SECTION 1

Change over Time

If someone asked you to describe a frog, you might say that a frog has long hind legs, has bulging eyes, and croaks. But what color skin would you say that a frog has?

Once you start to think about frogs, you realize that frogs differ in many ways. These differences set one kind of frog apart from another. The frogs in **Figures 1, 2,** and **3** look different from each other, yet they may live in the same areas.

READING WARM-UP

Objectives

- Identify two kinds of evidence that show that organisms have evolved.
- Describe one pathway through which a modern whale could have evolved from an ancient mammal.
- Explain how comparing organisms can provide evidence that they have ancestors in common.

Terms to Learn

adaptation
species
evolution
fossil
fossil record

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

Differences Among Organisms

As you can see, each frog has a different characteristic that might help the frog survive. A characteristic that helps an organism survive and reproduce in its environment is called an **adaptation.** Adaptations may be physical, such as a long neck or striped fur. Or adaptations may be behaviors that help an organism find food, protect itself, or reproduce.

Living things that have the same characteristics may be members of the same species. A **species** is a group of organisms that can mate with one another to produce fertile offspring. For example, all strawberry poison arrow frogs are members of the same species and can mate with each other to produce more strawberry poison arrow frogs. Groups of individuals of the same species living in the same place make up a *population.*

Reading Check **How can you tell that organisms are members of the same species?** *(See the Appendix for answers to Reading Checks.)*

Figure 1 The red-eyed tree frog hides among a tree's leaves during the day and comes out at night.

Figure 2 The bright coloring of the strawberry poison arrow frog warns predators that the frog is poisonous.

Figure 3 The smoky jungle frog blends into the forest floor.

Do Species Change over Time?

In a single square mile of rain forest, there may be dozens of species of frogs. Across the Earth, there are millions of different species of organisms. The species that live on Earth today range from single-celled bacteria, which lack cell nuclei, to multicellular fungi, plants, and animals. Have these species always existed on Earth?

Scientists think that Earth has changed a great deal during its history, and that living things have changed, too. Scientists estimate that the planet is 4.6 billion years old. Since life first appeared on Earth, many species have died out, and many new species have appeared. **Figure 4** shows some of the species that have existed during Earth's history.

Scientists observe that species have changed over time. They also observe that the inherited characteristics in populations change over time. Scientists think that as populations change over time, new species form. Thus, newer species descend from older species. The process in which populations gradually change over time is called **evolution.** Scientists continue to develop theories to explain exactly how evolution happens.

adaptation a characteristic that improves an individual's ability to survive and reproduce in a particular environment

species a group of organisms that are closely related and can mate to produce fertile offspring

evolution the process in which inherited characteristics within a population change over generations such that new species sometimes arise

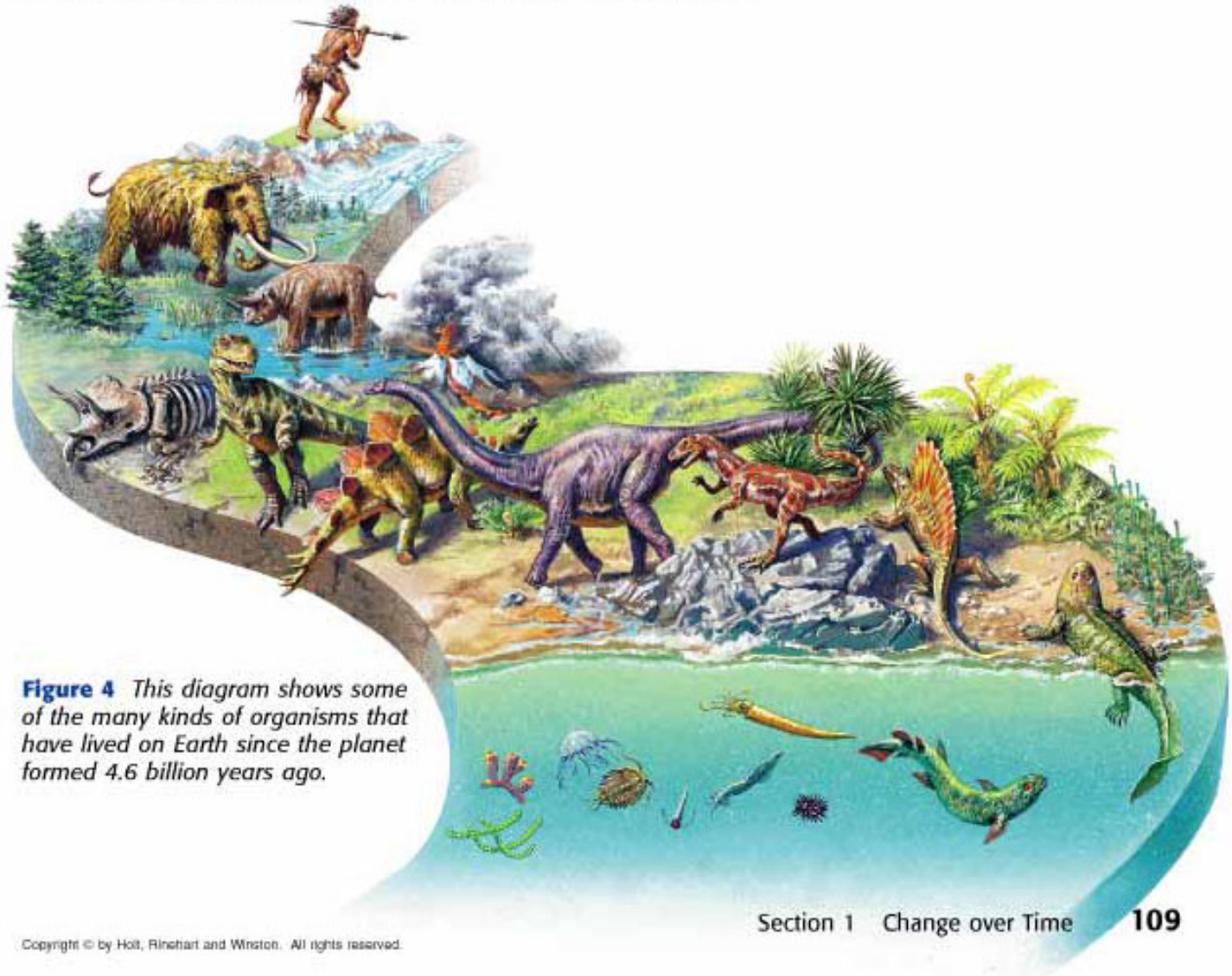


Figure 4 *This diagram shows some of the many kinds of organisms that have lived on Earth since the planet formed 4.6 billion years ago.*

Figure 5 *The fossil on the left is of a trilobite, an ancient aquatic animal. The fossils on the right are of seed ferns.*

Evidence of Changes over Time

Evidence that evolution has happened is buried within Earth. Earth's crust is arranged in layers. These layers are made up of different kinds of rock and soil stacked on top of each other. These layers form when *sediments*, particles of sand, dust, or soil, are carried by wind and water and are deposited in an orderly fashion. Older layers are deposited before newer layers and are buried deeper within Earth.

Fossils

fossil the remains or physical evidence of an organism preserved by geological processes

fossil record a historical sequence of life indicated by fossils found in layers of the Earth's crust

Sometimes, the remains or imprints of once-living organisms are found in the layers of rock. These remains are called **fossils.** Examples of fossils are shown in **Figure 5.** Fossils can be complete organisms, parts of organisms, or just a set of footprints. Fossils usually form when a dead organism is covered by a layer of sediment. Over time, more sediment settles on top of the organism. Minerals in the sediment may seep into the organism and gradually replace the organism with stone. If the organism rots away completely after being covered, it may leave an imprint of itself in the rock.

The Fossil Record

By studying fossils, scientists have made a timeline of life that is known as the **fossil record.** The fossil record organizes fossils by their estimated ages and physical similarities. Fossils found in newer layers of Earth's crust tend to be similar to present-day organisms. This similarity indicates that the fossilized organisms were close relatives of present-day organisms. Fossils from older layers are less similar to present-day organisms than fossils from newer layers are. The older fossils are of earlier life-forms, which may not exist anymore.

Reading Check **How does the fossil record organize fossils?**

Evidence of Ancestry

The fossil record provides evidence about the order in which species have existed. Scientists observe that all living organisms have characteristics in common and inherit characteristics in similar ways. So, scientists think that all living species descended from common ancestors. Evidence of common ancestors can be found in fossils and in living organisms.

Drawing Connections

Scientists examine the fossil record to figure out the relationships between extinct and living organisms. They draw models, such as the one shown in **Figure 6,** that illustrate their hypotheses. The short horizontal line at the top left in the diagram represents a species that lived in the past. Each branch in the diagram represents a group of organisms that descended from that species.

As shown in **Figure 6,** scientists think that whales and some types of hoofed mammals have a common ancestor. This ancestor was probably a mammal that lived on land between 50 million and 70 million years ago. During this time period, the dinosaurs died out and a variety of mammals appeared in the fossil record. The first ocean-dwelling mammals appeared about 50 million years ago. Scientists think that all mammal species alive today evolved from common ancestors.

Scientists have named and described hundreds of thousands of living and ancient species. Scientists use information about these species to sketch out a "tree of life" that includes all known organisms. But scientists know that their information is incomplete. For example, parts of Earth's history lack a fossil record. In fact, fossils are rare because specific conditions are necessary for fossils to form.

CONNECTION TO Geology

Sedimentary Rock Fossils are most often found in sedimentary rock. *Sedimentary rock* usually forms when rock is broken into sediment by wind, water, and other means. The wind and water move the sediment around and deposit it. Over time, layers of sediment pile up. Lower layers are compressed and changed into rock. Find out if your area has any sedimentary rocks that contain fossils. Mark the location of such rocks on a copy of a local map.

ACTIVITY

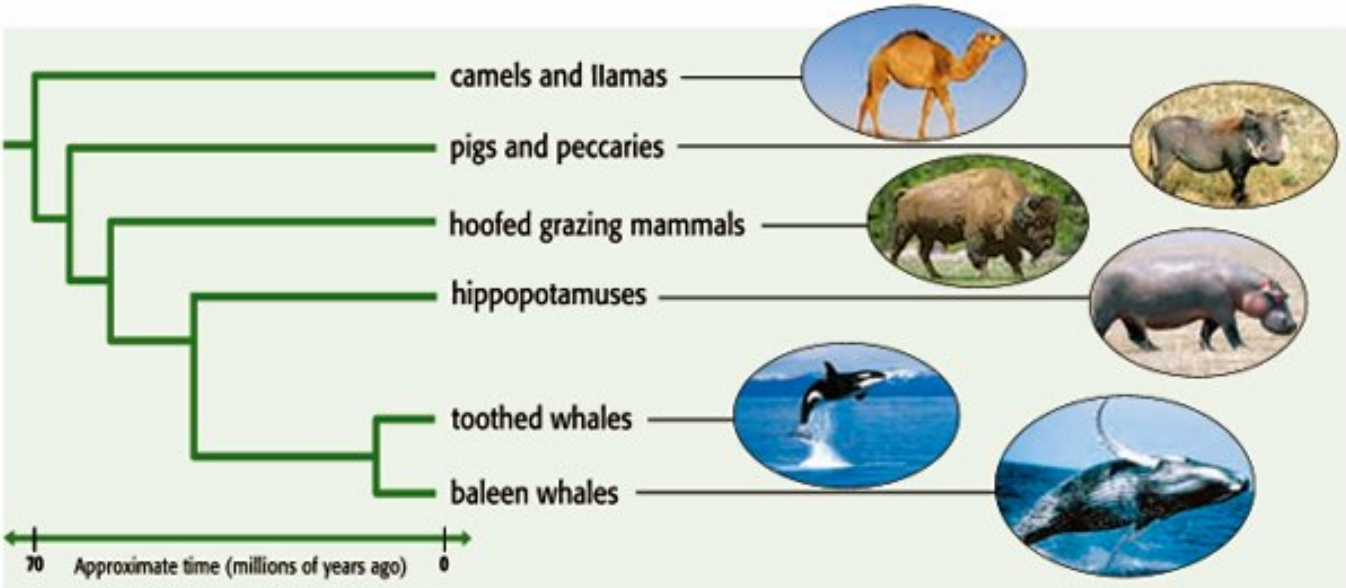


Figure 6 *This diagram is a model of the proposed relationships between ancient and modern mammals that have characteristics similar to whales.*

Examining Organisms

Examining an organism carefully can give scientists clues about its ancestors. For example, whales seem similar to fish. But unlike fish, whales breathe air, give birth to live young, and produce milk. These traits show that whales are *mammals*. Thus, scientists think that whales evolved from ancient mammals.

Case Study: Evolution of the Whale

Scientists think that the ancient ancestor of whales was probably a mammal that lived on land and that could run on four legs. A more recent ancestor was probably a mammal that spent time both on land and in water. Comparisons of modern whales and a large number of fossils have supported this hypothesis. **Figure 7** illustrates some of this evidence.

Reading Check **What kind of organism do scientists think was an ancient ancestor of whales?**

Figure 7 **Evidence of Whale Evolution**

a ***Pakicetus*** (PAK uh SEE tuhs)
Scientists think that whales evolved from land-dwelling mammals that could run on four legs. One of these ancestors may have been *Pakicetus*, which lived about 50 million years ago. The fossil skeleton and an artist's illustration of *Pakicetus* are shown here. *Pakicetus* was about the size of a wolf.

b ***Ambulocetus*** (AM byoo loh SEE tuhs)
This mammal lived in coastal waters about 49 million years ago. It could swim by kicking its legs and using its tail for balance. It could also waddle on land by using its short legs. *Ambulocetus* was about the size of a dolphin.

Walking Whales

The organisms in **Figure 7** form a sequence between ancient four-legged mammals and modern whales. Several pieces of evidence indicate that these species are related by ancestry. Each species shared some traits with an earlier species. However, some species had new traits that were shared with later species. Yet, each species had traits that allowed it to survive in a particular time and place in Earth's history.

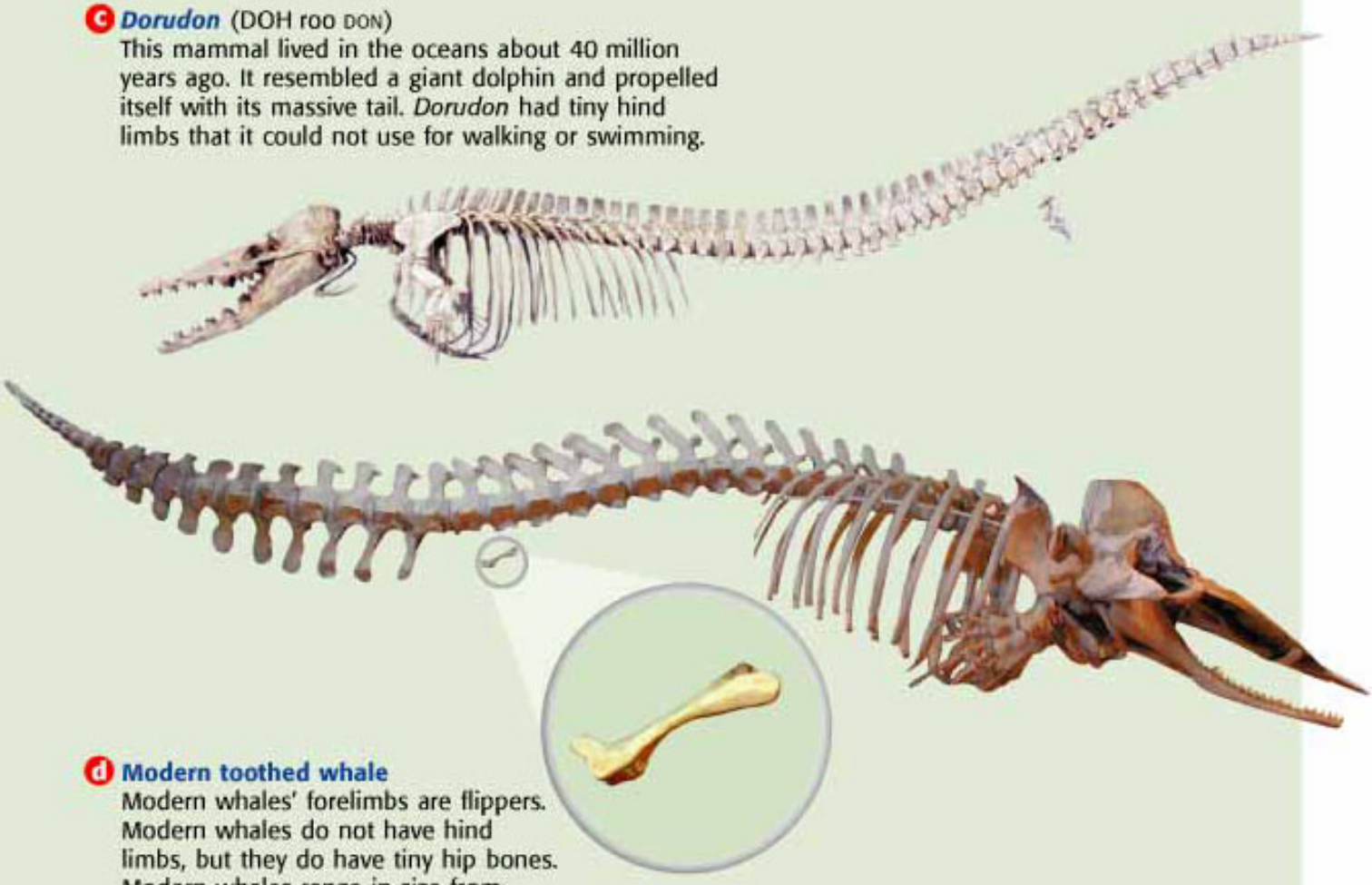
Further evidence can be found inside the bodies of living whales. For example, although modern whales do not have hind limbs, inside their bodies are tiny hip bones, as shown in **Figure 7.** Scientists think that these hip bones were inherited from the whales' four-legged ancestors. Scientists often look at this kind of evidence when they want to determine the relationships between organisms.

MATH PRACTICE

The Weight of Whales

Whales are the largest animals ever known on Earth. One reason whales can grow so large is that they live in water, which supports their weight in a way that their bones could not. The blue whale—the largest type of whale in existence—is about 24 m long and has a mass of about 99,800 kg. Convert these measurements into feet and pounds, and round to whole numbers.

c ***Dorudon*** (DOH roo DON)
This mammal lived in the oceans about 40 million years ago. It resembled a giant dolphin and propelled itself with its massive tail. *Dorudon* had tiny hind limbs that it could not use for walking or swimming.



d **Modern toothed whale**
Modern whales' forelimbs are flippers. Modern whales do not have hind limbs, but they do have tiny hip bones. Modern whales range in size from 1.4 m porpoises to 33 m blue whales.

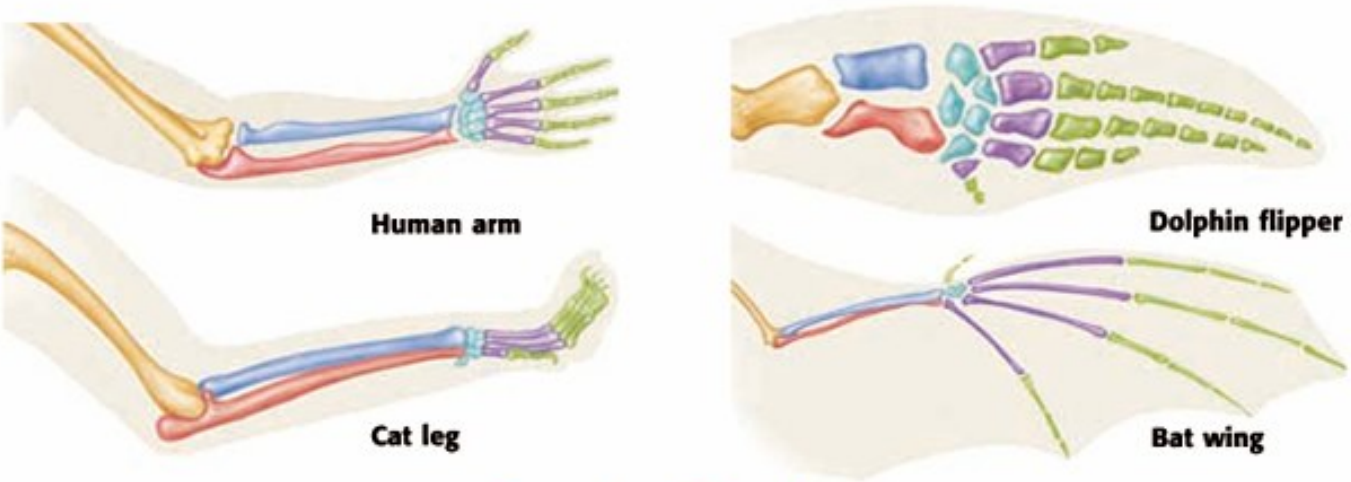


Figure 8 *The bones in the front limbs of these animals are similar. Similar bones are shown in the same color. These limbs are different sizes in life.*

Comparing Organisms

Evidence that groups of organisms have common ancestry can be found by comparing the groups' DNA. Because every organism inherits DNA, every organism inherits the traits determined by DNA. Organisms contain evidence that populations and species undergo changes in traits and DNA over time.

Comparing Skeletal Structures

What does your arm have in common with the front leg of a cat, the front flipper of a dolphin, or the wing of a bat? You might notice that these structures do not look alike and are not used in the same way. But under the surface, there are similarities. Look at **Figure 8.** The structure and order of bones of a human arm are similar to those of the front limbs of a cat, a dolphin, and a bat.

These similarities suggest that cats, dolphins, bats, and humans had a common ancestor. Over millions of years, changes occurred in the limb bones of the ancestor's descendants. Eventually, the bones performed different functions in each type of animal.

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5EVOW.**

Comparing DNA

Interestingly, the DNA of a house cat is similar to the DNA of a tiger. Scientists have learned that traits are inherited through DNA's genetic code. So, scientists can test the following hypothesis: If species that have similar traits evolved from a common ancestor, the species will have similar genetic information. In fact, scientists find that species that have many traits in common do have similarities in their DNA. For example, the DNA of house cats is more similar to the DNA of tigers than to the DNA of dogs. The fact that all existing species have DNA supports the theory that all species share a common ancestor.

Reading Check **If two species have similar DNA, what hypothesis is supported?**

SECTION Review

Summary

- Evolution is the process in which inherited characteristics within a population change over generations, sometimes giving rise to new species. Scientists continue to develop theories to explain how evolution happens.
- Evidence that organisms evolve can be found by comparing living organisms to each other and to the fossil record. Such comparisons provide evidence of common ancestry.
- Scientists think that modern whales evolved from an ancient, land-dwelling mammal ancestor. Fossil organisms that support this hypothesis have been found.
- Evidence of common ancestry among living organisms is provided by comparing DNA and inherited traits. Species that have a common ancestor will have traits and DNA that are more similar to each other than to those of distantly related species.

Using Key Terms

Complete each of the following sentences by choosing the correct term from the word bank.

adaptation	species
fossil	evolution

1. Members of the same ___ can mate with one another to produce offspring.
2. A(n) ___ helps an organism survive.
3. When populations change over time, ___ has occurred.

Understanding Key Ideas

4. A human's arm, a cat's front leg, a dolphin's front flipper, and a bat's wing
   - **a.** have similar kinds of bones.
   - **b.** are used in similar ways.
   - **c.** are very similar to insect wings and jellyfish tentacles.
   - **d.** have nothing in common.
5. How does the fossil record show that species have changed over time?
6. What evidence do fossils provide about the ancestors of whales?

Critical Thinking

7. **Making Comparisons** Other than the examples provided in the text, how are whales different from fishes?
8. **Forming Hypotheses** Is a person's DNA likely to be more similar to the DNA of his or her biological parents or to the DNA of one of his or her cousins? Explain your answer.

Interpreting Graphics

9. The photograph below shows the layers of sedimentary rock exposed during the construction of a road. Imagine that a species that lived 200 million years ago is found in layer **b**. Would the species' ancestor, which lived 250 million years ago, most likely be found in layer **a** or in layer **c**? Explain your answer.

SCILINKS. NSTA

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Species and Adaptation; Fossil Record

SciLinks code: HSM1433; HSM0615

SECTION 2

How Does Evolution Happen?

Imagine that you are a scientist in the 1800s. Fossils of some very strange animals have been found. And some familiar fossils have been found where you would least expect them. How did seashells end up on the tops of mountains?

In the 1800s, geologists began to realize that the Earth is much older than anyone had previously thought. Evidence showed that gradual processes had changed the Earth's surface over millions of years. Some scientists saw evidence of evolution in the fossil record. However, no one had been able to explain *how* evolution happens—until Charles Darwin.

READING WARM-UP

Objectives

- List four sources of Charles Darwin's ideas about evolution.
- Describe the four parts of Darwin's theory of evolution by natural selection.
- Relate genetics to evolution.

Terms to Learn

trait
selective breeding
natural selection

READING STRATEGY

Brainstorming The key idea of this section is natural selection. Brainstorm words and phrases related to natural selection.

Charles Darwin

In 1831, 21-year-old Charles Darwin, shown in **Figure 1,** graduated from college. Like many young people just out of college, Darwin didn't know what he wanted to do with his life. His father wanted him to become a doctor, but seeing blood made Darwin sick. Although he eventually earned a degree in theology, Darwin was most interested in the study of plants and animals.

So, Darwin signed on for a five-year voyage around the world. He served as the *naturalist*—a scientist who studies nature—on the British ship the HMS *Beagle,* similar to the ship in **Figure 2.** During the trip, Darwin made observations that helped him form a theory about how evolution happens.

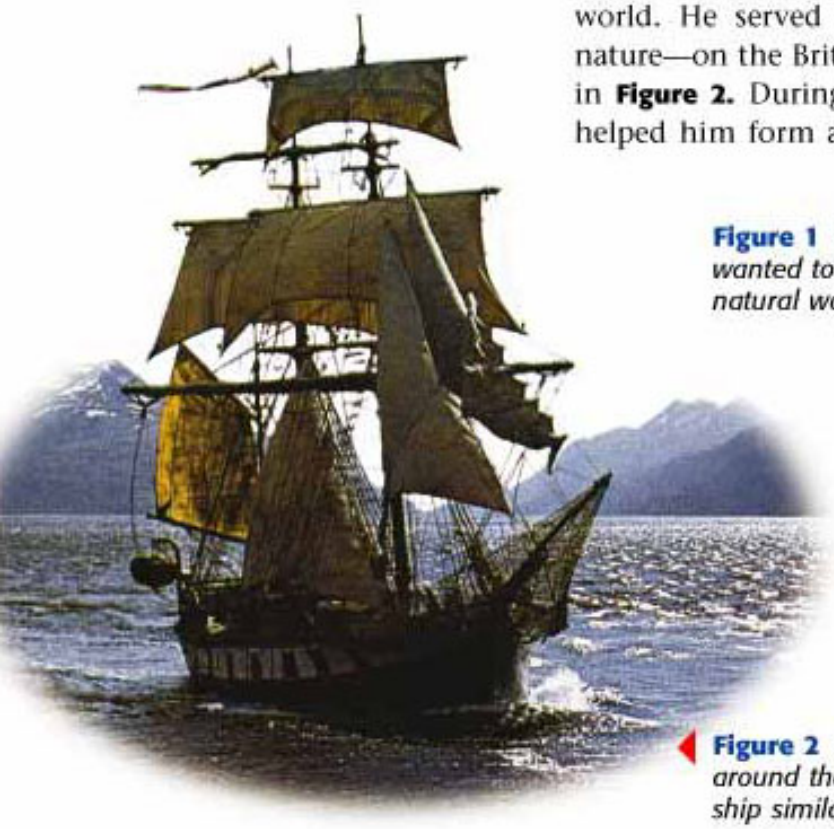


Figure 2 *Darwin sailed around the world on a ship similar to this one.*

Figure 1 *Charles Darwin wanted to understand the natural world.*

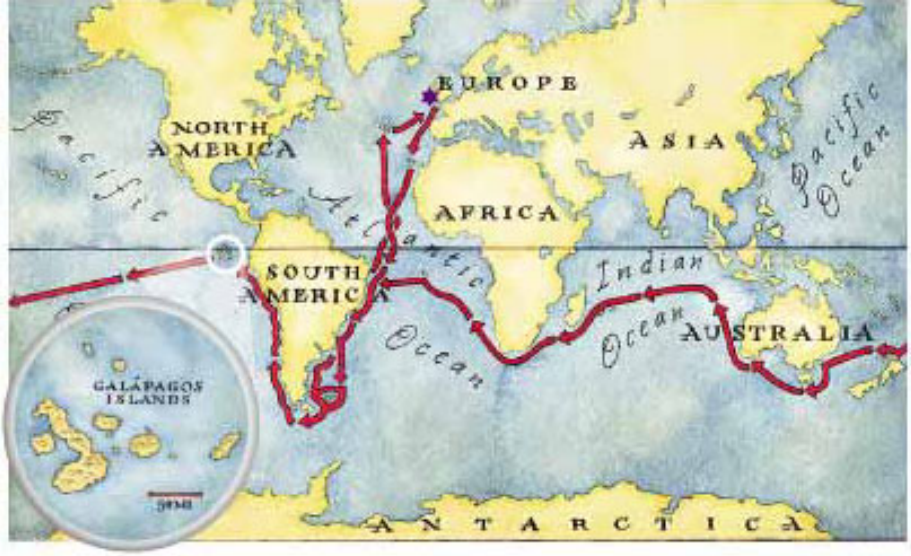


Figure 3 *The course of the HMS* Beagle *is shown by the red line. The journey began and ended in England.*

Darwin's Excellent Adventure

The *Beagle*'s journey is charted in **Figure 3.** Along the way, Darwin collected thousands of plant and animal samples. He kept careful notes of his observations. One interesting place that the ship visited was the Galápagos Islands. These islands are found 965 km (600 mi) west of Ecuador, a country in South America.

Reading Check **Where are the Galápagos Islands?** (*See the Appendix for answers to Reading Checks.*)

Darwin's Finches

Darwin noticed that the animals and plants on the Galápagos Islands were a lot like those in Ecuador. However, they were not exactly the same. The finches of the Galápagos Islands, for example, were a little different from the finches in Ecuador. And the finches on each island differed from the finches on the other islands. As **Figure 4** shows, the beak of each finch is adapted to the way the bird usually gets food.

Figure 4 **Some Finches of the Galápagos Islands**

The **large ground finch** has a wide, strong beak that it uses to crack open big, hard seeds. This beak works like a nutcracker.

The **cactus finch** has a tough beak that it uses for eating cactus parts and insects. This beak works like a pair of needle-nose pliers.

The **warbler finch** has a small, narrow beak that it uses to catch small insects. This beak works like a pair of tweezers.

Darwin's Thinking

After returning to England, Darwin puzzled over the animals of the Galápagos Islands. He tried to explain why the animals seemed so similar to each other yet had so many different adaptations. For example, Darwin hypothesized that the island finches were descended from South American finches. The first finches on the islands may have been blown from South America by a storm. Over many generations, the finches may have adapted to different ways of life on the islands.

During the course of his travels, Darwin came up with many new ideas. Before sharing these ideas, he spent several years analyzing his evidence. He also gathered ideas from many other people.

Ideas About Breeding

trait a genetically determined characteristic

selective breeding the human practice of breeding animals or plants that have certain desired characteristics

In Darwin's time, farmers and breeders had produced many kinds of farm animals and plants. These plants and animals had traits that were desired by the farmers and breeders. **Traits** are specific characteristics that can be passed from parent to offspring through genes. The process in which humans select which plants or animals to reproduce based on certain desired traits is called **selective breeding.** Most pets, such as the dogs in **Figure 5,** have been bred for various desired traits.

You can see the results of selective breeding in many kinds of organisms. For example, people have bred horses that are particularly fast or strong. And farmers have bred crops that produce large fruit or that grow in specific climates.

Figure 5 *Over the past 12,000 years, dogs have been selectively bred to produce more than 150 breeds.*

QUICK LAB

Population Growth Versus Food Supply

1. Get an **egg carton** and a **bag of rice.** Use a **marker** to label one row of the carton "Food supply." Then, label the second row "Human population."
2. In the row labeled "Food supply," place one grain of rice in the first cup. Place two grains of rice in the second cup, and place three grains of rice in the third cup. In each subsequent cup, place one more grain than you placed in the previous cup. Imagine that each grain represents enough food for one person's lifetime.
3. In the row labeled "Human population," place one grain of rice in the first cup. Place two grains in the second cup, and place four grains in the third cup. In each subsequent cup, place twice as many grains as you placed in the previous cup. This rice represents people.
4. How many units of food are in the sixth cup? How many "people" are in the sixth cup? If this pattern continued, what would happen?
5. Describe how the patterns in the food supply and in the human population differ. Explain how the patterns relate to Malthus's hypothesis.

Ideas About Population

During Darwin's time, Thomas Malthus wrote a famous book entitled *An Essay on the Principle of Population.* Malthus noted that humans have the potential to reproduce rapidly. He warned that food supplies could not support unlimited population growth. **Figure 6** illustrates this relationship. However, Malthus pointed out that human populations are limited by choices that humans make or by problems such as starvation and disease.

After reading Malthus's work, Darwin realized that any species can produce many offspring. He also knew that the populations of all species are limited by starvation, disease, competition, and predation. Only a limited number of individuals survive to reproduce. Thus, there is something special about the survivors. Darwin reasoned that the offspring of the survivors inherit traits that help the offspring survive in their environment.

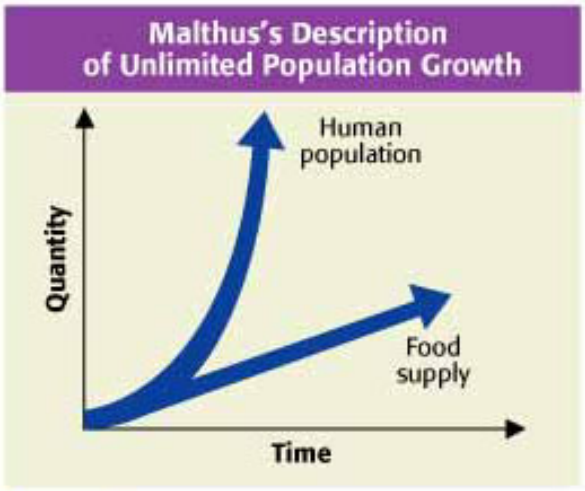


Figure 6 *Malthus thought that the human population could increase more quickly than the food supply, with the result that there would not be enough food for everyone.*

Ideas About Earth's History

Darwin had begun to think that species could evolve over time. But most geologists at the time did not think that Earth was old enough to allow for slow changes. Darwin learned new ideas from *Principles of Geology,* a book by Charles Lyell. This book presented evidence that Earth had formed by natural processes over a long period of time. It became clear to Darwin that Earth was much older than anyone had imagined.

Reading Check **What did Darwin learn from Charles Lyell?**

Darwin's Theory of Natural Selection

natural selection the process by which individuals that are better adapted to their environment survive and reproduce more successfully than less well adapted individuals do; a theory to explain the mechanism of evolution

After he returned from his voyage on the HMS *Beagle*, Darwin privately struggled with his ideas for about 20 years. Then, in 1858, Darwin received a letter from a fellow naturalist named Alfred Russel Wallace. Wallace had arrived at the same ideas about evolution that Darwin had. Darwin grew more and more motivated to present his ideas. In 1859, Darwin published a famous book called *On the Origin of Species by Means of Natural Selection*. In his book, Darwin proposed the theory that evolution happens through a process that he called **natural selection.** This process, explained in **Figure 7,** has four parts.

Reading Check What is the title of Darwin's famous book?

Figure 7 **Four Parts of Natural Selection**

1 Overproduction A tarantula's egg sac may hold 500–1,000 eggs. Some of the eggs will survive and develop into adult spiders. Some will not.

2 Inherited Variation Every individual has its own combination of traits. Each tarantula is similar to, but not identical to, its parents.

3 Struggle to Survive Some tarantulas may be caught by predators, such as this wasp. Other tarantulas may starve or get a disease. Only some of the tarantulas will survive to adulthood.

4 Successful Reproduction The tarantulas that are best adapted to their environment are likely to have many offspring that survive.

Genetics and Evolution

Darwin lacked evidence for parts of his theory. For example, he knew that organisms inherit traits, but not *how* they inherit traits. He knew that there is great variation among organisms, but not *how* that variation occurs. Today, scientists have found most of the evidence that Darwin lacked. They know that variation happens as a result of differences in genes. Changes in genes may happen whenever organisms produce offspring. Some genes make an organism more likely to survive to reproduce. The process called *selection* happens when only organisms that carry these genes can survive to reproduce. New fossil discoveries and new information about genes add to scientists' understanding of natural selection and evolution.

SECTION Review

Summary

- Darwin explained that evolution occurs through natural selection. His theory has four parts:
  1. Each species produces more offspring than will survive to reproduce.
  2. Individuals within a population have slightly different traits.
  3. Individuals within a population compete with each other for limited resources.
  4. Individuals that are better equipped to live in an environment are more likely to survive to reproduce.
- Modern genetics helps explain the theory of natural selection.

Using Key Terms

1. In your own words, write a definition for the term *trait*.
2. Use the following terms in the same sentence: *selective breeding* and *natural selection*.

Understanding Key Ideas

3. Modern scientific explanations of evolution
   - **a.** have replaced Darwin's theory.
   - **b.** rely on genetics instead of natural selection.
   - **c.** fail to explain how traits are inherited.
   - **d.** combine the principles of natural selection and genetic inheritance.
4. Describe the observations that Darwin made about the species on the Galápagos Islands.
5. Summarize the ideas that Darwin developed from books by Malthus and Lyell.
6. Describe the four parts of Darwin's theory of evolution by natural selection.
7. What knowledge did Darwin lack that modern scientists now use to explain evolution?

Math Skills

8. In a sample of 80 beetles, 50 beetles had 4 spots each, and the rest had 6 spots each. What was the average number of spots per beetle?

Critical Thinking

9. **Making Comparisons** In selective breeding, humans influence the course of evolution. What determines the course of evolution in natural selection?
10. **Predicting Consequences** Suppose that an island in the Pacific Ocean was just formed by a volcano. Over the next million years, how might species evolve on this island?

SCILINKS. NSTA

For a variety of links related to this chapter, go to www.scilinks.org

Topic: Galápagos Islands; Darwin and Natural Selection

SciLinks code: HSM0631; HSM0378

SECTION 3

Natural Selection in Action

Have you ever had to take an antibiotic? Antibiotics are supposed to kill bacteria. But sometimes, bacteria are not killed by the medicine. Do you know why?

A population of bacteria might develop an adaptation through natural selection. Most bacteria are killed by the chemicals in antibiotics. But in some cases, a few bacteria are naturally *resistant* to the chemicals, so they are not killed. These survivors are then able to pass this adaptation to their offspring. This situation is an example of how natural selection works.

READING WARM-UP

Objectives

- Give three examples of natural selection in action.
- Outline the process of speciation.

Terms to Learn

generation time
speciation

READING STRATEGY

Prediction Guide Before reading this section, write the title of each heading in this section. Next, under each heading, write what you think you will learn.

Changes in Populations

The theory of natural selection explains how a population changes in response to its environment. If natural selection is always taking place, a population will tend to be well adapted to its environment. But not all individuals are the same. The individuals that are likely to survive and reproduce are those that are best adapted at the time.

Adaptation to Hunting

Changes in populations are sometimes observed when a new force affects the survival of individuals. In Uganda, scientists think that hunting is affecting the elephant population. In 1930, about 99% of the male elephants in one area had tusks. Only 1% of the elephants were born without tusks. Today, as few as 85% of the male elephants in that area have tusks. What happened?

A male African elephant that has tusks is shown in **Figure 1.** The ivory of an elephant's tusks is very valuable. People hunt the elephants for their tusks. As a result, fewer of the elephants that have tusks survive to reproduce, and more of the tuskless elephants survive. When the tuskless elephants reproduce, they pass the tuskless trait to their offspring.

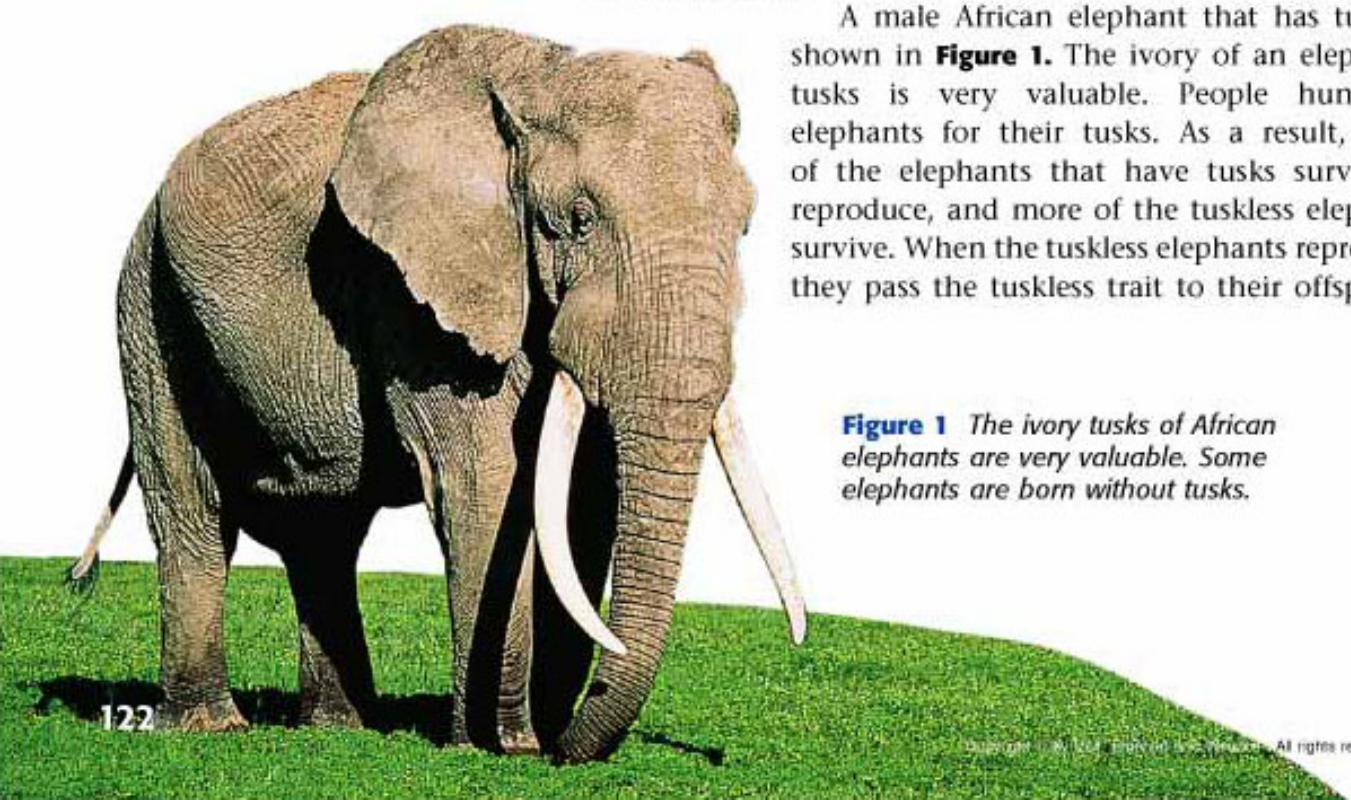


Figure 1 *The ivory tusks of African elephants are very valuable. Some elephants are born without tusks.*

Figure 2 **Natural Selection of Insecticide Resistance**

1. An insecticide will kill most insects, but a few may survive. These survivors have genes that make them resistant to the insecticide.

2. The survivors then reproduce, passing the insecticide-resistance genes to their offspring.

3. In time, the replacement population of insects is made up mostly of individuals that have the insecticide-resistance genes.

4. When the same kind of insecticide is used on the insects, only a few are killed because most of them are resistant to that insecticide.

Insecticide Resistance

People have always wanted to control the insect populations around their homes and farms. Many insecticides are used to kill insects. But some chemicals that used to work well do not work as well anymore. Some individual insects within the population are resistant to certain insecticides. **Figure 2** shows how a population of insects might become resistant to common insecticides.

More than 500 kinds of insects are now resistant to certain insecticides. Insects can quickly develop resistance because they often produce many offspring and have short generation times. **Generation time** is the average time between one generation of offspring and the next.

generation time the period between the birth of one generation and the birth of the next generation

Reading Check **Why do insects quickly develop resistance to insecticides?** *(See the Appendix for answers to Reading Checks.)*

Competition for Mates

In the process of evolution, survival is simply not enough. Natural selection is at work when individuals reproduce. In organisms that reproduce sexually, finding a mate is part of the struggle to reproduce. Many species have so much competition for mates that interesting adaptations result. For example, the females of many bird species prefer to mate with males that have certain types of colorful feathers.

Forming a New Species

Sometimes, drastic changes that can form a new species take place. In the animal kingdom, a *species* is a group of organisms that can mate with each other to produce fertile offspring. A new species may form after a group becomes separated from the original population. This group forms a new population. Over time, the two populations adapt to their different environments. Eventually, the populations can become so different that they can't mate anymore. Each population may then be considered a new species. The formation of a new species as a result of evolution is called **speciation** (SPEE shee AY shuhn). **Figure 3** shows how new species of Galápagos finches may have formed. Speciation may happen in other ways as well.

speciation the formation of new species as a result of evolution

Separation

Speciation often begins when a part of a population becomes separated from the rest. The process of separation can happen in several ways. For example, a newly formed canyon, mountain range, or lake can divide the members of a population.

Reading Check **How can parts of a population become separated?**

Figure 3 **The Evolution of Galápagos Finch Species**

1 Some finches left the mainland and reached one of the islands (separation).

2 The finches reproduced and adapted to the environment (adaptation).

3 Some finches flew to a second island (separation).

4 The finches reproduced and adapted to the different environment (adaptation).

5 Some finches flew back to the first island but could no longer interbreed with the finches there (division).

6 This process may have occurred over and over again as the finches flew to the other islands.

Adaptation

Populations constantly undergo natural selection. After two groups have separated, natural selection may act on each group in different ways. Over many generations, the separated groups may evolve different sets of traits. If the environmental conditions for each group differ, the adaptations in the groups will also differ.

Division

Over many generations, two separated groups of a population may become very different. Even if a geographical barrier is removed, the groups may not be able to interbreed anymore. At this point, the two groups are no longer the same species.

Figure 4 shows another way that populations may stop interbreeding. Leopard frogs and pickerel frogs probably had the same ancestor species. Then, at some point, some of these frogs began to mate at different times during the year.

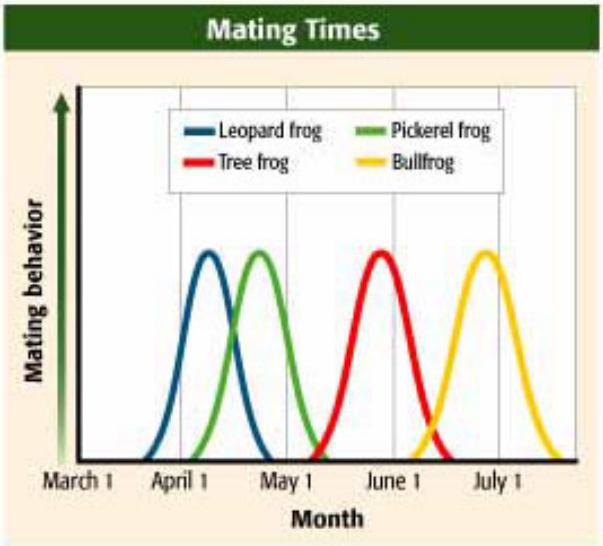


Figure 4 *The leopard frog and the pickerel frog are similar species. However, leopard frogs do not search for mates at the same time of year that pickerel frogs do.*

SECTION Review

Summary

- Natural selection explains how populations adapt to changes in their environment. A variety of examples of such adaptations can be found.
- Natural selection also explains how one species may evolve into another. Speciation occurs as populations undergo separation, adaptation, and division.

Using Key Terms

1. In your own words, write a definition for the term *speciation*.

Understanding Key Ideas

2. Two populations have evolved into two species when
   a. the populations are separated.
   b. the populations look different.
   c. the populations can no longer interbreed.
   d. the populations adapt.
3. Explain why the number of tuskless elephants in Uganda may be increasing.

Math Skills

4. A female cockroach can produce 80 offspring at a time. If half of the offspring produced by a certain female are female and each female produces 80 offspring, how many cockroaches are there in the third generation?

Critical Thinking

5. **Forming Hypotheses** Most kinds of cactus have leaves that grow in the form of spines. The stems or trunks become thick, juicy pads or barrels. Explain how these cactus parts might have evolved.
6. **Making Comparisons** Suggest an organism other than an insect that might evolve an adaptation to human activities.

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Using Scientific Methods

Inquiry Lab

Survival of the Chocolates

Imagine a world populated with candy, and hold that delicious thought in your head for just a moment. Try to apply the idea of natural selection to a population of candy-coated chocolates. According to the theory of natural selection, individuals who have favorable adaptations are more likely to survive. In the "species" of candy-coated chocolates you will study in this experiment, the characteristics of individual chocolates may help them "survive." For example, shell strength (the strength of the candy coating) could be an adaptive advantage. Plan an experiment to find out which characteristics of the chocolates are favorable "adaptations."

OBJECTIVES

Form a hypothesis about the fate of the candy-coated chocolates.

Predict what will happen to the candy-coated chocolates.

Design and conduct an experiment to test your hypothesis.

MATERIALS

- chocolates, candy-coated, small, in a variety of colors (about 100)
- items to be determined by the students and approved by the teacher

SAFETY

Ask a Question

1. What might "survival" mean for a candy-coated chocolate? What are some ways you can test which chocolates are the "strongest" or "most fit" for their environment? Also, write down any other questions that you could ask about the "survival" of the chocolates.

Form a Hypothesis

2. Form a hypothesis, and make a prediction. For example, if you chose to study candy color, your prediction might be similar to this: If the ___ colored shell is the strongest, then fewer of the chocolates with this color of shell will ___ when ___.