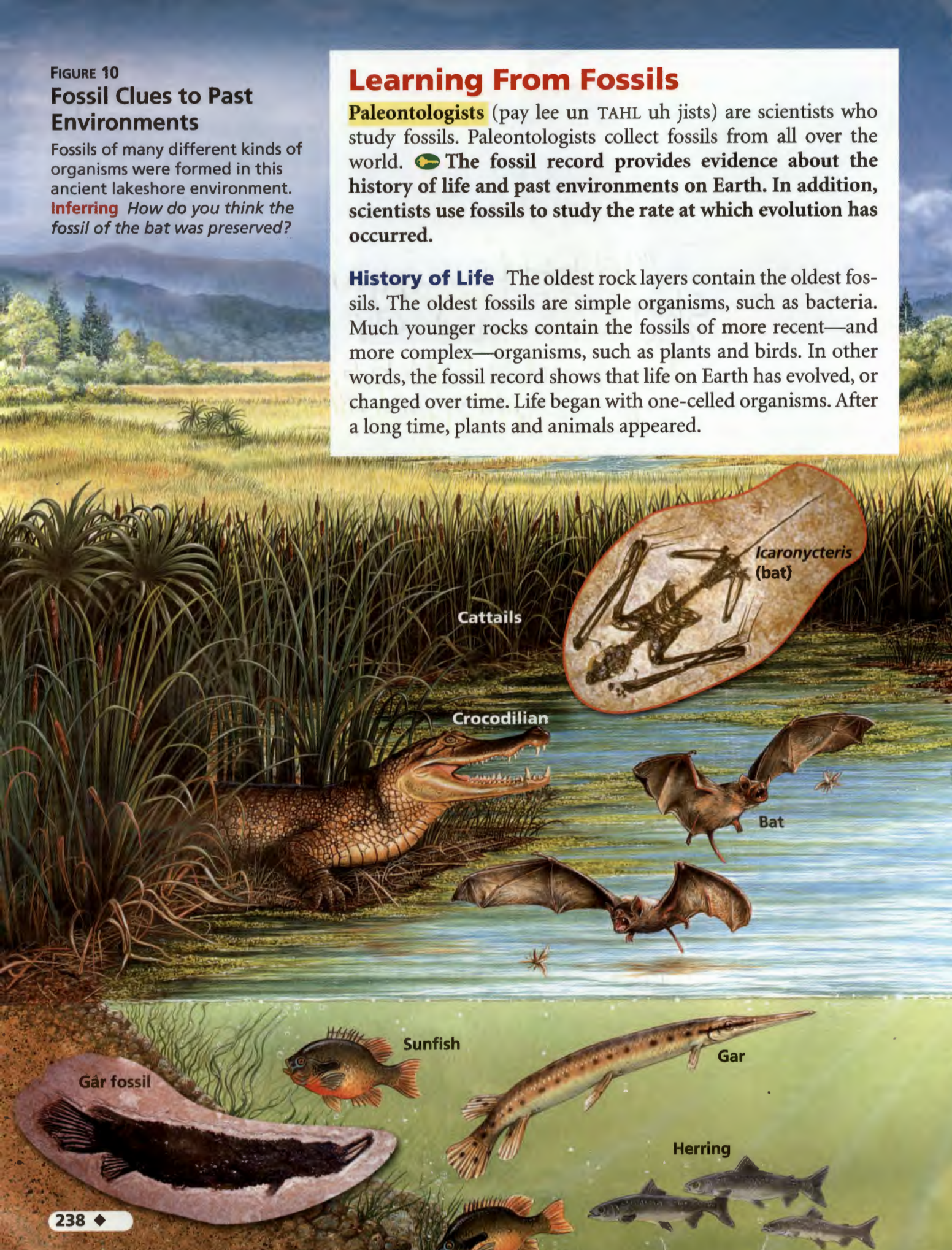
Fossil Clues to Past Environments

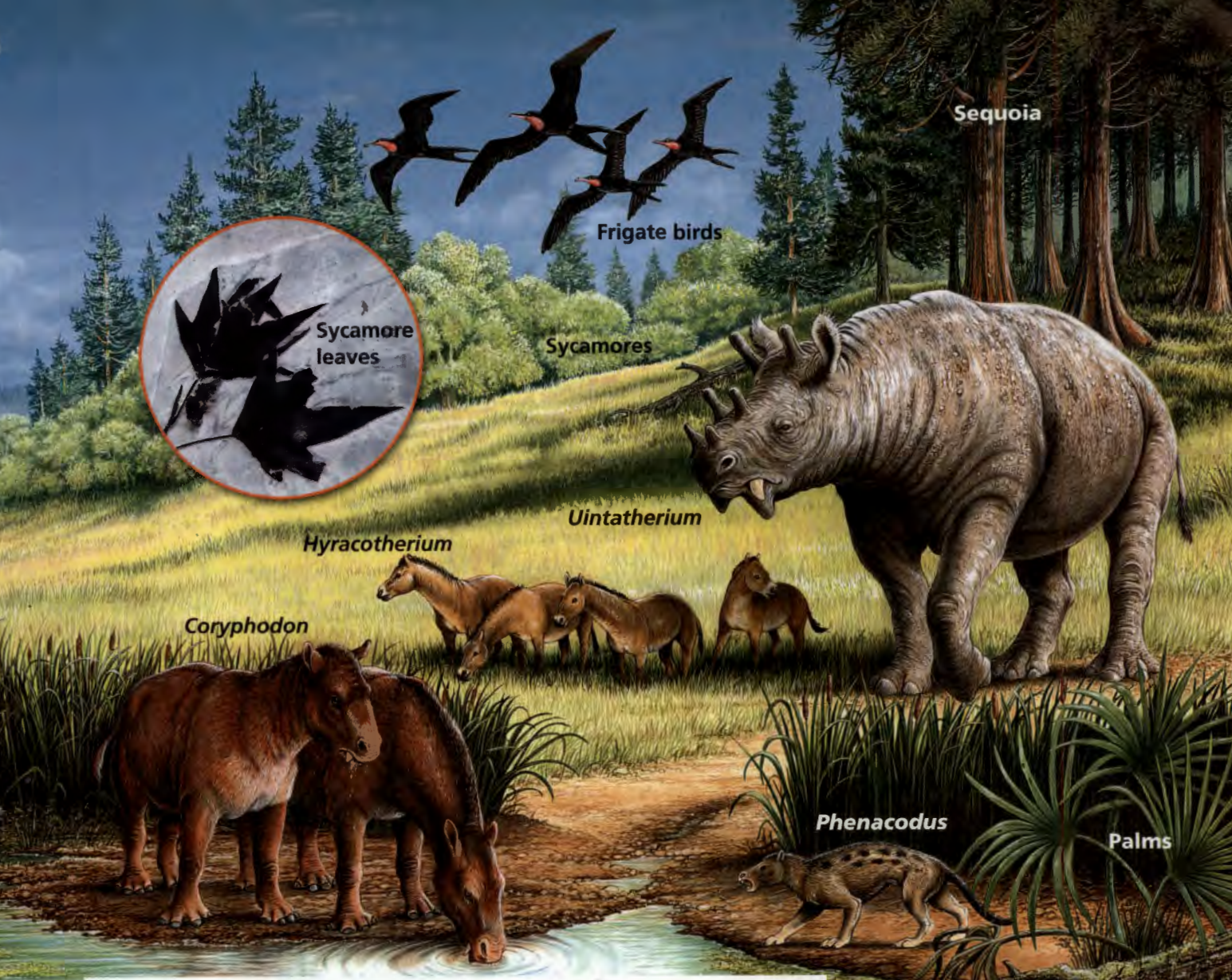
Fossils of many different kinds of organisms were formed in this ancient lakeshore environment. **Inferring** *How do you think the fossil of the bat was preserved?*

Learning From Fossils

Paleontologists (pay lee un TAHL uh jists) are scientists who study fossils. Paleontologists collect fossils from all over the world. **The fossil record provides evidence about the history of life and past environments on Earth. In addition, scientists use fossils to study the rate at which evolution has occurred.**

History of Life The oldest rock layers contain the oldest fossils. The oldest fossils are simple organisms, such as bacteria. Much younger rocks contain the fossils of more recent—and more complex—organisms, such as plants and birds. In other words, the fossil record shows that life on Earth has evolved, or changed over time. Life began with one-celled organisms. After a long time, plants and animals appeared.





Past Environments Paleontologists use fossils to build up a picture of Earth's past environments. The fossils found in an area tell whether the area was a desert, a forest, or a freshwater swamp. Suppose, for example, a fossil looks a lot like a clam. Modern clams live in water. Therefore, the fossil animal probably lived in water, too.

Fossils can show how an environment has changed. For example, coal has been found in Antarctica. But coal only forms from the remains of plants that grow in warm regions. Ice and snow now cover Antarctica. The presence of coal shows that the climate of Antarctica was once much warmer than today.

Scientists can use fossils to learn about changes in Earth's surface. For example, the fossils in Figure 10 are about 50 million years old. They were found in a region of dry plains and plateaus in Wyoming. From these fossils, scientists have inferred that back then the region had many shallow lakes and swamps. Lush forests flourished in a warm, subtropical climate.

Gradualism Scientists also study fossils to try to determine the rate at which evolution occurs. Scientists are not sure how rapidly species change. One hypothesis, called **gradualism**, proposes that evolution occurs slowly but steadily. According to this hypothesis, 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 gradualism is correct, the fossil record should include intermediate forms between a fossil organism and its descendants. However, there are often long periods in which fossils show little or no change. Then, quite suddenly, fossils appear that are very 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 The hypothesis of **punctuated equilibria** accounts for the gaps in the fossil record. According to this hypothesis, 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 hypothesis proposes that evolution occurs slowly but steadily?**

Section 2 Assessment

S 7.3.c, 7.4.e, E-LA: Reading 7.2.0

Target Reading Skill **Identify Supporting Evidence** Refer to your graphic organizer about evidence for evolution as you answer the questions below.

Reviewing Key Concepts

1. a. **Listing** List four types of evidence that support evolution.
   b. **Applying Concepts** What is comparative anatomy and how do scientists use it to study evolution?
   c. **Interpreting Diagrams** Compare the dolphin, bird, and dog forelimb bones in Figure 8. List one specific way in which the bone structures are similar.
2. a. **Reviewing** What are sediments? How are they involved in the formation of fossils?
   b. **Classifying** Identify five types of fossils.
   c. **Comparing and Contrasting** Which of the major types of fossils does not form in sediments? Describe how this type can form.
3. a. **Defining** What is a paleontologist?
   b. **Reviewing** What can paleontologists learn from fossils?
   c. **Inferring** A paleontologist finds a fossil fish in rocks located in what is now a dry area. What was the environment of that area probably like when the fish was alive?

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.

Section 3

Evolution of Species

California Standards Focus

S 7.3.a Students know that both genetic variation and environmental factors are causes of evolution and diversity of organisms.

S 7.3.e Students know that extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient for its survival.

- What factors have contributed to the diversity of species?
- How do new species form?
- How do scientists infer evolutionary relationships among species?
- What causes the extinction of species?

Key Terms

- habitat
- extinct

Lab zone Standards Warm-Up

Which Is the Closer Relative?

1. The pictures show a dog, a coyote, and a wolf. Compare and contrast the pictures carefully.
2. On the basis of your comparison, decide which animal—a coyote or a wolf—is more closely related to a dog.

Think It Over

Classifying Besides anatomical characteristics, what characteristics might scientists use to determine how closely organisms are related?


Dog


Wolf


Coyote

You are hiking in the Mariposa Grove in Yosemite National Park. All around you are giant sequoias, those ancient evergreens that tower over the landscape. Sequoia needles cover the ground, and in some places you see the sequoia's huge cones.

You glimpse a bright spot of red on the forest floor and walk over to examine it. What in the world is it? It looks like a living thing, but you aren't sure what it is. Could it be a fungus? Is it a plant? Whatever it is, it is both strange and beautiful.

You have seen a flower of the snow plant, which grows in the Sierra Nevada mountains. Unlike most plants, the snow plant gets energy from dead and decaying material rather than through photosynthesis. The snow plant is just one of many interesting species of organisms that live in Yosemite.

◀ Flower of the snow plant

A Variety of Species

Millions of species exist on Earth, from tiny bacteria to huge sequoias. What factors account for this diversity of species? **Over time, different environments and genetic variation have produced, through natural selection, the variety of organisms that exist today.**

Different Environments Think of the many different kinds of environments on Earth, from the deep sea to the tops of mountains. Organisms live in each of those environments. Over millions of years, natural selection has produced different species, each with adaptations enabling it to live in a specific habitat. An organism's **habitat** is the specific environment that provides the things the organism needs to live, grow, and reproduce.

Genetic Diversity Organisms within the same species do not all have identical traits. Think of how humans, for example, are different from one another. Therefore, organisms in a species have different alleles for the genes that govern traits. Some genetic differences, or variations, may result from mutations in DNA. Others may be caused by the rearrangement of genes during meiosis. All the genetic variations in a species make up the total "gene pool" of that species.

Many species have much variety in their gene pools. These species can often adapt to changes in the environment. That is because some individuals will have traits that let them survive in the new conditions.

In some species, however, most of the organisms are genetically similar. Those species may have difficulty surviving environmental change. For example, a fungus once wiped out much of the corn crop in the United States. The corn plants were all very much like one another, and few plants had any resistance to the fungus. Today, many endangered species, such as cheetahs, have little genetic variation. This lack of genetic variation may make them more likely to be destroyed by environmental change.

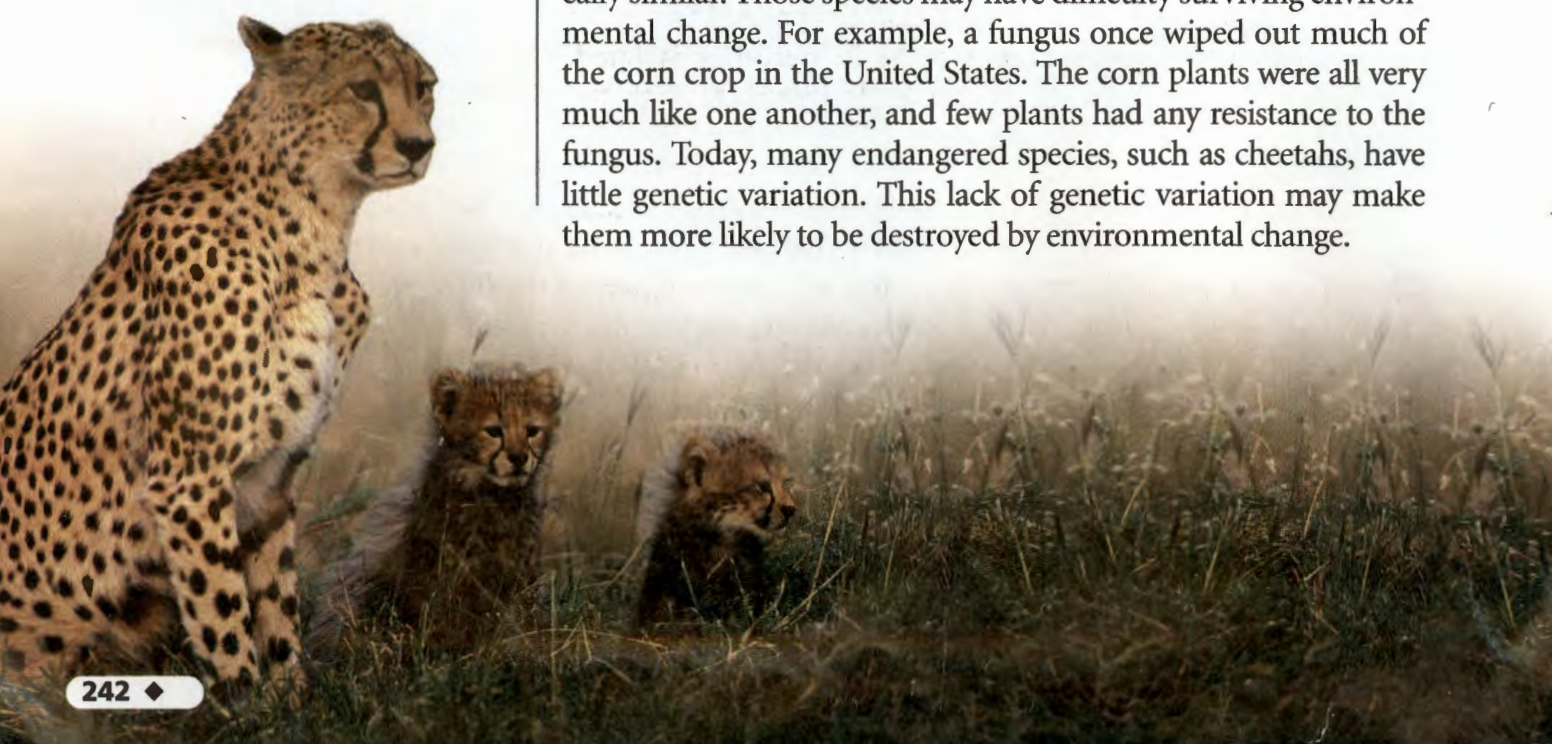


FIGURE 11
Lack of Diversity
The worldwide population of cheetahs lacks genetic diversity.
Relating Cause and Effect *Why might this lack of genetic variation endanger the cheetah population?*

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.

How Do New Species Form?

Darwin's theory on evolution by natural selection explains how variations can lead to changes in a species. But how does an entirely new species evolve? **A new species can form when a group of individuals remains isolated from the rest of its species long enough to evolve different traits.**

Geographic Isolation Scientists now hypothesize that geographic isolation is one of the main ways new species form. Isolation, or complete separation, happens when some members of a species become cut off from the rest of the species.

Sometimes a group is separated from the rest of its species by a river, volcano, or mountain range. Even an ocean wave can separate a few individuals from the rest of their species. The wave can sweep some members of a species out to sea and later wash them up on an island. This may have happened to species on the Galápagos Islands. Once a group becomes isolated, members of the isolated group can no longer mate with the rest of the species.

An Example of Isolation Abert's squirrel and the Kaibab squirrel both live in forests in the Southwest. Look at the map in Figure 12. You can see that 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. One day Abert's squirrel and the Kaibab squirrel may become so different from each other that they will be separate species.

Reading Checkpoint **How can some members of a species become separated from the main group?**

Inferring Species Relationships

Some species are closely related to one another. Other species are distantly related. How do scientists determine relationships between species? 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 13, 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 hypotheses 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.

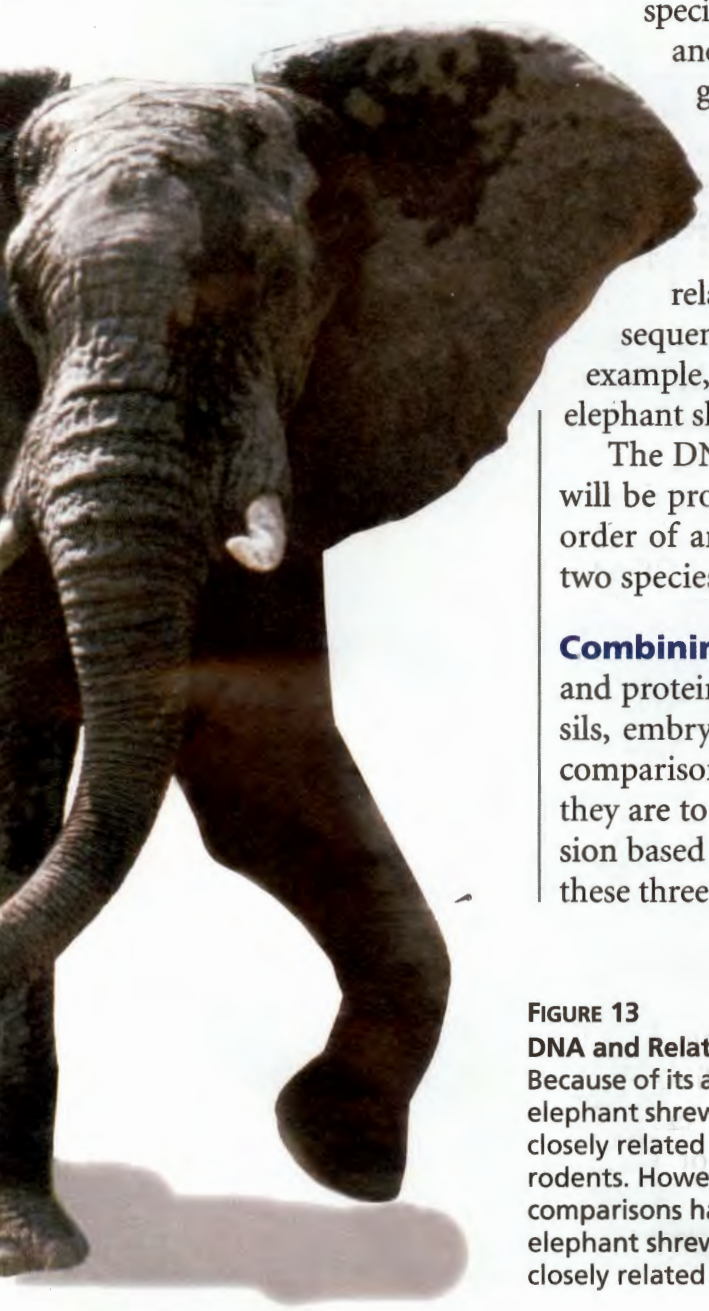


FIGURE 13
DNA and Relationships
Because of its appearance, the tiny elephant shrew was thought to be closely related to mice and other rodents. However, DNA comparisons have shown that the elephant shrew is actually more closely related to elephants.

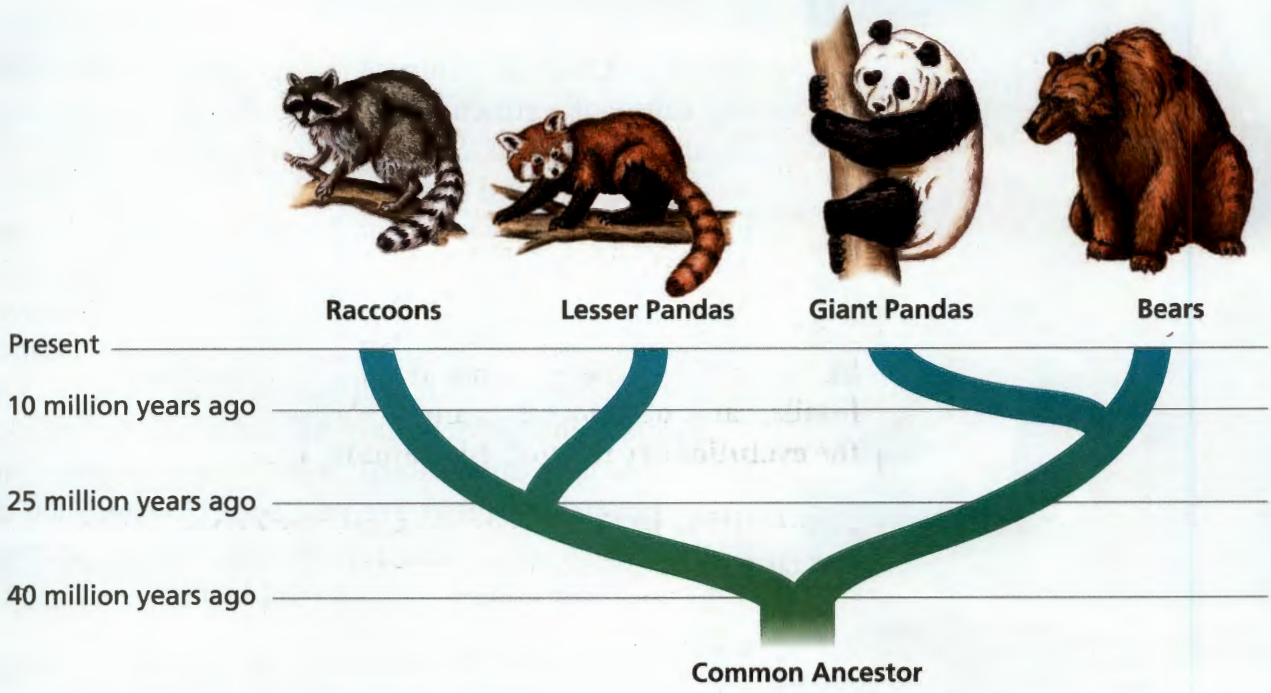


FIGURE 14
Species Relationships
This diagram shows how scientists now think that raccoons, lesser pandas, giant pandas, and bears are related.
Interpreting Diagrams *Are giant pandas more closely related to lesser pandas or to bears?*

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.

Extinction of Species

Thousands of years ago, artists painted graceful pictures of woolly mammoths on the walls of caves. Woolly mammoths, which looked a bit like present-day elephants, once lived all over the world. However, they are now extinct. A species is **extinct** if no members of that species are still alive.

Extinction and the Environment Most species that were preserved as fossils are now extinct. What makes a species become extinct? **Extinction is caused by a change in a species' environment. The members of the species may not have adaptations that allow them to survive and reproduce in the changed environment.**

There are many ways in which an environment can change. A new disease may strike a species. Predators may kill so many prey animals that the prey becomes extinct. For example, humans may have contributed to the extinction of woolly mammoths by hunting and killing too many of them.

Reading Checkpoint **What happened to most fossil species?**

FIGURE 15
Wooly Mammoth
Woolly mammoths became extinct after the climate warmed up.

Climate Change Climate change has been the leading cause of extinction. Climate change can destroy organisms' habitats. Suppose, for example, an area that was once warm and moist becomes cool and dry. Many plants that need warmth and a lot of water may die. Animals that feed on those plants will be affected, too. Animal species may compete fiercely for the few surviving plants. This competition could result in the extinction of the plants and the animals that eat them.

Climate change may have helped cause the extinction of woolly mammoths. Woolly mammoths had traits that helped them live in a cool climate, such as thick coats of hair. When the climate became warmer, however, these traits were no longer helpful.

Adaptation and Survival Environmental change does not always lead to extinction. Some organisms in a species may have traits that help them survive in a changed environment. Horseshoe crabs, for example, first appeared on Earth long before the dinosaurs. These animals, which are related to spiders, have changed little over time, in spite of the fact that Earth's climate has changed several times.

Section 3 Assessment

S 7.3.a, 7.3.e, E-LA: Writing 7.2.5, Reading 7.1.0

Vocabulary Skill **Identify Multiple Meanings**
In the term *gene pool,* what does *pool* mean? What is a more common meaning of *pool*?

Reviewing Key Concepts

1. a. **Identifying** Identify two factors that account for the diversity of species.
   b. **Explaining** What is genetic variation?
   c. **Relating Cause and Effect** Explain why species with a diverse gene pool are usually less threatened by environmental change than are species whose members all have similar genes.
2. 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 snakes from another. Is it likely that these two groups of snakes will become separate species? Why or why not?
3. a. **Listing** What kinds of evidence indicate how closely species are related?
   b. **Inferring** Of the kinds of evidence you listed above, which are probably the most reliable? Explain your answer.
4. a. **Reviewing** What causes extinction?
   b. **Relating Cause and Effect** What two factors may have caused the extinction of woolly mammoths?
   c. **Making Generalizations** Explain how natural selection is at work when a species becomes extinct.

Writing in Science

Museum Interpretation Suppose Figure 14 were part of a museum exhibit. Write an explanation of the diagram for museum visitors. Describe the relationships shown in the diagram.

Lab zone Skills Lab

Telltale Molecules

S 7.3.a, 7.7.b

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

Besides amino acid sequences, what characteristics make horses different from donkeys? Do library and World Wide Web research to find out. Then write a report communicating what you have learned.

Section of Cytochrome c Protein in Animals

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

Section 4

Classifying Organisms

CALIFORNIA Standards Focus

S 7.3.d Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.

- Why do biologists organize living things into groups?
- What do the levels of classification indicate about the relationship between organisms?
- What characteristics are used to classify organisms into domains and kingdoms?

Key Terms

- classification
- taxonomy
- binomial nomenclature
- genus
- prokaryote
- eukaryote

Lab zone Standards Warm-Up

Can You Organize a Junk Drawer?

1. Your teacher will give you some items that you might find in the junk drawer of a desk. Your job is to organize the items.
2. Examine the objects and decide on three groups into which you can sort them.
3. Place each object into one of the groups, based on how the item's features match the characteristics of the group.
4. Compare your grouping system with those of your classmates.

Think It Over

Classifying Which of your classmates' grouping systems seemed most useful? Why?

Suppose you had only ten minutes to run into a supermarket to get what you needed—milk and tomatoes. Could you do it? In most supermarkets this would be an easy task. You'd probably find out where the dairy and produce sections are, and head straight to those areas. Now imagine if you had to shop for these same items in a market where things were randomly placed throughout the store. Where would you begin? You'd have to search through a lot of things before you found what you needed. You could be there for a long time!

FIGURE 16
Classifying Vegetables
Vegetables in the produce section of a supermarket are neatly organized.

Why Do Scientists Classify?

Just as shopping can be a problem in a disorganized store, finding information about a specific organism can also be a problem. Recall that scientists have identified more than 1.7 million species. Imagine how difficult it would be to find information about one particular organism if you had no idea even where to begin. It would be a lot easier if similar organisms were placed into groups.

Biologists group organisms based on similarities, just as grocers group milk with dairy products and tomatoes with produce. **Classification** is the process of grouping things based on their similarities. Biologists classify fossil organisms as well as those that are alive today.

Biologists use classification to organize living things into groups so that the organisms are easier to study. The scientific study of how living things are classified is called **taxonomy** (tak SAHN uh mee). Taxonomy and evolution are closely related. Scientists infer that organisms in the same group, such as the beetles in Figure 17, descended from a common ancestor. Taxonomy is part of the larger field called systematics. In addition to classifying organisms, systematics tries to figure out their evolutionary relationships.

Taxonomists sometimes change the way they classify organisms. New evidence, such as the organism's DNA, might show that the organism belongs in a different group. Also, taxonomists may look at old evidence in a new way.

Reading Checkpoint **What is the scientific study of how living things are classified called?**

FIGURE 17
Classifying Beetles
These beetles belong to a large insect collection in a natural history museum. They have been classified according to characteristics they share.
Observing *What characteristics may have been used to group these beetles?*

The Naming System of Linnaeus

In addition to grouping organisms, taxonomy involves naming them. In the 1750s, the Swedish naturalist Carolus Linnaeus devised a system of naming organisms that is still used today. Linnaeus placed organisms in groups based on their observable features. Based on his observations, Linnaeus gave each organism a unique, two-part scientific name. This naming system Linnaeus used is called **binomial nomenclature** (by NOH mee ul NOH men klay chur). The word *binomial* means "two names."

Genus and Species The first word in an organism's scientific name is its genus. A **genus** (JEE nus) (plural *genera*) is a classification grouping that contains similar, closely related organisms. For example, pumas, marbled cats, and house cats are all classified in the genus *Felis*. Organisms that are classified in the genus *Felis* share characteristics such as sharp, retractable claws and behaviors such as hunting other animals.

The second word in a scientific name often describes a distinctive feature of an organism, such as where it lives or its appearance. Together, the two words indicate a unique species. Recall that species is a group of similar organisms that can mate with each other and produce offspring that can also mate and reproduce.

Reading Checkpoint **What kind of name did Linnaeus give each organism?**

FIGURE 18
Binomial Nomenclature

These three species of cats belong to the same genus. Their scientific names, written in Latin, share the same first word, *Felis*. The second word of their names describes a feature of the animal. **Classifying** *What characteristics do these species share?*

Felis concolor (Puma)
Concolor means "the same color." Notice that this animal's coat is mostly the same color.

Felis domesticus
(House cat)
Domesticus means "of the house."

Felis marmorata (Marbled cat)
Notice the marbled pattern of this animal's coat. *Marmorata* means "marble."

Using Binomial Nomenclature Notice in Figure 19 that a complete scientific name is written in italics. Only the first letter of the first word is capitalized. Notice also that scientific names contain Latin words. Linnaeus used Latin because it was the language that scientists used during that time.

Binomial nomenclature makes it easy for scientists to communicate because everyone uses the same name for the same organism. Using different names can get confusing. For instance, people call the animal in Figure 19 a woodchuck, groundhog, or whistlepig. Fortunately, it has only one scientific name—*Marmota monax*.

Levels of Classification

The classification system that scientists use today is based on the contributions of Linnaeus. But today's classification system uses a series of many levels to classify organisms.

To help you understand the levels in classification, imagine a room filled with everybody from your state. First, all of the people from your town raise their hands. Then, those from your neighborhood raise their hands. Then, those from your street raise their hands. Finally, those from your house raise their hands. Each time, fewer people raise their hands. But you'd be in all of the groups. The most general group you belong to is the state. The most specific group is the house. The more levels you share with others, the more you have in common with them. Of course, organisms are not grouped by where they live, but rather by their shared characteristics.

The Major Levels of Classification Most biologists today classify organisms into eight levels. First, an organism is placed in a broad group, which in turn is divided into more specific groups. **The more classification levels that two organisms share, the more characteristics they have in common.**

Here are the eight classification levels that biologists commonly use.

- A domain is the highest level of organization.
- Within a domain, there are kingdoms.
- Within kingdoms, there are phyla (FY luh) (singular *phylum*).
- Within phyla are classes.
- Within classes are orders.
- Within orders are families.
- Each family contains one or more genera.
- Each genus contains one or more species.

FIGURE 19
Marmota monax
Although there are many common names for this animal, it has only one scientific name, *Marmota monax*.

Go Online
NSTA SCILINKS
For: Links on kingdoms
Visit: www.SciLinks.org
Web Code: scn-0113

Classifying an Owl Look at Figure 20 to see how the great horned owl is classified. The top row shows a wide variety of organisms that share the owl's domain. Notice that as you move down the levels, there are fewer kinds of organisms in each group. The organisms in each new group have more in common, however. For example, the class Aves includes all birds. The order Strigiformes includes only owls.

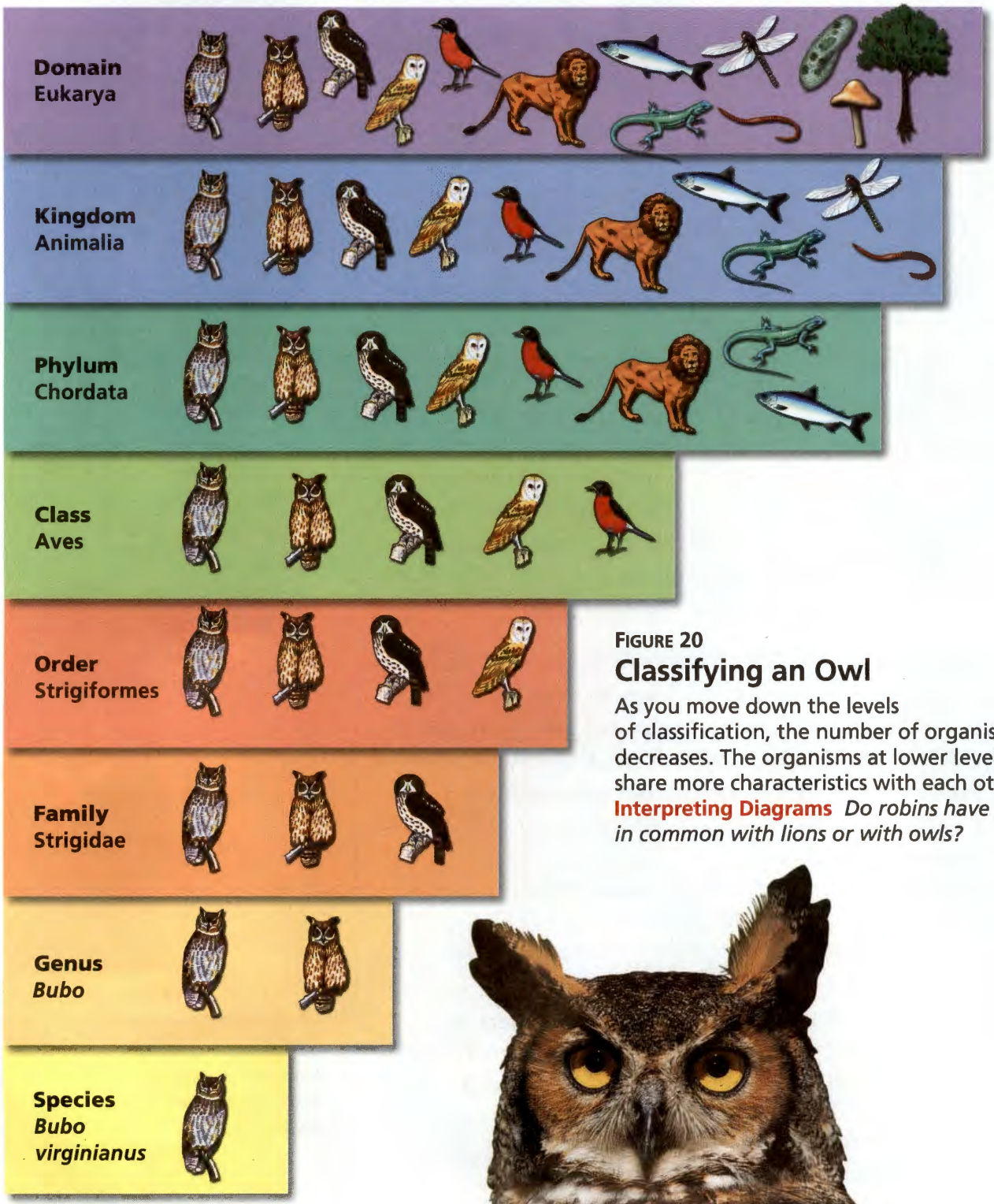
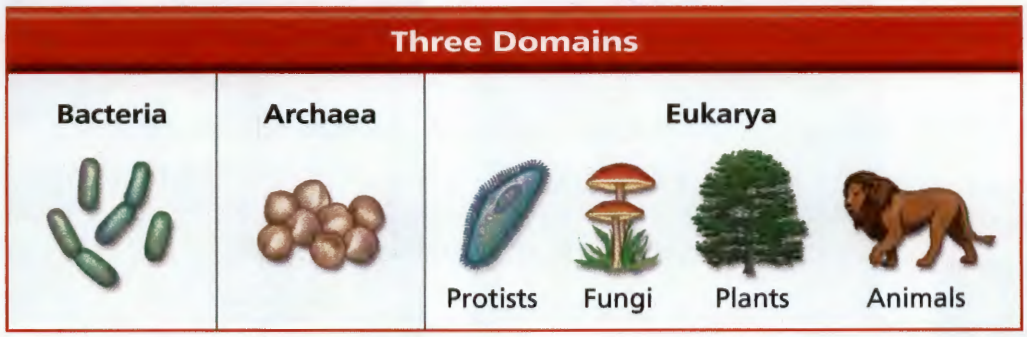


FIGURE 20
Classifying an Owl
As you move down the levels of classification, the number of organisms decreases. The organisms at lower levels share more characteristics with each other.
Interpreting Diagrams *Do robins have more in common with lions or with owls?*



Domains and Kingdoms

Today, a three-domain system of classification is commonly used. Shown in Figure 21, the three domains are Bacteria, Archaea, and Eukarya. Within the domains are kingdoms. **Organisms are placed into domains and kingdoms based on their cell type, their ability to make food, and the number of cells in their bodies.**

FIGURE 21
Three Domains
In the three-domain system of classification, all known organisms belong to one of three domains—Bacteria, Archaea, or Eukarya.

Bacteria Although you may not know it, members of the domain Bacteria are all around you. You can find them in the yogurt you eat, on every surface you touch, and inside your body, both when you are healthy and sick. Some bacteria are autotrophs, while others are heterotrophs.

Members of the domain Bacteria are prokaryotes (proh KA ree ohtz). **Prokaryotes** are organisms whose cells lack a nucleus. Remember that a nucleus is a dense area in a cell that contains nucleic acids—the chemical instructions that direct the cell's activities. In prokaryotes, nucleic acids are not contained within a nucleus.

Archaea Deep in the Pacific Ocean, hot gases and molten rock spew out from a vent in the ocean floor. Surprisingly, a group of tiny organisms thrives there. They are members of the domain Archaea (ahr KEE uh), whose name comes from the Greek word for "ancient." Archaea can be found in some of the most extreme environments on Earth, including hot springs, very salty water, swamps, and the intestines of cows! Scientists think that the harsh conditions in which archaea live are similar to those of ancient Earth.

Like bacteria, archaea are unicellular prokaryotes. And like bacteria, some archaea are autotrophs while others are heterotrophs. Archaea are classified in their own domain, however, because their structure and chemical makeup differ from that of bacteria.

Reading Checkpoint **What is a nucleus?**

Lab zone Skills Activity

Classifying

Test your classifying skills using Figure 20. Look carefully at the organisms pictured together at the kingdom level. Make a list of the characteristics that the organisms share. Then make two more lists of shared characteristics—one for the organisms at the class level and the other for those at the genus level. How does the number of shared characteristics on your lists change at each level?

FIGURE 22

Domain Eukarya

The four kingdoms in domain Eukarya are protists, fungi, plants, and animals.

Making Generalizations *What characteristic do all Eukarya share?*

Plants

Animal

Protist

Fungi

Eukarya What do seaweeds, mushrooms, tomatoes, and dogs have in common? They are all members of the domain Eukarya. Organisms in this domain are **eukaryotes** (yoo KA ree ohtz)—organisms with cells that contain nuclei. **Scientists classify eukaryotes into one of four kingdoms: protists, fungi, plants, and animals.**

Other than having cells with nuclei, the members of the four eukaryote kingdoms are very different from one another. A protist (PROH tist) is any eukaryote that cannot be classified as a plant, an animal, or a fungus. Most protists are unicellular.

Mushrooms, molds, and mildew are all fungi (FUN jy). All fungi are heterotrophs, and most are multicellular. In contrast, all plants are multicellular autotrophs. All animals, such as a dog and a flea on the dog's ear, are multicellular eukaryotes. In addition, all animals are heterotrophs.

Section 4 Assessment

S 7.3.d, E-LA: Reading 7.1.0

Vocabulary Skill **Identify Multiple Meanings** Contrast the common meaning of *kingdom* with the meaning of *kingdom* in the classification of living things.

Reviewing Key Concepts

1. a. **Reviewing** Why do biologists classify?
   b. **Inferring** A jaguarundi is classified in the same genus as a house cat. What characteristics do you think a jaguarundi might have?
2. a. **Listing** List in order the levels of classification, beginning with domain.
   b. **Applying Concepts** Woodchucks are classified in the same family as squirrels, but in a different family than mice. Do woodchucks have more characteristics in common with squirrels or mice? Explain.
3. a. **Identifying** What are the three domains into which organisms are classified?
   b. **Classifying** Which two domains include only organisms that are prokaryotes?
   c. **Comparing and Contrasting** How do the members of the two domains of prokaryotes differ?

Lab zone

At-Home Activity

Kitchen Classification With a family member, go on a "classification hunt" in the kitchen. Look in your refrigerator, cabinets, and drawers to discover what classification systems your family uses to organize items.

Section 5

Branching Trees

CALIFORNIA Standards Focus

S 7.3.d Students know how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.

How does a branching tree diagram show evolutionary relationships?

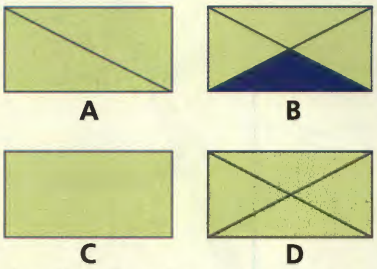
Key Terms

- branching tree diagram
- shared derived characteristic

Lab zone Standards Warm-Up

Which Is First?

1. Note the characteristics of figures A, B, C, and D.
2. Which figure is most similar to Figure B?



Think It Over

Inferring Suppose these shapes are fossils of extinct organisms. Which organism do you think might be the ancestor of all the others? Explain your reasoning.

Two groups of organisms with similar characteristics may be descended from a common ancestor. The more similar the two groups are, the more recent the common ancestor probably is. To understand this, think of human families. Brothers and sisters usually look more like one another than they look like their cousins. Cousins share one set of grandparents. But brothers and sisters share a more recent ancestor—their parents.

A **branching tree diagram** shows probable evolutionary relationships among organisms. It also shows the order in which specific characteristics may have evolved. Branching tree diagrams begin at the base with the common ancestor of all the organisms in the diagram. Figure 23, for example, begins with the ancestor of all animals.

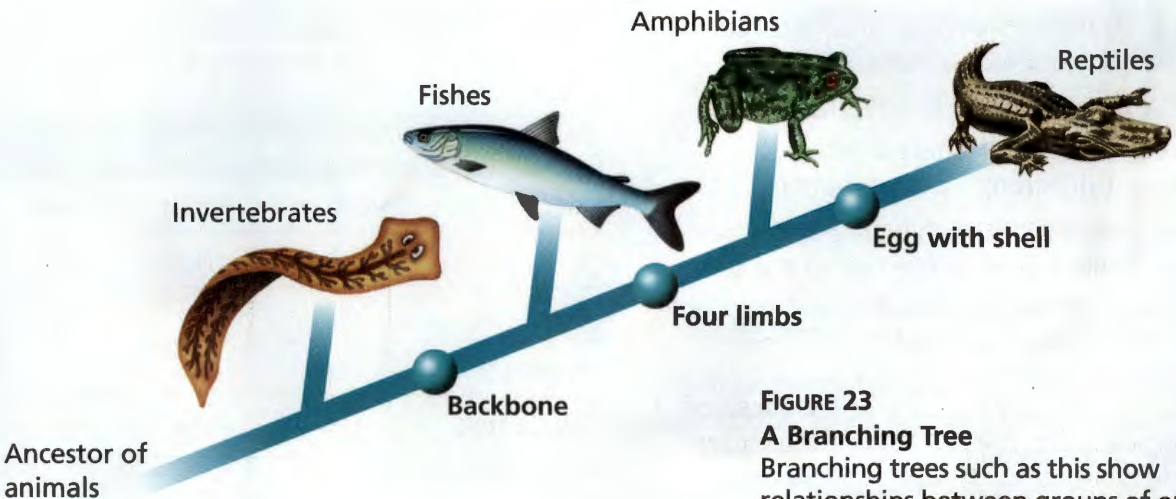


FIGURE 23
A Branching Tree
Branching trees such as this show relationships between groups of organisms.
Interpreting Diagrams *Are reptiles more closely related to fishes or to invertebrates?*

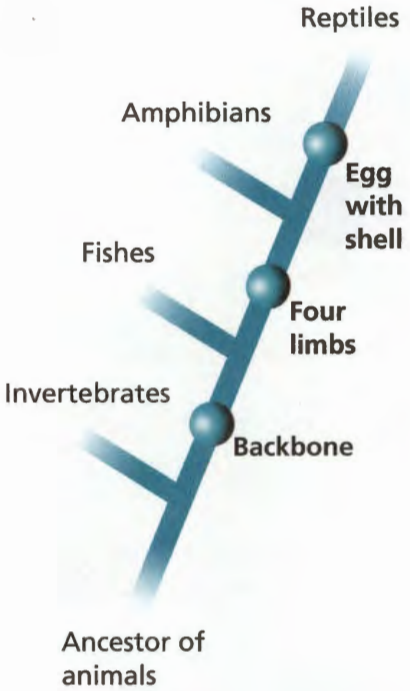


FIGURE 24
Groups of Animals
This branching tree shows relationships between groups of animals.

Shared Derived Characteristics

A branching tree diagram shows evolutionary relationships by grouping organisms according to shared derived characteristics. A **shared derived characteristic** is usually a homologous structure, such as a backbone, that is shared by all organisms in a group. Notice that, above each fork in Figure 24, a label indicates a shared derived characteristic, such as a backbone or four limbs. On a branching tree, all the organisms above the label have the trait. In Figure 24, for example, all organisms above the Backbone label have a backbone.

Evolutionary Groups A branching tree has groups within groups. In Figure 24, the largest subgroup is the group with backbones. Of the animals shown in the diagram, the backbone group includes fishes, amphibians, and reptiles. Within that group is a smaller group—animals with four limbs. Fishes are not in this group, but amphibians and reptiles are. The smallest group consists only of animals that produce eggs with shells—reptiles. Species within any group are more closely related to one another than to species not in the group.

Order of Characteristics Characteristics that appear lower on a branching tree probably developed before characteristics higher on the tree. Figure 24 shows that, during evolutionary history, animals with backbones appeared earlier than animals with both a backbone and four limbs.

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

Math: Statistics, Data Analysis, and Probability 7.1.1

Math Analyzing Data

Data for a Branching Tree Diagram

The data in the table show shared derived characteristics of different types of plants.

1. **Interpreting Data** Do mosses have any of the characteristics indicated at the top of the table?
2. **Interpreting Data** Which plant has the greatest number of the characteristics?
3. **Drawing Conclusions** Use the information in the table to draw a branching tree. (*Hint*: Mosses go at the base of the tree.)
4. **Inferring** A fossil plant shows evidence of flowers. Where in the diagram would the plant go?

Characteristics of Plants

Plant	True Roots	Seeds	Flowers
Moss	No	No	No
Fern	Yes	No	No
Spruce tree	Yes	Yes	No
Apple tree	Yes	Yes	Yes

FIGURE 25
Fossil Fish
The fossil bones of this fish show that it has a backbone but no legs.

Constructing a Branching Tree

Suppose you have a list of organisms and their characteristics. You want to use this information to draw a branching tree. At the base of the tree, write "Common Ancestor." Just above the common ancestor, put the group of organisms with none of the characteristics. On the next higher fork, put the group with one of the shared derived characteristics. On the branch above that, put the organism with two of the characteristics. Continue this process until you get to the organism or group with the greatest number of shared derived characteristics. That group goes at the top of the tree. In Figure 24, that group is reptiles.

Branching tree diagrams can sometimes show fossils as well as living organisms. For example, look at the fossil in Figure 25. The fossil has a backbone, but does it have four limbs? No. So you would put the fossil on the branch with fishes. In fact, the fossil in the photograph is an extinct fish.

Section 5 Assessment

S 7.3.d, E-LA: Writing 7.2.0, Reading 7.1.0

Vocabulary Skill **Identify Multiple Meanings** In the term *branching tree,* what does *tree* mean? What is a common meaning of *tree*?

Reviewing Key Concepts

1. **a.** **Reviewing** How does a branching tree diagram divide organisms into groups?
   b. **Interpreting Diagrams** Choose one animal group in Figure 23. Identify the characteristics shared by group members.
   c. **Classifying** A fossil animal has four legs. What additional information would you need to put it on a branch in Figure 23?

Writing in Science

Conversation Suppose that Carolus Linnaeus were alive today and saw Figure 23. Write an imaginary conversation in which he asks you questions about the diagram and you answer him.

Chapter 7 Study Guide

The BIG Idea Genetic variation and environmental factors have together resulted in evolution of species.

1 Darwin's Theory

Key Concepts S 7.3.a, 7.3.b

- Darwin's important observations included the diversity of organisms, 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 environmental factors 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 environments.
- Darwin proposed that, over a long period, natural selection can lead to change. Helpful variations may 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 S 7.3.c, 7.4.e

- Similar body structures, patterns of early development, molecular structure, and fossils all provide evidence of evolution.
- Most fossils form when organisms that die become buried in sediments.
- The fossil record provides evidence about the history of life and past environments on Earth.

Key Terms

comparative anatomy
homologous structures
mold
cast
petrified fossil
trace fossil
paleontologist
gradualism
punctuated equilibria

3 Evolution of Species

Key Concepts S 7.3.a, 7.3.e

- Over time, different environments and genetic variation have produced, through natural selection, the variety of organisms that exist today.
- A new species can form when a group of individuals remains isolated from the rest of its species long enough to evolve different traits.
- Extinction is caused by a change in a species' environment.
- DNA, protein structure, fossils, early development, and body structure are used to determine species relationships.

Key Terms

habitat
extinct

4 Classifying Organisms

Key Concepts S 7.3.d

- Biologists use classification to organize living things into groups so that the organisms are easier to study.
- The more classification levels that two organisms share, the more characteristics they have in common.
- Organisms are placed into domains and kingdoms based on cell type, ability to make food, and the number of cells in their bodies.

Key Terms

classification
taxonomy
binomial nomenclature
genus
prokaryote
eukaryote

5 Branching Trees

Key Concepts S 7.3.d

- A branching tree diagram shows evolutionary relationships by grouping organisms according to shared derived characteristics.

Key Terms

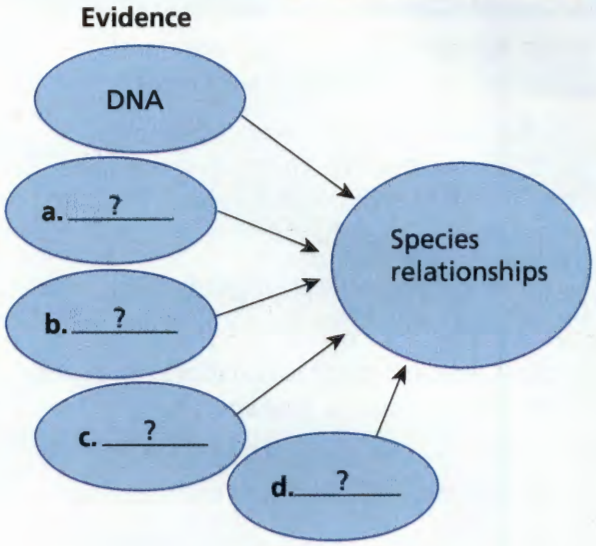
branching tree diagram
shared derived characteristic

Review and Assessment

Go Online PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cva-2070

Target Reading Skill

Identify Supporting Evidence In Section 3, you learned how scientists infer how closely species are related. To review this information, copy the partly completed graphic organizer at the right. Fill in the kinds of evidence that are missing.



Reviewing Key Terms

Choose the letter of the best answer.

1. Changes in a species over long periods of time are called
   a. scientific theories.
   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. The specific environment that provides an organism's needs is called the organism's
   a. genus.
   b. taxonomy.
   c. habitat.
   d. natural selection.
5. An organism whose cells lack nuclei is called a(n)
   a. protist
   b. fungus
   c. eukaryote
   d. prokaryote

Complete the following sentences so that your answers clearly explain the key terms.

6. Darwin's theory of evolution is an example of a **scientific theory**, which is a(n) _____ .
7. **Comparative anatomy** is the comparison of _____ .
8. A species is **extinct** only if _____ .
9. **Classification** brings order to the study of organisms because it is the process of _____ .
10. A **branching tree diagram** shows evolutionary relationships by _____ .

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.

Video Assessment
Discovery Channel School
Changes Over Time

Review and Assessment

Checking Concepts

11. What role does the overproduction of organisms play in natural selection?
12. On the basis of similar body structures, scientists hypothesize that two species are closely related. What other evidence would support their hypothesis?
13. Contrast the hypothesis of gradualism to the hypothesis of punctuated equilibria.
14. Explain how geographic isolation can result in the formation of a new species.
15. What is meant by *extinct?* Explain how environmental factors might cause extinction.
16. What are the advantages of identifying an organism by its scientific name?
17. What is a shared derived characteristic?

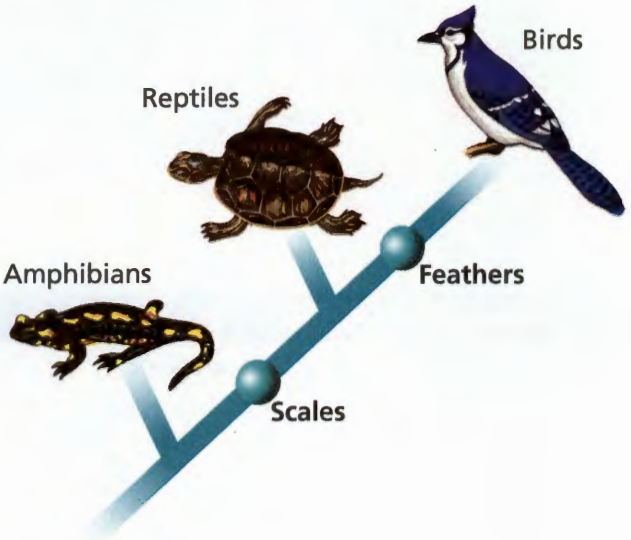
Thinking Critically

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.

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

Applying Skills

Use the diagram below to answer Questions 23–25.



23. **Applying Concepts** In the branching tree diagram above, what are the shared derived characteristics?
24. **Interpreting Diagrams** Which organisms in the diagram have scales? How do you know?
25. **Interpreting Diagrams** On the basis of the diagram, which group probably appeared first, birds or reptiles?

Lab zone Standards Investigation

Performance Assessment Complete your poster, booklet, or whatever way you choose to present your findings to the class. Be prepared to explain why you chose the fossil species that you did. Also indicate where you found information about that fossil.

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.

S 7.3.b

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

S 7.3.a

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.

S 7.3.c

4. Most members of species of cat depend mainly on mice for food. For several summers in a row, a disease kills off most of the mice in an area. Over time, what is the most likely effect on the cat species?
- **A** All of the cats will die of starvation.
- **B** Those cats that can eat foods other than mice will survive and reproduce.
- **C** The cat species will lose its genetic diversity.
- **D** There will be no long-term effect on the cat species.

S 7.3.a

Use the table below and your knowledge of science to answer Questions 5–7.

Some Types of Trees

Common Name of Tree	Kingdom	Family	Species
Bird cherry	Plants	Rosaceae	*Prunus avium*
Flowering cherry	Plants	Rosaceae	*Prunus serrula*
Smooth-leaved elm	Plants	Ulmaceae	*Ulmus minor*
Whitebeam	Plants	Rosaceae	*Sorbus aria*

5. Which of the following organisms is most different from the other three?
- **A** *Prunus avium*
- **B** *Prunus serrula*
- **C** *Ulmus minor*
- **D** *Sorbus aria*

S 7.3.d

6. Which of the following pairs of organisms should share the most characteristics?
- **A** *Prunus serrula* and *Prunus avium*
- **B** *Ulmus minor* and *Prunus avium*
- **C** *Sorbus aria* and *Prunus serrula*
- **D** *Prunus serrula* and *Ulmus minor*

S 7.3.d

7. Scientists have discovered fossils of ancient whalelike animals that had legs instead of flippers. This evidence most likely indicates that the ancestors of present-day whales
- **A** lived in the ocean.
- **B** lived on land.
- **C** evolved gradually rather than during short periods of rapid change.
- **D** never became extinct.

S 7.4.e

Apply the BIG Idea

8. Predict how an extreme change in climate might affect natural selection in a species with little genetic variation.

S 7.3.e